HUBBLESITE

HIGHLIGHTS

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the hubble deep field
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Hubble . . . shrinking the universe, one discovery at a time.
DISCOVERIES

SCI·TECH
From gadgets to Ganymede

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PLAYTIME... HUBBLE STYLE
Fun & Games

Out of the ordinary
...out of this world.

Chances are you haven't seen what NASA's orbiting Hubble Space Telescope sees. Hubble sees the raw beauty of the universe from above Earth's atmosphere and sends back a portrait of the universe in exquisite detail. Here's your chance to leave the ground for a while... and see what Hubble sees.

- News of Hubble's science and remarkable discoveries
- Gorgeous pictures of stars, planets, galaxies, nebulae, and more
- Richly illustrated facts about the telescope and its instruments
- Weather on Mars and comet collisions

NASA

news & views

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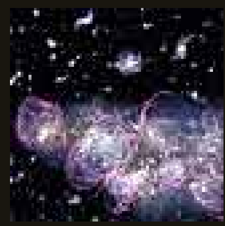
Featured News Release

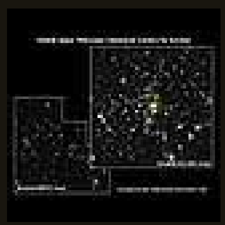


1/8/2002

[Stellar 'Fireworks Finale' Came First in the Young Universe]

The deepest views of the cosmos from the Hubble Space Telescope yield clues that the very first... (more)

Recent News Releases



2/15/2002

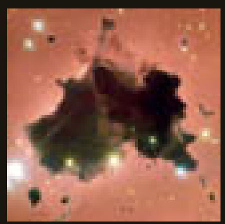
[New Instrument Package to Expand Space Telescope's Vision]

NASA's Servicing Mission 3B for the Hubble Space Telescope will give the orbiting observatory a... (more)

2/7/2002

[Hubble Reveals "Backwards" Spiral Galaxy]

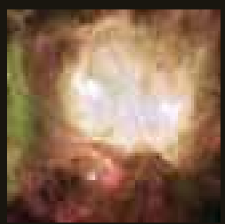
Astronomers have found a spiral galaxy that may be spinning to the beat of a different cosmic drummer.... (more)



1/3/2002

[Thackeray's Globules in IC 2944]

Strangely glowing dark clouds float serenely in this remarkable and beautiful image taken with the... (more)



12/19/2001

[Hubble Sends Season's Greetings from the Cosmos to Earth]

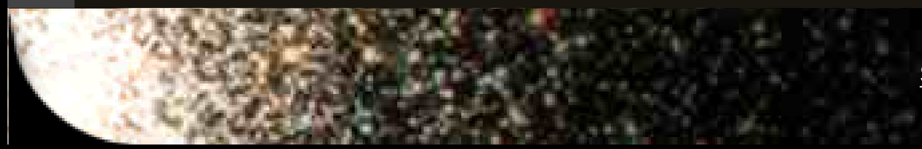
Looking like a colorful holiday card, this image from NASA's Hubble Space Telescope reveals a vibrant... (more)

12/6/2001

[A Giant Star Factory in Neighboring Galaxy NGC 6822]

Resembling curling flames from a campfire, this magnificent nebula in a neighboring galaxy is giving... (more)

ARCHIVE SORTED BY TOPIC | ARCHIVE SORTED BY YEAR




Gallery


SHOWCASE
View some of Hubble's most exciting images.
CHOOSE ONE
JAVA
NON-JAVA


see Hubble's
latest image
... and more in the News & Views section


A peek inside the image factory
Behind the Pictures


COLLECTION
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DISCOVERIES


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LOW-BAND
SKIP MOVIE


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OF DISCOVERY


the hubble deep field
a multimedia romp through the universe


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Hubble turned inside out.
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Who, what, where, when . . . and why.
facts & figures
SCI·TECH
Raw Data
Corrected

The Space Telescope Science Institute's Office of Public Outreach Education Group supports astronomy and space science education for grades K-12.

the following is a list of educational projects which are affiliated with hubblesite

AMAZING SPACE: Taking Education to the Farthest Reaches of Space! A collection of online, interactive, educational resources for grades K-12. Using spectacular Hubble images, students explore the universe while learning the principles of math and science.

ORIGINS: Galaxies, Stars, Planets....and Life. Join NASA on the search for astronomical origins and planetary systems.

GRANTS: IDEAS and HST Cycle E/PO. Funding for the development of educational outreach projects that team educators with scientists.

INFORMAL SCIENCE: Resources for museums, planetariums and others.

EDUCATION RESOURCES: A variety of educational materials and information about Hubble Space Telescope and more!

EDUCATION PROJECTS: Other education projects in and around the Space Telescope Science Institute

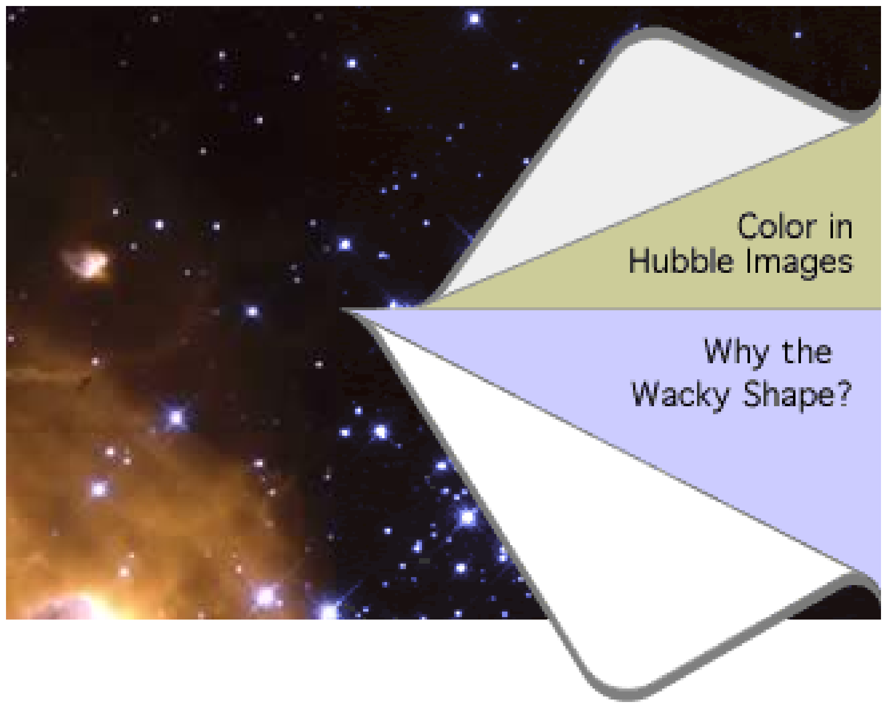
Not all galaxies look alike. . . .

Build your own comet without leaving Earth!

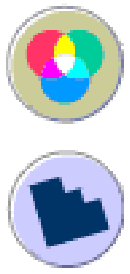
Track Hubble as it zips around its orbit!

Let HubbleSite launch you to Amazing Space interactive lessons!

HUBBLESITE



Behind the Pictures



The Hubble Space Telescope is noted for providing beautiful and often bizarre color pictures of galaxies, planets, and nebulae. Do the pictures really reflect the colors these objects would have if we visited them in a spacecraft? Why do some of the pictures have an unusual stair-step shape?

The answers to these questions require a peek behind the scenes — a look at how Hubble actually makes images.

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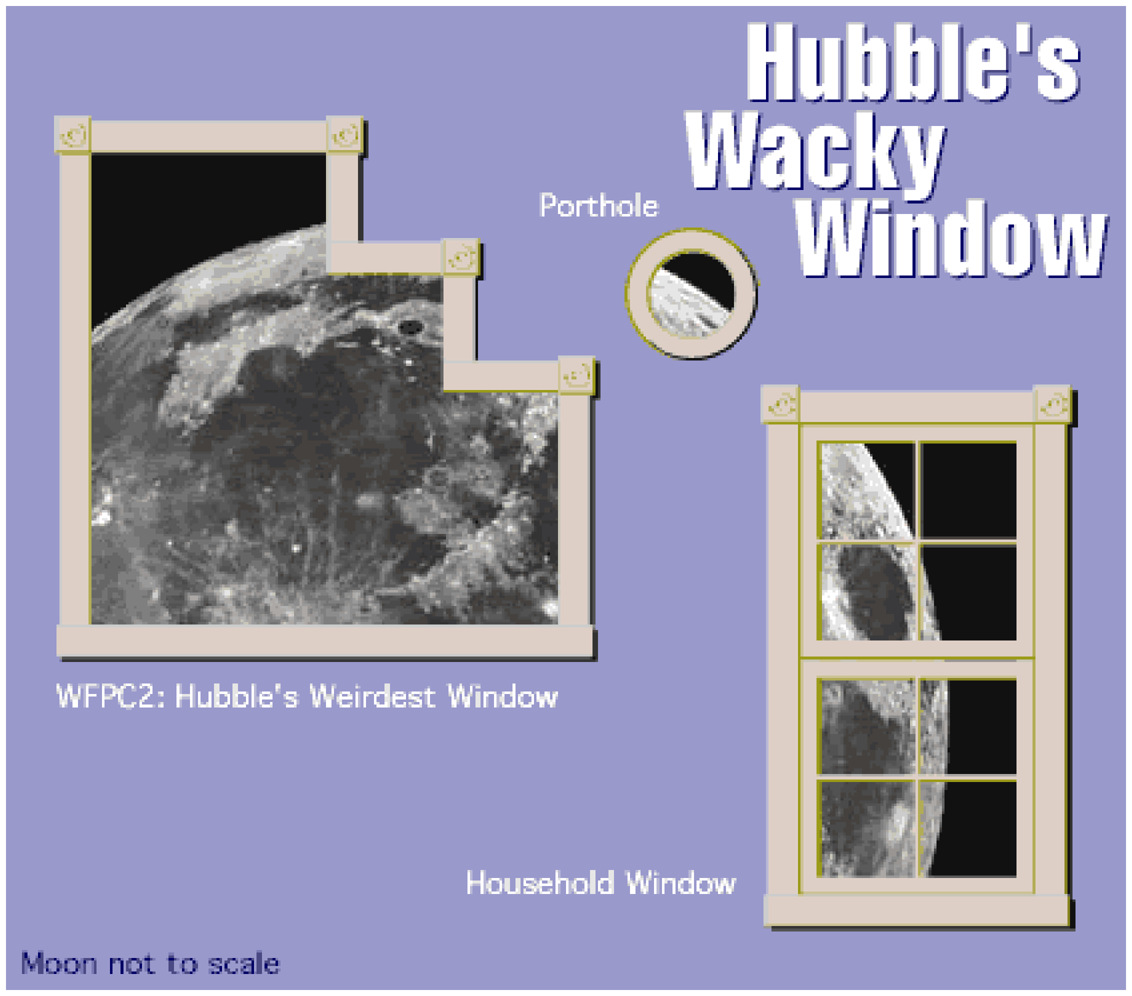
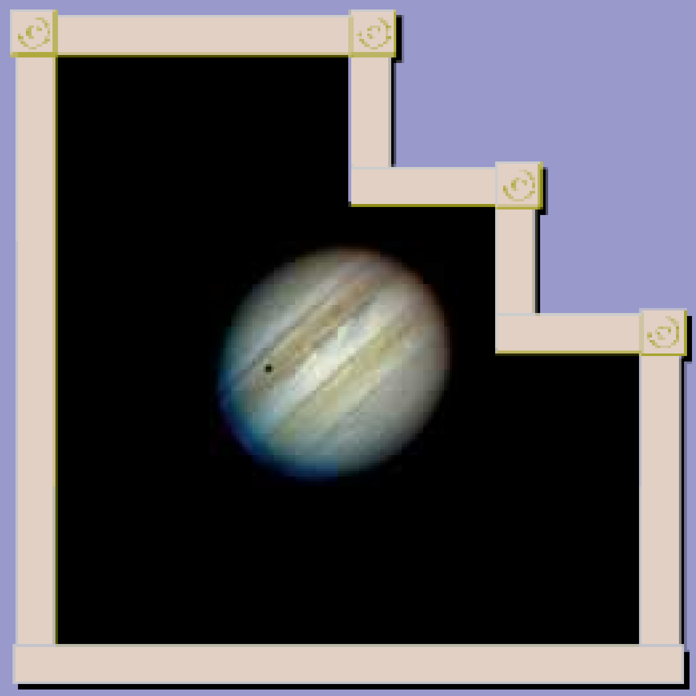


Many Hubble images have a curious stair-step shape. These images come from a scientific instrument called the Wide Field and Planetary Camera 2, or WFPC2 — one of the five instruments currently flown aboard the telescope. It is WFPC2's unique design that underlies the oddly-shaped images in Hubble's portfolio.

next >>

Constructing the View

When you look out your kitchen window, the view outside is framed by the shape of that window. Likewise, Hubble's view is framed by the instrument making the observation. One of Hubble's instruments — the Wide Field and Planetary Camera 2, or WFPC2 for short — results in images with a peculiar stair-step shape.



Jupiter

A Closer Look at WFPC2's Unique Vision

WFPC2 is actually made up of four cameras. Each camera records a separate image that represents one part of the overall view. It's rather like seeing a view through a four-paned household window. But WFPC2 has a unique feature. One of its cameras records a magnified view of the section it's observing, which allows us to see finer detail in that section.

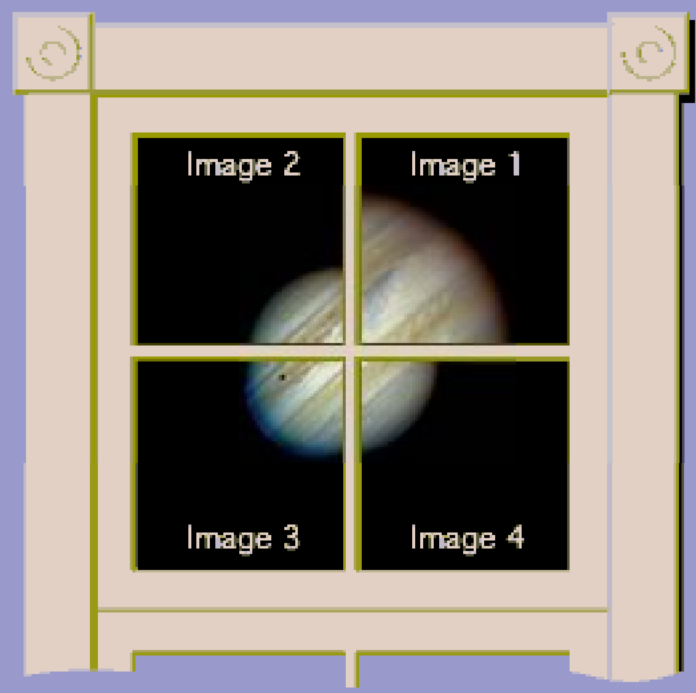
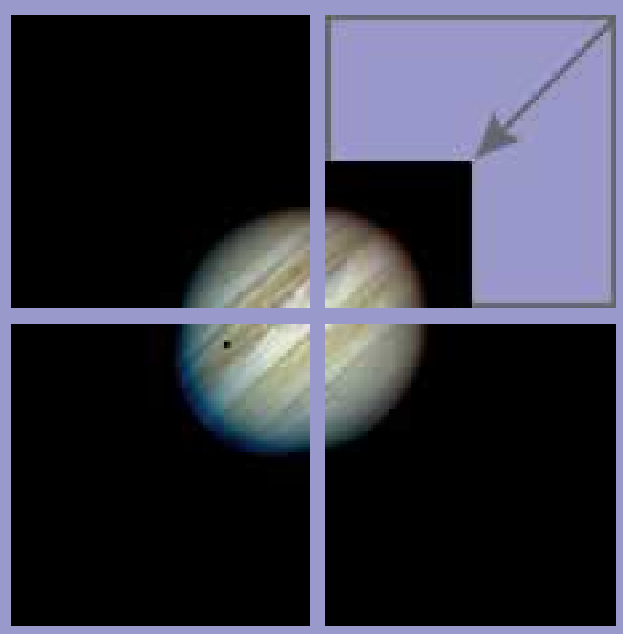


Image 1 has a magnified view.

Proportion Change

During image processing the magnified view is reduced to the proportion of the other three, resulting in one small image and three larger images.



Magnified view scaled down to correct proportions.

Move cursor over the image to see the magnified view.

Final Image

Image after being stitched together.

The stair-step shape emerges when the four images are stitched together to make the final image.

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  - education projects

fun & games

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- comets
- where's hubble now?

Help for search

The text search function allows you to search for information using search terms. Results are measured by a document's score: the higher the score, the more likely it is that the document will match the specified search criteria.

Simply type a number of words (separated by spaces) into the search field and choose "Search." Pages that contain all of your search terms will be displayed. They will be ranked by the frequency and positional relevance of your search terms.

HUBBLESITE

About Us...

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"Facts which at first seem improbable will, even on scant explanation, drop the cloak which has hidden them and stand forth in naked and simple beauty. —Galileo, Discourses Concerning Two New Sciences (1638)

Nearly 400 years after Galileo first observed the heavens through a telescope, we continue to seek answers to age-old questions about the universe. And while the technology has evolved over the centuries, the inquiry remains essentially the same: What's out there, where did it come from, and what does it mean?

At the Space Telescope Science Institute, we're working hard to study and explain the once-unimaginable celestial phenomena now made visible using Hubble's cutting-edge technology. In the course of this exploration we will continue to share with you the grace and beauty of the universe... because the discoveries belong to all of us.

Probe deeper! Explore the following links to learn more about who we are and what we do.

If you are visiting the Baltimore/Washington area, make it a point to come to our monthly Open Night and learn about Hubble's latest discoveries first-hand.

HubbleSite is produced by the Space Telescope Science Institute's Office of Public Outreach.

Also see:

Office of Public Outreach

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HUBBLESITE

About Us...

Bringing Outer Space... In.

At the heart of STScI's mission are outreach and education. Our Office of Public Outreach (OPO), which created this Web site, finds innovative ways to share Hubble's remarkable discoveries with the public. OPO exists as a unique blend of communications professionals and scientists working together to prepare and disseminate the photographs and animations seen in the news... as well as posters, slide shows, exhibits, and educational products in print and electronic formats.

[TOP]

Also see:

Office of Public Outreach

About Us...

Open Night

Public Lectures at the Space Telescope Science Institute

Are you interested in planets, stars, galaxies, black holes?

Come to the free public lectures at the Space Telescope Science Institute (STScI). Each month a noted scientist discusses a different cosmic topic. Lectures are at 8 p.m. the first Tuesday of every month in the STScI auditorium, on the campus of Johns Hopkins University. Free parking is available. For directions, call 410-338-4700.

Upcoming Lectures

Date	Speaker
March 5 , 2002	Mark Voit "Beyond the Boundaries of Galaxies"
April 2 , 2002	Andrew Fruchter "Gamma Ray Bursters"
May 7 , 2002	TBA
June 4 , 2002	TBA

Want to see some of the wonders of our universe?

Come peer into the heavens with the Johns Hopkins University's Bloomberg telescope. The telescope is open to the public every Friday evening, weather permitting. For more information, contact the observatory at (410)-516-6275 or via email at altan@pha.jhu.edu.

Can't get enough astronomy?

The Baltimore Astronomical Society (BAS), Baltimore's amateur astronomy club, meets the second Tuesday of every month at the Maryland Science Center. For information regarding meeting times, club activities, and other astronomy clubs in the Maryland area, visit the BAS website.

Also see:

Baltimore Astronomical Society

Maryland Science Center

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About Us...

Directions to the Space Telescope Science Institute

See preliminary directions below this map, then click to see the appropriate detail map.

From the east, west or north

Take the beltway (I-695) toward Towson to I-83 south; take I-83 south to Exit 9 (Cold Spring Lane) eastbound.

See detail for rest of the route from east, west or north.

From the south

From either route A or B, see detailed map for directions.

A
From I-95 north

B
From Md. 295 north (Russell St. in Baltimore)

About Us...

Hubble Space Telescope National Visitor Center

If you find yourself in Baltimore, Maryland, stop by the Hubble Space Telescope National Visitor Center, which resides at the popular Maryland Science Center in Baltimore's Inner Harbor. The Visitor Center is a Hubble-themed interactive space gallery with a variety of hands-on activities.

See some of the wonders of space through Hubble's eyes. Discover how and why astronomers search for new planets, asteroids, and comets... observe nebulae... create a star... and see yourself through the eye of an infrared camera.

While at the Maryland Science Center, take advantage of additional astronomical opportunities. See stars in the daytime at the Davis Planetarium. Experience astronomy through the eyepiece at the Crosby Ramsey Memorial Observatory. Witness the latest and greatest findings from space at SpaceLink.

Educators are invited to attend Teachers' Thursdays, informal evenings designed to enhance instruction in astronomy and space science.

Also see:

Maryland Science Center

Davis Planetarium

Crosby Ramsey Memorial Observatory

SpaceLink

HUBBLESITE

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Media Kit

Anyone can create a link to HubbleSite. Feel free to choose among the following designs:

Small Buttons

82 x 60 transparent | 90 x 30

Medium Buttons

160 x 40 | 160 x 40 transparent

160 x 40 | 80 x 96 transparent

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Large Buttons

250 x 50

Standard HubbleSite Logo Designs

The HubbleSite logo can be used in a variety of ways; however, the standard designs below are preferred.

gif 2k

eps 153k

tif 1,430k

gif 3k

eps 154k

tif 1,480k

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HUBBLESITE

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Credits

HubbleSite represents the culmination of years of hard work, unflagging dedication, and a massive group effort.

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  Deputy Head

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Nuts & Bolts

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The Hubble Deep Field

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Tour the Cosmos

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Ginger French	John Stoke
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New Views of the Universe

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A Decade of Discovery

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Edu·Space

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Special Thanks

J-TRACK WEB APPLICATION -- WHERE'S HUBBLE NOW?

Patrick Meyer - NASA, Marshall Space Flight Center

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Space Telescope Science Institute Staff

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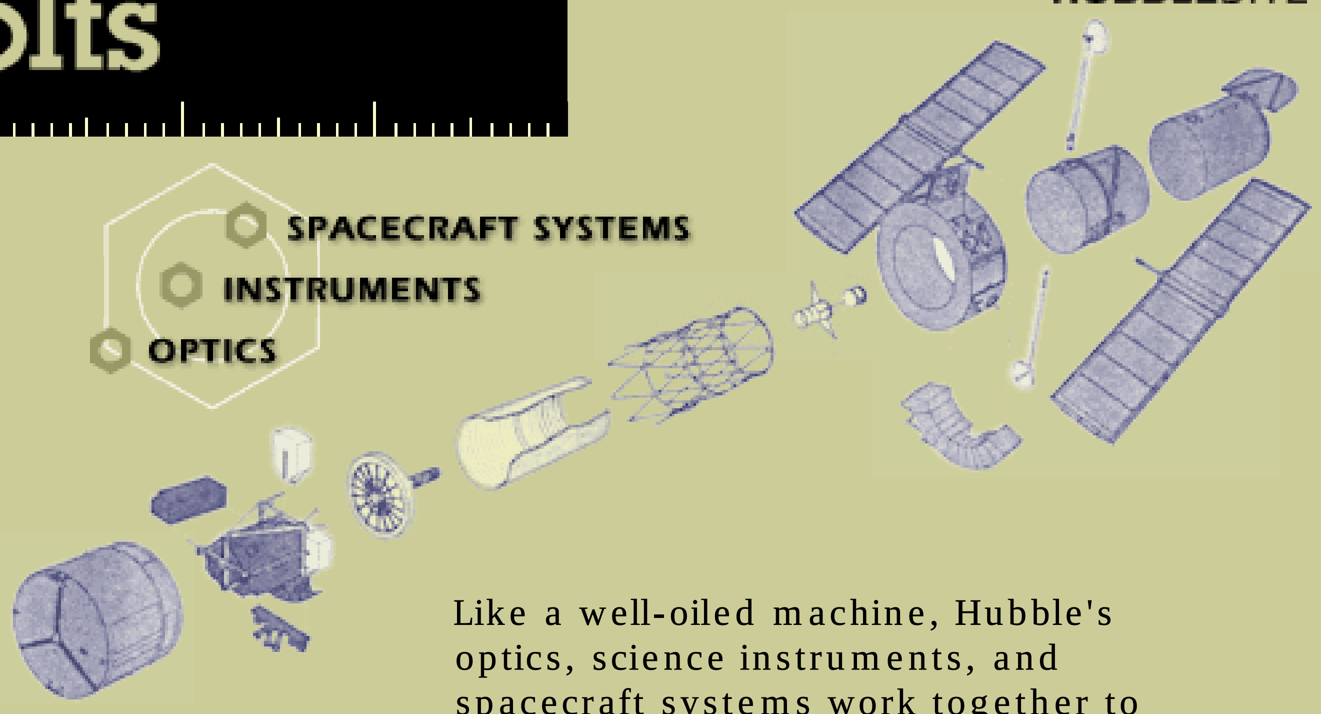
Pat Momberger

nuts & bolts

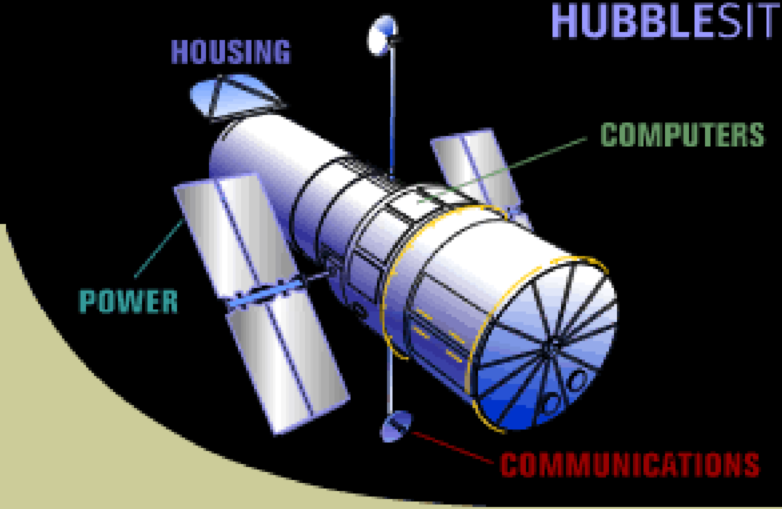
HUBBLESITE

SPACECRAFT SYSTEMS
INSTRUMENTS
OPTICS



Like a well-oiled machine, Hubble's optics, science instruments, and spacecraft systems work together to capture light from the cosmos, convert it into digital data, and transmit it back to Earth.

SPACECRAFT SYSTEMS



Communications

Power

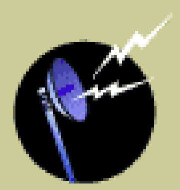
Computers

Housing

See also:
THE HUBBLE PROJECT GODDARD SPACE FLIGHT CENTER

Hubble Technology

All telescopes have optical systems, and some even have specialized instruments. Hubble has additional requirements because it operates in space — the telescope is actually "flown" as a spacecraft. Therefore, several spacecraft support systems are in place to keep Hubble functioning smoothly in space. These systems girdle the body of the telescope.



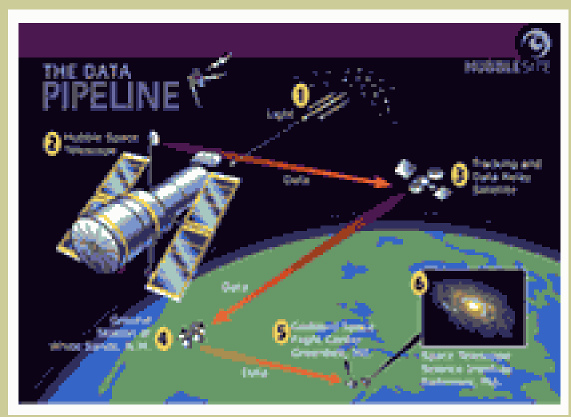
COMMUNICATIONS ANTENNAE

Much like a robot or computer in space, Hubble performs only in response to detailed instructions from the people on the ground. Hubble has communications antennae so that astronomers and technicians can communicate with the telescope — telling it what to do and when to do it. Four antennae send and receive information between the telescope and the Flight Operations Team at the Space Telescope Science Institute.

Scientists communicate with the telescope via the Tracking and Data Relay Satellite (TDRS) system. There are currently five TDRS satellites located at various locations in the sky.

In order for this system to work, at least one of the five satellites must be visible from the spacecraft's line of sight. Scientists can interact directly with the telescope during times of satellite visibility, allowing them to make small changes in the spacecraft pointing to fine-tune their observations.

Satellite visibility does not affect a planned observation because the commanding is done well in advance. When none of the satellites are visible from the spacecraft, a special data recorder stores the



The data "pipeline" from HST to final images observation. The data are stored and then transmitted during periods of satellite visibility.

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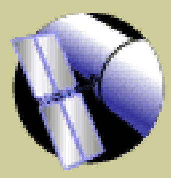

SOLAR ARRAYS FOR POWER

The yellow undersides of Hubble's solar arrays

Hubble needs electricity to operate. Since it can't be plugged in to a ground-based power source, it runs on sunlight, making it the ultimate cordless power tool. Flanking the telescope's tube are two thin, blue solar arrays. Each wing-like array has a solar cell "blanket" that converts the Sun's energy into 3,000 watts of electricity — enough to power 30 household lightbulbs. The solar arrays convert sunlight directly into electricity to run the telescope's scientific instruments, computers, and radio transmitters.

Some of the energy generated is stored in onboard batteries so the telescope can operate while it's in Earth's shadow (which is about 36 minutes out of each 97-minute orbit). Fully charged, each battery contains enough energy to sustain the telescope in normal science operations mode for 7.5 hours, or five orbits.

The solar arrays are designed for replacement by visiting astronauts. They can be rolled up or folded for shuttle trips to and from Hubble.

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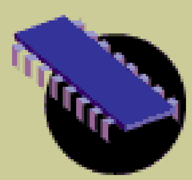

HUBBLE'S COMPUTERS AND AUTOMATION

In order to run all the many subsystems onboard the Hubble, several computers and microprocessors reside in the Hubble body and in each science instrument. Two main computers, which girdle Hubble's "waist," direct the show. One talks to the instruments, receives their data and telemetry, sends the data off to interface units for transmission to the ground, and sends commands and timing information to the instruments. The other main computer handles the gyroscopes, the pointing control subsystem, and other system-wide functions. Special backup computers keep Hubble safe in the event of a problem.

Each instrument itself also houses small computers and microprocessors, which direct their activities. These computers direct the rotation of filter wheels, open and close exposure shutters, maintain the temperature of the instruments, collect data, and talk to the main computers.

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View of
Hubble's shell

HOUSING
HUBBLE'S FLESH AND BONES

Designers of the Hubble Space Telescope had to take into account the conditions in which it was to operate. Hubble would be subject to the rigors of zero gravity and temperature extremes — fluctuations of more than 100 degrees Fahrenheit during each trip around Earth.

To accommodate this less-than-hospitable operating environment, Hubble was given a "skin," or blanket, of multilayered insulation (MLI), which protects the telescope from temperature extremes. Beneath the MLI is a lightweight aluminum shell, which provides an external structure to the spacecraft and houses its optical system and science instruments.

Hubble's optical system is held together by a truss (supporting "skeleton") measuring 210 in (5.3 m) in length and 115 in (2.9 m) in diameter. The 252 lb (114 kg) truss is made of graphite epoxy — the same material used in many golf clubs, tennis racquets, and bicycles. Graphite epoxy is a stiff, strong, and lightweight material that resists expanding and contracting in extremes of temperature.

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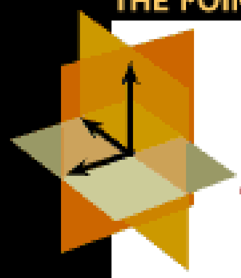
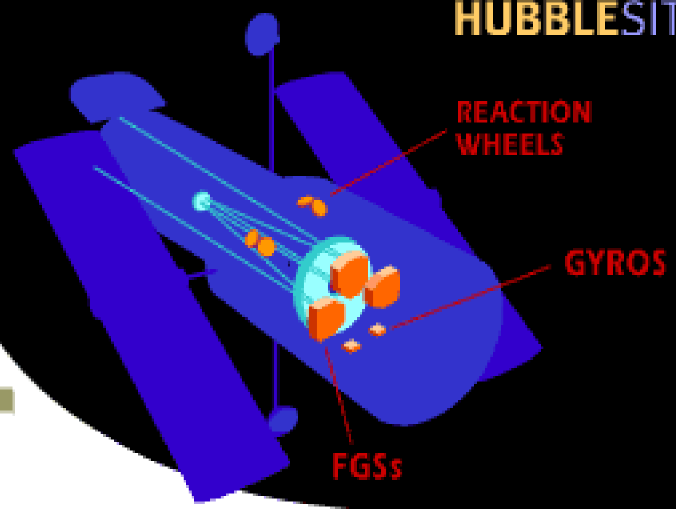
INTRO TO
THE POINTING CONTROL SYSTEM



GETTING TO THE POINT



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SPACECRAFT SYSTEMS

Aiming and steadying a telescope in space is somewhat like trying to photograph just one person on a crowded beach — from the deck of a distant, swaying boat. Hubble uses a collection of special tools that work together to maneuver the telescope and keep it aimed precisely on its target during an observation.

GYROSCOPES

The gyroscopes, Hubble's pointing assistants, always face the same direction, like the needle of a compass. They sense the telescope's angular motion and provide a short-term reference point to help Hubble zero in on its target.

REACTION WHEELS

Reaction wheels are Hubble's "steering" system. The reaction wheels spin one way, and Hubble spins the other. Flight software commands the reaction wheels to spin, accelerating or decelerating as needed to rotate the telescope toward a new target.

FINE GUIDANCE SENSORS

Three **Fine Guidance Sensors** are Hubble's targeting devices. They aim the telescope by locking onto "guide stars" and measuring the position of the telescope relative to the target. The sensors provide the precise reference point from which the telescope can begin repositioning.

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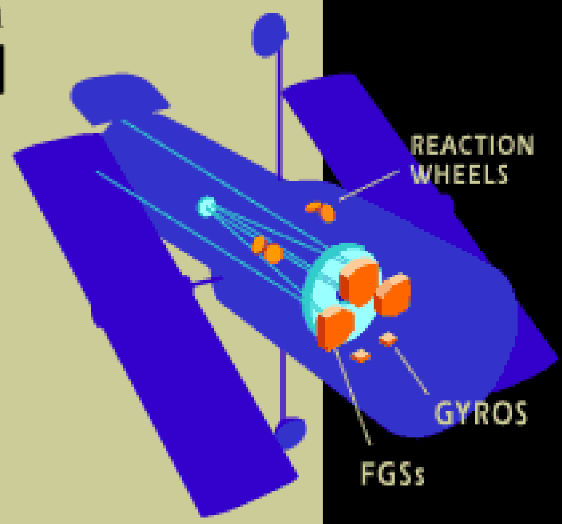
HUBBLE'S POINTING CONTROL SYSTEM



Holding a 12-ton orbiting telescope steady on a tiny target is no mean feat. This task falls to Hubble's pointing control system, which is made up of Fine Guidance Sensors, reaction wheels, and gyroscopes.

Gyros and Reaction Wheels

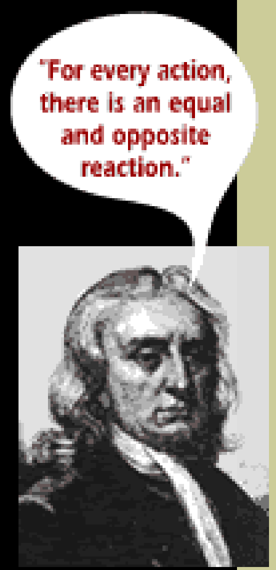
Although Hubble doesn't "visit" celestial objects — it never leaves its orbit — it does need to point itself to different directions to see different objects. But there are no rockets on Hubble, because rockets would fill the space near the telescope with contaminating jet propellant residue.

Looking upward through the underside of the telescope's midsection. (Courtesy Lockheed Martin)

Therefore, Hubble uses some very basic physics to turn itself around and look at different parts of the sky. Located on the telescope are six gyroscopes (which, like a compass, always point in the same direction) and four free-spinning steering devices called reaction wheels.

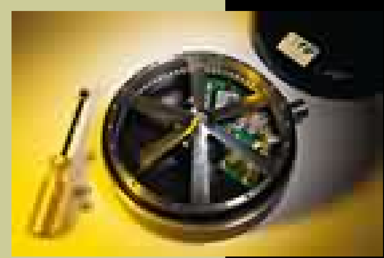
The gyroscopes sense when the telescope needs to be repointed. When they "tell" Hubble that it needs to turn itself, a computer gives a command to give the reaction wheels a "push" or "spin."

According to Newton's Third Law of Motion, every action has an equal and opposite reaction. Therefore, as Hubble accelerates its reaction wheels in one direction, Hubble's reaction is to rotate in the opposite direction.



Sir Isaac Newton

Since the rotation axes of the four reaction wheels point in different directions, Hubble is able to use combinations of them to point itself toward any location in the sky.



A reaction wheel

FOCUS FURTHER

On gyros: Lockheed Martin

On reaction wheels: Lockheed Martin

On FGSs: Lockheed Martin

On FGSs: NASA

Fine Guidance Sensors

Before Hubble can make an observation, it must find a pair of "guide stars" located alongside the observational target. To find these directional beacons, mission planners refer to an immense catalog containing the sky "addresses" for 15 million stars.

Hubble's Fine Guidance Sensors — its "targeting" devices — help aim the telescope by locking onto those guide stars and measuring the telescope's position relative to the target.

The three curved shapes make up the field of view of the three Fine Guidance Sensors.

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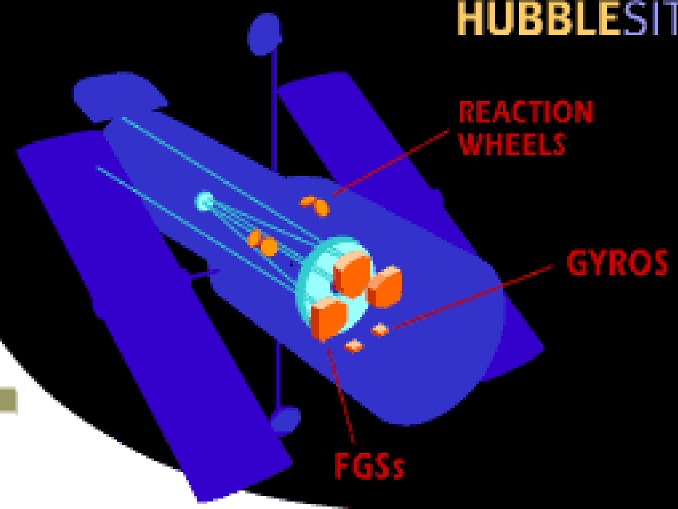

INTRO TO
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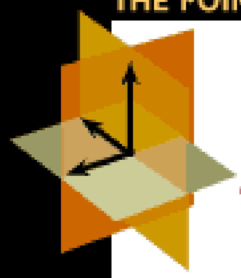

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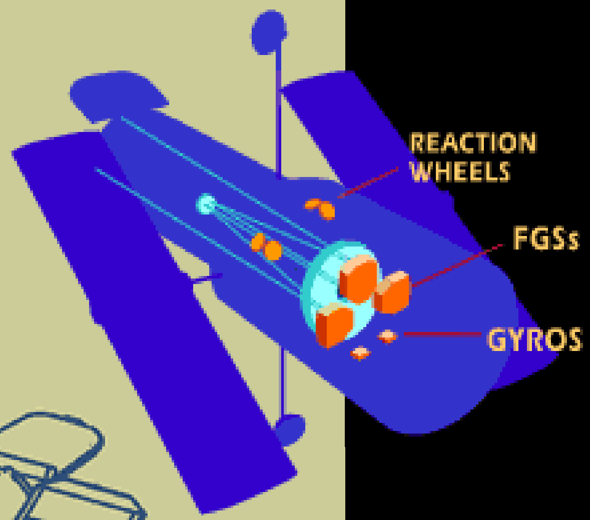
Looking upward, through the underside of the telescope's midsection

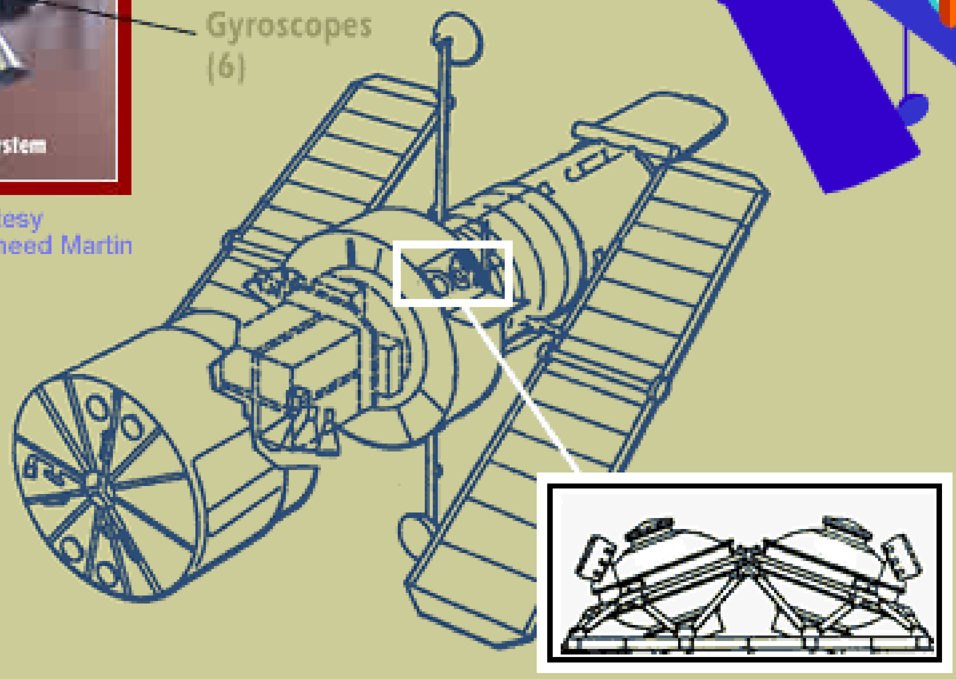
Reaction Wheels (4)

Fine Guidance Sensors (3)

Gyroscopes (6)

Courtesy Lockheed Martin





Two reaction wheels

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THE SCIENCE INSTRUMENTS

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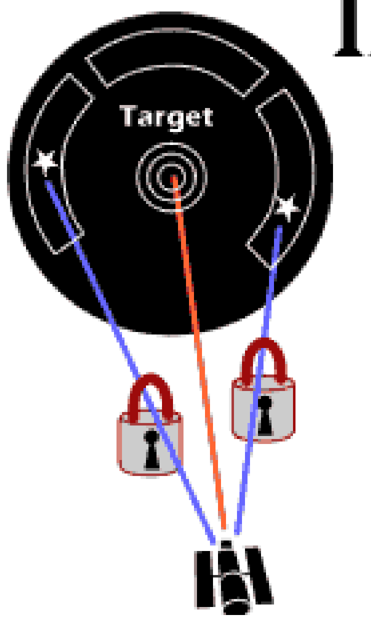
Wide Field and Planetary Camera 2

Near Infrared Camera and Multi-Object Spectrometer

Space Telescope Imaging Spectrograph

Faint Object Camera



Hubble's three Fine Guidance Sensors — its targeting cameras — provide feedback used to maneuver the telescope and perform celestial measurements. Two of the sensors point the telescope at an astronomical target and then hold that target in a scientific instrument's field of view. The third sensor is available to perform scientific observations.

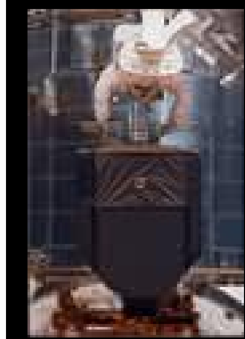
The sensors aim the telescope by locking onto "guide stars" and measure the position of the telescope relative to the object being viewed. Adjustments based on these constant, minute measurements keep Hubble pointed precisely in the right direction.

Hubble is, in principle, free to roll about its optical axis (not end-over-end, but more of a "log roll"). This freedom is limited, however, by the need to keep sunlight shining on the solar arrays, and by a thermal design that assumes that the Sun always heats the same side of the telescope.

Resolution 101

The Pointing Control System

FGS changeout



FOCUS FURTHER

Space Telescope Science Institute

Astrometry Team

Lockheed Martin

NASA/Goddard

Pointing Control System parts (FGSs in turquoise), as viewed by looking upward, through the underside of the telescope's midsection (Courtesy Lockheed Martin)

Hubble's Steering Committee

Hubble's pointing control system uses the Fine Guidance Sensors to point the telescope at a target with an accuracy of 0.01 arcsec. The sensors detect when the telescope drifts even a miniscule amount and return it to its target. This gives Hubble the ability to remain pointed at that target with no more than 0.007 arcsec of deviation over long periods of time. This level of stability and precision is like being able to hold a laser beam focused on a dime 200 miles away (about the distance from Washington, D.C. to New York) for 24 hours.

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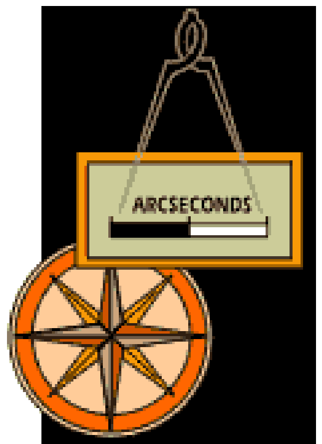
Measuring the Universe



Astrometry is the science that determines the precise positions and motions of stars and other celestial objects. These measurements are helping to advance knowledge of stars' distances, masses, and motions. The Fine Guidance Sensors can provide star positions that are about 10 times more precise than those observed from a ground-based telescope. When used as science instruments, the sensors allow Hubble to:

• Search for a "wobble" in the motion of nearby stars, which may indicate that they have planets orbiting around them
• Determine if certain stars are actually double stars
• Measure the angular diameter of stars and other celestial objects
• Refine the positions and the absolute magnitude (brightness) scale for stars
• Help determine the true distance scale for the universe.

The Fine Guidance Sensors, which were built by the Perkin-Elmer Corporation, are refurbished and monitored by Raytheon Optical in Danbury, CT.

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Wide Field and Planetary Camera 2

Near Infrared Camera and Multi-Object Spectrometer

Space Telescope Imaging Spectrograph

Faint Object Camera

Fine Guidance Sensors

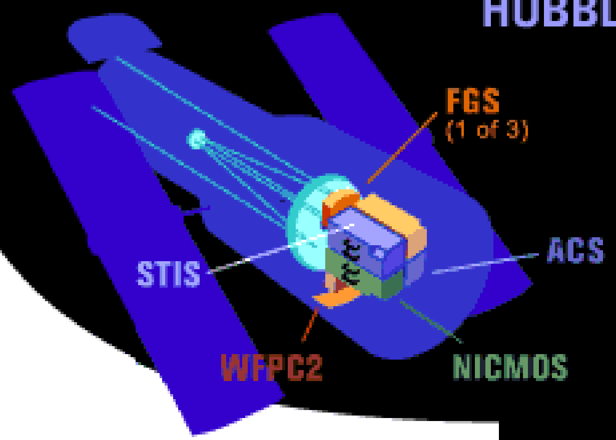
GRAPHIC:

What light does each instrument see?

FOCUS FURTHER

Is that what the pictures really look like?

THE SCIENCE INSTRUMENTS



The Hubble Space Telescope's five science instruments — its cameras, spectrographs, and fine guidance sensors — work either together or individually to bring us stunning images from the farthest reaches of space. Each instrument was designed to observe the universe in a unique way.

ACS SURVEYOR

The Advanced Camera for Surveys, which will be installed in early 2002, represents the third generation of science instruments flown aboard the Hubble Space Telescope. Among other tasks, the new camera will be used to observe weather on other planets in our solar system, conduct new surveys of the universe, and study the nature and distribution of galaxies.

WFPC2 SMILE!

The Wide Field and Planetary Camera is the "workhorse" instrument behind nearly all of the most famous Hubble pictures. As Hubble's main camera, it is used to observe just about everything. See just two of its many images at right.

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NICMOS DUST BUSTER

The Near Infrared Camera and Multi-Object Spectrometer is Hubble's heat sensor. Its sensitivity to infrared light makes it useful for observing objects obscured by interstellar gas and dust (such as stellar birthsites and planetary atmospheres) and for peering into deepest space.

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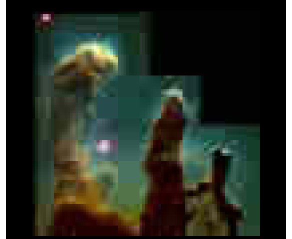
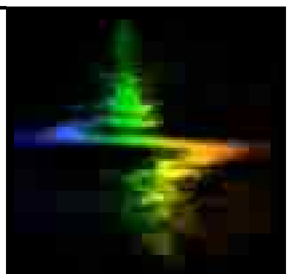
SAMPLE IMAGES


Eagle Nebula


Spiral Galaxy NGC 4414


Saturn

The Space Telescope Imaging Spectrograph is a versatile instrument that can act somewhat like a prism, separating light from the cosmos into its component colors, as shown at right.



Sign of a black hole

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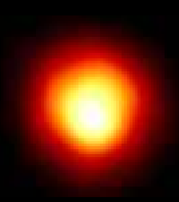
The Faint Object Camera has the sharpest vision. It is Hubble's telephoto lens, recording the most detailed images over a small field of view. This instrument will be replaced by the Advanced Camera for Surveys in early 2002.



Betelgeuse

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The Fine Guidance Sensors are targeting devices that lock onto "guide stars" and measure their positions relative to the object being viewed. Adjustments based on these precise readings keep Hubble pointed in the right direction. The sensors also are used to perform celestial measurements.

The Fine Guidance Sensors don't take images.

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More on WFPC2

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Space Telescope Imaging Spectrograph

Faint Object Camera

Fine Guidance Sensors

NEED MORE DATA?

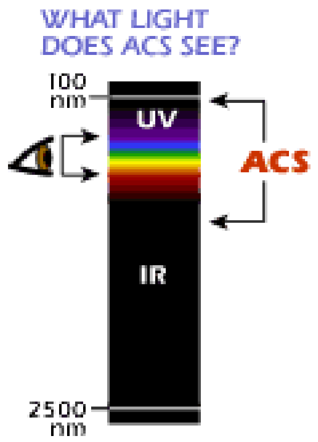
Spectrum 101

Resolution 101

FOCUS FURTHER

Space Telescope Science Institute

NASA



Hubble's newest science instrument—the Advanced Camera for Surveys, or ACS—will bring the nearly 12-year-old telescope into the 21st century. With its wider field of view, sharper image quality, and enhanced sensitivity, the new camera will double Hubble's field of view and expand its capabilities significantly. Upgrading the telescope with ACS's cutting-edge technology will make it ten times more effective and prolong its useful life.

Three Cameras in One

ACS is expected to outperform all previous intruments flown aboard the Hubble Space Telescope, primarily because of its expanded wavelength range. Designed to study some of the earliest activity in the universe, ACS will see in wavelengths ranging from far ultraviolet to infrared.

On the inside, the new instrument is actually a team of three different cameras: the wide field camera, the high-resolution camera, and the solar blind camera.

What Will ACS See?

Among other tasks, ACS will be used to map the distribution of dark matter, detect the most distant objects in the universe, search for massive planets, and study the evolution of clusters of galaxies. To accommodate these science goals, each of ACS's three cameras was designed to perform a specific function.

For example, with a field of view twice that of WFPC2 (Hubble's current wide field instrument), ACS's wide field camera will conduct broad surveys of the universe. Astronomers will use it to study the nature and distribution of galaxies, which will reveal clues about how our universe evolved.

The high-resolution camera will take extremely detailed pictures of the inner regions of galaxies. Among its many tasks will be to search neighboring stars for planets and planets-to be, and to take close-up images of the planets in our own solar system.

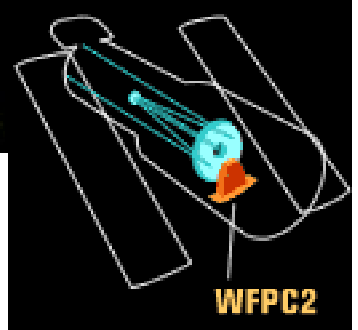
The solar blind camera, which blocks visible light to enhance ultraviolet sensitivity, will focus on hot stars radiating in ultraviolet wavelengths.

Making Room

ACS will occupy the space created by the removal of the Faint Object Camera (FOC), Hubble's "zoom lens" for nearly 12 years. The new instrument was built between 1996 and 1999 by scientists and engineers at The Johns Hopkins University, Ball Aerospace, the Space Telescope Science Institute, and NASA's Goddard Space Flight Center.

TOP

Colliding galaxies



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NEED MORE DATA?

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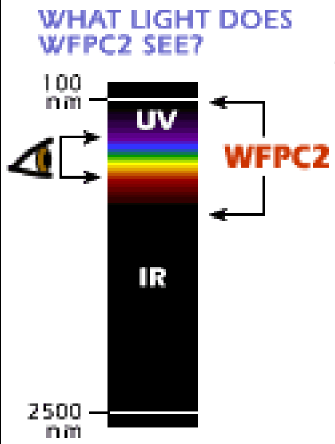
Why do the images have that funny shape?

FOCUS FURTHER

Space Telescope Science Institute

NASA



Hubble's "workhorse" instrument — the Wide Field and Planetary Camera 2 (WFPC2) — is behind nearly all of the most famous Hubble pictures. WFPC2 is the telescope's main camera. It observes just about everything, recording razor-sharp images of faraway objects in relatively broad views. Its 48 filters allow scientists to study precise wavelengths of light and to sense a range of wavelengths from ultraviolet to near-infrared light.

No Film Required

WFPC2 doesn't use film to record its images. Instead, four postage stamp-sized pieces of high-tech circuitry called Charge-Coupled Devices (CCDs) collect information from stars and galaxies to make photographs. These detectors are very sensitive to the extremely faint light of distant galaxies. They can see objects that are 1,000 million times fainter than the naked eye can see. Less sensitive CCDs are now in some videocassette recorders and all of the new digital cameras.

From Pixels to Pictures

CCDs are electronic circuits composed of light-sensitive picture elements (pixels), tiny cells that, placed together, resemble a screen-door mesh. Each of the four CCDs contains 640,000 pixels. The light collected by each pixel is translated into a number. These numbers (all 2,560,000 of them) are sent to ground-based computers, which convert them into an image.

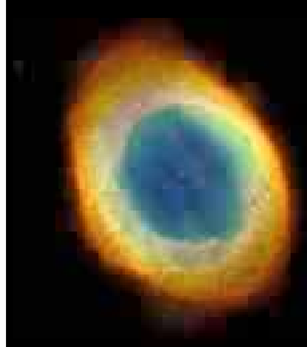
MORE...

COOL VIEWS FROM WFPC2

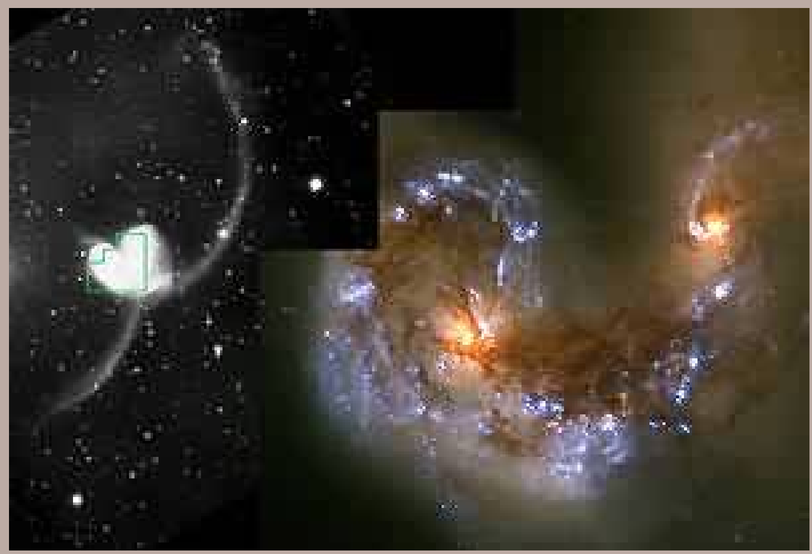
Star formation in Eagle Nebula

The most distant galaxies ever seen

Planetary nebulae



Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions



The Hubble telescope has uncovered over 1,000 bright; young star clusters bursting to life in a brief, intense, brilliant "fireworks show" at the heart of a pair of colliding galaxies.

The picture on the left provides a sweeping view of the two galaxies, called the Antennae. The green shape pinpoints Hubble's view. Hubble's close-up view [right] provides a detailed look at the "fireworks" at the center of this wreck. The respective cores of the twin galaxies are the orange blobs, left and right of center, crisscrossed by filaments of dark dust. A wide band of chaotic dust stretches between the cores of the two galaxies. The sweeping spiral-like patterns, traced by bright blue star clusters, are the result of a firestorm of star birth that was triggered by the collision.

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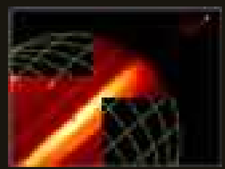
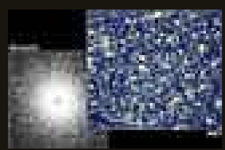
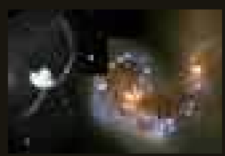

Nov 20, 1997 [Hubble Provides Infrared View of Moon, Ring, and Clouds]


Nov 20, 1997 [Hubble Watches Uranus]

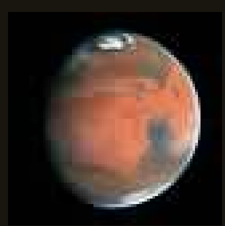

Oct 29, 1997 [Hubble Catches Up with a Blue Straggler Star]


Oct 21, 1997 [Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions]


Oct 8, 1997 [Hubble Identifies What May Be the Most Luminous Star Known]


Sep 24, 1997 [Hubble Sees a Neutron Star Alone in Space]


Sep 18, 1997 [Blobs in Space: The Legacy of a Nova]


Sep 17, 1997 [Hubble Watches the Red Planet as Mars Global Surveyor Begins Aerobraking]

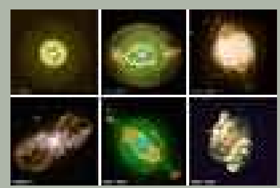
news & views

HUBBLESITE

1997

Hubble Witnesses the Final Blaze of Glory of Sun-Like Stars

The end of a Sun-like star's life was once thought to be simple: the star gracefully casts off a shell of glowing gas and then settles into a long retirement as a burned-out white dwarf.



Now, a dazzling collection of detailed views from the Hubble telescope reveals surprisingly intricate, glowing patterns spun into space by aging stars: pinwheels, lawn sprinkler-style jets, elegant goblet shapes, and even some that look like a rocket engine's exhaust. In this picture of M2-9, twin lobes of material emanate from a central, dying star. Astronomers have dubbed this object the "Twin Jet Nebula" because of the shape of the lobes. If the nebula is sliced across the star, each side appears much like a pair of exhausts from jet engines. Indeed, because of the nebula's shape and the measured velocity of the gas, in excess of 200 miles per second, astronomers believe that the description as a super-super-sonic jet exhaust is quite apt.

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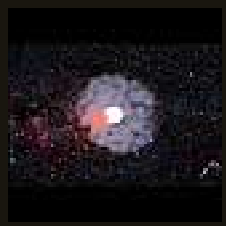
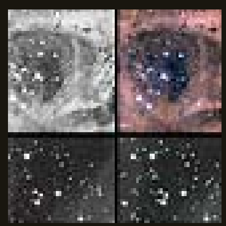
2001

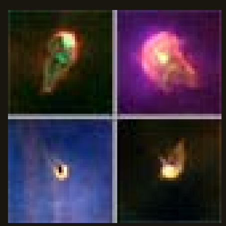
Nov 27, 2001 [Hubble Makes First Direct Measurements of Atmosphere on World Around Another Star]



Jul 12, 2001 [Magnetic Fields Weave Rings Around Stars]



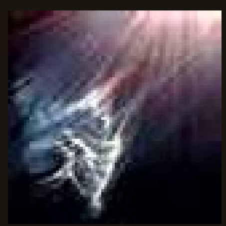
Jun 4, 2001 [Bigger, Better Catalog Unveils Half a Billion Celestial Objects]



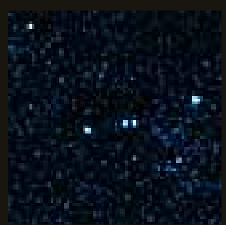
Apr 26, 2001 [Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction]

Jan 4, 2001 ["X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy]

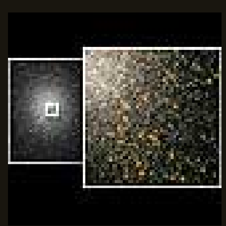
2000



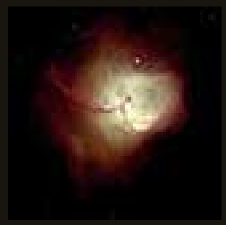
Dec 6, 2000 [Ghostly Reflections in the Pleiades]



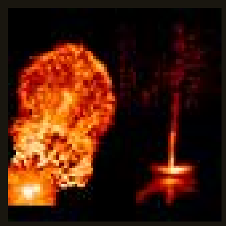
Nov 9, 2000 [Hubble Sees Bare Neutron Star Streaking Across Space]



Oct 31, 2000 [Astronomers Ponder Lack of Planets in Globular Cluster]



Oct 5, 2000 [Hubble Peeks into a Stellar Nursery in a Nearby Galaxy]



Sep 21, 2000 [Movies from Hubble Show the Changing Faces of Infant Stars]

Matches 1-10 of 86 shown
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Hubble Makes First Direct Measurements of Atmosphere on World Around Another Star

Artist's Concept

Astronomers using the Hubble Space Telescope have made the first direct detection of the atmosphere of a planet orbiting a star outside our solar system. Their unique observations demonstrate that it is possible with Hubble and other telescopes to measure the chemical makeup of alien planet atmospheres and to potentially search for the chemical markers of life beyond Earth. The planet orbits a yellow, Sun-like star called HD 209458, located 150 light-years away in the constellation Pegasus.

You may wish to find out the answers to questions such as these:

- How did they detect the atmosphere?
- What does sodium reveal about the planet?
- What are the conditions for life?

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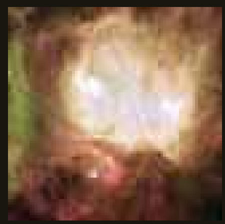
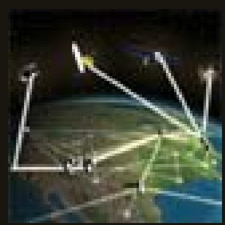


Dec 19, 2001 Hubble Sends Season's Greetings from the Cosmos to Earth

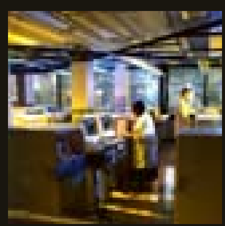
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822

Nov 27, 2001 Hubble Makes First Direct Measurements of Atmosphere on World Around Another Star

Nov 1, 2001 Hubble Reveals Ultraviolet Galactic Ring



Oct 29, 2001 $10 Million NSF Grant to Fund "National Virtual Observatory"



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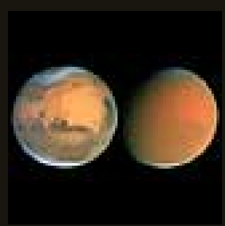

Oct 11, 2001 Scientists Track "Perfect Storm" on Mars

Oct 5, 2001 Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block

Oct 4, 2001 Peering into the Core of a Globular Cluster

Sep 12, 2001

[Ancient Black Hole Speeds Through Sun's Galactic Neighborhood, Devouring Companion Star]

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Hubble Sends Season's Greetings from the Cosmos to Earth

Looking like a colorful holiday card, this image from NASA's Hubble Space Telescope reveals a vibrant green and red nebula far from Earth, where nature seems to have put on the traditional colors of the season. These colors, produced by the light emitted by oxygen and hydrogen, help astronomers investigate the star-forming processes in nebulas such as NGC 2080. Nicknamed the "Ghost Head Nebula," NGC 2080 is one of a chain of star-forming regions lying south of the 30 Doradus nebula in the Large Magellanic Cloud that have attracted special attention. These regions have been studied in detail with Hubble and have long been identified as unique star-forming sites. 30 Doradus is the largest star-forming complex in the whole local group of galaxies.

You may wish to find out the answers to questions such as these:

- What do the image colors tell us about the chemical composition of NGC 2080?
- What gives this nebula its distinct shape?

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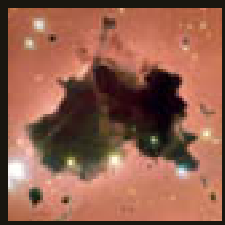
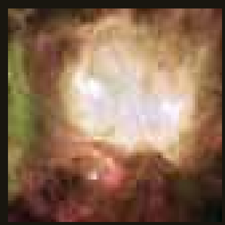


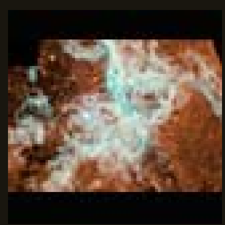
Jan 3, 2002 Thackeray's Globules in IC 2944

2001

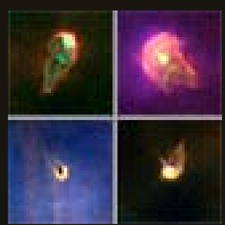


Dec 19, 2001 Hubble Sends Season's Greetings from the Cosmos to Earth

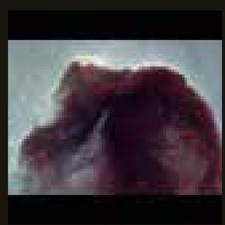
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822



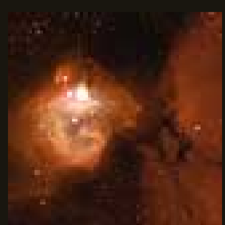
Jul 26, 2001 Hubble's Panoramic Portrait of a Vast Star-forming Region



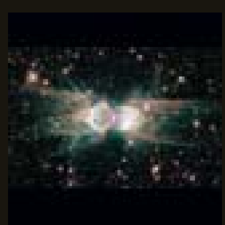
Apr 26, 2001 Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction



Apr 24, 2001 By Popular Demand: Hubble Observes the Horsehead Nebula



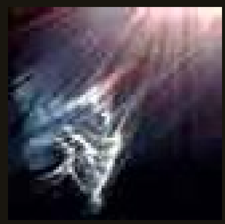
Mar 28, 2001 Massive Infant Stars Rock their Cradle



Feb 1, 2001 Astro-Entomology? Ant-like Space Structure Previews Death of Our Sun

Jan 4, 2001 "X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy

2000



Dec 6, 2000 Ghostly Reflections in the Pleiades

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Thackeray's Globules in IC 2944

Strangely glowing dark clouds float serenely in this remarkable and beautiful image taken with the Hubble Space Telescope. These dense, opaque dust clouds -- known as "globules" -- are silhouetted against nearby bright stars in the busy star-forming region, IC 2944. Astronomer A.D. Thackeray first spied the globules in IC 2944 in 1950. Globules like these have been known since Dutch-American astronomer Bart Bok first drew attention to such objects in 1947. But astronomers still know very little about their origin and nature, except that they are generally associated with areas of star formation, called "HII regions" due to the presence of hydrogen gas. IC 2944 is filled with gas and dust that is illuminated and heated by a loose cluster of massive stars. These stars are much hotter and much more massive than our Sun.

You may wish to find out the answers to questions such as these:

- How big is the largest globule?
- What does Hubble's view reveal to astronomers?

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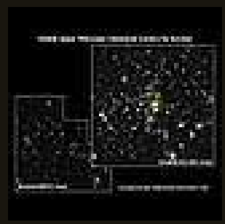
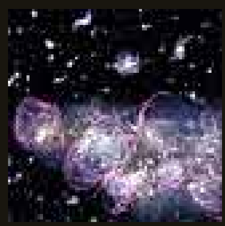
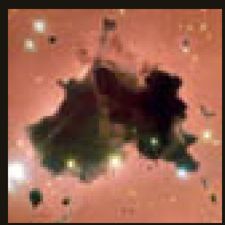


Feb 15, 2002 New Instrument Package to Expand Space Telescope's Vision

Feb 7, 2002 Hubble Reveals "Backwards" Spiral Galaxy



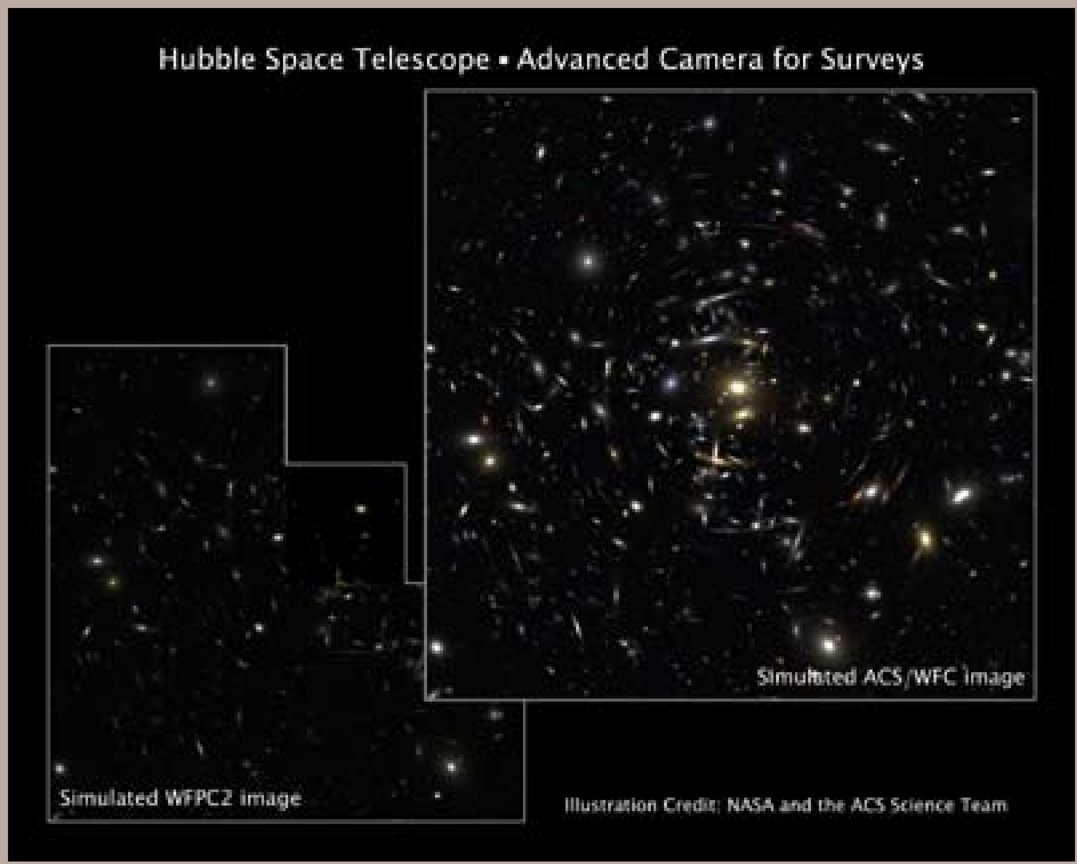
Jan 8, 2002 Stellar 'Fireworks Finale' Came First in the Young Universe



Jan 3, 2002 Thackeray's Globules in IC 2944

Matches 1-4 of 4 shown

New Instrument Package to Expand Space Telescope's Vision



NASA's Servicing Mission 3B for the Hubble Space Telescope will give the orbiting observatory a new camera that will significantly increase Hubble's abilities and enable a broad array of new astronomical discoveries. The Advanced Camera for Surveys (ACS) covers twice the area, has twice the sharpness, and is up to five times more sensitive to light than Hubble's workhorse camera, the Wide Field and Planetary Camera 2. The servicing mission will begin on Feb. 28 with the launch of the space shuttle Columbia. The simulated image [above, right] depicts how the cosmos will look through the "eyes" of the ACS.

You may wish to find out the answers to questions such as these:

- What do both simulated images show?
- What will the Advanced Camera for Surveys hunt for?

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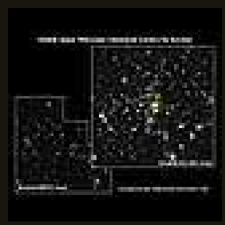

Feb 15, 2002 New Instrument Package to Expand Space Telescope's Vision

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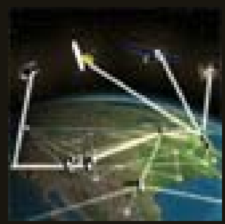

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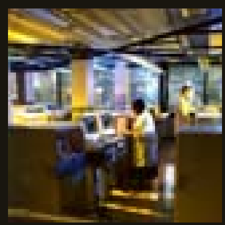
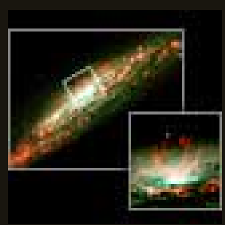
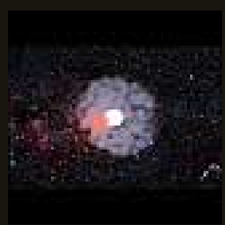


Oct 23, 2001 AURA's OPUS Software Licensed to Celera Genomics



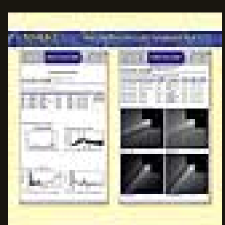
Aug 16, 2001 Burst of Star Formation Drives Bubble in Galaxy's Core

Aug 9, 2001 New View of Primordial Helium Traces the Structure of Early Universe

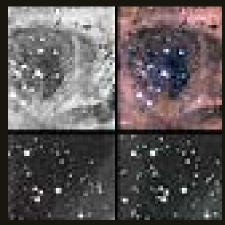


Jul 12, 2001 Magnetic Fields Weave Rings Around Stars

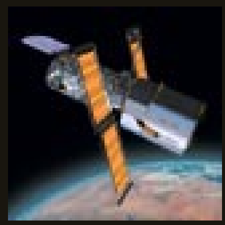
Jun 27, 2001 Hint of Planet-Sized Drifters Bewilders Hubble Scientists



Jun 4, 2001 Build Your Own Space Scrapbook



Jun 4, 2001 [Bigger, Better Catalog Unveils Half a Billion Celestial Objects]



Feb 8, 2001 [New Web Site Brings Popular Hubble Exhibition to Millions]

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$10 Million NSF Grant to Fund "National Virtual Observatory"

Artist's Concept

The National Virtual Observatory (NVO) will unite astronomical databases of many earthbound and orbital observatories, taking advantage of the latest computer technology and data storage and analysis techniques. The goal is to maximize the potential for new scientific insights from the data by making them available in an accessible, seamlessly unified form to professional researchers, amateur astronomers, and students. The new project is funded by a five- year, $10 million Information Technology Research grant from the National Science Foundation. Organizers characterize their goal as "building the framework" for the National Virtual Observatory.

You may wish to find out the answers to questions such as these:

- What is the major goal of the NVO and how will it accomplish this goal?
- How will the NVO complement how science is now being done?

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2001

AURA's OPUS Software Licensed to Celera Genomics

The Association of Universities for Research in Astronomy, Inc. (AURA) has reached an agreement with Celera Genomics Group, an Applera Corporation business in Rockville, MD, on the use of AURA's Operational Pipeline Unified Systems (OPUS) software package. Originally designed for use in the Hubble Space Telescope program, OPUS is being used by Celera to process bioinformatics data. OPUS was developed by the Space Telescope Science Institute, which is managed by AURA under contract with NASA's Goddard Space Flight Center. It is used to process astronomical data generated by the Hubble Space Telescope for use by researchers studying the universe, and it has been widely employed in other space observatories and NASA projects. Facing similar needs for the use of their large databases, Celera is licensing OPUS from AURA to assist in the processing of data from their proteomics and genomics projects.

You may wish to find out the answers to questions such as these:

- What is OPUS and how does it help the Hubble Space Telescope?
- How is OPUS being used to help the Celera Genomics company for gene research?

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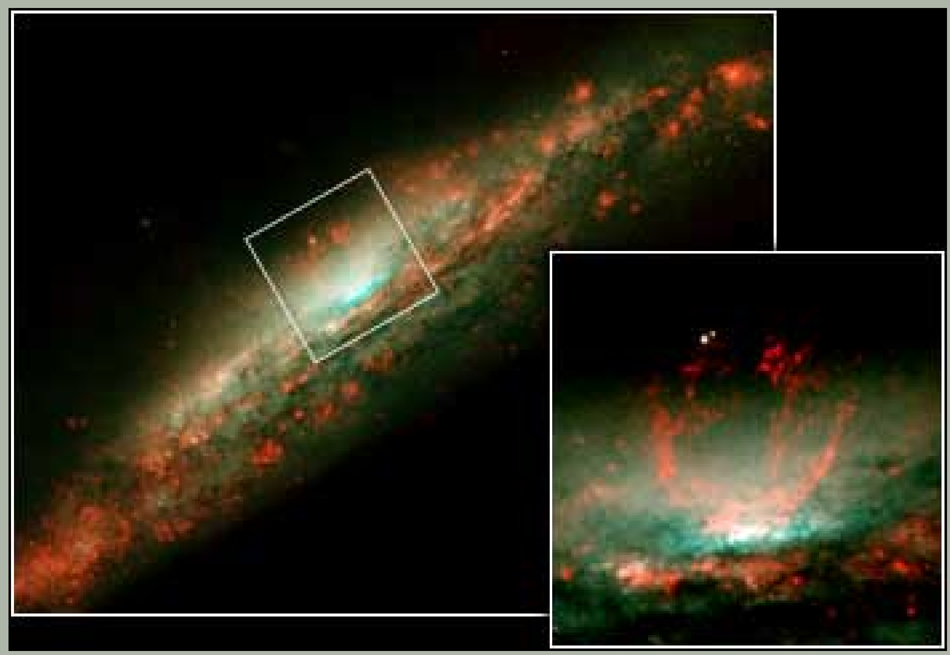
Burst of Star Formation Drives Bubble in Galaxy's Core



These NASA Hubble Space Telescope snapshots reveal dramatic activities within the core of the galaxy NGC 3079, where a lumpy bubble of hot gas is rising from a cauldron of glowing matter. The picture at left shows the bubble in the center of the galaxy's disk. The structure is more than 3,000 light-years wide and rises 3,500 light-years above the galaxy's disk. The smaller photo at right is a close-up view of the bubble. Astronomers suspect that the bubble is being blown by "winds" (high-speed streams of particles) released during a burst of star formation. Gaseous filaments at the top of the bubble are whirling around in a vortex and are being expelled into space. Eventually, this gas will rain down upon the galaxy's disk where it may collide with gas clouds, compress them, and form a new generation of stars. The two white dots just above the bubble are probably stars in the galaxy.

You may wish to find out the answers to questions such as these:

- How was the bubble created?

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Feb 7, 2002 Hubble Reveals "Backwards" Spiral Galaxy

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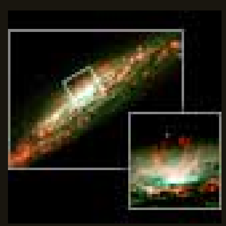
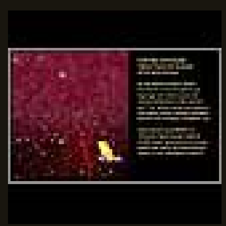
Nov 1, 2001 Hubble Reveals Ultraviolet Galactic Ring

Oct 5, 2001 Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block

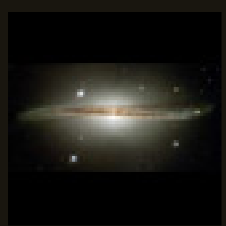
Sep 6, 2001 A Galaxy Blazes With Star Formation



Aug 16, 2001 Burst of Star Formation Drives Bubble in Galaxy's Core



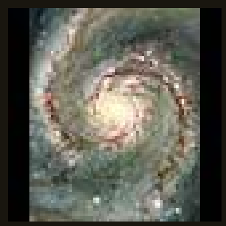
Aug 9, 2001 New View of Primordial Helium Traces the Structure of Early Universe



Aug 2, 2001 Hubble Photographs Warped Galaxy as Camera Passes Milestone

Jul 19, 2001 Star Clusters Born in the Wreckage of Cosmic Collisions

May 31, 2001 Hubble Unveils a Galaxy in Living Color



Apr 5, 2001 Hubble Reveals the Heart of the Whirlpool Galaxy

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Hubble Reveals "Backwards" Spiral Galaxy

Astronomers have found a spiral galaxy that may be spinning to the beat of a different cosmic drummer. To the surprise of astronomers, the galaxy, called NGC 4622, appears to be rotating in the opposite direction to what they expected. Pictures from NASA's Hubble Space Telescope helped astronomers determine that the galaxy may be spinning clockwise by showing which side of the galaxy is closer to Earth. This Hubble telescope photo of the oddball galaxy is presented by the Hubble Heritage team. The image shows NGC 4622 and its outer pair of winding arms full of new stars [shown in blue].

You may wish to find out the answers to questions such as these:

- Why are astronomers surprised about the galaxy's clockwise rotation?
- What may have caused the clockwise rotation and "leading" outer arms?

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Hubble Reveals Ultraviolet Galactic Ring

The appearance of a galaxy can depend strongly on the color of the light with which it is viewed. This Hubble Heritage image of NGC 6782 illustrates a pronounced example of this effect. This spiral galaxy, when seen in visible light, exhibits tightly wound spiral arms that give it a pinwheel shape similar to that of many other spirals. However, when the galaxy is viewed in ultraviolet light with NASA's Hubble Space Telescope, its shape is startlingly different.

You may wish to find out the answers to questions such as these:

- What does the ultraviolet-light image reveal about NGC 6782?

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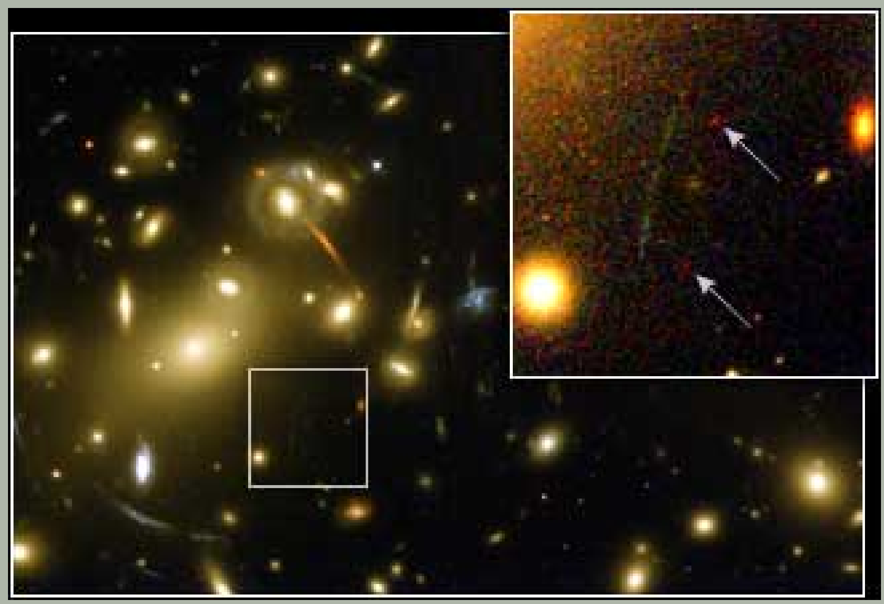
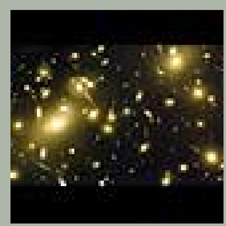
Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block



A very small, faint galaxy -- possibly one of the long sought "building blocks" of present-day galaxies -- has been discovered by a collaboration between NASA's Hubble Space Telescope and the 10-meter Keck Telescopes at a tremendous distance of 13.4 billion light-years (based on the estimate of 14 billion years as the age of the universe). The discovery was made possible by examining small areas of the sky viewed through massive intervening clusters of galaxies. These act as a powerful gravitational lens, magnifying distant objects and allowing scientists to probe how galaxies assemble at very early times. This has profound implications for our understanding of how and when the first stars and galaxies formed in the universe.

You may wish to find out the answers to questions such as these:



- What are gravitational lenses and how do they work?
- What is the nearer object that is acting as a lens?
- What is the further object that is being lensed by Abell 2218?

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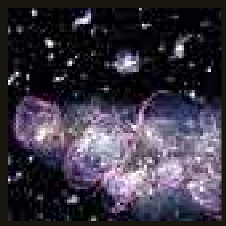

Jan 8, 2002 Stellar 'Fireworks Finale' Came First in the Young Universe

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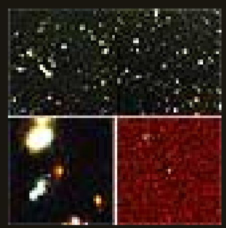
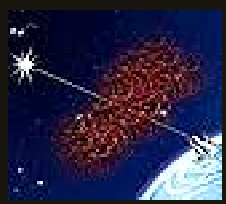


Apr 2, 2001 Blast from the Past: Farthest Supernova Ever Seen Sheds Light on Dark Universe

2000



May 3, 2000 Lost and Found: Hubble Finds Much of the Universe's Missing Hydrogen

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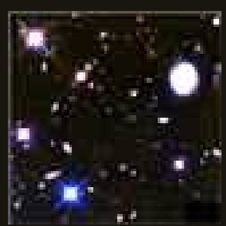
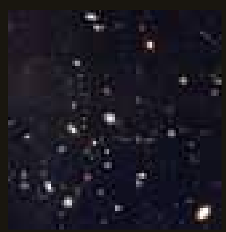
Jun 3, 1999 Magnificent Details in a Dusty Spiral Galaxy

May 25, 1999 Hubble Completes Eight-Year Effort to Measure Expanding Universe



Jan 7, 1999 Combined Deep View of Infrared- and Visible-Light Galaxies

1998



Nov 23, 1998 The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View

Oct 8, 1998 [Hubble Goes to the Limit In Search Of Farthest Galaxies]

Aug 27, 1998 [Far-Flung Galaxy Clusters May Reveal Fate of Universe]

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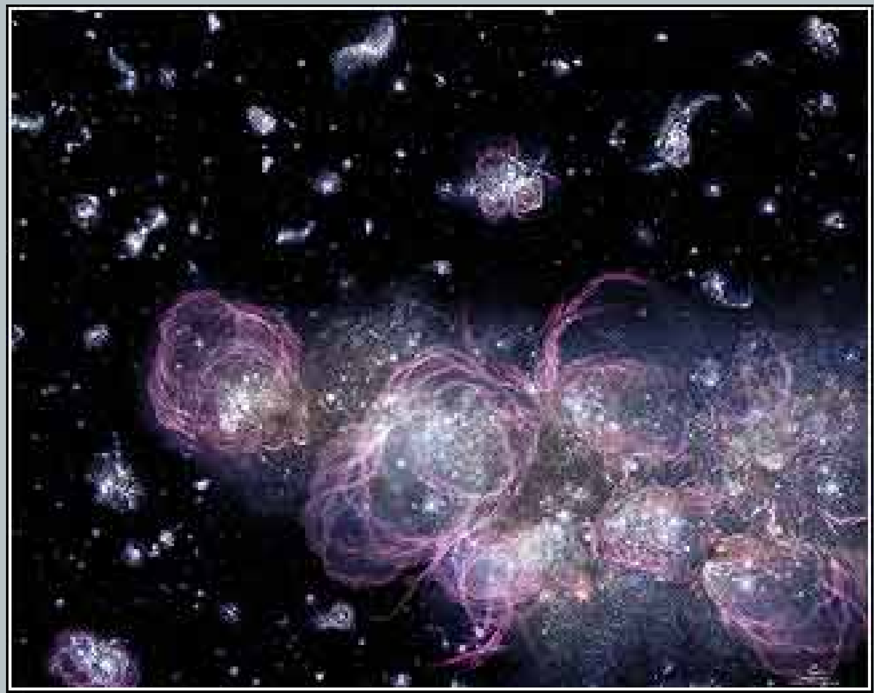
2002

Stellar 'Fireworks Finale' Came First in the Young Universe



Artist's Concept

The deepest views of the cosmos from the Hubble Space Telescope yield clues that the very first stars may have burst into the universe as brilliantly and spectacularly as a fireworks finale. Except in this case, the finale came first, long before Earth, the Sun and the Milky Way Galaxy formed. Studies of Hubble's deepest views of the heavens lead to the preliminary conclusion that the universe made a significant portion of its stars in a torrential firestorm of star birth, which abruptly lit up the pitch-dark heavens just a few hundred million years after the "big bang," the tremendous explosion that created the cosmos. Though stars continue to be born today in galaxies, the star birth rate could be a trickle compared to the predicted gusher of stars in those opulent early years.

You may wish to find out the answers to questions such as these:

- How did astronomers reach this conclusion?

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TOP STORY 2001

Blast from the Past: Farthest Supernova Ever Seen Sheds Light on Dark Universe

VIDEO

Artist's Concept

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Gazing to the far reaches of space and time, NASA's Hubble Space Telescope identified the farthest stellar explosion ever seen, a supernova that erupted 10 billion years ago. By examining the glow from this dying star, astronomers have amassed more evidence that a mysterious, repulsive force is at work in the cosmos, making galaxies rush ever faster away from each other.

The Expanding Universe

GO

Astro Files

CHASING THE LIGHT FROM AN ANCIENT SUPERNOVA: AN ASTRONOMER'S ADVENTURE

GO

What does it mean?

Q: Why do astronomers consider this discovery so important?

A: This faraway supernova provides convincing evidence that the expansion of the cosmos is actually accelerating. In 1998 information from a passel of other distant supernovas hinted at an increasing expansion rate. Some astronomers, however, had proposed alternative theories to explain why the universe's expansion is accelerating. This discovery refutes those theories.

Q: What is the mysterious, repulsive force?

A: This invisible force, also called "dark energy," comprises the bulk of the cosmos. Albert Einstein originally suggested its existence about 80 years ago. Even today astronomers and physicists are still debating the nature of this mysterious force. Many scientists do, however, think this force is responsible for prying galaxies apart at an accelerating rate. The rapidly widening gaps between galaxies mean that the universe is expanding at a faster rate than in the past. Galaxies have been migrating apart since the Big Bang 15 billion years ago.

Q: What is a supernova, and why is it an important tool in gauging the universe's behavior?

A: A supernova is the explosive death of a star, which unleashes a burst of light through the cosmos. These violent deaths occur once every 100 years in a typical spiral galaxy like our Milky Way. Some astronomers call some types of supernovas nature's "60-watt light bulbs" because they burn at nearly the same brightness. By measuring their predictable light output, astronomers can estimate how far they are from Earth. Many of them are billions of years away. But supernovas blaze so brightly that they can be seen far across space. That's why some astronomers also call them "cosmic mile markers": their light provides important information about the universe's behavior. Supernovas illuminate the dark corners of space, allowing astronomers to map the history of the universe's expansion.

NASA Televised Press Conference BLAST FROM THE PAST GO

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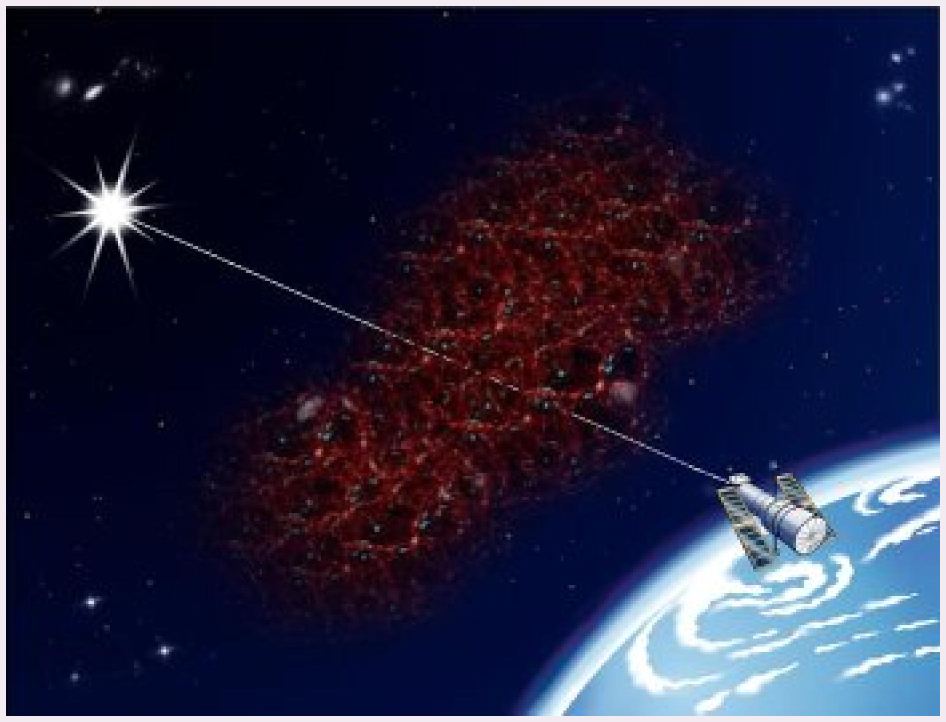
Lost and Found: Hubble Finds Much of the Universe's Missing Hydrogen



Artist's Concept

For the past decade astronomers have looked for vast quantities of hydrogen that were cooked up in the Big Bang but somehow managed to disappear in the empty blackness of space. Now, NASA's Hubble Space Telescope has uncovered this long-sought missing hydrogen. This gas accounts for nearly half of the "normal" matter in the universe -- the rest is locked up in galaxies. The confirmation of this missing hydrogen will shed new light on the large-scale structure of the universe. The detection also confirms fundamental models of how so much hydrogen was manufactured in the first few minutes of the universe's birth in the Big Bang.

You may wish to find out the answers to questions such as these:

- How did Hubble detect this elusive hydrogen?
- How did the hydrogen heat up?
- How was the oxygen created?

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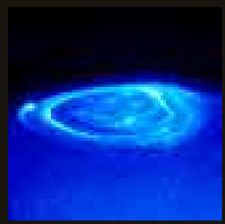
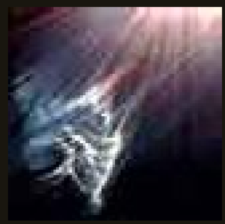


Dec 14, 2000 Satellite Footprints Seen in Jupiter Aurora



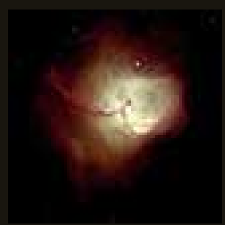
Dec 6, 2000 Ghostly Reflections in the Pleiades

Nov 30, 2000 Hubble Captures an Extraordinary and Powerful Active Galaxy

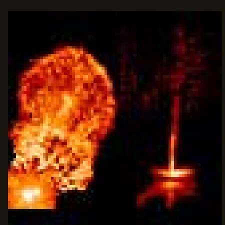
Nov 9, 2000 Hubble Sees Bare Neutron Star Streaking Across Space

Nov 2, 2000 A Bird's Eye View of a Galaxy Collision

Oct 31, 2000 Astronomers Ponder Lack of Planets in Globular Cluster



Oct 5, 2000 Hubble Peeks into a Stellar Nursery in a Nearby Galaxy



Sep 21, 2000 Movies from Hubble Show the Changing Faces of Infant Stars

Sep 14, 2000 Centaur's Bright Surface Spot Could be Crater of Fresh Ice

Sep 7, 2000 IC 418: The "Spirograph" Nebula

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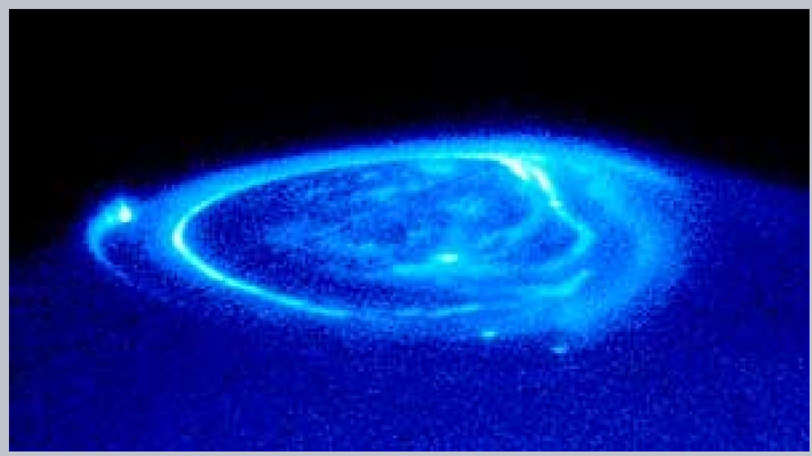
Satellite Footprints Seen in Jupiter Aurora



In this Hubble telescope picture, a curtain of glowing gas is wrapped around Jupiter's north pole like a lasso. This curtain of light, called an aurora, is produced when high-energy electrons race along the planet's magnetic field and into the upper atmosphere where they excite atmospheric gases, causing them to glow. The aurora resembles the same phenomenon that crowns Earth's polar regions. But this Hubble image, taken in ultraviolet light, also shows the glowing "footprints" of three of Jupiter's largest moons: Io, Ganymede, and Europa. Over the next two months, Jupiter's aurora will be scrutinized by two observatories: the Hubble telescope and the Cassini spacecraft, which will fly by the planet on its voyage to Saturn.

You may wish to find out the answers to questions such as these:

- Where are the footprints of Jupiter's moons, and what causes them?

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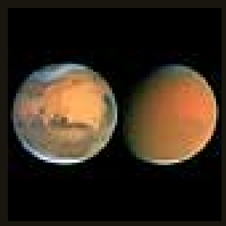
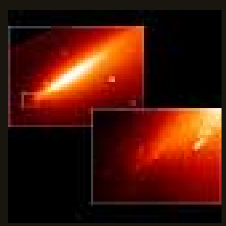


Oct 11, 2001 Scientists Track "Perfect Storm" on Mars

Jul 5, 2001 Hubble Captures Best View of Mars Ever Obtained From Earth

Jun 7, 2001 A Change of Seasons on Saturn

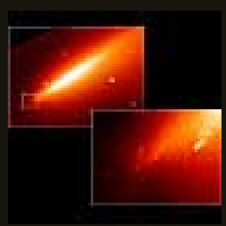


May 17, 2001 Astronomers Puzzled over Comet LINEAR's Missing Pieces

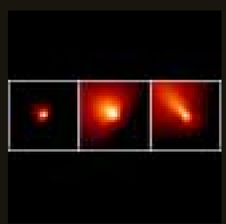
2000

Dec 14, 2000 Satellite Footprints Seen in Jupiter Aurora

Sep 14, 2000 Centaur's Bright Surface Spot Could be Crater of Fresh Ice



Aug 7, 2000 Hubble Discovers Missing Pieces of Comet Linear



Jul 28, 2000 Hubble Sees Comet Linear Blow its Top

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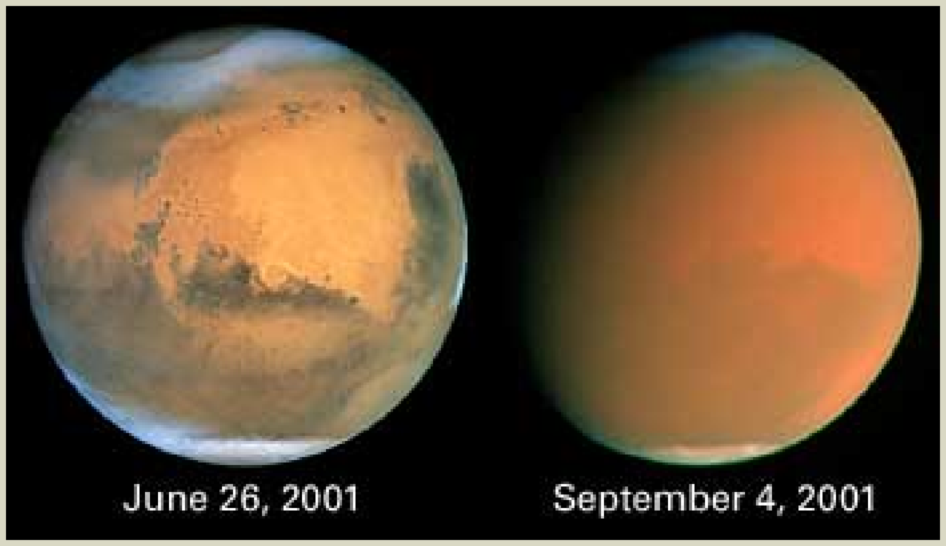
Aug 5, 1999 [Hubble Views Ancient Storm in the Atmosphere of Jupiter]

Jun 30, 1999 [A Closer Encounter with Mars]

2001

Scientists Track "Perfect Storm" on Mars



A pair of eagle-eyed NASA spacecraft — the Mars Global Surveyor (MGS) and Hubble Space Telescope — are giving amazed astronomers a ringside seat to the biggest global dust storm seen on Mars in several decades. The Martian dust storm, larger by far than any seen on Earth, has raised a cloud of dust that has engulfed the entire planet for several months.

You may wish to find out the answers to questions such as these:

- What does the Mars Global Surveyor optical camera reveal about this storm?
- What does the Mars Global Surveyor thermal detector reveal?

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Hubble Captures Best View of Mars Ever Obtained From Earth

Frosty white water ice clouds and swirling orange dust storms above a vivid rusty landscape reveal Mars as a dynamic planet in this sharpest view ever obtained by an Earth-based telescope. The Earth-orbiting Hubble telescope snapped this picture on June 26, when Mars was approximately 43 million miles (68 million km) from Earth -- its closest approach to our planet since 1988. Hubble can see details as small as 10 miles (16 km) across. Especially striking is the large amount of seasonal dust storm activity seen in this image. One large storm system is churning high above the northern polar cap [top of image], and a smaller dust storm cloud can be seen nearby. Another large duststorm is spilling out of the giant Hellas impact basin in the Southern Hemisphere [lower right].

You may wish to find out the answers to questions such as these:

- Why does this picture represent Mars' closest approach to Earth in 13 years?

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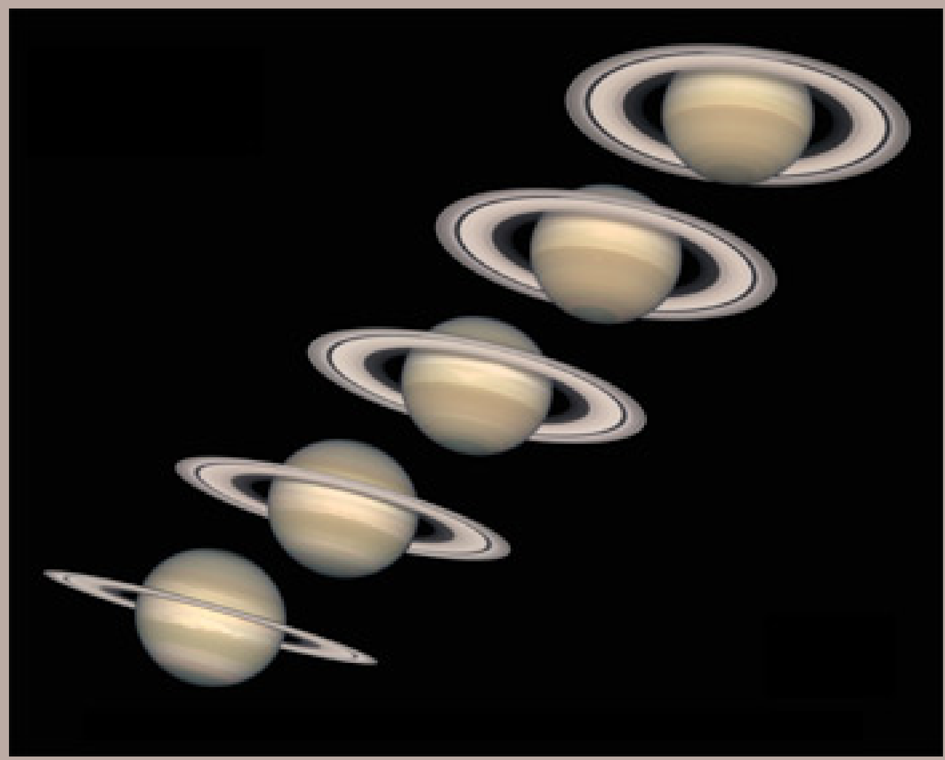
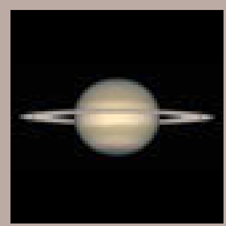
A Change of Seasons on Saturn



Looming like a giant flying saucer in our outer solar system, Saturn puts on a show as the planet and its magnificent ring system nod majestically over the course of its 29-year journey around the Sun. These Hubble telescope images, captured from 1996 to 2000, show Saturn's rings open up from just past edge-on to nearly fully open as it moves around the Sun.

You may wish to find out the answers to questions such as these:



- Why are Saturn's rings at a different angle in each image?
- How thick are Saturn's rings?

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Astronomers Puzzled over Comet LINEAR's Missing Pieces

Hubble Space Telescope NEWS

Astronomers analyzing debris from a comet that broke apart last summer spied pieces as small as smoke-sized particles and as large as football-field-sized fragments. But it's the material they didn't see that has aroused their curiosity. Tracking the doomed comet, named LINEAR, the Hubble telescope and the Very Large Telescope in Chile found tiny particles that made up the 62,000-mile-long dust tail and 16 large fragments, some as wide as 330 feet. But the telescopes didn't detect any intermediate-sized pieces. If they exist, then the fundamental building blocks that comprised LINEAR's nucleus may be somewhat smaller than current theories suggest..

You may wish to find out the answers to questions such as these:

- How do astronomers know that pieces are missing?
- Where are the missing pieces?

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Centaur's Bright Surface Spot Could be Crater of Fresh Ice

Artist's Concept

The unexpectedly varied surface of a wayward piece of space debris has given astronomers new insights into the characteristics and behavior of a ghostly population of faintly observed comet-like bodies that lie just beyond Pluto's orbit. While observing an object called 8405 Asbolus, a 48-mile-wide (80-kilometer-wide) chunk of ice and dust that lies between Saturn and Uranus, astronomers using the Hubble telescope were surprised to find that one side of the object looks like it has a fresh crater less than 10 million years old, exposing underlying ice that is apparently unlike any yet seen. This shows that these mysterious objects, called Centaurs, do not have a simple homogenous surface. Hubble didn't directly see the crater - the object is too small and far away - but a measure of its surface composition with its near-infrared camera shows a complex chemistry.

You may wish to find out the answers to questions such as these:

- What is the composition of the ice?
- Have astronomers observed other Centaurs?

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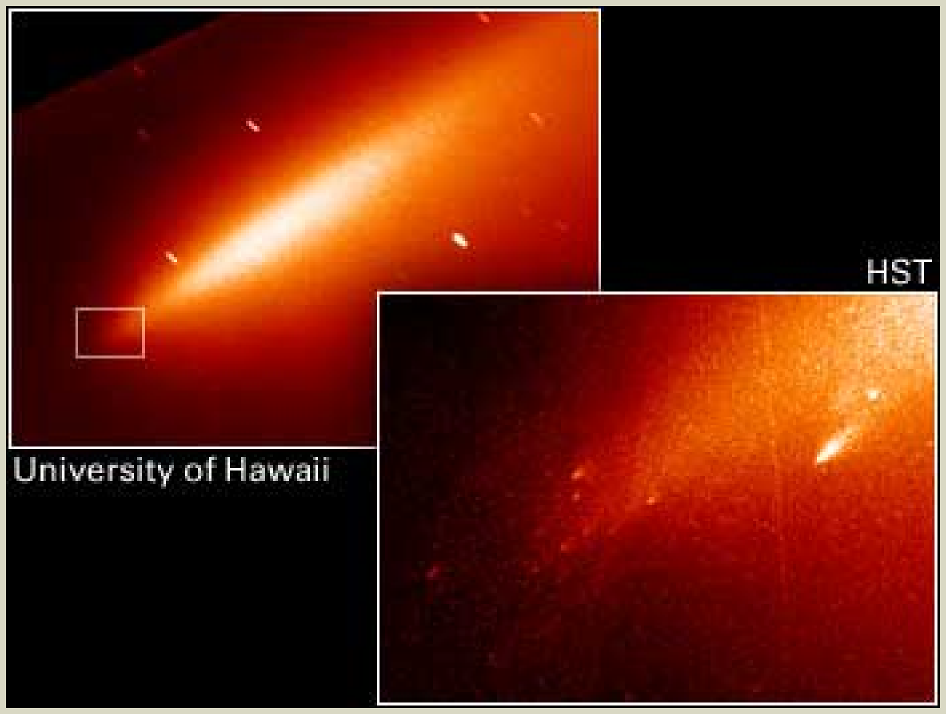
Hubble Discovers Missing Pieces of Comet Linear



To the surprise and delight of astronomers, the Hubble telescope discovered a small armada of "mini-comets" left behind from what some scientists had prematurely thought was a total disintegration of the explosive Comet LINEAR. In one observation, Hubble's powerful vision has settled the fate of the mysteriously vanished solid nucleus of Comet LINEAR, which was reported "missing in action" following its passage around the Sun on July 26. Though comets have been known to break apart and vanish before, for the first time astronomers are getting a close-up view of the dismantling of a comet's nucleus due to warming by the Sun. The results support the popular theory that comet nuclei are really made up of a cluster of smaller icy bodies called "cometesimals."

You may wish to find out the answers to questions such as these:

- What do the pictures show?
- What are comets?
- Why did the nucleus break apart?

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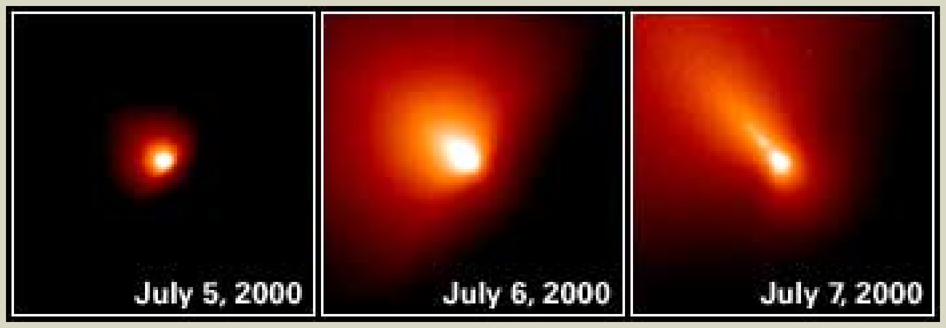
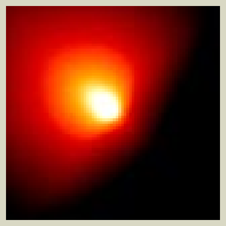
Hubble Sees Comet Linear Blow its Top



Lackluster comet LINEAR (C/1999 S4) unexpectedly threw astronomers a curve. Using the Hubble telescope, researchers were surprised to catch the icy comet in a brief, violent outburst when it blew off a piece of its crust, like a cork popping off a champagne bottle. The eruption, the comet's equivalent of a volcanic explosion (though temperatures are far below freezing, at about minus 100 degrees Fahrenheit in the icy regions of the nucleus or core), spewed a great deal of dust into space. This mist of dust reflected sunlight, dramatically increasing the comet's brightness over several hours. Hubble's sharp vision recorded the entire event and even snapped a picture of the chunk of material jettisoned from the nucleus and floating away along the comet's tail.

You may wish to find out the answers to questions such as these:

- What do the pictures show?
- What caused the eruption?



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1999

Hubble Views Ancient Storm in the Atmosphere of Jupiter

When 17th-century astronomers first turned their telescopes to Jupiter, they noted a conspicuous reddish spot on the giant planet. This Great Red Spot is still present in Jupiter's atmosphere, more than 300 years later. It is now known that it is a vast storm, spinning like a cyclone. Unlike a low-pressure hurricane in the Caribbean Sea, however, the Red Spot rotates in a counterclockwise direction in the Southern Hemisphere, showing that it is a high-pressure system. Winds inside this Jovian storm reach speeds of about 270 mph.

The Red Spot is the largest known storm in the solar system. With a diameter of 15,400 miles, it is almost twice the size of the entire Earth and one-sixth the diameter of Jupiter itself. However, the Red Spot does change its shape, size, and color, sometimes dramatically. Such changes are demonstrated in these Hubble telescope pictures.

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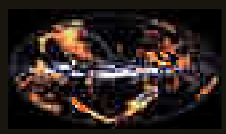
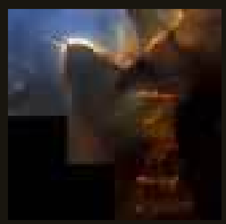
Dec 2, 1999 Hubble Telescope Reveals Swarm of Glittering Stars in Nearby Galaxy



Nov 24, 1999 A Puzzle of Galactic Evolution is Solved: Massive Gas Clouds Seed the Galaxy with the Stuff of Stars

Nov 22, 1999 Multiple Galaxy Collisions Surprise Hubble Astronomers

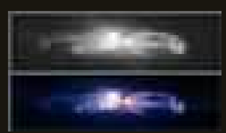


Nov 9, 1999 The Trifid Nebula: Stella Sibling Rivalry

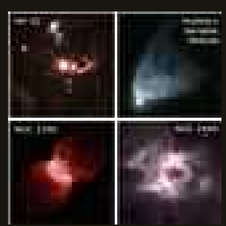
Nov 4, 1999 A Grazing Encounter between Two Spiral Galaxies

Oct 27, 1999 Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole

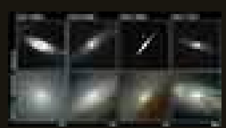
Oct 26, 1999 Hubble Identifies Source of Ultraviolet Light in an Old Galaxy



Oct 19, 1999 The "Rotten Egg" Nebula: A Planetary Nebula in the Making



Oct 7, 1999 Hubble Heritage Project's First Anniversary



Oct 6, 1999 Starry Bulges Yield Secrets to Galaxy Growth

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Hubble Telescope Reveals Swarm of Glittering Stars in Nearby Galaxy

Peering at a small area within the Large Magellanic Cloud (LMC), the Hubble telescope has provided the deepest color picture ever obtained in this satellite galaxy of the Milky Way. More than 10,000 stars can be seen in this photo, covering a region about 130 light-years wide. The LMC is a small companion galaxy of the Milky Way, visible only from Earth's southern hemisphere. It attracts the attention of modern-day astronomers because, at a distance of only 168,000 light-years, it is one of the nearest galaxies.

You may wish to find out the answers to questions such as these:

- What does Hubble see?

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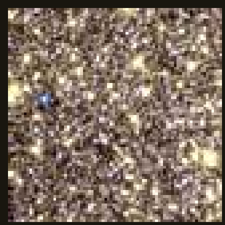
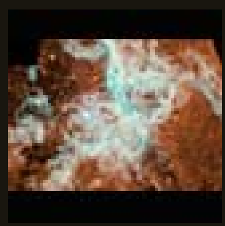
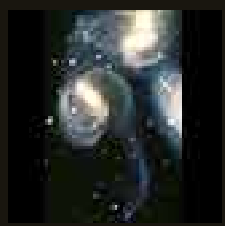
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822



Oct 4, 2001 Peering into the Core of a Globular Cluster

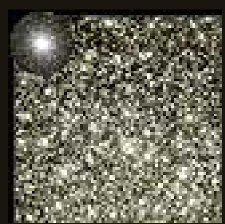


Jul 26, 2001 Hubble's Panoramic Portrait of a Vast Star-forming Region

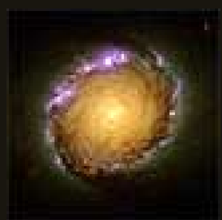


Jul 19, 2001 Star Clusters Born in the Wreckage of Cosmic Collisions

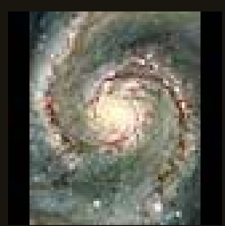
Jul 10, 2001 Hubble Snaps Picture of Remarkable Double Cluster



Jun 27, 2001 Hint of Planet-Sized Drifters Bewilders Hubble Scientists



May 31, 2001 Hubble Unveils a Galaxy in Living Color



Apr 5, 2001 Hubble Reveals the Heart of the Whirlpool Galaxy

Mar 28, 2001 Massive Infant Stars Rock their Cradle

Mar 7, 2001

Hubble Spies Huge Clusters of Stars Formed by Ancient Encounter

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2001

A Giant Star Factory in Neighboring Galaxy NGC 6822

Resembling curling flames from a campfire, this magnificent nebula in a neighboring galaxy is giving astronomers new insight into the fierce birth of stars, which may have been more a typical occurrence in the early universe. The glowing gas cloud, called Hubble-V, has a diameter of about 200 light-years. A faint tail of gas trailing off the top of this Hubble Space Telescope image sits opposite a dense cluster of bright stars at the bottom of the irregularly shaped nebula.

You may wish to find out the answers to questions such as these:

- What does the picture show?

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Peering into the Core of a Globular Cluster

Astronomers have used NASA's Hubble Space Telescope to peer into the center of a dense swarm of stars called Omega Centauri. Located some 17,000 light-years from Earth, Omega Centauri is a massive globular star cluster, containing several million stars swirling in locked orbits around a common center of gravity. The stars are packed so densely in the cluster's core that it is difficult for ground-based telescopes to make out individual stars. Hubble's high resolution is able to pick up where ground-based telescopes leave off, capturing distinct points of light from stars at the very center of the cluster.

You may wish to find out the answers to questions such as these:

- How many stars are in this Hubble image?
- Do the stars in globular clusters ever collide?

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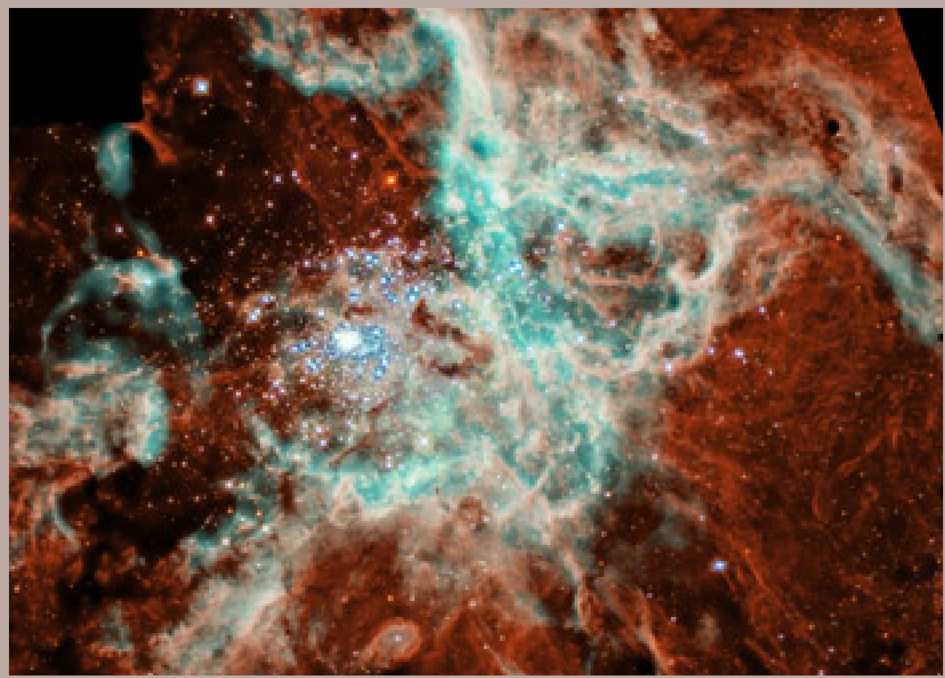
Hubble's Panoramic Portrait of a Vast Star-forming Region



NASA's Hubble Space Telescope has snapped a panoramic portrait of a vast, sculpted landscape of gas and dust where thousands of stars are being born. This fertile star-forming region, called the 30 Doradus Nebula, has a sparkling stellar centerpiece: the most spectacular cluster of massive stars in our cosmic neighborhood of about 25 galaxies. The mosaic picture shows that ultraviolet radiation and high-speed material unleashed by the stars in the cluster, called R136 [the large blue blob left of center], are weaving a tapestry of creation and destruction, triggering the collapse of looming gas and dust clouds and forming pillar-like structures that are incubators for nascent stars.

You may wish to find out the answers to questions such as these:

- Where is the new generation of stars?
- How did the pillar-like structures form?
- How massive are the stars in the R136 cluster?

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2001

Star Clusters Born in the Wreckage of Cosmic Collisions

In the beginning of the 1946 holiday film classic "It's a Wonderful Life," angelic figures take on the form of a famous group of compact galaxies known as Stephan's Quintet. In reality, these galaxies aren't so heavenly. Pictures from the Hubble telescope show that Stephan's Quintet has been doing some devilish things. At least two of the galaxies have been involved in high-speed, hit-and-run accidents, which have ripped stars and gas from neighboring galaxies and tossed them into space. But the galactic carnage also has spawned new life. Arising from the wreckage are more than 100 star clusters and several dwarf galaxies. The young clusters, each harboring up to millions of stars, are shown clearly for the first time in pictures taken by Hubble's Wide Field and Planetary Camera 2.

You may wish to find out the answers to questions such as these:

- Where are the star clusters and dwarf galaxies?
- How old are the star clusters?
- Why do astronomers study galactic encounters?

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Hubble Snaps Picture of Remarkable Double Cluster

These two dazzling clusters of stars, called NGC 1850, are found in one of our neighboring galaxies, the Large Magellanic Cloud. The photo's centerpiece is a young, "globular-like" star cluster -- a type of object unknown in our own Milky Way Galaxy. The smaller second cluster is below and to the right of the main cluster. The stars are surrounded by a filigree pattern of diffuse gas [left], which scientists believe was created by the explosion of massive stars.

You may wish to find out the answers to questions such as these:

- What are globular star clusters?

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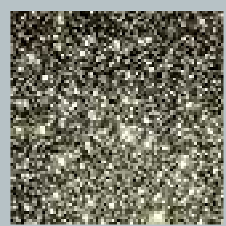
Hint of Planet-Sized Drifters Bewilders Hubble Scientists

Piercing the heart of a globular star cluster, NASA's Hubble Space Telescope uncovered tantalizing clues to what could be a strange and unexpected population of wandering, planet-sized objects. The orbiting observatory detected these bodies in the globular cluster M22 by the way their gravity bends the light from background stars, a phenomenon called microlensing. These microlensing events were unusually brief, indicating that the mass of the the intervening objects could be as little as 80 times that of Earth. Bodies this small have never been detected by microlensing observations.

You may wish to find out the answers to questions such as these:



- What are these "mystery objects"?
- How does microlensing work?

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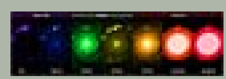
Hubble Unveils a Galaxy in Living Color

In this view of the center of the magnificent barred spiral galaxy NGC 1512, the Hubble telescope reveals a stunning 2,400 light-year-wide circle of infant star clusters. Astronomers generally believe that the giant bar, which is too faint to be seen in this image, funnels the gas to the inner ring, where massive stars are formed within numerous star clusters. Located 30 million light-years away, NGC 1512 is a neighbor of our Milky Way galaxy.

You may wish to find out the answers to questions such as these:



- What is a barred spiral galaxy?
- Why is this picture so colorful?

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Hubble Reveals the Heart of the Whirlpool Galaxy

New pictures from the Hubble telescope are giving astronomers a detailed view of the Whirlpool galaxy's spiral arms and dust clouds, which are the birth sites of massive and luminous stars. This galaxy, also called M51 or NGC 5194, is having a close encounter with a nearby companion galaxy, NGC 5195, just off the upper edge of this image. The companion's gravitational influence is triggering star formation in the Whirlpool, as seen by the numerous clusters of bright, young stars [highlighted in red].

You may wish to find out the answers to questions such as these:

- What have astronomers learned by studying this picture?

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Massive Infant Stars Rock their Cradle

Extremely intense radiation from newly born, ultra-bright stars has blown a glowing spherical bubble in the nebula N83B, also known as NGC 1748. A new Hubble telescope image has helped to decipher the complex interplay of gas and radiation of a star-forming region in the nearby galaxy, the Large Magellanic Cloud. The image graphically illustrates just how these massive stars sculpt their environment by generating powerful winds that alter the shape of the parent gaseous nebula. These processes are also seen in our Milky Way in regions like the Orion Nebula.

You may wish to find out the answers to questions such as these:

- Where are these young, hefty stars?

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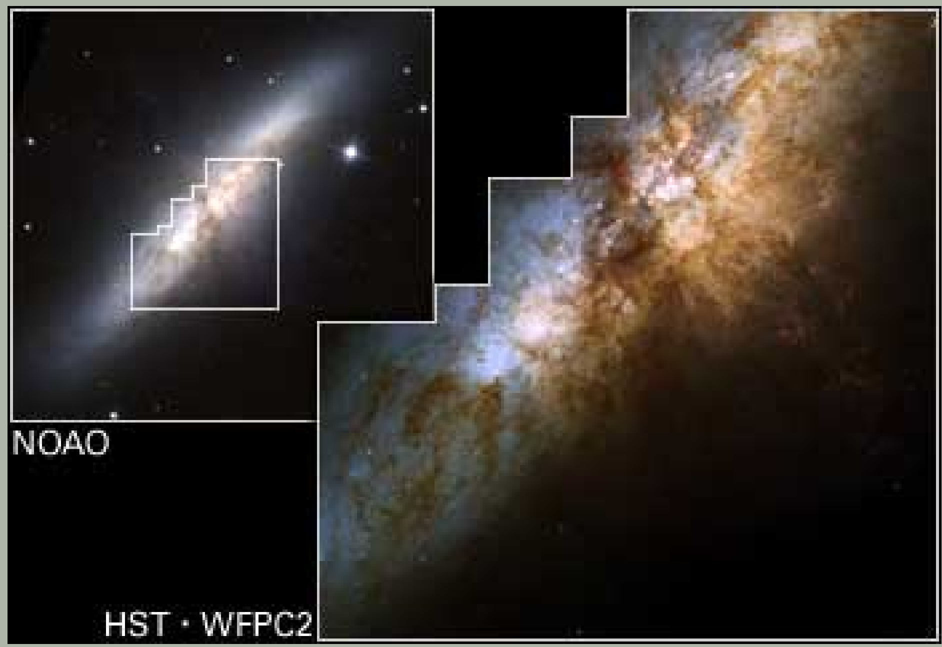
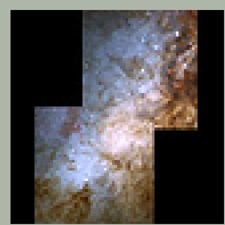
Hubble Spies Huge Clusters of Stars Formed by Ancient Encounter



Studying galactic interactions is like sifting through the forensic evidence at a crime scene. Astronomers wade through the debris of a violent encounter, collecting clues so that they can reconstruct the celestial crime to determine when it happened. Take the case of M82, a small, nearby galaxy that long ago bumped into its larger neighbor, M81. When did this violent encounter occur? New infrared and visible-light pictures from the Hubble telescope reveal for the first time important details of large clusters of stars, which arose from the interaction.

You may wish to find out the answers to questions such as these:



- What did Hubble see?
- What are these massive super star clusters?

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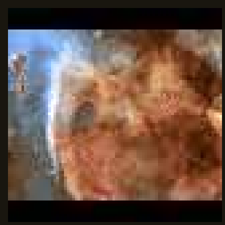
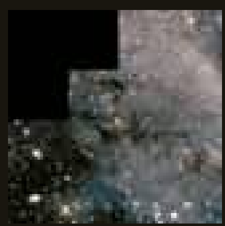
Aug 3, 2000 A Dying Star in Globular Cluster M15



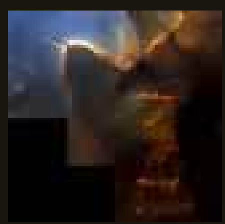
Feb 3, 2000 Light and Shadow in the Carina Nebula

Jan 6, 2000 Fireworks of Star Formation Light up a Galaxy

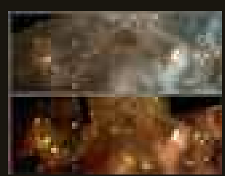
1999



Dec 2, 1999 Hubble Telescope Reveals Swarm of Glittering Stars in Nearby Galaxy

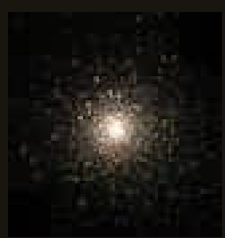


Nov 9, 1999 The Trifid Nebula: Stella Sibling Rivalry

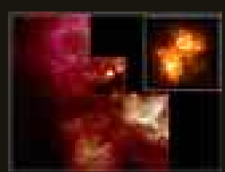


Sep 29, 1999 Hubble Captures a Grand View of the Birth of "Hefty" Stars

Sep 16, 1999 Hubble Spies Giant Star Clusters Near Galactic Center



Jul 1, 1999 Hubble Images a Swarm of Ancient Stars



Jun 10, 1999 A Butterfly-Shaped "Papillon" Nebula Yields Secrets of Massive Star Birth

Jun 1, 1999 [Hubble Snapshot Captures Life Cycle of Stars]

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A Dying Star in Globular Cluster M15

The globular cluster M15 is shown in this color image obtained with the Hubble telescope. Lying some 40,000 light-years from Earth in the constellation Pegasus, M15 is one of nearly 150 known globular clusters that form a vast halo surrounding our Milky Way galaxy. Each of these spherically shaped clusters contains hundreds of thousands of ancient stars. The stars in M15 and other globular clusters are estimated to be about 12 billion years old. They were among the first generations of stars to form in the Milky Way.

You may wish to find out the answers to questions such as these:

- What kinds of stars are visible in the image?

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Light and Shadow in the Carina Nebula

When 19th century astronomer Sir John Herschel spied a swirling cloud of gas with a hole punched through it, he dubbed it the Keyhole Nebula. Now the Hubble telescope has taken a peek at this region, and the resulting image reveals previously unseen details of the Keyhole's mysterious, complex structure. The Keyhole is part of a larger region called the Carina Nebula (NGC 3372), about 8,000 light-years from Earth.

You may wish to find out the answers to questions such as these:

- Where is the "keyhole" in the Hubble picture?

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Fireworks of Star Formation Light up a Galaxy

Pictures obtained with the Hubble telescope reveal episodes of star formation that are occurring across the face of the nearby galaxy NGC 4214. Located some 13 million light-years from Earth, NGC 4214 is forming clusters of new stars from its interstellar gas and dust. In the Hubble image, we can see a sequence of steps in the formation and evolution of stars and star clusters. Clouds of glowing gas surrounding bright stellar clusters dominate the picture.

You may wish to find out the answers to questions such as these:

- Where are the young star clusters?
- What is the blue and white blob in the center of the galaxy?

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The Trifid Nebula: Stella Sibling Rivalry

This Hubble telescope image of the Trifid Nebula reveals a stellar nursery being torn apart by radiation from a nearby, massive star. The picture also provides a peek at embryonic stars forming within an ill-fated cloud of dust and gas, which is destined to be eaten away by the glare from the massive neighbor. This stellar activity is a beautiful example of how the life cycles of stars like our Sun are intimately connected with their more powerful siblings.

You may wish to find out the answers to questions such as these:

- What's the dark, mountainous object that dominates this picture?
- Where is the massive star?
- Where is this stellar nursery?

Ground (Palomar) image with location of WFPC2 field

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Hubble Captures a Grand View of the Birth of "Hefty" Stars

Pictures taken in infrared and visible light by the Hubble telescope recount a vivid story of the turbulent birthing process of massive stars.

The images show that powerful radiation and high-speed material unleashed by "hefty" adult stars residing in the hub of the 30 Doradus Nebula are triggering a new burst of star birth in the surrounding suburbs. Like their adult relatives, the fledgling stars are creating all sorts of havoc in their environment. Nascent stars embedded in columns of gas and dust, for example, are blowing away the tops of their nurseries, like a volcano blasting material into the sky. Jets of material streaming from another developing star are slamming into surrounding dust and gas in opposite directions, causing it to glow in moving patterns. These views [the top panel taken in visible light, the bottom in infrared] represent part of the highly active region of star birth.

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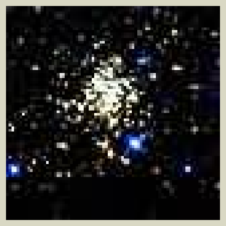
Hubble Spies Giant Star Clusters Near Galactic Center

Penetrating 25,000 light-years of obscuring dust and myriad stars, the Hubble telescope has provided the clearest view yet of a pair of the largest young clusters of stars inside our Milky Way Galaxy. The clusters reside less than 100 light-years from the very center of our galaxy.



Having an equivalent mass greater than 10,000 stars like our Sun, the monster clusters are 10 times larger than typical young star clusters scattered throughout our Milky Way. Both clusters are destined to be ripped apart in just a few million years by gravitational tidal forces in the galaxy's core. But in the brief time they are around, they shine more brightly than any other star cluster in the galaxy. The Arches Cluster is on the left; the Quintuplet Cluster on the right.

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Hubble Images a Swarm of Ancient Stars

This stellar swarm is M80 (NGC 6093), one of the densest of the 147 known globular star clusters in the Milky Way Galaxy. Located about 28,000 light-years from Earth, M80 contains hundreds of thousands of stars, all held together by their mutual gravitational attraction.

Globular clusters are particularly useful for studying stellar evolution, since all of the stars in the cluster have the same age (about 15 billion years), but cover a range of stellar masses. Every star visible in this image is either more highly evolved than, or in a few rare cases more massive than, our own Sun. Especially obvious are the bright red giants, which are stars similar to the Sun in mass that are nearing the ends of their lives.

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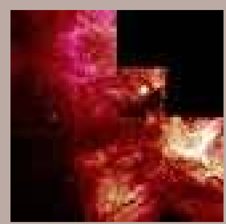
A Butterfly-Shaped "Papillon" Nebula Yields Secrets of Massive Star Birth

Here is a Hubble telescope view of a turbulent cauldron of star birth called N159, which is taking place 170,000 light-years away in our satellite galaxy, the Large Magellanic Cloud. Torrential stellar winds from hot, newborn, massive stars within the nebula sculpt ridges, arcs, and filaments in the vast cloud, which is over 150 light-years across.

A rare type of compact, illuminated "blob" is resolved for the first time to be a butterfly-shaped or "Papillon" (French for "butterfly") Nebula, buried in the center of the maelstrom of glowing gases and dark dust. The unprecedented details of the structure of the Papillon, itself less than 2 light-years in size, are seen in the inset picture.



FULL WFPC2 image: A "true color" composite image of the LMC HII region N159 as seen by WFPC2, based on images taken with filters Halpha, (red), [OIII], (green), and Hbeta, (blue). The Papillon nebula (N159-5) is the high excitation compact object lying in the center of the smaller PC frame.

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Hubble Snapshot Captures Life Cycle of Stars

In this stunning picture of the giant galactic nebula NGC 3603, the Hubble telescope's crisp resolution captures various stages of the life cycle of stars in one single view.

This picture nicely illustrates the entire stellar life cycle of stars, starting with the Bok globules and giant gaseous pillars (evidence of embryonic stars), followed by circumstellar disks around young stars, and progressing to aging, massive stars in a young starburst cluster. The blue super-giant with its ring and bipolar outflow [upper left of center] marks the end of the life cycle.

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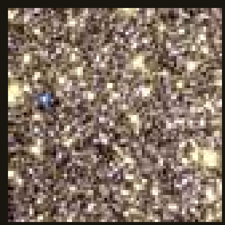
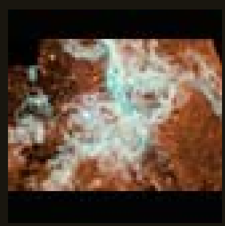
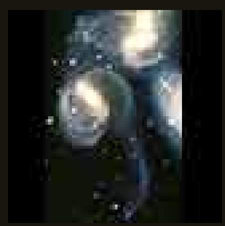
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822



Oct 4, 2001 Peering into the Core of a Globular Cluster

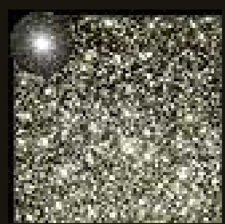


Jul 26, 2001 Hubble's Panoramic Portrait of a Vast Star-forming Region



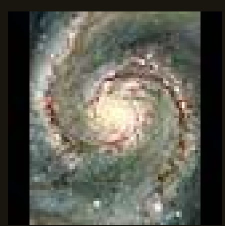
Jul 19, 2001 Star Clusters Born in the Wreckage of Cosmic Collisions

Jul 10, 2001 Hubble Snaps Picture of Remarkable Double Cluster

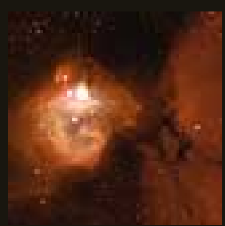


Jun 27, 2001 Hint of Planet-Sized Drifters Bewilders Hubble Scientists

May 31, 2001 Hubble Unveils a Galaxy in Living Color



Apr 5, 2001 Hubble Reveals the Heart of the Whirlpool Galaxy



Mar 28, 2001 Massive Infant Stars Rock their Cradle

Mar 7, 2001 [Hubble Spies Huge Clusters of Stars Formed by Ancient Encounter]

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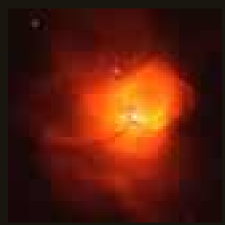
Apr 1, 1999 Multiple Generations of Stars in the Tarantula Nebula

Feb 18, 1999 Hubble Finds More Evidence of Galactic Cannibalism

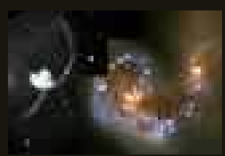
1998



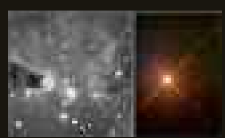
Jul 23, 1998 Nearby Massive Star Cluster Yields Insights into Early Universe

Mar 22, 1998 Hubble Captures the Heart of Star Birth

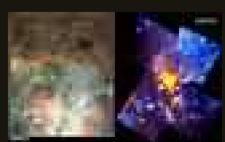
1997



Oct 21, 1997 Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions

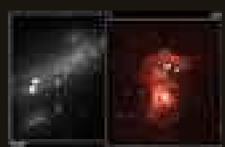


Jun 9, 1997 Hubble Snaps "Family Portrait"

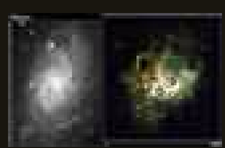


May 12, 1997 Hubble Captures the Heart of the Orion Nebula

1996



Oct 11, 1996 Bright Star Birth Region in a Dim Galaxy



Aug 7, 1996 Giant Star Birth Region in Neighboring Galaxy

Apr 24, 1996 [Swirling Galaxy Parents Generations of Stars in Its Center]

Matches 21-30 of 36 shown

Multiple Generations of Stars in the Tarantula Nebula

In the most active starburst region in the local universe resides a cluster of brilliant, massive stars, known to astronomers as Hodge 301.

Hodge 301, seen in the lower right hand corner of this image, lives inside the Tarantula Nebula, which resides in our galactic neighbor, the Large Magellanic Cloud. Many of the stars in Hodge 301 are so old that they have exploded as supernovae. These exploded stars are blasting material into the surrounding region at speeds of almost 200 miles per second. The high-speed matter is plowing into the surrounding Tarantula Nebula, shocking and compressing the gas into a multitude of sheets and filaments, seen in the upper left portion of the picture.

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Hubble Finds More Evidence of Galactic Cannibalism

This beautiful, eerie silhouette of dark dust clouds against the glowing nucleus of the elliptical galaxy NGC 1316 may represent the aftermath of a 100-million-year-old cosmic collision between the elliptical and a smaller companion galaxy.

Hubble's superb resolution has enabled the identification of a class of small and very faint star clusters in this galaxy's central region. Many of these clusters are so small that they are barely held together by the mutual gravity of their constituent stars. Though such clusters are common in spiral galaxies like our Milky Way, they have rarely been seen in elliptical galaxies. The astronomers conclude that these clusters are among the last visible remains of a galaxy that was cannibalized by NGC 1316.

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Nearby Massive Star Cluster Yields Insights into Early Universe

The Hubble telescope has taken a "family portrait" of young, ultra-bright stars nested in their embryonic cloud of glowing gases. The celestial maternity ward, called N81, is located 200,000 light-years from Earth in the Small Magellanic Cloud, a small, irregular satellite galaxy of our Milky Way. These are probably the youngest massive stars ever seen in the magellanic cloud.

The nebula offers a unique opportunity for a close-up glimpse of the "firestorm" accompanying the birth of extremely massive stars, each blazing with the brilliance of 300,000 suns. Such galactic fireworks were much more common billions of years ago in the early universe, when most star formation took place.

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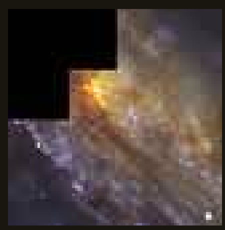
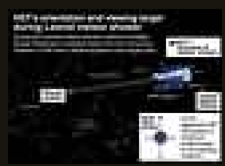


Dec 3, 1998 Behind a Dusty Veil Lies a Cradle of Star Birth

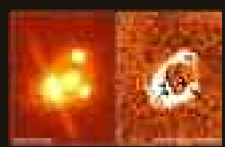
Nov 23, 1998 The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View



Nov 10, 1998 Leonid Meteor Storm Won't Deter Hubble from Space Observations

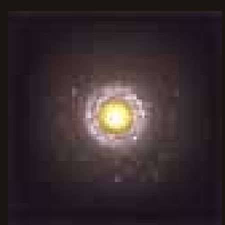
Nov 5, 1998 A Glowing Pool of Light

Nov 5, 1998 Great Balls of Fire! Hubble Sees Bright Knots Ejected From Brilliant Star



Oct 26, 1998 Quasar PG1115+080 and Gravitational Lens

Oct 22, 1998 Turtle in Space Describes New Hubble Image



Oct 21, 1998 Astronomers Unveil Colorful Hubble Photo Gallery

Oct 14, 1998 Hubble Finds Many Bright Clouds on Uranus

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Extraterrestrial Civilizations: Coming of Age in the Milky Way

If civilizations exist around other stars, they are likely to be just emerging across our galaxy right now, like an apple orchard suddenly maturing and ripening in the autumn sun. So concludes Space Telescope Science Institute theorist Mario Livio.

Livio emphasizes that his theoretical work doesn't necessarily mean extraterrestrial civilizations really do exist, but it shows they cannot be dismissed either. We would be a lonely, isolated quirk of cosmic evolution if intelligent life forms appear on a planet at some random time in the parent star's life, say theorists. Instead, Livio makes the case for a possible causal link between the Sun's lifetime and the appearance of intelligent life on earth. This link should hold true for Sun-like stars elsewhere in the universe: offering an equal opportunity for intelligent life to arise elsewhere in space.

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Magnetic Fields Weave Rings Around Stars

Artist's Concept

There are stars with planets. Stars with companion stars. Stars with pancake-shaped disks of rocky debris. But how about young, hot, hefty stars embedded in large inner tube-shaped clouds of shimmering gas? Astronomers had suspected that the thick rings are the signatures of stars with strong magnetic fields. Sometimes, the surfaces of those "magnetic stars" possess peculiar chemical compositions, namely low amounts of "heavy elements" like iron. Now a team of astronomers analyzing archival information on four stars provides convincing evidence of the link between rings and magnetic fields. The team also suggests that rings around massive stars are more common than scientists thought. The study shows that magnetic stars with normal chemical abundances can have rings, too.

You may wish to find out the answers to questions such as these:

- How does a magnetic field form a ring?

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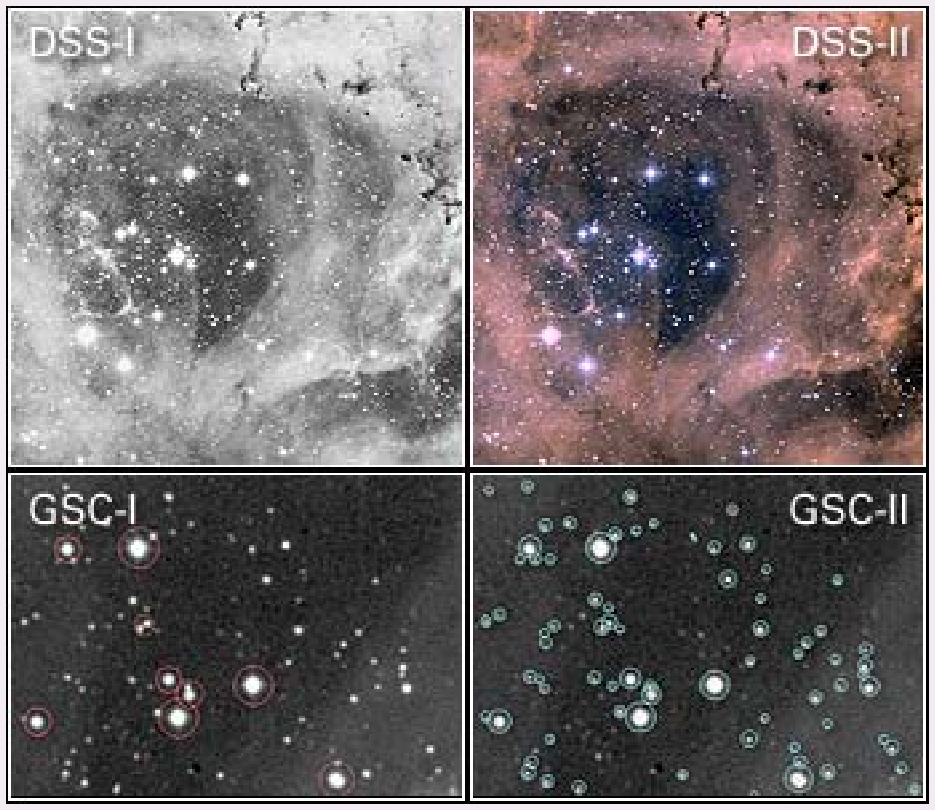
Bigger, Better Catalog Unveils Half a Billion Celestial Objects



It's a very big universe out there, and an astronomer's work is never done when it comes to simply counting and cataloging the sheer number of stars in the heavens. Completing a seven-year effort at digitizing the entire sky for a second time, astronomers at the Space Telescope Science Institute and the Osservatorio Astronomico di Torino are releasing the Guide Star Catalog II. This new version, which replaces the historic 1989 catalog, provides important information on nearly one-half billion stars — over 20 times as many as the original Guide Star Catalog.

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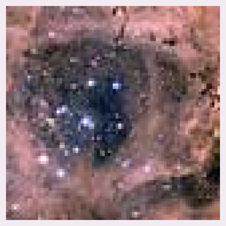

- How is this catalog useful to astronomers?

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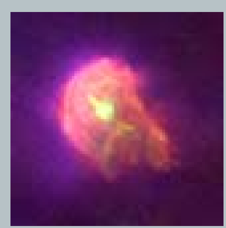
Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction

Planet formation is a hazardous process. New pictures from the Hubble telescope are giving astronomers the first direct visual evidence for the growth of planetary "building blocks" inside the dusty disks of young stars in the Orion Nebula, a giant "star factory" near Earth. But these snapshots also reveal that the disks are being "blowtorched" by a blistering flood of ultraviolet radiation from the region's brightest star, making planet formation extremely difficult.

You may wish to find out the answers to questions such as these:



- How large are these planetary building blocks?
- How do astronomers know the sizes of the building blocks?
- Can planets form in Orion?

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"X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy

The saying "X" marks the spot holds true in this Hubble telescope image. In this case, X marks the location of Hubble-X, a glowing gas cloud in one of the most active star-forming regions in galaxy NGC 6822. The galaxy lies 1.6 million light-years from Earth in the constellation Sagittarius, one of the Milky Way's closest neighbors. This hotbed of star birth is similar to the fertile regions in the Orion Nebula in our Milky Way Galaxy, but on a vastly greater scale. The intense star birth in Hubble-X occurred about 4 million years ago, a small fraction of the approximate 10-billion-year age of the universe.

You may wish to find out the answers to questions such as these:

- What does the picture reveal to astronomers?

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Ghostly Reflections in the Pleiades

This ghostly apparition is actually an interstellar cloud caught in the process of destruction by strong radiation from a nearby hot star. This haunting picture, snapped by the Hubble telescope, shows a cloud illuminated by light from the bright star Merope. Located in the Pleiades star cluster, the cloud is called IC 349 or Barnard's Merope Nebula.

You may wish to find out the answers to questions such as these:

- How did the cloud get its shape?
- Where is the bright star Merope?
- What is the cloud's fate?

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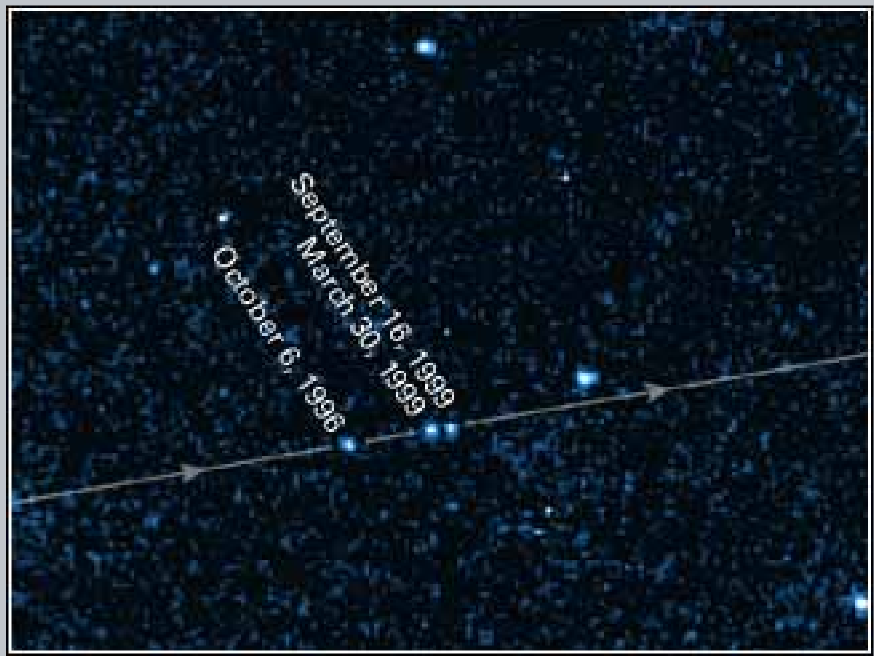
Hubble Sees Bare Neutron Star Streaking Across Space



It's as big as Manhattan Island, is 10 trillion times denser than steel, and is hurtling our way at speeds over 100 times faster than a supersonic jet. An alien spaceship? No, it's a runaway neutron star, called RX J185635-3754, forged in a stellar explosion that was visible to our ancestors in 1 million B.C. Precise observations made with the Hubble telescope confirm that the interstellar interloper is the closest neutron star ever seen. The object also doesn't have a companion star that would affect its appearance. Now located 200 light-years away in the southern constellation Corona Australis, it will swing by Earth at a safe distance of 170 light-years in about 300,000 years.

You may wish to find out the answers to questions such as these:

- Why is the neutron star's closeness to Earth and lack of a companion so important to astronomers?
- How fast is the neutron star traveling?

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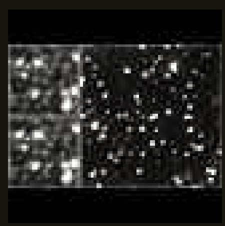
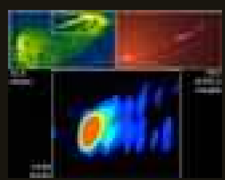
Nov 9, 2000 Hubble Sees Bare Neutron Star Streaking Across Space

Jan 24, 2000 Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass

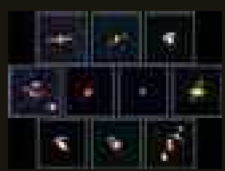


Jan 13, 2000 Lone Black Holes Discovered Adrift in the Galaxy

1999



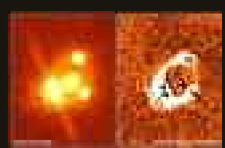
Oct 27, 1999 Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole



May 13, 1999 Natural Lenses in Space Stretch Hubble's View of the Universe

Mar 11, 1999 Hubble Views Home Galaxy of Record-Breaking Explosion

1998

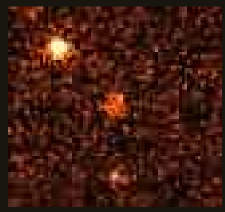


Oct 26, 1998 Quasar PG1115+080 and Gravitational Lens

May 6, 1998 Gamma-Ray Burst Found to be Most Energetic Event in Universe

1997

Sep 24, 1997 Hubble Sees a Neutron Star Alone in Space



Sep 16, 1997 [Hubble Stays on Trail of Fading Gamma-Ray Burst Fireball, Results Point to Extragalactic Origin]

Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass

The Hubble telescope reopened its "eye" on the universe following a successful December 1999 servicing mission by imaging a hefty cluster of galaxies, Abell 2218, which acts like a giant zoom lens, magnifying the light of faraway galaxies.

You may wish to find out the answers to questions such as these:

- What does the picture of Abell 2218 reveal to astronomers?

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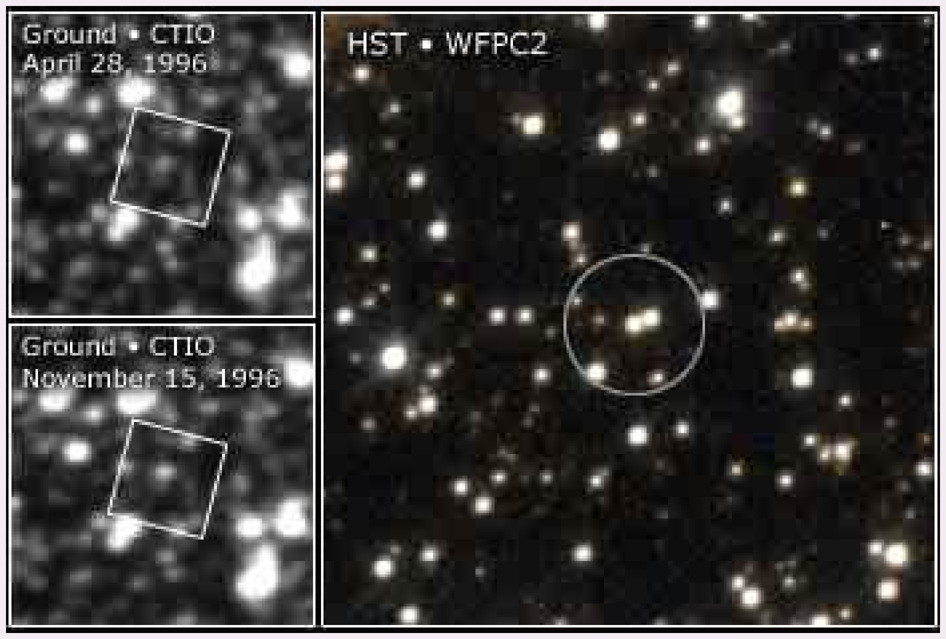
Lone Black Holes Discovered Adrift in the Galaxy



Astronomers using the Hubble telescope and ground-based observatories have discovered the first examples of isolated, stellar-mass black holes adrift among the stars in our Milky Way Galaxy. They detected two of these lonely, invisible objects indirectly by measuring how their extreme gravity bends the light of a more distant star behind them. All previously known "stellar" black holes have been found orbiting normal stars. Astronomers determined the presence of those compact powerhouses by examining their effect on their companion star. These new results suggest that black holes are common and that many massive but normal stars may end their lives as black holes instead of neutron stars, the crushed cores of massive stars that end their lives in supernova explosions. The findings also suggest that stellar-mass black holes do not require some sort of interaction in a double-star system to form but may be produced in the collapse of isolated, massive stars, as has long been proposed by stellar theorists.

You may wish to find out the answers to questions such as these:

- What are stellar-mass black holes, and how are they different from supermassive black holes?
- Explain the technique astronomers use to find the "drifting" stellar black holes.
- If astronomers can't see the objects passing in front of the stars, how do they know they're black holes?

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Sep 12, 2001 — Ancient Black Hole Speeds Through Sun's Galactic Neighborhood, Devouring Companion Star

Jan 11, 2001 — 'Death Spiral' Around a Black Hole Yields Tantalizing Evidence of an Event Horizon

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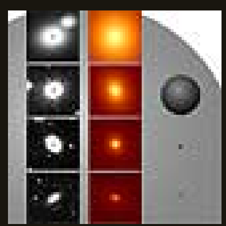
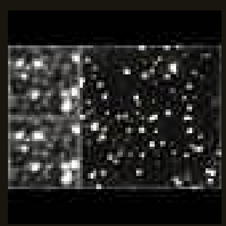
Nov 30, 2000 — Hubble Captures an Extraordinary and Powerful Active Galaxy

Jul 6, 2000 — A Cosmic Searchlight

Jun 5, 2000 — Feasting Black Hole Blows Bubbles

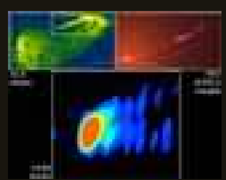


Jun 5, 2000 — Black Holes Shed Light on Galaxy Formation



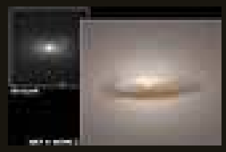
Jan 13, 2000 — Lone Black Holes Discovered Adrift in the Galaxy

1999

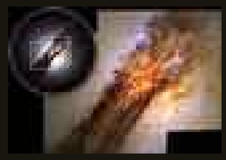


Oct 27, 1999 — Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole

1998



Jun 18, 1998 Hubble Uncovers Dust Disk around a Massive Black Hole



May 14, 1998 Hubble Provides Multiple Views of How to Feed a Black Hole

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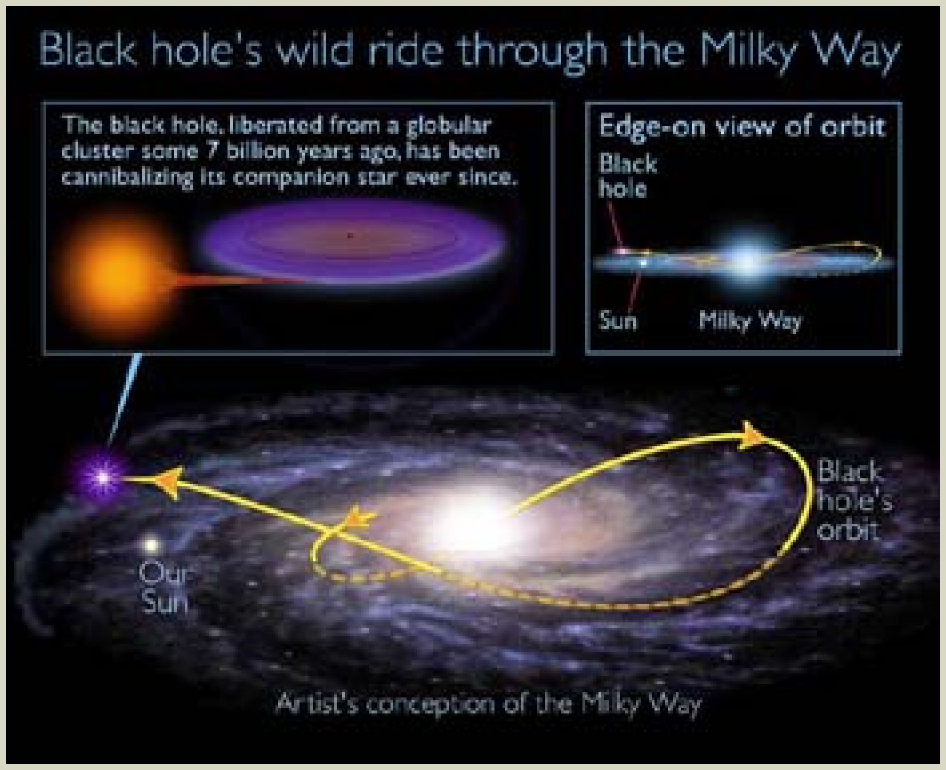
Ancient Black Hole Speeds Through Sun's Galactic Neighborhood, Devouring Companion Star



Artist's Concept

Data from the Space Telescope Science Institute's Digitized Sky Survey has played an important supporting role in helping radio and X-ray astronomers discover an ancient black hole speeding through the Sun's galactic neighborhood. The rogue black hole is devouring a small companion star as the pair travels in an eccentric orbit looping to the outer reaches of our Milky Way galaxy. It is believed that the black hole is the remnant of a massive star that lived out its brief life billions of years ago and later was gravitationally kicked from its home star cluster to wander the Galaxy with its companion.

You may wish to find out the answers to questions such as these:

- Which telescopes were used to observe this black hole?
- How did it get into such an orbit?

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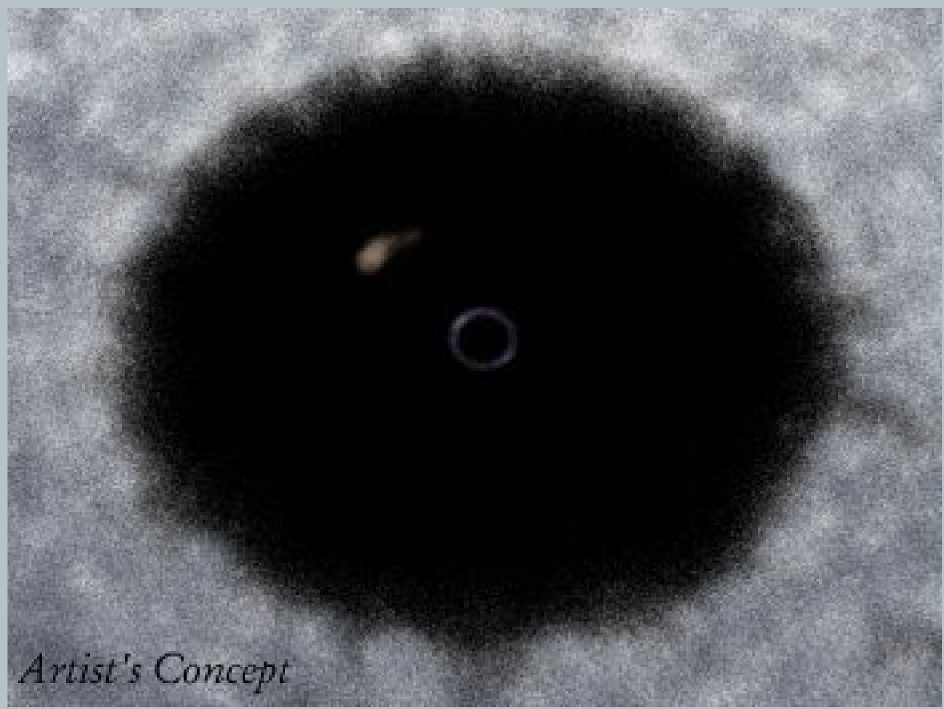
'Death Spiral' Around a Black Hole Yields Tantalizing Evidence of an Event Horizon



The Hubble telescope may have, for the first time, provided direct evidence for the existence of black holes by observing how matter disappears when it falls beyond the "event horizon," the boundary between a black hole and the outside universe. Astronomers found their evidence by watching the fading and disappearance of pulses of ultraviolet light from clumps of hot gas swirling around a massive, compact object called Cygnus XR-1. This activity suggests that the hot gas fell into a black hole.

You may wish to find out the answers to questions such as these:

- What is an event horizon, and how do astronomers know it exists?
- Did the Hubble telescope see an event horizon?

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Hubble Captures an Extraordinary and Powerful Active Galaxy

The Hubble telescope has taken a snapshot of a nearby active galaxy known as Circinus. This active galaxy belongs to a class of mostly spiral galaxies called Seyferts, which have compact centers and are believed to contain massive black holes. Seyfert galaxies are themselves part of a larger class of objects called Active Galactic Nuclei or AGN. AGN have the ability to remove gas from the centers of their galaxies by blowing it out into space at phenomenal speeds. Astronomers studying the Circinus galaxy are seeing evidence of a powerful AGN at its center.

You may wish to find out the answers to questions such as these:

- What does this picture reveal to astronomers?

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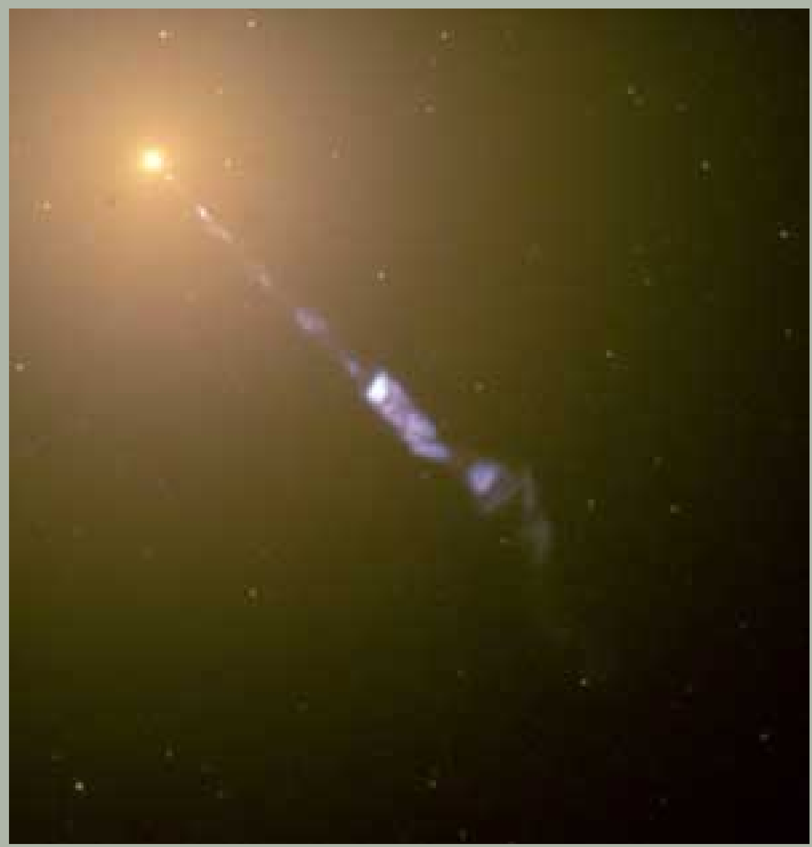
A Cosmic Searchlight



Streaming out from the center of the galaxy M87 like a cosmic searchlight is one of nature's most amazing phenomena, a black-hole-powered jet of electrons and other sub-atomic particles traveling at nearly the speed of light. In this Hubble telescope image, the blue jet contrasts with the yellow glow from the combined light of billions of unseen stars and the yellow, point-like clusters of stars that make up this galaxy. Lying at the center of M87, the monstrous black hole has swallowed up matter equal to 2 billion times our Sun's mass. M87 is 50 million light-years from Earth.

You may wish to find out the answers to questions such as these:

- How does the black hole create the jet?

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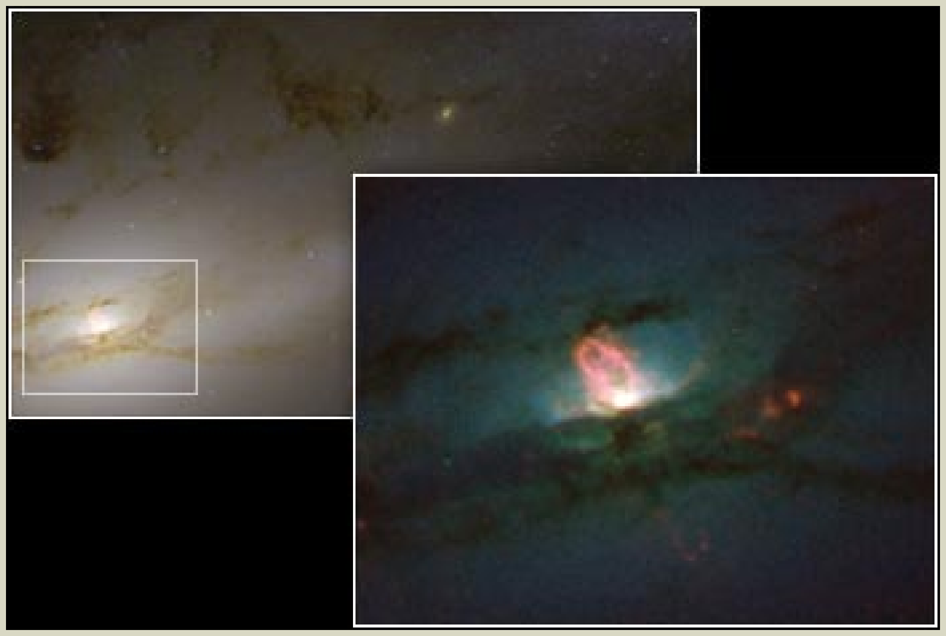
Feasting Black Hole Blows Bubbles



A monstrous black hole's rude table manners include blowing huge bubbles of hot gas into space. At least, that's the gustatory practice followed by the supermassive black hole residing in the hub of the nearby galaxy NGC 4438. These NASA Hubble Space Telescope images of the galaxy's central region clearly show one of the bubbles rising from a dark band of dust. The other bubble, emanating from below the dust band, is barely visible, appearing as dim red blobs in the close-up picture of the galaxy's hub (the colorful picture at right). The background image represents a wider view of the galaxy, with the central region defined by the white box.

You may wish to find out the answers to questions such as these:

- Why is the black hole blowing bubbles?

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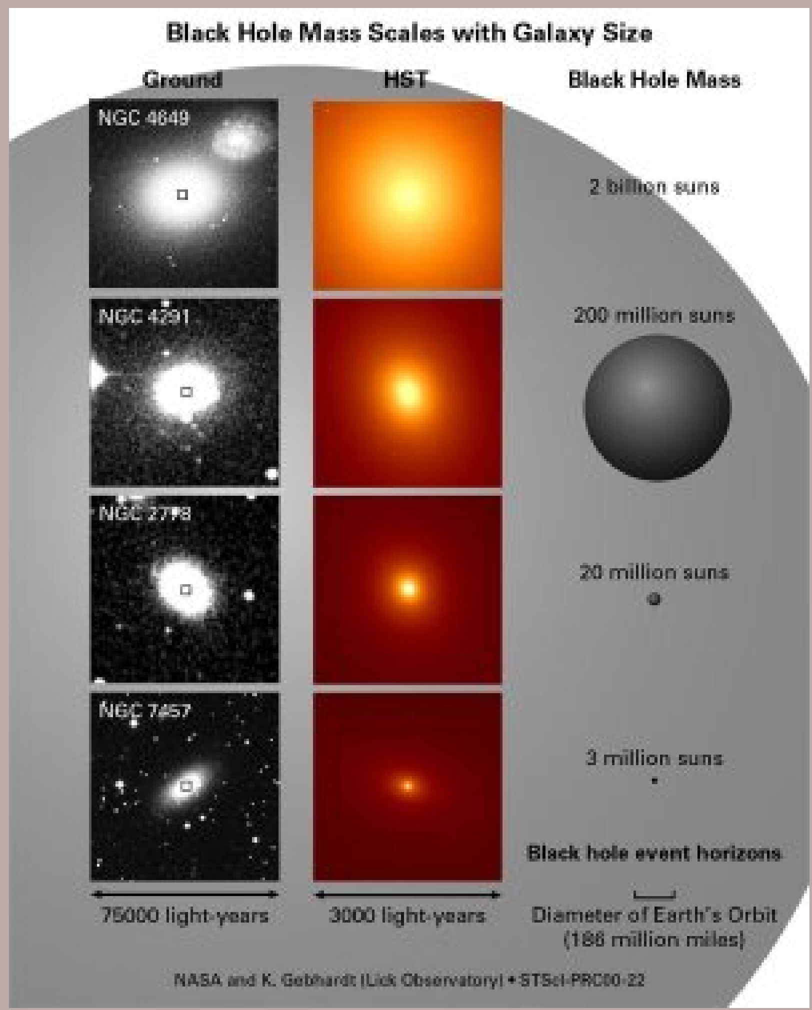
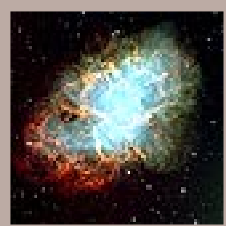
Black Holes Shed Light on Galaxy Formation



Astronomers are concluding that monstrous black holes weren't simply born big but instead grew on a measured diet of gas and stars controlled by their host galaxies in the early formative years of the universe. These results, gleaned from a NASA Hubble Space Telescope census of more than 30 galaxies, are painting a broad picture of a galaxy's evolution and its long and intimate relationship with its central giant black hole. Though much more analysis remains, an initial look at Hubble evidence favors the idea that titanic black holes did not precede a galaxy's birth but instead co-evolved with the galaxy by trapping a surprisingly exact percentage of the mass of the central hub of stars and gas in a galaxy.

You may wish to find out the answers to questions such as these:



- Black holes cannot be seen, so how did the Hubble telescope obtain these results?
- What do these results mean to astronomers?

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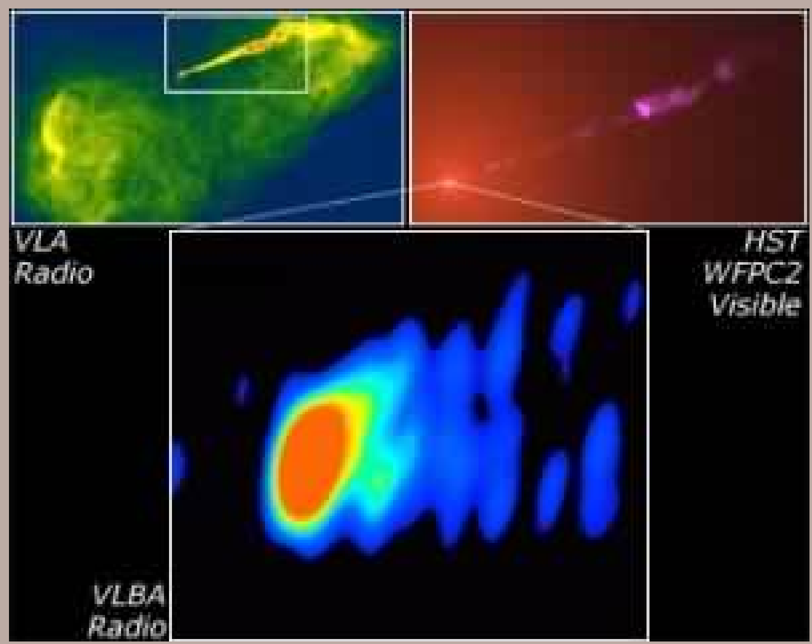
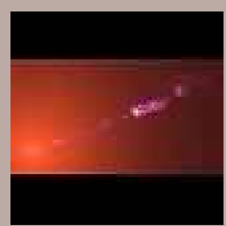
Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole



Astronomers have seen the exhaust products of black hole "engines": narrow beams of material traveling at nearly the speed of light. But they could only speculate where and how those beams were created. Now astronomers have gained their first glimpse at the mysterious region near a black hole at the heart of a distant galaxy where those columns of material are formed. Images of this phenomenon, taken by radio telescopes in Europe and the U.S., are the most detailed ever of the center of the galaxy M87, some 50 million light-years from Earth.

You may wish to find out the answers to questions such as these:



- What causes the beams?
- What does this finding mean?

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Hubble Uncovers Dust Disk around a Massive Black Hole

Resembling a gigantic hubcap in space, a 3,700-light-year-wide dust disk encircles a 300-million- solar-mass black hole in the center of the elliptical galaxy NGC 7052.

The disk, possibly a remnant of an ancient galaxy collision, will be swallowed up by the black hole in several billion years. The black-and-white image on the left, taken by a ground-based telescope, shows the complete galaxy. The Hubble picture on the right is a close-up view of the dust disk surrounding the black hole.

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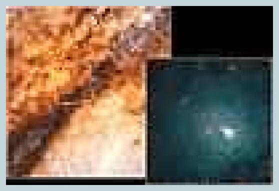
Hubble Provides Multiple Views of How to Feed a Black Hole

Astronomers have obtained an unprecedented look at the nearest example of galactic cannibalism — a massive black hole hidden at the center of a nearby giant galaxy that is feeding on a smaller galaxy in a spectacular collision. Such fireworks were common in the early universe, as galaxies formed and evolved, but are rare today.

The Hubble telescope offers a stunning unprecedented close-up view of a turbulent firestorm of star birth along a nearly edge-on dust disk girdling Centaurus A, the nearest active galaxy to Earth. The picture at upper left shows the entire galaxy. The blue outline represents Hubble's field of view. The larger, central picture is Hubble's close-up view of the galaxy. Brilliant clusters of young blue stars lie along the edge of the dark dust lane. Outside the rift the sky is filled with the soft hazy glow of the galaxy's much older resident population of red giant and red dwarf stars.



Astronomers have used NASA's Hubble Space Telescope to probe the core of the nearest active galaxy to Earth, Centaurus A.

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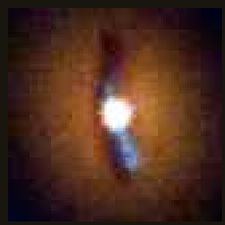
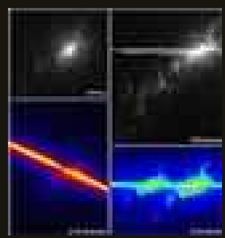
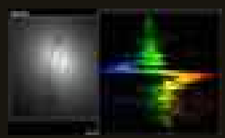


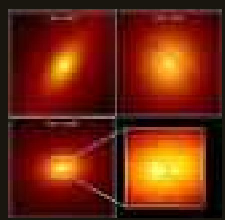
Sep 10, 1997 Hubble Finds a Bare Black Hole Pouring Out Light



Jun 9, 1997 Fireworks Near a Black Hole in the Core of Seyfert Galaxy NGC 4151



May 12, 1997 Hubble Records a Black Hole's Signature

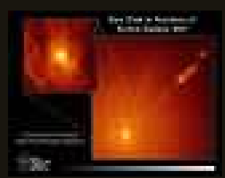


Jan 13, 1997 Massive Black Holes Dwell in Most Galaxies, According to Hubble Census

1995

Dec 4, 1995 Hubble Finds a New Black Hole — and Unexpected New Mysteries

1994



May 25, 1994 Hubble Confirms Existence of Massive Black Hole at Heart of Active Galaxy

Matches 11-16 of 16 shown

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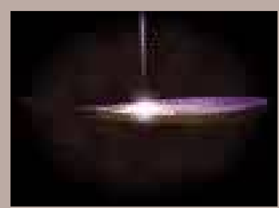
Hubble Finds a Bare Black Hole Pouring Out Light

Probing the heart of the active galaxy NGC 6251, the Hubble telescope has provided a never-before-seen view of a warped disk or ring of dust caught in a blazing torrent of ultraviolet light from a suspected massive black hole.



This discovery suggests that the environments around black holes may be more varied than thought previously and may provide a new link in the evolution of black holes in the centers of galaxies. This composite picture of the galaxy's core of the galaxy combines visible- and ultraviolet-light observations. While the visible-light image shows a dark dust disk, the ultraviolet image [color-coded blue] reveals a bright feature along one side of the disk. Because Hubble sees ultraviolet light reflected from only one side of the disk, astronomers conclude it must be warped like the brim of a hat. The bright white spot at the image's center is light from the vicinity of the black hole, which is illuminating the disk.

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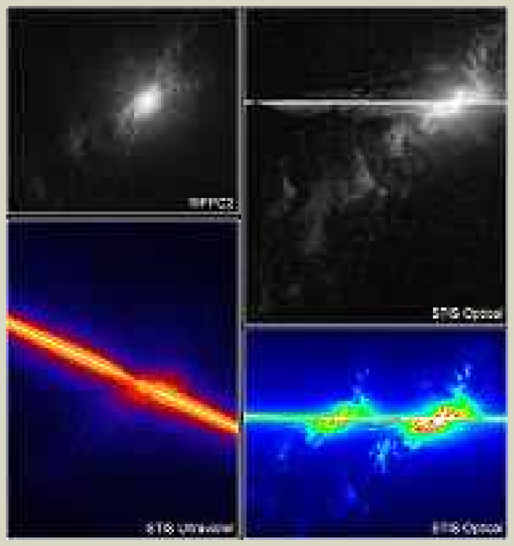
Fireworks Near a Black Hole in the Core of Seyfert Galaxy NGC 4151



The Hubble telescope's imaging spectrograph simultaneously records, in unprecedented detail, the velocities of hundreds of gas knots streaming at hundreds of thousands of miles per hour from the nucleus of NGC 4151, thought to house a super-massive black hole. This is the first time the velocity structure in the heart of this object, or similar objects, has been mapped so vividly this close to its central black hole.

The heart of NGC 4151 was captured in visible light in the upper left picture. In the other images, Hubble's imaging spectrograph has zeroed in on the galaxy's active central region. The Hubble data clearly show that the some material in the galaxy's hub is rapidly moving towards us, while other matter rapidly receding from us. This information is strong evidence for the existence of a black hole, an extremely compact, dense object that feeds on material swirling around it.

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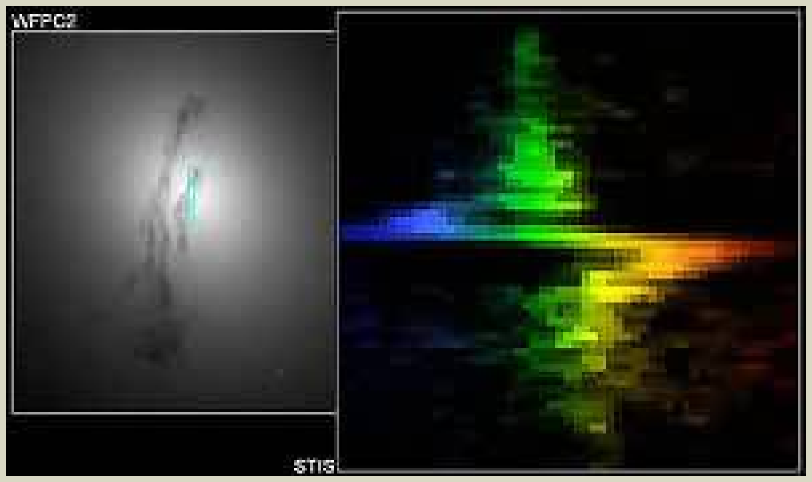
Hubble Records a Black Hole's Signature



The colorful "zigzag" on the right is not the work of a flamboyant artist, but the signature of a super-massive black hole in the center of galaxy M84, discovered by the Hubble telescope's imaging spectrograph.

The image on the left, also taken by Hubble, shows the core of the galaxy where the suspected black hole dwells. In a single exposure, astronomers mapped the motions of gas in the grip of the black hole's powerful gravitational pull by aligning Hubble's spectroscopic slit across the nucleus.

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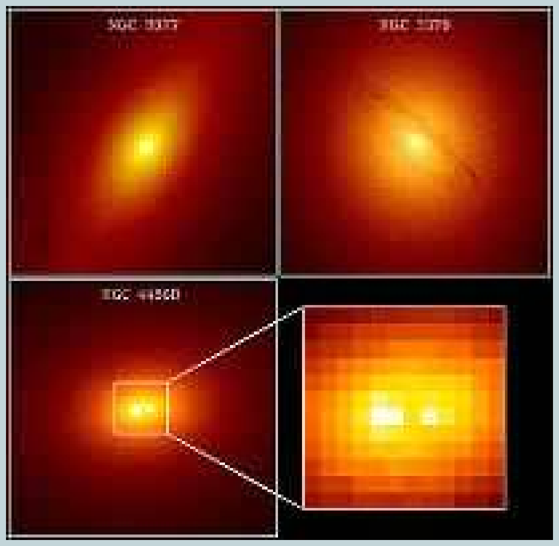
1997

Massive Black Holes Dwell in Most Galaxies, According to Hubble Census



Announcing the discovery of three black holes in three normal galaxies, astronomers suggest that nearly all galaxies may harbor super-massive black holes that once powered quasars (extremely luminous objects in the centers of galaxies), but are now quiescent.

This conclusion is based on a census of 27 nearby galaxies carried out by the Hubble telescope and ground-based observatories in Hawaii. The three galaxies in these images are believed to contain central, super-massive black holes. The galaxy NGC 4486B [lower left] shows a double nucleus [lower right]. The picture at lower right is a close-up of the central region of NGC 4486B.

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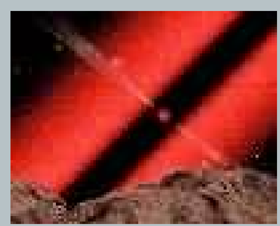
Hubble Finds a New Black Hole — and Unexpected New Mysteries

Confirming the presence of yet another super-massive black hole in the universe, astronomers using the Hubble telescope have found unexpected mysteries. The black hole and an 800-light-year-wide, spiral-shaped disk of dust fueling it are slightly offset from the center of the host galaxy, NGC 4261.

Prior to Hubble observations, astronomers did not think dust was common in elliptical galaxies like NGC 4261, which were thought to have stopped making stars long ago due to the absence of the requisite raw materials: gas and dust. However, Hubble is showing that dust and dust disks are common in the centers of elliptical galaxies.



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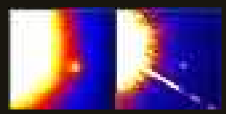
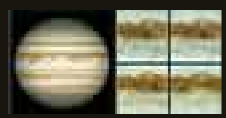


Nov 29, 1995 Astronomers Announce First Clear Evidence of a Brown Dwarf

Nov 20, 1995 Panoramic Hubble Picture Surveys Star Birth, Proto-Planetary Systems in the Great Orion Nebula



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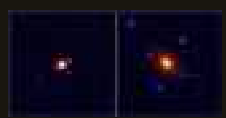
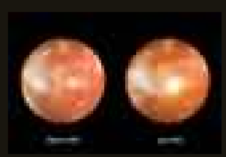
Nov 2, 1995 Embryonic Stars Emerge from Interstellar "Eggs"



Oct 18, 1995 Hubble Discovers New Class of Gravitational Lens for Probing the Structure of the Cosmos

Oct 10, 1995 Hubble Sees Thin Disk Around the Star Beta Pictoris



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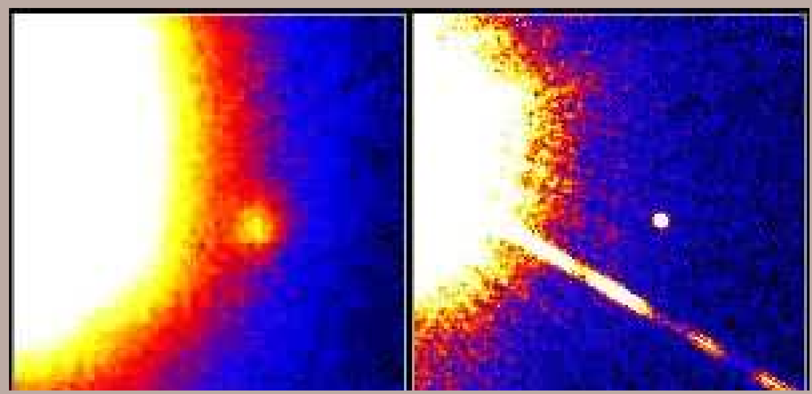
Astronomers Announce First Clear Evidence of a Brown Dwarf



Astronomers have made the first unambiguous detection of an elusive type of object known as a brown dwarf.

The evidence consists of observations from 60-inch and 200-inch telescopes on Mount Palomar, and a confirmatory image from the Hubble telescope. The brown dwarf, called Gliese 229B (GL229B), is a small companion to the cool, red star Gliese 229, located 19 light-years from Earth in the constellation Lepus. Estimated to be 20 to 50 times the mass of Jupiter, GL229B is too massive and hot to be classified as a planet, but too small and cool to shine like a star. At least 100,000 times dimmer than Earth's Sun, the brown dwarf is the faintest object ever seen orbiting another star.

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Panoramic Hubble Picture Surveys Star Birth, Proto-Planetary Systems in the Great Orion Nebula

This spectacular color panorama of the center of the Orion Nebula is one of the largest pictures ever assembled from individual images taken with the Hubble telescope.

The seemingly infinite tapestry of rich detail revealed by Hubble shows a churning, turbulent star factory set within a maelstrom of flowing, luminescent gas. Though this 2.5-light-year-wide view is a small portion of the entire nebula, it includes a star cluster and almost all of the light from the bright glowing clouds of gas that make up the nebula.

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Hubble Views the Galileo Probe Entry Site on Jupiter

This Hubble telescope image of Jupiter [left] was taken when the giant planet was 534 million miles (854 million kilometers) from Earth. The arrow points to the predicted site at which the Galileo probe will enter Jupiter's atmosphere on December 7, 1995. At this latitude, the eastward winds have speeds of about 250 mph (110 meters per second). The white oval to the north of the probe site drifts westward at 13 mph (6 meters per second), rolling in the winds, which increase sharply toward the equator.

The four enlarged Hubble images of Jupiter's equatorial region [right] show clouds sweeping across the predicted Galileo probe entry site, which is at the exact center of each frame. A tiny white dot marks the predicted entry site.

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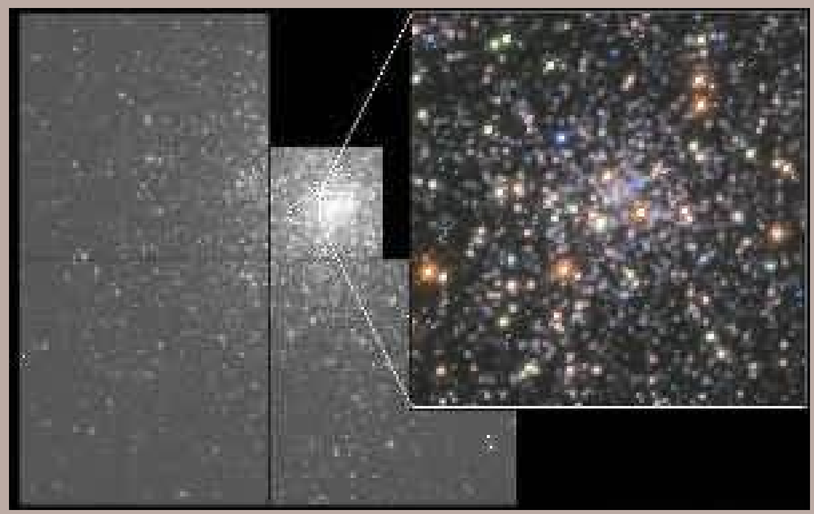
Hubble Peers Deep into the Crowded Heart of the Densest Known Star Cluster



By pinpointing individual suns in the glare of the most tightly packed cluster of stars in our galaxy, the Hubble telescope has unveiled hints of either a massive black hole or another remarkable phenomenon: a "core collapse" driven by the intense gravitational pull of so many stars in such a small volume of space.

Astronomers used the telescope's sharp images to count an extraordinary number of stars in the ancient globular cluster M15, about 37,000 light-years from Earth. Hubble spied hundreds of stars in a tiny area at the center of this cluster. Careful analysis of the distribution of these and thousands of neighboring stars suggest that at some point in the distant past, the stars converged on M15's core, like bees swarming to their hive. An alternate scenario also could explain the pileup of stars at M15's core: a black hole that may have formed early in the cluster's history. The black hole would have gradually gained mass as more stars spiraled inward. The black-and-white picture shows the cluster's central region; the color image is a close-up of the core.

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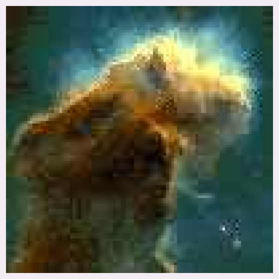
Embryonic Stars Emerge from Interstellar "Eggs"

Eerie, dramatic pictures from the Hubble telescope show newborn stars emerging from "eggs" — not the barnyard variety — but rather, dense, compact pockets of interstellar gas called evaporating gaseous globules (EGGs). Hubble found the "EGGs," appropriately enough, in the Eagle nebula, a nearby star-forming region 7,000 light-years from Earth in the constellation Serpens.



These striking pictures resolve the EGGs at the tip of finger-like features protruding from monstrous columns of cold gas and dust in the Eagle Nebula (also called M16). The columns — dubbed "elephant trunks" — protrude from the wall of a vast cloud of molecular hydrogen, like stalagmites rising above the floor of a cavern. Inside the gaseous towers, which are light-years long, the interstellar gas is dense enough to collapse under its own weight, forming young stars that continue to grow as they accumulate more and more mass from their surroundings.

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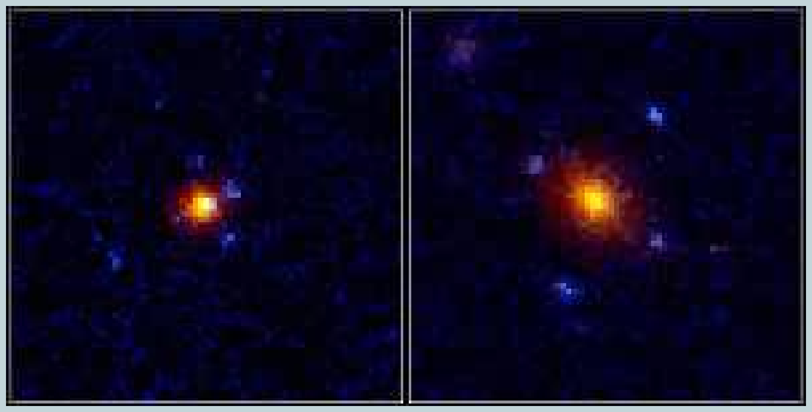
Hubble Discovers New Class of Gravitational Lens for Probing the Structure of the Cosmos



The Hubble telescope has discovered a new, distant class of quadruple or cross-shaped gravitational lenses. The new class of objects might eventually provide astronomers with a powerful "magnifying glass" for probing a variety of characteristics of the universe: the distribution of dark matter, the abundance of super-massive black holes, and the eventual fate of the universe.

In Hubble pictures of two such objects, astronomers have found four images of a faraway galaxy [the blue blobs] gathered around a red elliptical galaxy. A gravitational lens is produced by a massive object's enormous gravitational field, which bends light to magnify, brighten, and distort the image of a more distant object.

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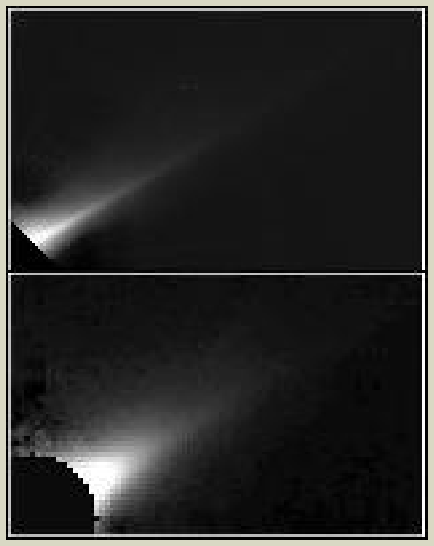
Hubble Sees Thin Disk Around the Star Beta Pictoris



This Hubble telescope image of a portion of a vast dust disk around the star Beta Pictoris [top picture] shows that the disk is thinner than previously thought. Estimates based on the Hubble snapshot place the disk's thickness as no more than one billion miles (600 million kilometers). For comparison the disk appears four times thicker in a ground-based image.

The disk is tilted nearly edge-on to Earth and may be older than some previous estimates because its dust has had enough time to settle into a flat plane. A thin disk also increases the probability that comet-sized or larger bodies have formed through accretion in the disk. Both conditions are believed to be characteristic of a hypothesized circumstellar disk around our own Sun, which was a necessary precursor to the planet-building phase of our solar system, according to current theory.

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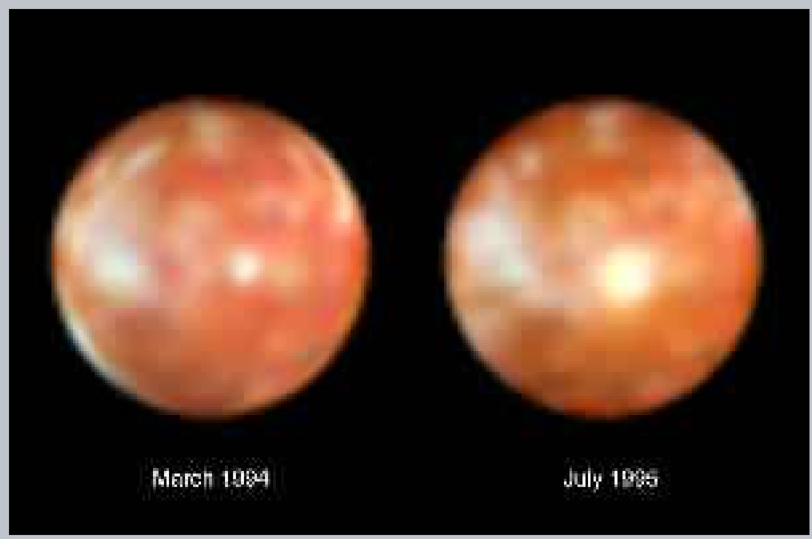
Hubble Discovers Bright New Spot on Io



This pair of images of Jupiter's volcanic moon Io, taken with the Hubble telescope, shows the surprising emergence of a 200-mile-wide, yellowish-white feature near the center of the moon's disk [photo on the right]. This represents a more dramatic change in 16 months than any seen over the previous 15 years, say researchers. They suggest the spot may be a new class of transient feature on the moon. For comparison the photo on the left was taken in March 1994, before the spot emerged. The photo indicates that Io's surface had undergone only subtle changes since it was last seen close-up by the Voyager 2 probe in 1979.

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Hubble Photo Gallery of Jupiter's Galilean Satellites

This is a Hubble telescope "family portrait" of Jupiter's four largest moons.

Located approximately a half billion miles away, the moons are so small that, in visible light, they appear as fuzzy disks in the largest ground-based telescopes. Hubble can resolve surface details seen previously only by the Voyager space probes in the early 1980s. While the Voyager probes provided close-up snapshots of the satellites, Hubble can now follow changes on the moons and reveal other characteristics at ultraviolet and near-infrared wavelengths.

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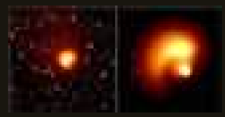

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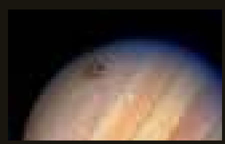
Oct 10, 1995 — Hubble Maps the Asteroid Vesta

Oct 10, 1995 — Hubble Provides the First Images of Saturn's Aurorae



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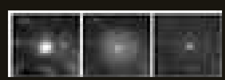

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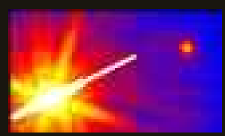

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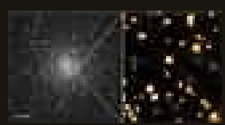
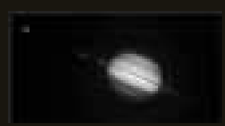
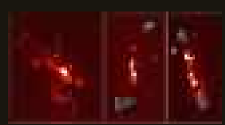


Aug 28, 1995 — Hubble Space Telescope Finds Stellar Graveyard



Aug 11, 1995 — Hubble Again Views Saturn's Rings Edge-On



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Aug 1, 1995 — Hubble Discovers New Moons Orbiting Saturn

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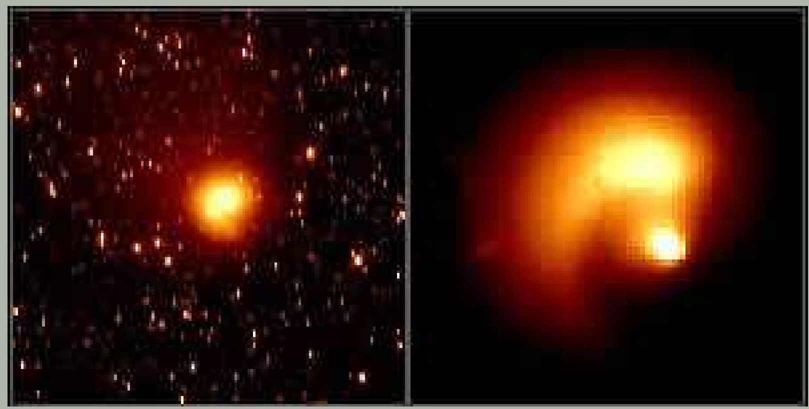
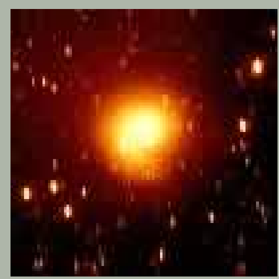


These Hubble telescope pictures of comet Hale-Bopp show a remarkable "pinwheel" pattern and a blob of free-flying debris near its center. The image at left shows the entire comet; the picture at right is a close-up of the nucleus.

The bright clump of light along the spiral [just above the center of the picture] may be a piece of the comet's icy crust. Although the "blob" is about 3.5 times fainter than the brightest portion at the comet's center, the lump appears brighter because it covers a larger area. The debris follows a spiral pattern outward because the solid center is rotating like a lawn sprinkler, completing a single rotation about once per week.



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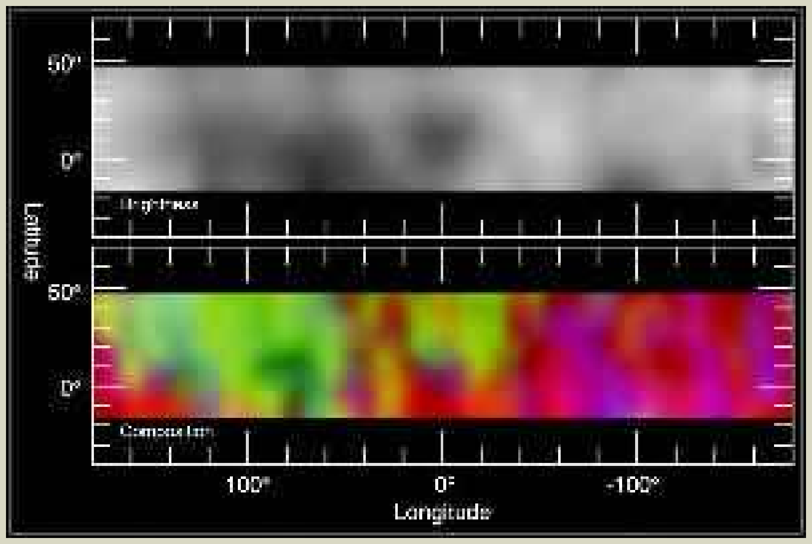

These two surface maps of the asteroid Vesta are derived from Hubble telescope images taken between November 28 and December 1, 1994. The pictures show surface details as small as 35 miles across. Vesta is 320 miles in diameter, and the map covers the asteroid's entire surface area, about 200,000 miles.

The top panel indicates sharp contrasts in Vesta's surface color. The surface markings may represent ancient volcanic activity such as lava flows and, in addition, regions where major collisions have stripped away the surface. The bottom panel reveals that Vesta's surface is made up of igneous rock, indicating that either the entire surface was once melted or lava flowing from its interior once completely covered its surface.

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Hubble Provides the First Images of Saturn's Aurorae

The Hubble telescope has taken the first picture of bright aurorae at Saturn's northern and southern poles [top picture]. The picture at the bottom was taken in visible light.

Hubble's far-ultraviolet-light image resolves a luminous, circular band centered on the north pole, where an enormous curtain of light rises as far as 1,200 miles (2,000 kilometers) above the cloud tops. This curtain changed rapidly in brightness and extent over the two-hour period of observations.

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Color Hubble Image of Large Comet Impact on Jupiter

This Hubble telescope image of the giant planet Jupiter reveals the impact sites of two fragments from comet Shoemaker-Levy 9. Twenty-one large chunks of the comet rained down upon Jupiter in July 1994.

The impact sites, located in the planet's Southern Hemisphere, are the dark spots in the upper left of the photograph.

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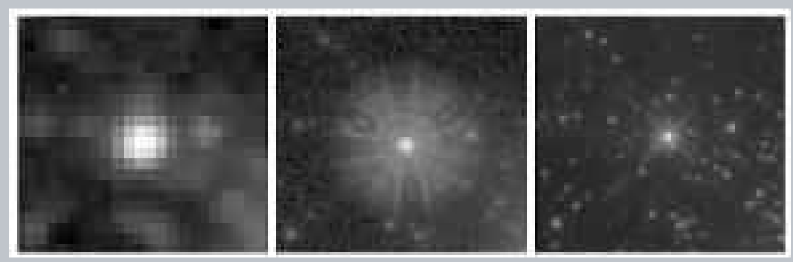
Hubble Space Telescope Images of a Bright Star in the Large Magellanic Cloud



These three images are of a very bright (Wolf-Rayet) star, Melnick 34, located in the giant star-forming region called 30 Doradus in the Large Magellanic Cloud. In the background are a number of fainter stars that are comparable in brightness to our Sun.

A ground-based telescope captured the image at left. Hubble's first-generation visible-light camera, the Wide Field and Planetary Camera, snapped the center picture before the telescope's blurred vision was corrected. The image at right was taken by Hubble's new visible-light camera, the Wide Field and Planetary Camera 2, which is equipped with a corrective optics system. In this new image the star appears sharper, and a larger number of fainter stars are visible.

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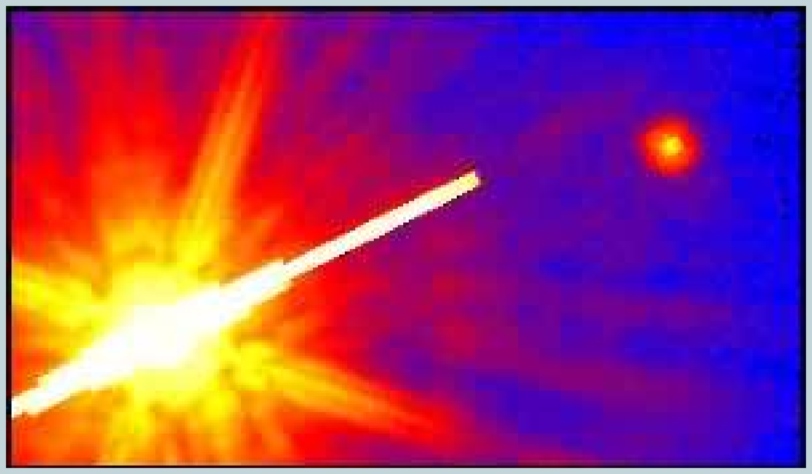
Hubble Spies a Really Cool Star



This Hubble telescope picture reveals one of the least massive and coolest stars ever seen [upper right]. This star is a diminutive companion to the K dwarf star called GL 105A (also known as HD 16160), seen at lower left. The pair is located 27 light-years from Earth in the constellation Cetus.

Based on the Hubble observation, astronomers calculate that the cool, lightweight star, called GL 105C, is 25,000 times fainter than GL 105A in visible light. If the dim companion were at the distance of our Sun, it would be only four times brighter than the full moon.

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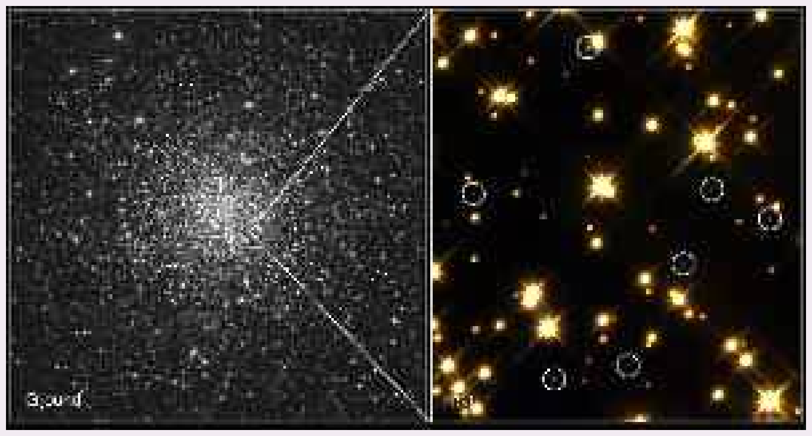

Peering deep into the globular star cluster M4 with the Hubble telescope, Canadian and American astronomers have discovered a large number of "stellar corpses," called white dwarf stars, which may be used eventually to refine age estimates of the universe.

The observation was so sensitive that even the brightest of the detected white dwarfs was no more luminous than a 100-watt light bulb seen at the moon's distance (239,000 miles). A Hubble color image of a small portion of the cluster reveals eight white dwarf stars [inside the white circles] among the cluster's much brighter population of yellow, Sun-like stars and cooler red dwarf stars. Hubble reveals a total of 75 white dwarfs in one small area within M4 out of a total of about 40,000 white dwarfs that the cluster is predicted to contain. The picture on the left is a view of the cluster taken by a ground-based telescope.

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Hubble Again Views Saturn's Rings Edge-On

Saturn's magnificent ring system is seen tilted edge-on — for the second time in 1995 — in this Hubble telescope picture taken Aug. 10, when the planet was 895 million miles (1,440 million kilometers) away from Earth. Hubble snapped the image as Earth sped back across Saturn's ring plane to the sunlit side of the rings.

Several of Saturn's icy moons are visible as tiny star-like objects in or near the ring plane. On May 22, 1995 Earth dipped below the ring plane, giving observers a brief look at the backlit side of the rings. Ring-plane crossing events occur approximately every 15 years. Earthbound observers won't have as good a view until the year 2038.

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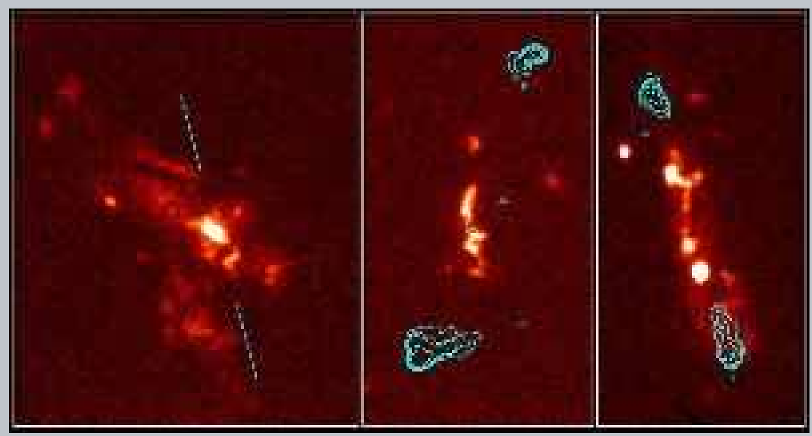
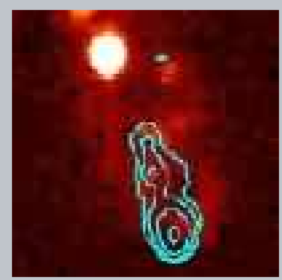
Hubble Uncovers Surprisingly Complex Structures in Radio Galaxies



Probing some of the most distant and energetic galaxies in the universe, the Hubble telescope has uncovered surprisingly varied and intricate structures of stars and gas, suggesting that the processes powering these so-called radio galaxies are more complex than previously thought.



The radio galaxies observed are far across the cosmos, existing when the universe was half its present age. Light from these galaxies is just now reaching Earth. The Hubble observations should shed light on galaxy evolution and on the nature of active galaxies, which may be powered by immense black holes at their cores. These Hubble images, combined with radio maps produced by the Very Large Array Radio Interferometer [blue contour lines], show surprisingly varied and intricate structures of gas and stars.

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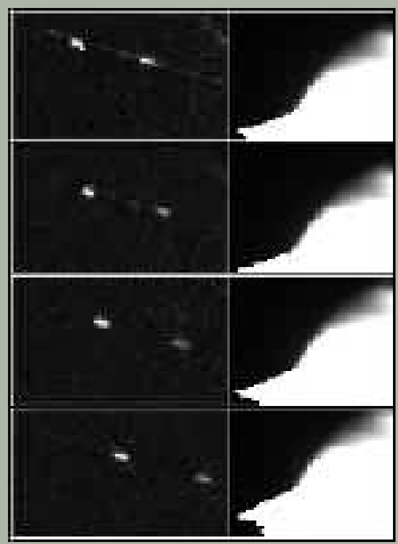
Hubble Discovers New Moons Orbiting Saturn



Astronomers have announced the discovery of at least two, and possibly as many as four, new moons orbiting the giant planet Saturn. This discovery was based upon Hubble telescope images that were taken when Saturn's rings were tilted edge-on to Earth.

Two of the satellites seen by Hubble are in orbits similar to those of Atlas and Prometheus, a pair of moons discovered in 1980 by the Voyager 1 spacecraft. Additional Hubble observations of Saturn will provide more images that can be used to determine whether two of the four satellites detected by Hubble are truly new or not. This four-picture sequence shows one of the new moons discovered by Hubble. Saturn appears as a bright white disk at far right, and the edge-on rings extend diagonally to the upper left.

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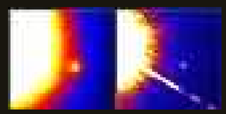

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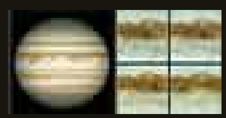

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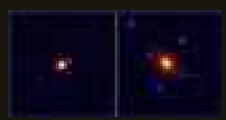

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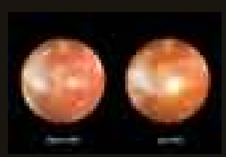

Oct 10, 1995 Hubble Discovers Bright New Spot on Io

Oct 10, 1995 Hubble Photo Gallery of Jupiter's Galilean Satellites

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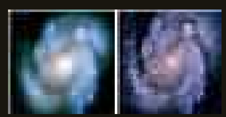
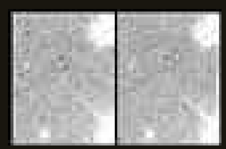
Jul 14, 1995 Hubble Maps Surface Features of Titan


Jul 7, 1995 Hubble Sees Changes in Gas Shell around Nova Cygni 1992


Jul 7, 1995 Picture Perfect: Hubble's New Improved Optics Probe the Core of a Distant Galaxy


Jun 26, 1995 Hubble Monitors Weather on Neighboring Planets


Jun 14, 1995 Galaxy NGC 4881 and the Coma Cluster


Jun 14, 1995 Hubble Identifies a Long-Sought Population of Comets Beyond Neptune


Jun 14, 1995 Hubble Portrait of the "Double Planet" Pluto & Charon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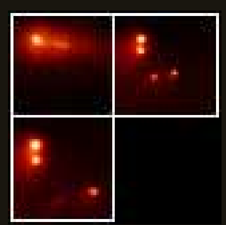
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1995

Hubble Sheds Light on the "Faint Blue Galaxy" Mystery

Astronomers using the Hubble telescope have solved a 20-year-old mystery by showing that a class of galaxies once thought to be rare is actually the most common type of galaxy in the universe.

Analyzing some of the deepest images ever taken of the heavens, the astronomers conclude that small irregular objects called "blue dwarfs" were more numerous several billion years ago, outnumbering giant elliptical galaxies and spiral galaxies like our Milky Way. This means that blue dwarfs are a more important constituent of the universe and figure more prominently in the evolution of galaxies than previously thought.

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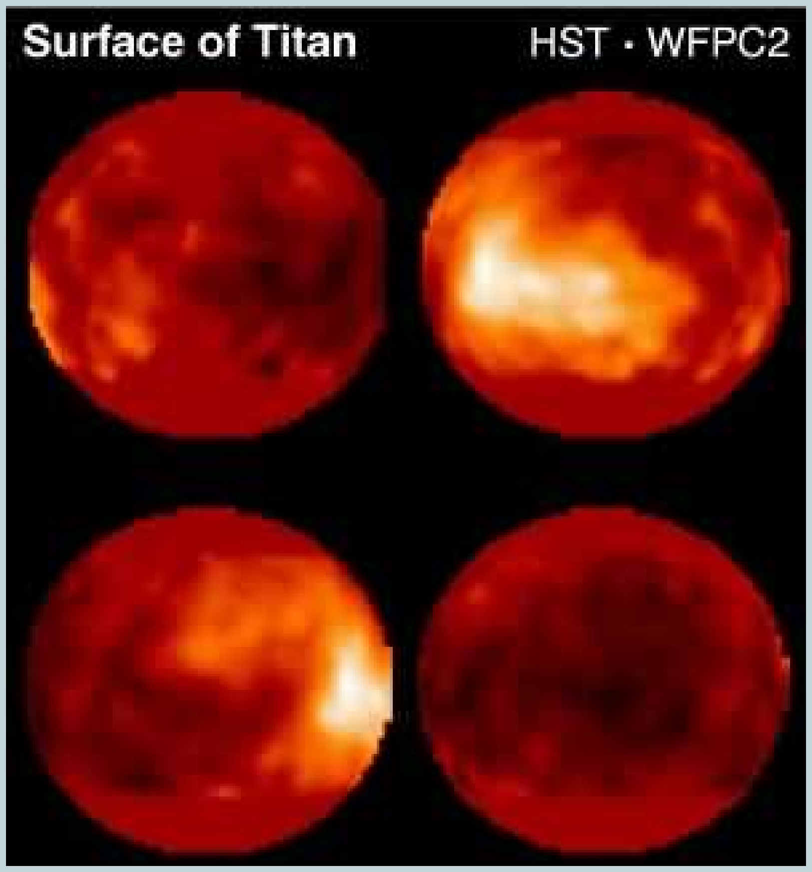
Hubble Maps Surface Features of Titan



Scientists for the first time have made images of the surface of Saturn's giant, haze-shrouded moon, Titan. They mapped light and dark features over the surface of the satellite during nearly a complete 16-day rotation. One prominent bright area they discovered is a surface feature 2,500 miles across, about the size of the continent of Australia.

Titan, which is larger than Mercury and slightly smaller than Mars, is the only body in the solar system, other than Earth, that may have oceans and rainfall on its surface. The oceans and rain are composed of ethane-methane rather than water.

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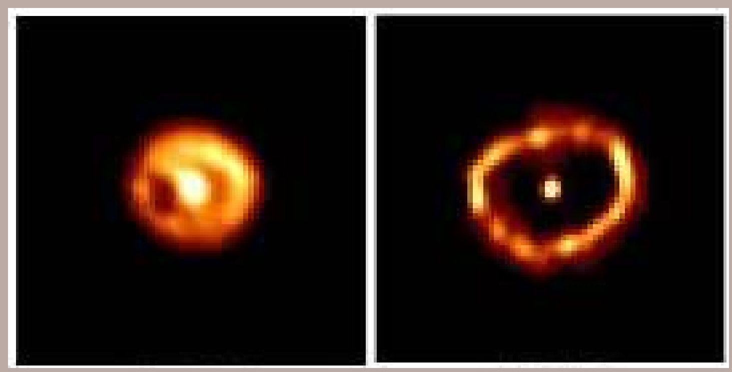
Hubble Sees Changes in Gas Shell around Nova Cygni 1992



The Hubble telescope has given astronomers their best look yet at a rapidly ballooning bubble of gas blasted off a star.

The shell surrounds Nova Cygni 1992, which erupted Feb. 19, 1992. A nova is a thermonuclear explosion that occurs on the surface of a white dwarf star in a double-star system. The image [right], taken after Hubble's near-sightedness had been corrected, reveals an elliptical and slightly lumpy ring-like structure. The ring is the edge of a bubble of hot gas blasted into space by the nova. Another Hubble picture taken 467 days after the explosion [left] provided the first glimpse of the ring and a mysterious bar-like structure. But the image interpretation was severely hampered by the telescope's blurred vision.

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Picture Perfect: Hubble's New Improved Optics Probe the Core of a Distant Galaxy

This comparison image of the core of galaxy M100 shows the dramatic improvement in the Hubble telescope's view of the universe. The new image (right) was taken with the second generation Wide Field and Planetary Camera (WFPC2), which was installed during the STS-61 Hubble Servicing Mission.

The picture beautifully demonstrates that the corrective optics incorporated within WFPC2 compensate fully for Hubble's near-sightedness. The new camera will allow Hubble to probe the universe with unprecedented clarity and sensitivity. The picture clearly shows faint structure as small as 30 light-years across in a galaxy tens of millions of light-years away.

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Hubble Monitors Weather on Neighboring Planets

What's the weather for Mars and Venus? The Hubble telescope has given astronomers a peak. The telescope is serving as an interplanetary weather satellite for studying the climate on Earth's neighboring worlds, Mars and Venus.

To the surprise of researchers, Hubble is showing that the Martian climate has changed considerably since the unmanned Viking spacecraft visited the Red Planet in the mid-1970s. The Hubble pictures indicate that the planet is cooler, clearer, and drier than a couple of decades ago. In striking contrast, Hubble's observations of Venus show that the atmosphere continues to recover from an intense bout of sulfuric "acid rain," triggered by the suspected eruption of a volcano in the late 1970s.

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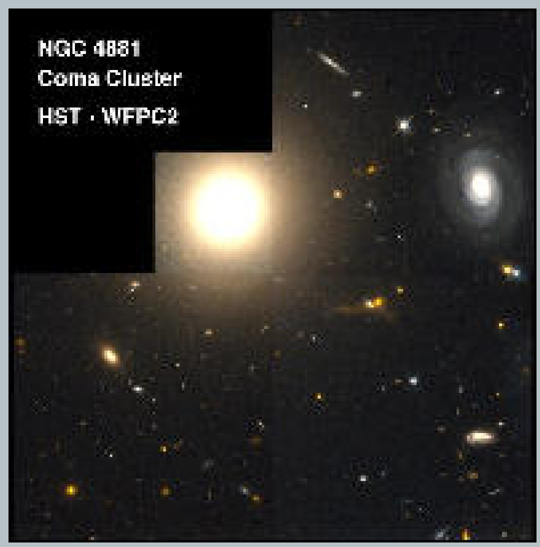
Galaxy NGC 4881 and the Coma Cluster



This Hubble telescope photo mosaic shows a field of distant galaxies.

The brightest object in this picture is NGC 4881 [just above center], an elliptical galaxy in the outskirts of the Coma Cluster, a great cluster of galaxies more than five times farther away than the Virgo Cluster. The distance to the Coma Cluster is an important cosmic yardstick for scaling the overall size of the universe.

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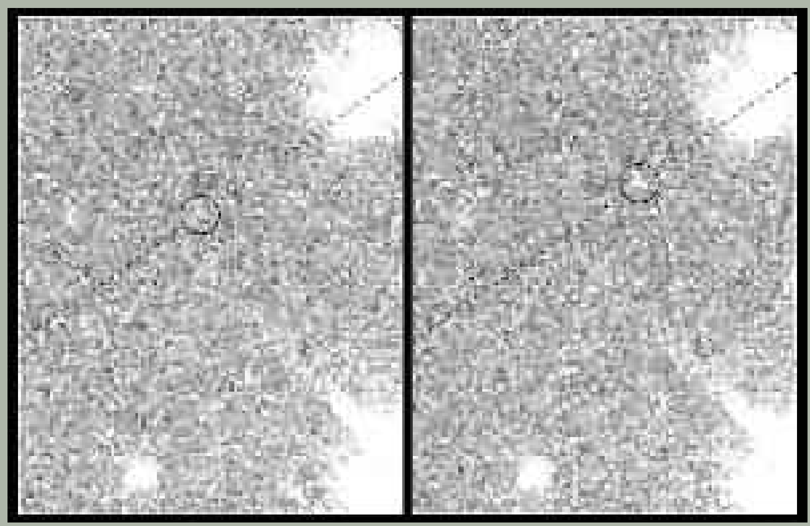
Hubble Identifies a Long-Sought Population of Comets Beyond Neptune



The Hubble telescope has detected a long-sought population of comets dwelling at the icy fringe of the solar system. The observation, which is the astronomical equivalent to finding the proverbial needle-in-a-haystack, bolsters proof for a primordial comet reservoir just beyond Neptune. The circles pinpoint one of the candidate Kuiper belt objects. The dotted lines represent a possible orbit that this Kuiper belt comet is following.

Based on the Hubble observations, a team of astronomers estimate that the belt contains at least 200 million comets, which have remained essentially unchanged since the birth of the solar system 4.5 billion years ago.

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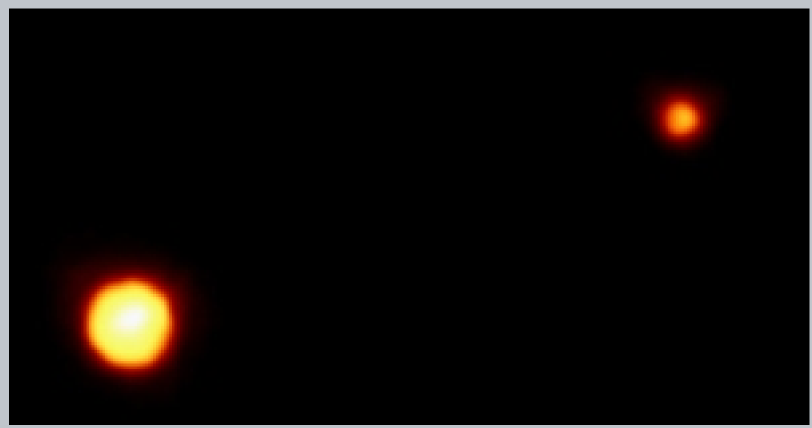

This is the clearest view yet of the distant planet Pluto [lower left] and its moon Charon [upper right], as revealed by the Hubble telescope.

Hubble snapped this image when the planet was 2.6 billion miles (4.4 billion kilometers) from Earth, or nearly 30 times the separation between Earth and the Sun. The two objects are shown as clearly separate and sharp disks.

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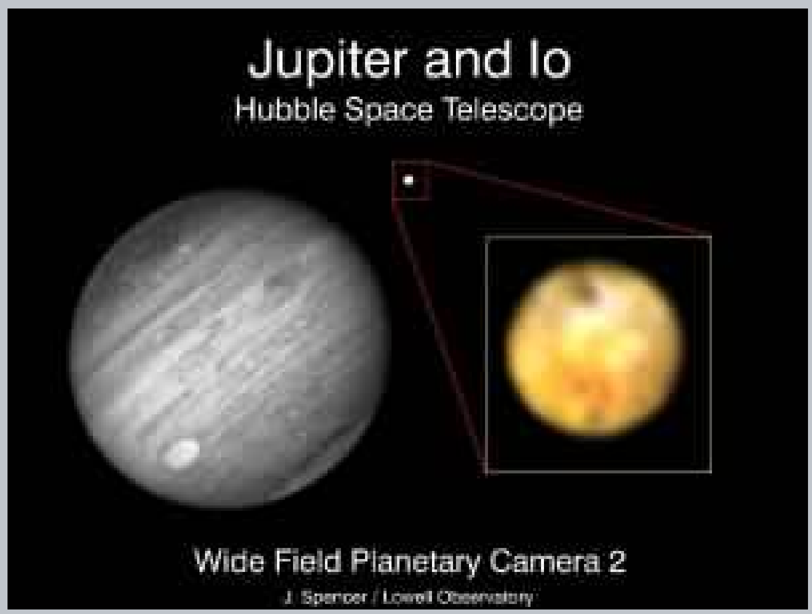
Hubble Space Telescope Resolves Volcanoes on Io



The giant gaseous planet Jupiter [left] and its moon Io [close-up on right] are featured in this Hubble telescope picture.

One of Io's many volcanoes, Pele, appears as a dark spot surrounded by an irregular orange oval on the lower part of the moon. The orange material has been ejected from the volcano and spread over a huge area. Though the volcano was first discovered by the Voyager spacecraft, the distinctive orange color of the volcanic deposits is a new discovery.

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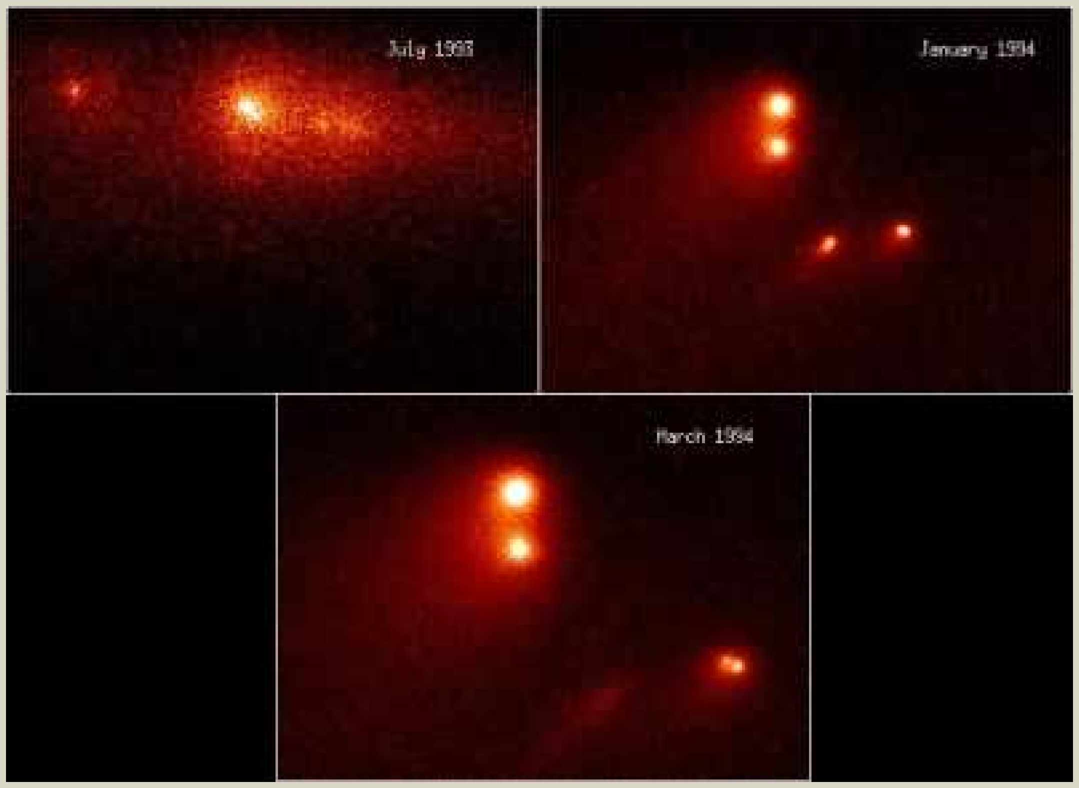
Comet P/Shoemaker-Levy 9 "Gang Of Four"



This is a composite HST image taken in visible light showing the temporal evolution of the brightest region of comet P/Shoemaker-Levy 9. In this false-color representation, different shades of red color are used to display different intensities of light.

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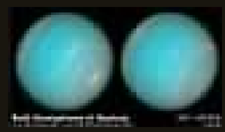
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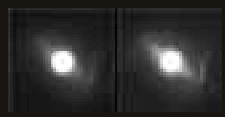
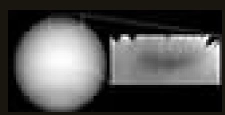
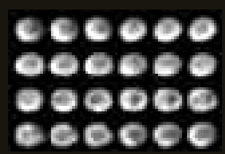

Jun 14, 1995 Hubble Resolves Quasars' Host Galaxies


Jun 6, 1995 Hubble Observes the Fire and Fury of a Stellar Birth


Jun 5, 1995 Hubble Views Saturn Ring-Plane Crossing


May 22, 1995 Hubble Probes the Workings of a Stellar Hydrogen Bomb


Apr 19, 1995 Hubble Discovers New Dark Spot on Neptune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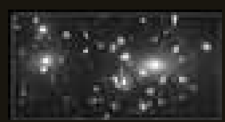
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Mar 31, 1995 Hubble Tracks Jupiter Storms

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1995

Hubble Space Telescope Observations of Neptune

Two groups have recently used the Hubble telescope to acquire high-resolution images of the planet Neptune. These images represent the clearest views of Neptune since the Voyager 2 flyby in August 1989. The observations are providing a wealth of new information about the structure, composition, and meteorology of this distant planet's atmosphere.

The pictures show several bright clouds, which are thought to be high above the main cloud deck and above much of the absorbing methane gas. The edge of the planet's disk also appears somewhat bright, indicating the presence of a ubiquitous, high-altitude haze layer.

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Hubble Resolves Quasars' Host Galaxies

This Hubble telescope image [right] reveals a faint galaxy, the home of a quasar. The wealth of new detail in this picture helps solve a three-decade-old mystery about the true nature of quasars, the most distant and energetic objects in the universe.

The picture clearly shows that the quasar, called 1229+204, lies in the core of a galaxy that has a common shape, consisting of two spiral arms of stars connected by a bar-like feature. The host galaxy is in a spectacular collision with a dwarf galaxy. That collision apparently fuels the quasar "engine" at the galaxy's center — presumably a massive black hole — and also triggers many sites of new star-formation. A ground-based telescope also snapped a view of the quasar and its host galaxy [left].

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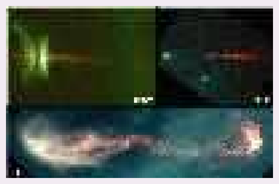
Hubble Observes the Fire and Fury of a Stellar Birth

The Hubble telescope has provided a detailed look at the fitful, eruptive, and dynamic processes accompanying the final stages of a star's "construction."



These three images provide a dramatically clear look at collapsing circumstellar disks of dust and gas that build stars and provide the ingredients for a planetary system. The pictures also show blowtorch-like jets of hot gas funneled from deep within several embryonic systems and machine gun-like bursts of material fired from the stars at speeds of a half-million mph. The Hubble observations shed new light on one of modern astronomy's central questions: How do tenuous clouds of interstellar gas and dust make stars like our Sun?

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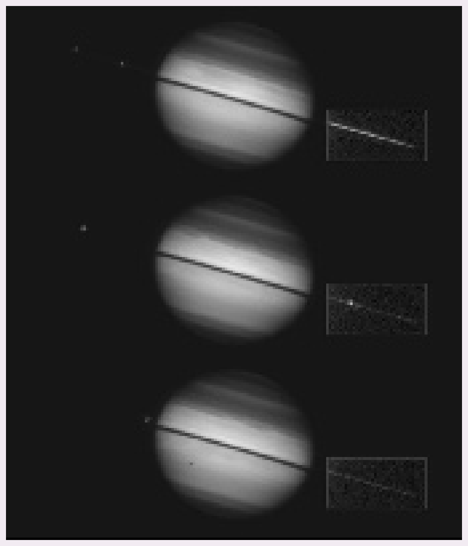
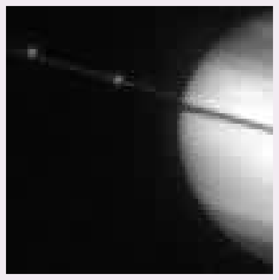
Hubble Views Saturn Ring-Plane Crossing



This sequence of images from the Hubble telescope documents a rare astronomical alignment: Saturn's magnificent ring system turned edge-on. This event occurs when the Earth passes through Saturn's ring plane, as it does about every 15 years.



In these pictures, Hubble can see details on Saturn as small as 450 miles (725 kilometers) across. In each image the dark band across Saturn is the ring shadow cast by the Sun, which is still slight above the planet's ring plane. The bright dots to the left of Saturn and in the boxes to the right are some of the planet's moons. The boxes around the western portion of the rings [on the right] indicate the area in which the faint light from the rings has been enhanced through image processing to make the rings more visible.

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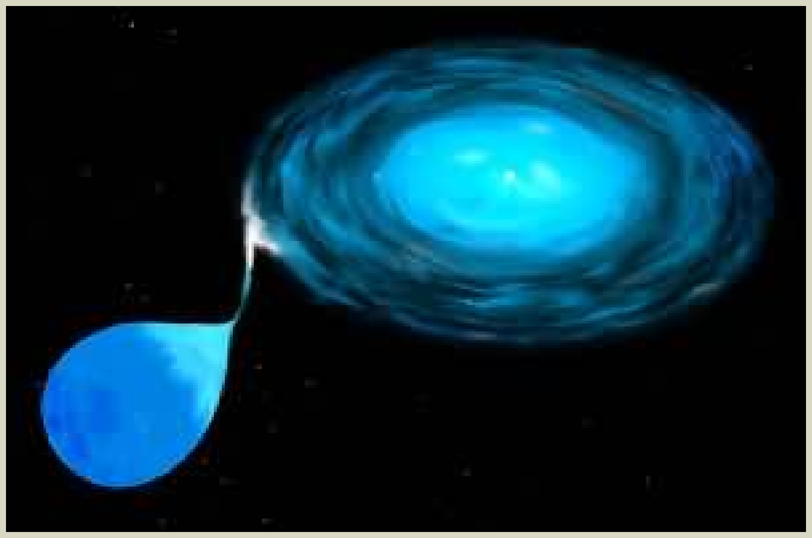
Hubble Probes the Workings of a Stellar Hydrogen Bomb



Peering into the heart of two recently exploded double-star systems, the Hubble telescope has surprised researchers by finding that the white dwarf stars at the center of the fireworks are cooler than expected and spin more slowly than previously thought.

Each dwarf — dense, burned-out stars that have collapsed to the size of Earth — is in a compact binary system, called a cataclysmic variable, where its companion is a normal star similar to, but smaller than the Sun. The stars are so close together that the entire binary system would fit inside the Sun. Their closeness allows gas to flow from the normal star onto the dwarf, where it swirls into a pancake-shaped disk [see illustration]. When the disk of gas periodically collapses onto the white dwarf, it unleashes a burst of kinetic energy, called a dwarf nova outburst. Once dumped onto the dwarf's surface, hydrogen accumulates until it undergoes thermonuclear fusion, which eventually triggers an explosion.

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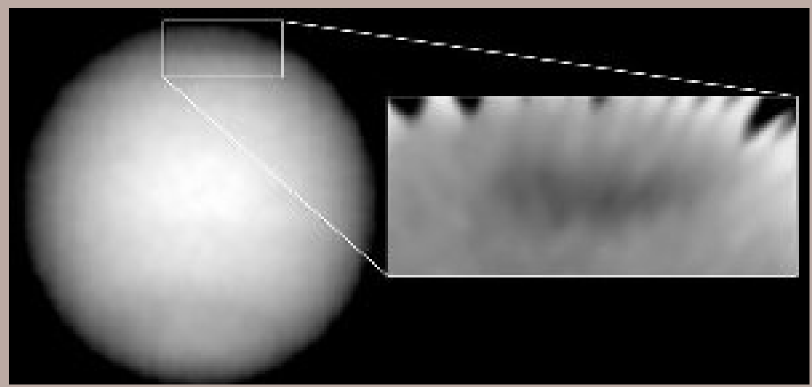
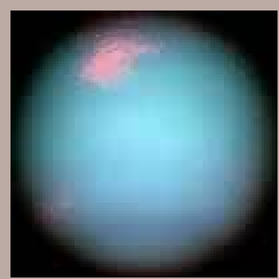
Hubble Discovers New Dark Spot on Neptune



The distant, blue-green planet Neptune has again surprised astronomers with the emergence of a new great dark spot in the cloudy planet's Northern Hemisphere, discovered by the Hubble telescope.



Only last June, Hubble images revealed that a great dark spot in the Southern Hemisphere — discovered by the Voyager 2 spacecraft during its1989 flyby — had mysteriously disappeared. The new dark spot is a near mirror image of the one found in the Southern Hemisphere. Bright, high-altitude clouds accompany the new northern dark spot. Atmospheric gases that flow up over the spot cool to form the methane-ice crystal clouds. The new spot might be a hole in Neptune's methane cloud tops, giving astronomers a peek at lower levels of the atmosphere.

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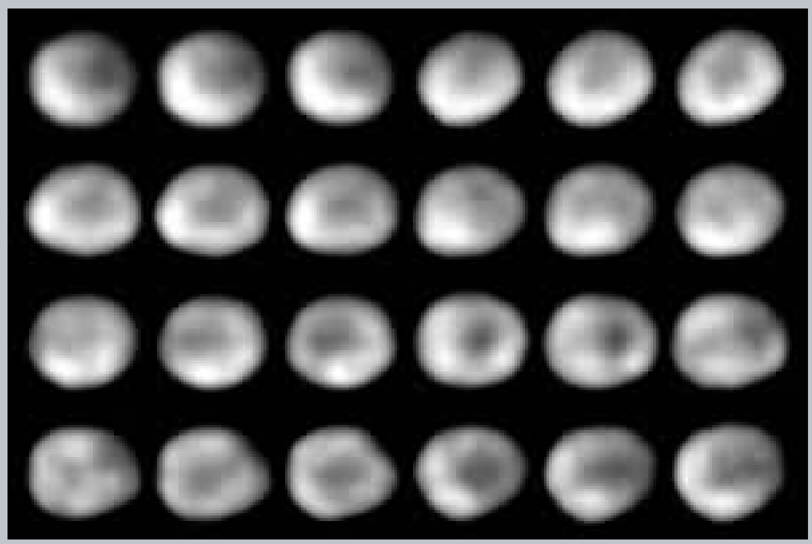
Asteroid or Mini-Planet? Hubble Maps the Ancient Surface of Vesta



Hubble telescope images of the asteroid Vesta are providing astronomers with a glimpse of the oldest terrain ever seen in the solar system and a peek into a broken-off section of the "mini-planet," which exposes its interior.

Hubble's pictures provide the best view yet of Vesta's complex surface, which has geologic features similar to that of terrestrial worlds such as Earth or Mars. The asteroid's ancient surface, battered by collisions eons ago, allows astronomers to peer below the asteroid's crust and into its past. These images trace the asteroid through a full rotation.

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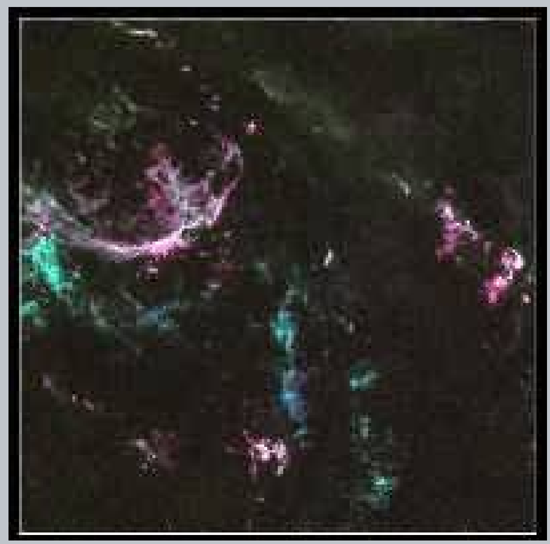
Oxygen-Rich Supernova Remnant in the Large Magellanic Cloud



This is a Hubble telescope image of the tattered debris of a star that exploded 3,000 years ago as a supernova. This supernova remnant, called N132D, lies 169,000 light-years from Earth in the satellite galaxy, the Large Magellanic Cloud.

A Hubble snapshot of the supernova's inner regions shows the complex collisions that take place as fast-moving material slams into cool, dense interstellar clouds. This level of detail in the expanding filaments could only be seen previously in much closer supernova remnants. Now, Hubble's capabilities extend the detailed study of supernovae to the distance of a neighboring galaxy.

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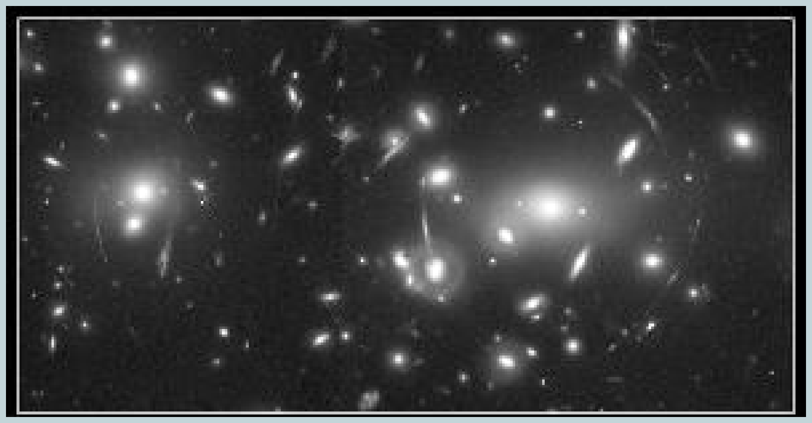
Hubble Views Distant Galaxies through a Cosmic Lens



This Hubble telescope image of a rich cluster of galaxies called Abell 2218 is a spectacular example of gravitational lensing. The arc-like pattern spread across the picture like a spider web is an illusion caused by the cluster's gravitational field.

This cluster of galaxies is so massive and compact that light rays passing through it are deflected by its enormous gravitational field, much as a camera's lens bends light to form an image. This phenomenon magnifies, brightens, and distorts images of those faraway objects, providing a powerful "zoom lens" for viewing galaxies that are so far away they could not normally be observed with the largest telescopes.

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Hubble Tracks Jupiter Storms

The Hubble telescope is following dramatic and rapid changes in Jupiter's turbulent atmosphere that will be critical for planning observations for the Galileo space probe when it arrives at the giant planet later this year.

This Hubble image provides a detailed look at a unique cluster of three white, oval-shaped storms that lie southwest [below and to the left] of Jupiter's Great Red Spot [dark oval-shaped object near the picture's right edge]. The appearance of the clouds is considerably different from their appearance only seven months earlier. Hubble shows these features moving closer together as the Great Red Spot is carried westward by the prevailing winds, while the white ovals are swept eastward.

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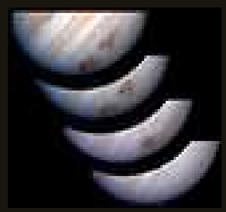
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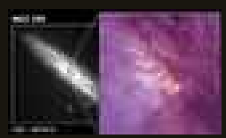
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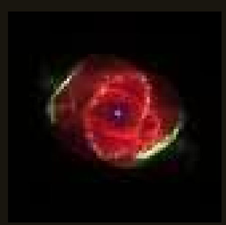
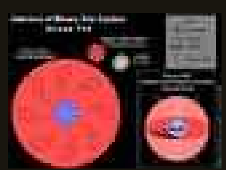

Jan 11, 1995 Hubble Probes the Complex History of a Dying Star


Jan 10, 1995 Hubble Views a Starry Ring World Born in a Head-On Collision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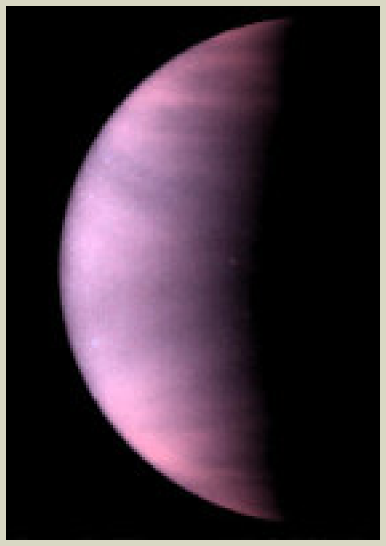
Venus in Ultraviolet Light



The Hubble telescope snapped this ultraviolet-light picture of Venus when the planet was 70.6 million miles (113.6 million kilometers) from Earth.

Venus is covered with clouds made of sulfuric acid, rather than the water-vapor clouds found on Earth. These clouds permanently shroud Venus's volcanic surface. At ultraviolet wavelengths cloud patterns become distinctive. In particular, a horizontal "Y"-shaped cloud feature is visible near the equator. Similar features were seen from the Mariner 10, Pioneer Venus, and Galileo space probes. This global feature might indicate atmospheric waves, analogous to high- and low-pressure cells on Earth.

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Comet Fragment Slams into Jupiter

In July 1994, 21 chunks of comet Shoemaker-Levy 9, which had broken apart a year earlier, slammed into Jupiter. The Hubble telescope recorded this spectacular event.

These images, beginning at lower right, chronicle the results of one such collision. Hubble began snapping pictures of the impact area just five minutes after the collision. Nothing can be seen. Less than two hours later, a plume of dark debris is visible [bull's- eye pattern]. Two impact sites are visible in the next picture, taken a few days later. The final snapshot shows three impact sites, the newest near the bull's-eye-shaped region.

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Hubble Finds Oxygen Atmosphere on Jupiter's Moon, Europa

Astronomers using the Hubble telescope have identified the presence of an extremely tenuous atmosphere of molecular oxygen around Jupiter's moon, Europa. This makes Europa the first satellite ever found to have an oxygen atmosphere and only the third such solar system object beyond Earth to possess this gaseous element.

If all the oxygen on Europa were compressed to the surface pressure of Earth's atmosphere, it would fill only about a dozen Astrodome-sized stadiums.

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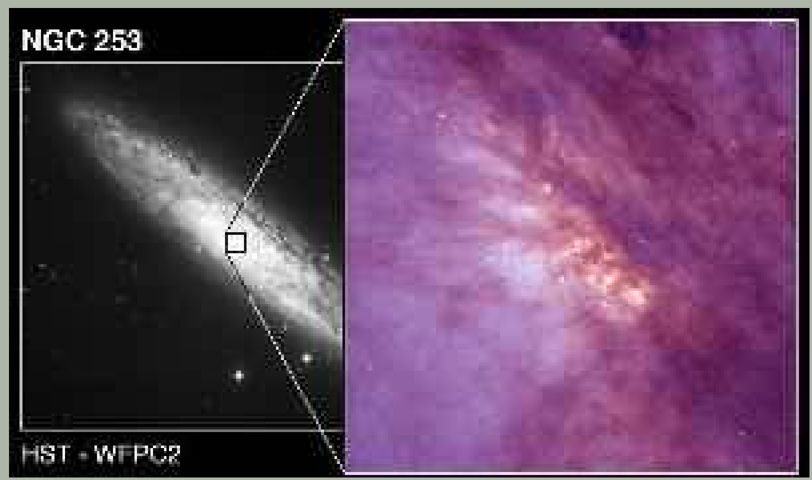
Hubble Probes the Violent Birth of Stars in Galaxy NGC 253



This Hubble telescope image of the core of the nearest starburst spiral galaxy, NGC 253, reveals violent star formation within a region 1,000 light-years across.

Hubble's sharp vision allows astronomers to see complex structures in the starburst core for the first time, including luminous star clusters, filaments of glowing gas, and dust lanes that trace regions of dense gas. Hubble identifies several regions of intense star formation, including a bright, super-compact star cluster. The entire galaxy is shown in the left-hand image, taken by a ground-based telescope.

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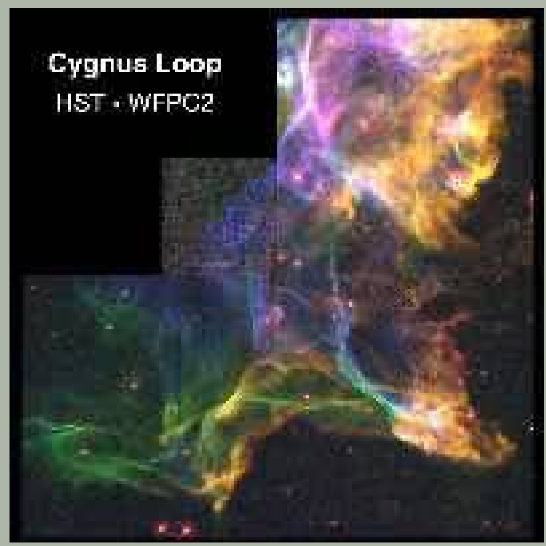
Hubble's Close-Up View of a Shock Wave from a Stellar Explosion



This Hubble telescope image shows a small portion of a nebula called the "Cygnus Loop." This nebula is an expanding blast wave from a stellar cataclysm, a supernova explosion, which occurred about 15,000 years ago.

The supernova blast wave, which is moving from left to right across the picture, has recently hit a cloud of denser-than-average interstellar gas. This collision drives shock waves into the cloud that heats interstellar gas, causing it to glow.

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Surprising Hubble Images Challenge Quasar Theory

Astronomers report today that new observations from the Hubble telescope challenge 30 years of scientific theory about quasars, the most energetic objects in the universe. Hubble images show, to the surprise of researchers, that the environment surrounding quasars is far more violent and complex than expected, providing evidence of galactic collisions and mergers.

This Hubble picture provides evidence for a merger between a quasar and a companion galaxy. The bright central object is the quasar itself, located several billion light-years away. The two wisps on the left of the central object are remnants of a bright galaxy that have been disrupted by the mutual gravitational attraction between the quasar and the companion galaxy.

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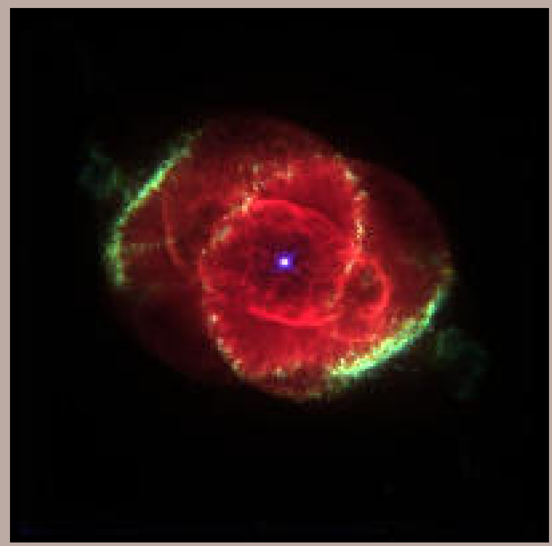
Hubble Probes the Complex History of a Dying Star



This Hubble telescope image shows one of the most complex planetary nebulae ever seen, NGC 6543, nicknamed the "Cat's Eye Nebula." Hubble reveals surprisingly intricate structures including concentric gas shells, jets of high-speed gas, and unusual shock-induced knots of gas. Estimated to be 1,000 years old, the nebula is a visual "fossil record" of the dynamics and late evolution of a dying star.

A preliminary interpretation suggests that the object might be a double-star system. The dynamical effects of two stars orbiting one another most easily explains the intricate structures, which are much more complicated than features seen in most planetary nebulae. The two stars are too close together to be individually resolved by Hubble and instead appear as a single point of light at the center of the nebula.

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Hubble Views a Starry Ring World Born in a Head-On Collision

A rare and spectacular head-on collision between two galaxies appears in this Hubble telescope picture of the Cartwheel Galaxy, located 500 million light-years from Earth in the constellation Sculptor.

The striking ring-like feature is a direct result of a smaller intruder galaxy — possibly one of two objects to the right of the ring — that careened through the core [close-up image at lower left] of the host galaxy. Like a rock tossed into a lake, the collision sent a ripple of energy into space, plowing gas and dust in front of it. Expanding at 200,000 mph, this cosmic tsunami leaves in its wake a firestorm of new star creation. Hubble resolves bright blue knots that are gigantic clusters of newborn stars [close-up image at upper left] and immense loops and bubbles blown into space by exploding stars (called supernovae) going off like a string of firecrackers.

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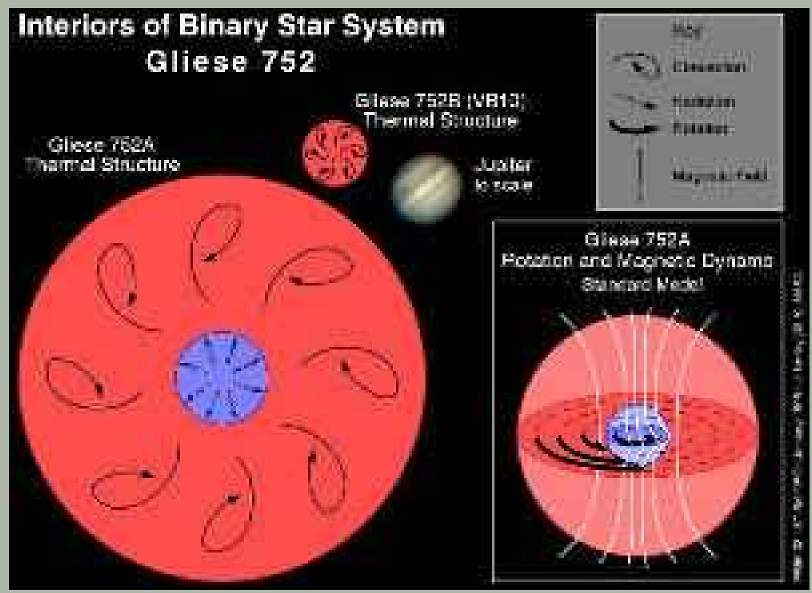
Red Dwarf Dynamo Raises Puzzle over Interiors of Lowest Mass Stars



Artist's Concept

The Hubble telescope has uncovered surprising evidence that powerful magnetic fields may exist around the lowest mass stars in the universe, which barely have enough nuclear fuel to burn as stars.

Hubble detected a high-temperature outburst, called a flare, on the surface of the extremely small, cool red dwarf star Van Biesbroeck 10, also known as Gliese 752B. Stellar flares are caused by intense, twisted magnetic fields that accelerate and contain gases that are much hotter than a star's surface. The illustration demonstrates the complex nature of this star.

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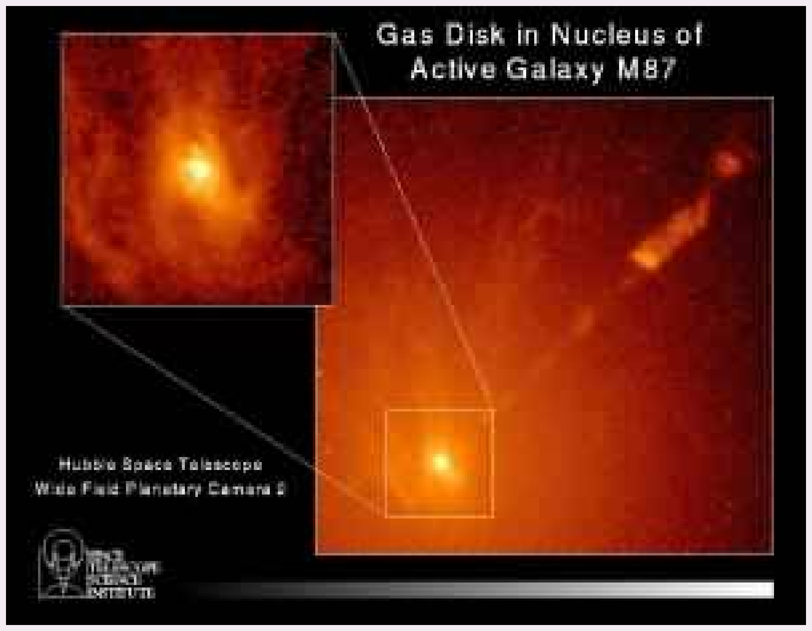
Hubble Confirms Existence of Massive Black Hole at Heart of Active Galaxy



Astronomers using the Hubble telescope have found seemingly conclusive evidence for a massive black hole in the center of the giant elliptical galaxy M87, located 50 million light-years from Earth in the constellation Virgo. Earlier observations suggested that the black hole was present, but they were not decisive.

This observation provides very strong support for the existence of gravitationally collapsed objects, which were predicted 80 years ago by Albert Einstein's general theory of relativity. This image shows a spiral-shaped disk of hot gas in the core of M87. Hubble measurements indicate that the disk's rapid rotation is strong evidence that it contains a massive black hole. A black hole is so massive and compact that nothing can escape its gravitational pull, not even light.

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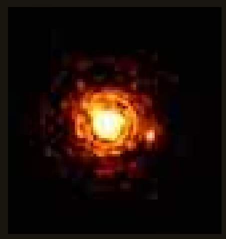

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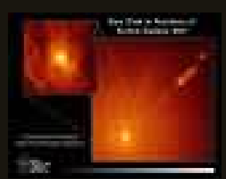

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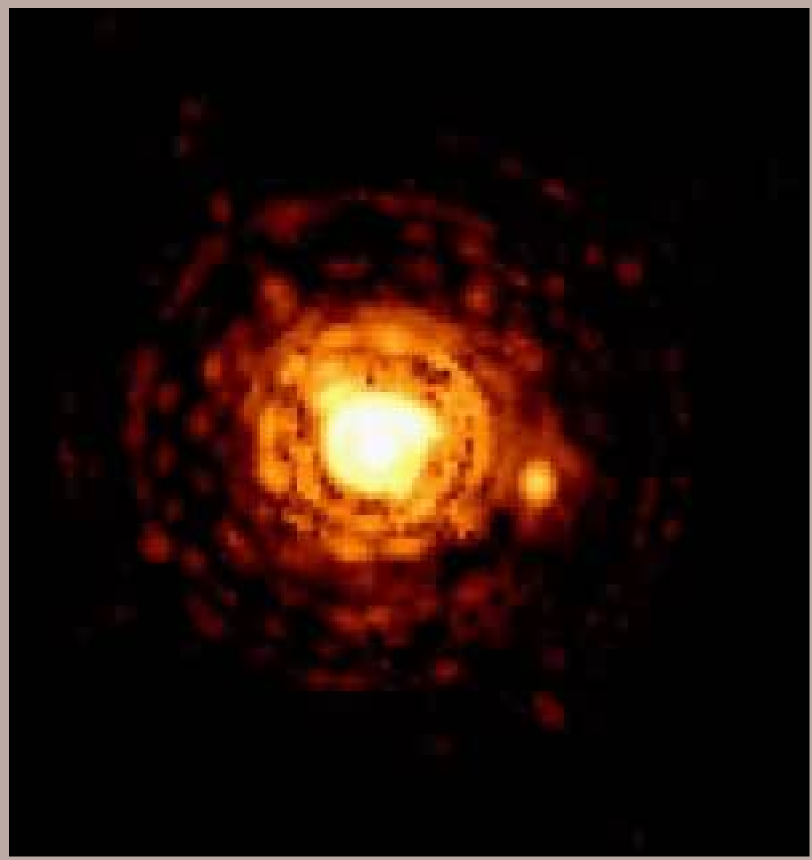
Hubble Finds One of the Smallest Stars in the Universe



The Hubble telescope's crisp vision has captured a first-time view of one of the smallest stars in our Milky Way Galaxy. Called Gliese 623b or Gl623b, the diminutive star [right of center] is 10 times less massive than the Sun and 60,000 times fainter. (If it were as far away as the Sun, it would be only eight times brighter than the full Moon).

Located 25 light-years from Earth in the constellation Hercules, Gl623b is the smaller component of a double-star system, where the separation between the two members is only twice the distance between Earth and the Sun (approximately 200 million miles). The small star completes one orbit around its larger companion every four years.

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Hubble Observes A New Saturn Storm

This Hubble telescope picture of Saturn captures a rare storm that appears as a white arrowhead-shaped feature near the planet's equator. An upwelling of warmer air, similar to a terrestrial thunderhead, generates the storm.

The east-west extent of this storm is equal to the diameter of the Earth (about 7,900 miles). Hubble provides new details about the effects of Saturn's prevailing winds on the storm. These winds shape a dark "wedge" that eats into the left side of the bright central cloud. The new image shows that the storm's motion and size have changed little since its discovery in September 1994.

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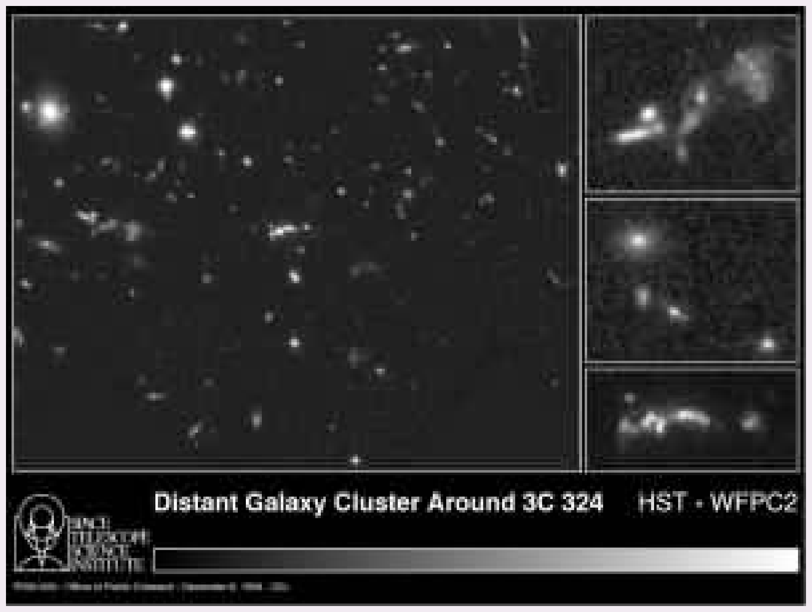
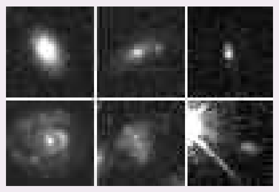
Hubble Identifies Primeval Galaxies, Uncovers New Clues to the Universe's Evolution



Astronomers using the Hubble telescope as a "time machine" have obtained the clearest views yet of distant galaxies that existed when the universe was a fraction of its current age.



A series of remarkable pictures, spanning the life history of the cosmos, are providing the first clues to the life history of galaxies. The Hubble results suggest that elliptical galaxies developed remarkably quickly into their present shapes. However, spiral galaxies that existed in large clusters evolved over a much longer period — the majority being built and then torn apart by dynamic processes in a restless universe. These pictures of faraway galaxies, located 5 to 10 billion light-years from Earth, illustrate the findings.

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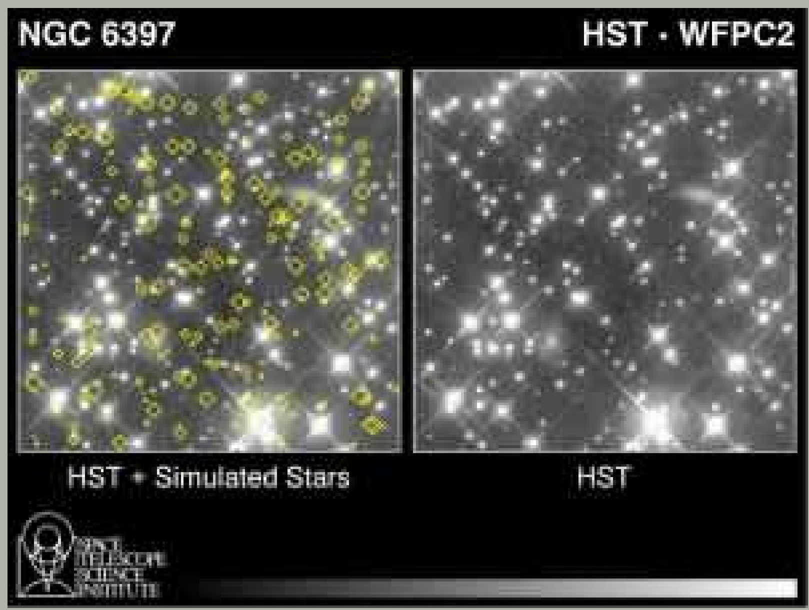
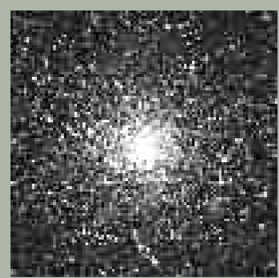
Hubble Rules Out a Leading Explanation for Dark Matter



Astronomers have ruled out the possibility that red dwarf stars constitute the invisible matter, called dark matter, believed to account for more than 90 percent of the universe's mass.



Until now, the dim, small stars were considered ideal candidates for dark matter. Whatever dark matter is, its gravitational pull ultimately will determine whether the universe will expand forever or will someday collapse. Picking a region in our Milky Way Galaxy, astronomers predicted that Hubble should have spied 38 red dwarf stars if this class of objects harbored most of the dark matter. The diamond-shaped symbols in the left-hand image illustrate what scientists expected to see. Instead, they saw no stars [right-hand photo].

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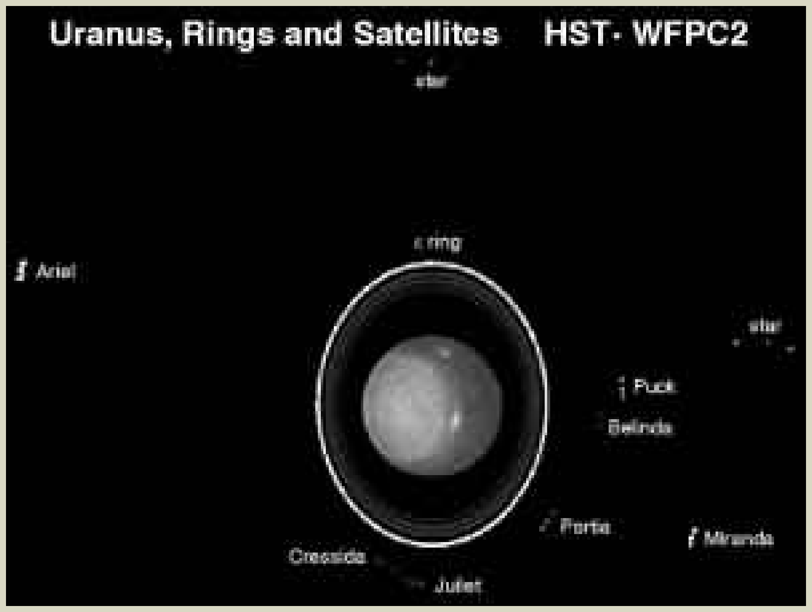
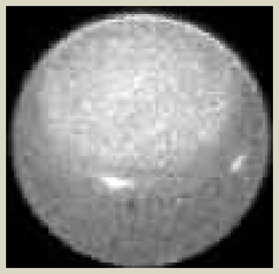
Hubble Observes the Moons and Rings of the Planet Uranus



This Hubble telescope snapshot of the planet Uranus reveals the planet's rings, at least five of the inner moons, and bright clouds in the Southern Hemisphere. Hubble allows astronomers to revisit the planet at a level of detail not possible since the Voyager 2 spacecraft flew by the planet briefly, nearly a decade ago.

This picture is a combination of images showing the motion of the inner moons. Each inner moon appears as a string of three dots. Thanks to Hubble's capabilities, astronomers will be able to precisely determine the moons' orbits.



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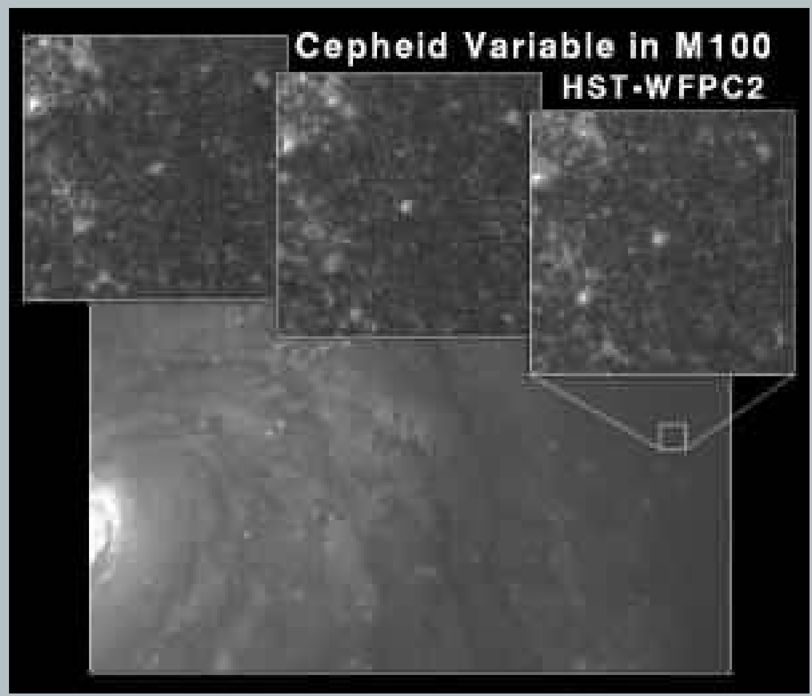
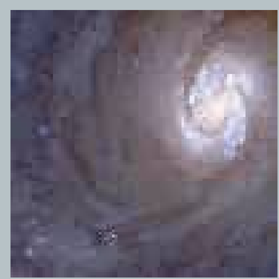
Hubble Space Telescope Measures Precise Distance to the Most Remote Galaxy Yet



Astronomers using the Hubble telescope have announced the most accurate distance measurement yet to the remote galaxy M100, located in the Virgo cluster of galaxies.



This measurement will help provide a precise calculation of the expansion rate of the universe, called the Hubble Constant, which is crucial to determining the age and size of the universe. They calculated the distance — 56 million light-years — by measuring the brightness of several Cepheid variable stars in the galaxy. Cepheid variables are a class of pulsating star used as "milepost markers" to calculate the distance to nearby galaxies. The bottom image shows a region of M100. This Hubble telescope image [bottom] is a close-up of a region of the galaxy M100. The top three frames, taken over several weeks, reveal the rhythmic changes in brightness of a Cepheid variable [center of each box].

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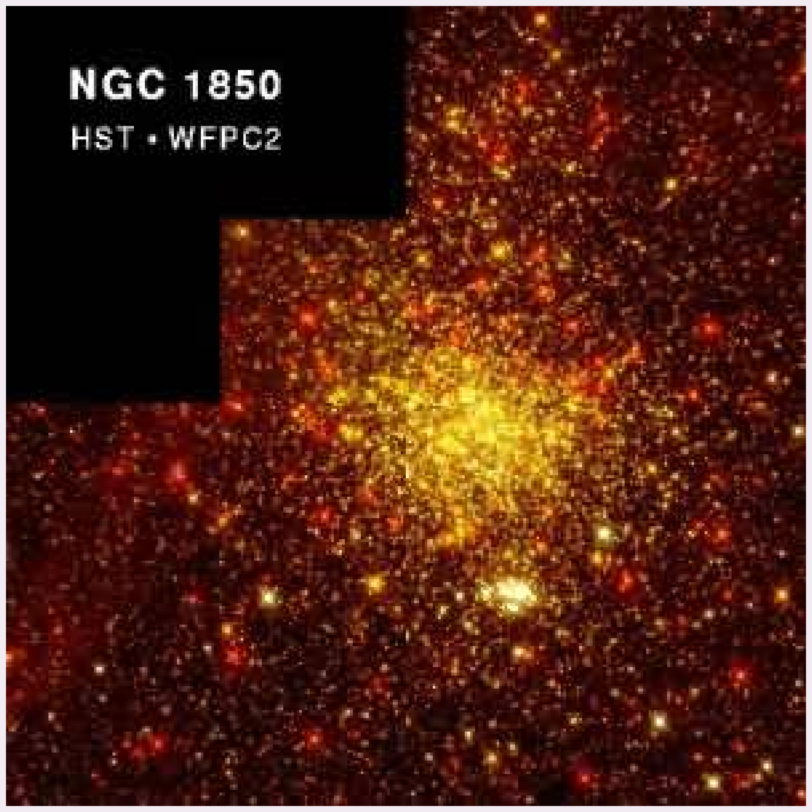
Tale Of Two Clusters Yields Secrets of Star Birth in the Early Universe



The Hubble telescope has provided new insights into how stars may have formed many billions of years ago in the early universe. Hubble observations of a pair of star clusters suggest they might be linked through stellar evolution processes.

The pair of clusters is 166,000 light-years from Earth in the Large Magellanic Cloud in the southern constellation Doradus. The clusters are unusually close together for being distinct and separate objects, suggesting that they might be evolutionary relatives.

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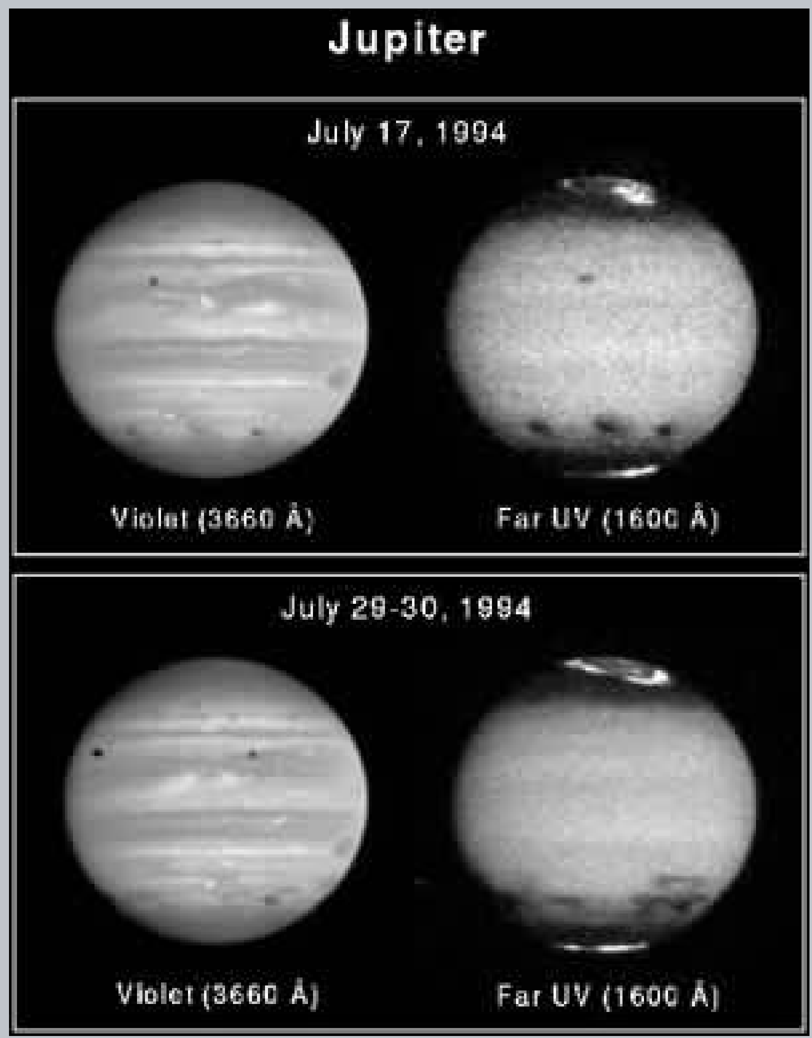
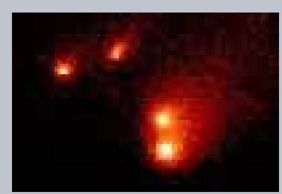


In the weeks following comet P/Shoemaker-Levy 9's spectacular July collision with Jupiter, a team of Hubble telescope astronomers has pored over imaging and spectroscopic data gleaned during the interplanetary bombardment. Their initial findings, combined with results from other space-borne and ground-based telescopes, shed new light on Jupiter's atmospheric winds, it's immense magnetic field, the mysterious dark debris from the impacts, and the composition of the doomed comet itself.



These four Hubble telescope images of Jupiter, as seen in visible and far-ultraviolet wavelengths, show the remarkable dispersion of the clouds of smoke and dust thrown into the atmosphere after chunks of the comet slammed into Jupiter's southern region [lower center of each image. These dark regions provide the only information ever obtained on the wind direction and speed in Jupiter's upper atmosphere.

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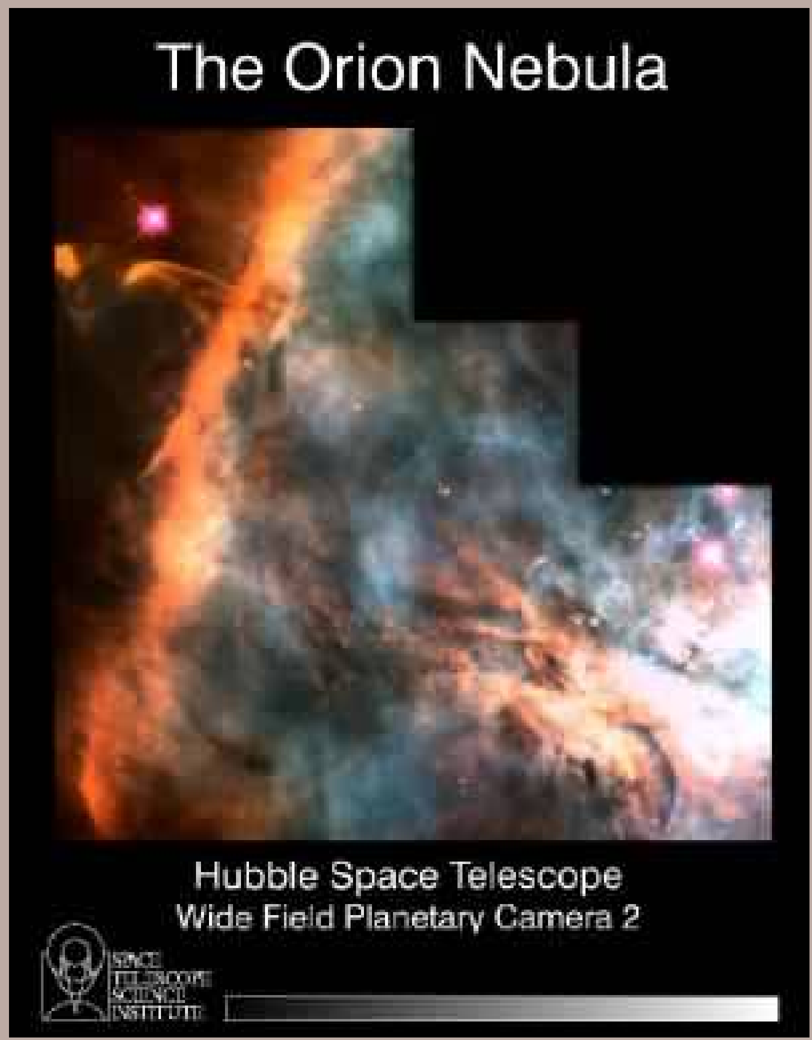
Hubble Confirms Abundance of Protoplanetary Disks around Newborn Stars



Astronomers using the Hubble telescope have uncovered the strongest evidence yet that the planet-making process is common in the Milky Way Galaxy.

Observations clearly reveal that great disks of dust — the raw material for planet formation — are swirling around at least half and probably many more of the stars in the Orion Nebula, a star-forming region only 1,500 light-years from Earth.

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Matches 11-12 of 12 shown
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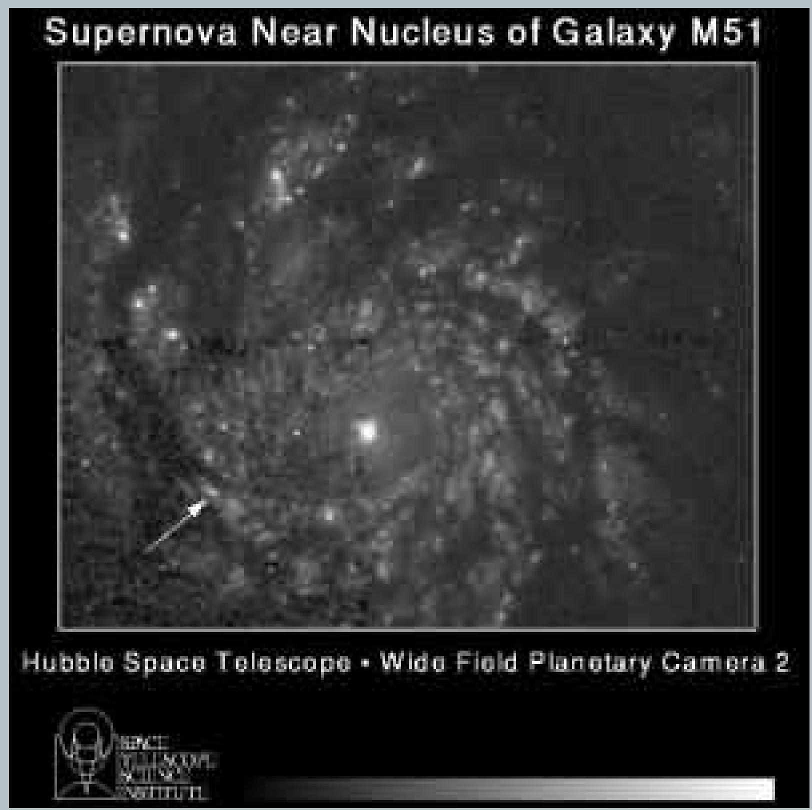
Hubble Observes the Supernova in the Whirlpool Galaxy



The Hubble telescope has returned valuable new images of supernova 1994I in the inner regions of the "Whirlpool Galaxy," M51, located 20 million light-years from Earth in the constellation Canes Venatici. The arrow marks the supernova's location.

The supernova was discovered by amateur astronomers on April 2, 1994 and has been the target of investigations by astronomers using ground-based optical and radio telescopes. At its brightest, around April 10, the supernova was about 100 million times more luminous than the Sun. A supernova is a violent stellar explosion that destroys a massive star.

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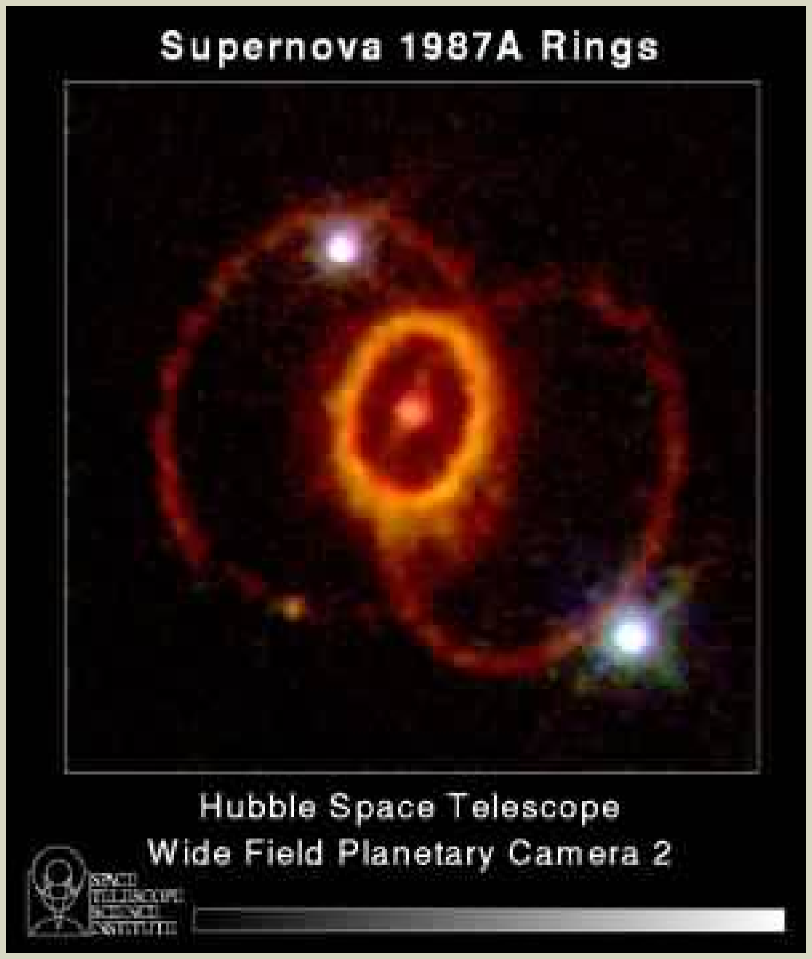
Hubble Finds Mysterious Ring Structure around Supernova 1987a



The Hubble telescope has obtained the best images yet of a mysterious mirror-imaged pair of rings of glowing gas encircling the site of the stellar explosion called supernova 1987A.

One possibility for these "hula hoops" of gas is that the two rings might be caused by a high-energy beam of radiation that is sweeping across the gas, like a searchlight sweeping across clouds. Though all of the rings appear inclined to our view (so that they appear to intersect), they are probably in three different planes. The small, bright ring lies in a plane containing the supernova; one larger ring lies in front of and the other behind the smallest one.

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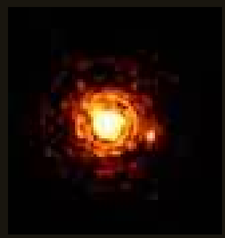

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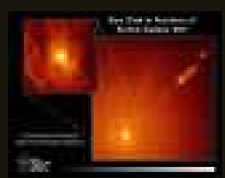

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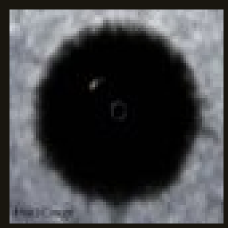
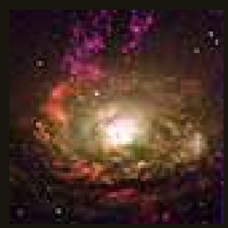
Sep 12, 2001 Ancient Black Hole Speeds Through Sun's Galactic Neighborhood, Devouring Companion Star



Jan 11, 2001 'Death Spiral' Around a Black Hole Yields Tantalizing Evidence of an Event Horizon

2000



Nov 30, 2000 Hubble Captures an Extraordinary and Powerful Active Galaxy

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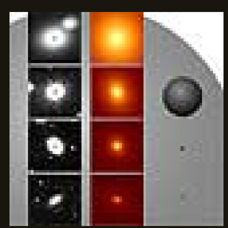
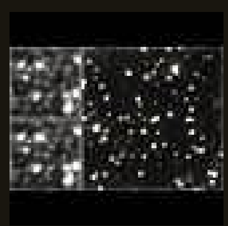
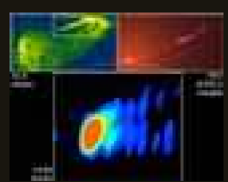


Jun 5, 2000 Black Holes Shed Light on Galaxy Formation



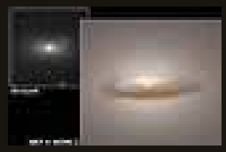
Jan 13, 2000 Lone Black Holes Discovered Adrift in the Galaxy

1999

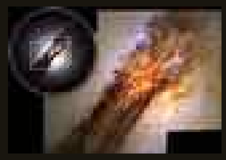


Oct 27, 1999 Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole

1998

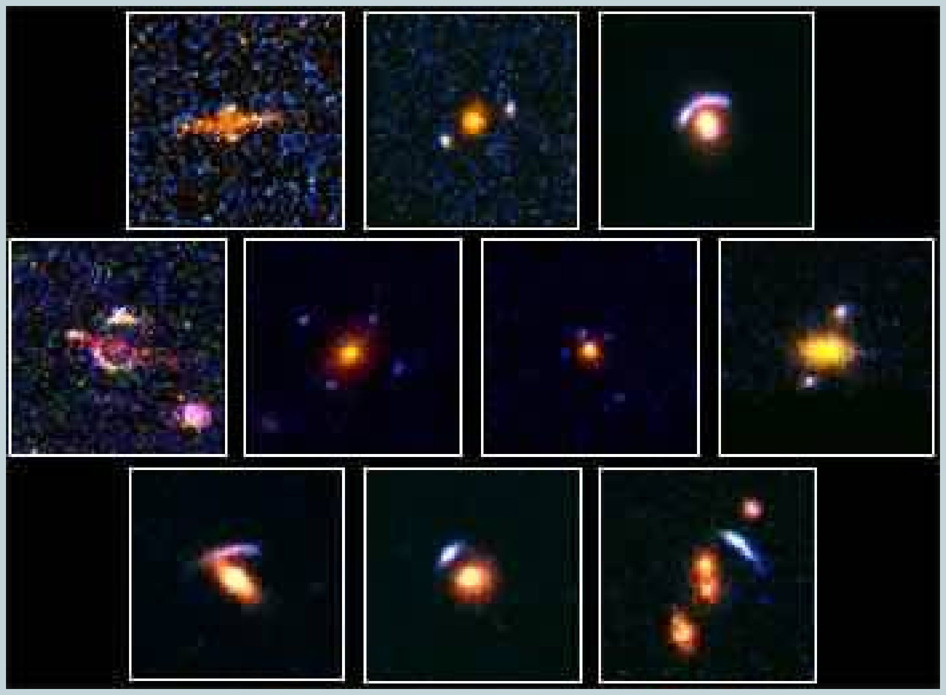


Jun 18, 1998 [Hubble Uncovers Dust Disk around a Massive Black Hole]



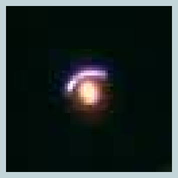
May 14, 1998 [Hubble Provides Multiple Views of How to Feed a Black Hole]

Natural Lenses in Space Stretch Hubble's View of the Universe



A Hubble telescope survey of the sky has uncovered exotic patterns, rings, arcs, and crosses that are all mirages produced by a gravitational lens, nature's equivalent of having a giant magnifying glass in space.

A gravitational lens is created when the gravity of a massive foreground object, such as a galaxy or a black hole, bends the light coming from a far more distant galaxy directly behind it. This "gravitational muscle" focuses the light to give multiple or distorted images of the background object as seen by the observer. Shown are 10 examples from the survey.



HST 15433+5352 is a very good lens candidate with a bluer lensed source in the form of an extended arc about the redder elliptical lensing galaxy.

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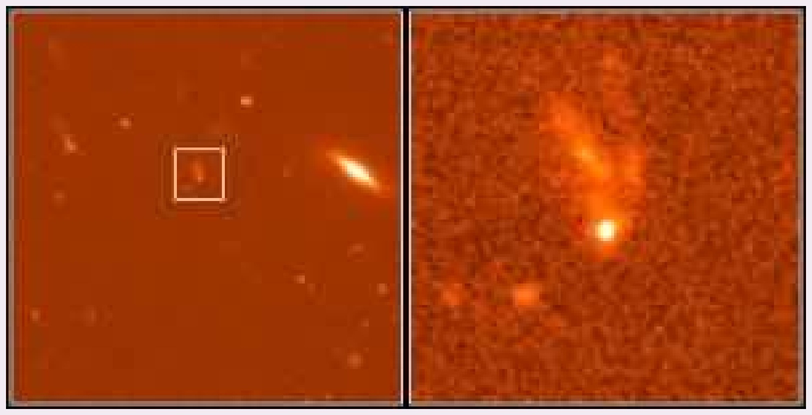
1999

Hubble Views Home Galaxy of Record-Breaking Explosion



Here are Hubble telescope views of the rapidly fading visible-light fireball from the most powerful cosmic explosion recorded to date. For a brief moment the light from the blast was equal to the radiance of 100 million billion stars. The initial explosion began as an intense burst of gamma rays, which happened on Jan. 23, 1999.

The blast had already faded to one four-millionth of its original brightness when Hubble made observations on February 8 and 9 [image on left]. Hubble captured the fading fireball embedded in a galaxy located two-thirds of the way to the horizon of the observable universe. The picture on the right is a close-up view of the galaxy, the finger-like filaments extending above the bright white blob of the gamma-ray fireball.

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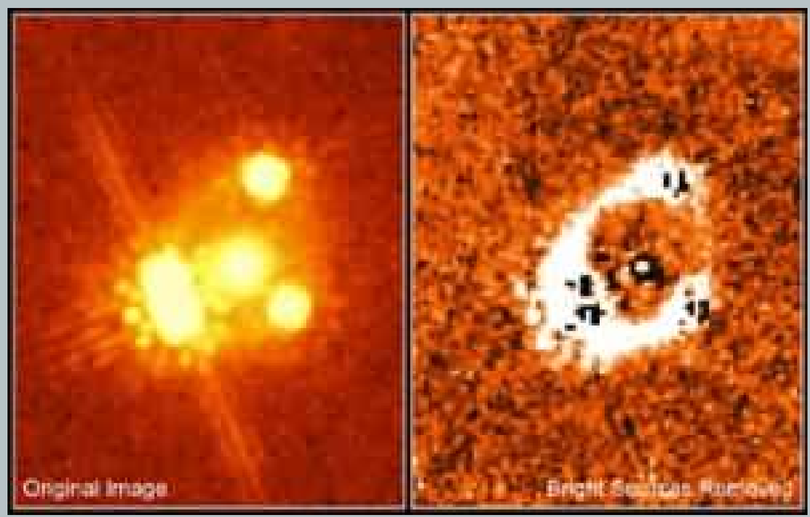
Quasar PG1115+080 and Gravitational Lens



Astronomers who are using the Hubble telescope to observe the gravitational lensing of light from distant quasars have discovered new evidence about the rate at which the universe is expanding.

The lensing study shows that the universe is expanding at rates slightly slower than, but similar to, rates calculated from the Hubble Key Project to measure the size and age of the universe. The distance scale was one of the primary science problems that Hubble was built to address. In the infrared picture on the left, the light from the quasar PG 1115+080 is split and distorted. In the infrared picture on the right, the four quasar images and the lens galaxy have been subtracted, revealing a nearly complete ring of infrared light. A gravitational lens is created when the gravity of a massive foreground object, such as a galaxy or a black hole, bends the light coming from a far more distant galaxy directly behind it. This "gravitational muscle" focuses the light to give multiple or distorted images of the background object as seen by the observer.

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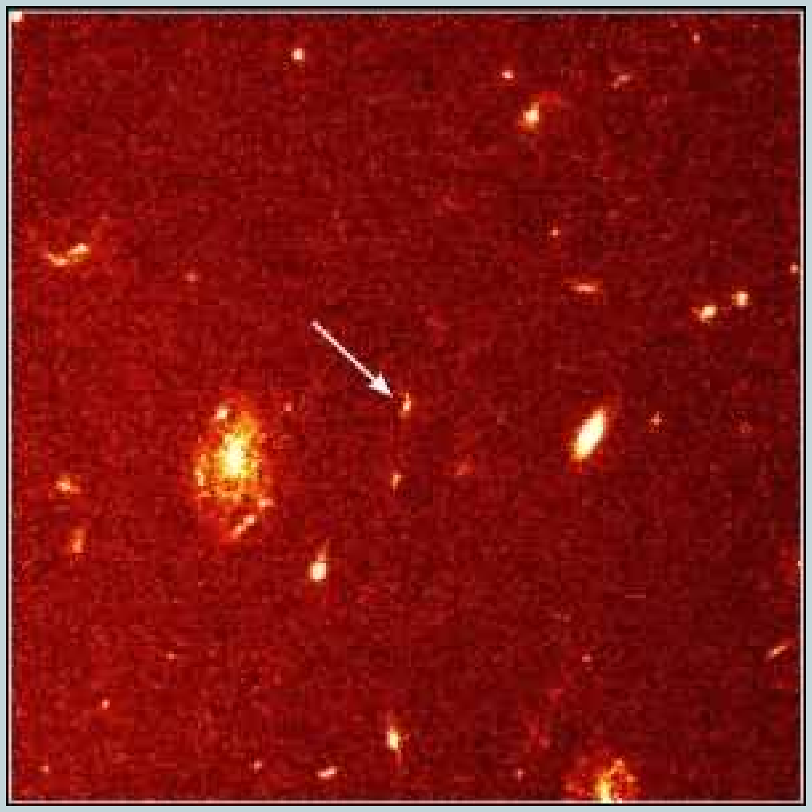
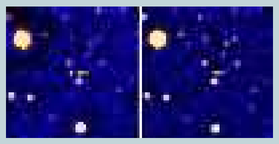
Gamma-Ray Burst Found to be Most Energetic Event in Universe



A team of astronomers has announced that a recently detected gamma-ray burst was as bright as the rest of the universe, releasing a hundred times more energy than previously theorized.



The team has measured the distance to a faint galaxy from which the burst, designated GRB 971214, originated. It is about 12 billion light-years from Earth. The astronomers used a suite of satellites and ground-based telescopes to follow the burst. This Hubble image of the GRB 971214 field was taken about four months after the burst, well after the afterglow has faded away. The extremely faint and distant object marked with an arrow is the host galaxy of the gamma-ray burst.

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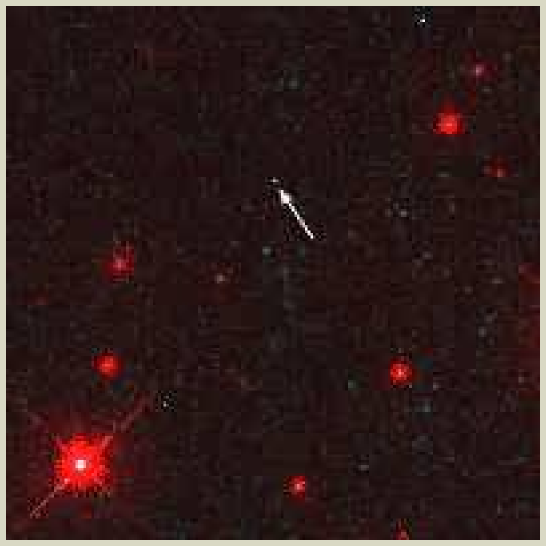
Hubble Sees a Neutron Star Alone in Space



Astronomers using the Hubble telescope have taken their first direct look in visible light at a lone neutron star. This view offers a unique opportunity to pinpoint the star's size and to narrow theories about the composition and structure of this bizarre class of gravitationally collapsed, burned out stars.

The Hubble results show that the star [marked by white arrow] is very hot and can be no larger than 16.8 miles (28 kilometers) across. These findings prove that the object must be a neutron star, for no other known type of object can be this hot, small, and dim.

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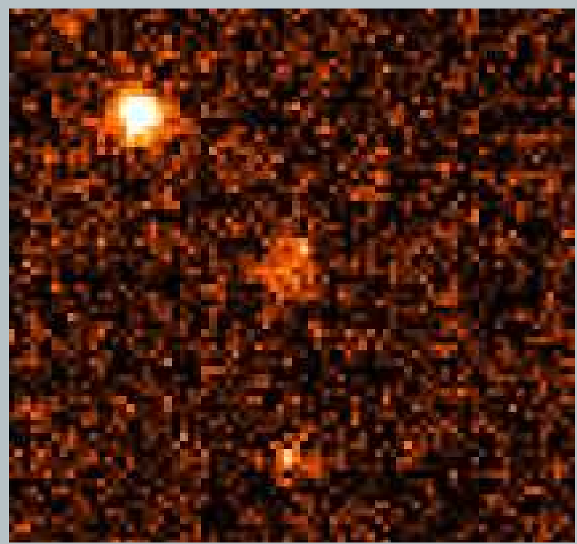
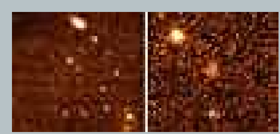
Hubble Stays on Trail of Fading Gamma-Ray Burst Fireball, Results Point to Extragalactic Origin



Hubble telescope observations of the ever-fading fireball from one of the universe's most mysterious phenomena — a gamma-ray burst — is reinforcing the emerging view that these titanic explosions happen far away in other galaxies and are among the most spectacularly energetic events in the universe.

In this Hubble image of the gamma-ray burst's visible-light component, the fireball has faded to 1/500th its brightness since its discovery in March 1997 by ground-based telescopes. Hubble continues to clearly see the fireball [center of picture] and a cloud of material surrounding it, which is considered to be its host galaxy.



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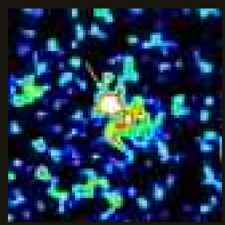
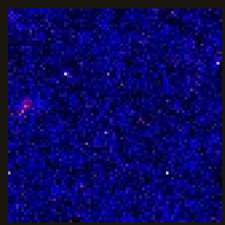


Jun 10, 1997 Gamma-Ray Bursts Common To Normal Galaxies? Hubble Data Offer New Clues and Puzzles



Apr 1, 1997 Hubble Tracks the Fading Optical Counterpart of a Gamma-Ray Burst

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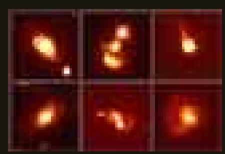

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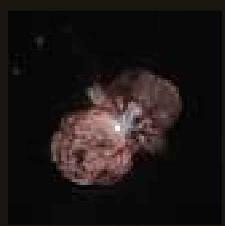
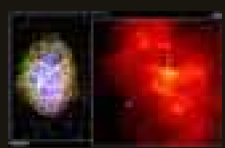
Jul 18, 1996 Hubble Achieves Milestone: 100,000th Exposure



Jun 10, 1996 Doomed Star Eta Carinae



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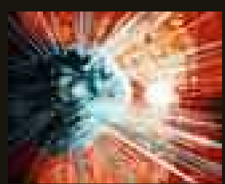
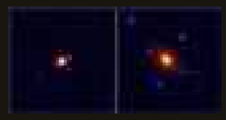
Apr 24, 1996 Hubble Space Telescope Completes Sixth Year of Exploration



Jan 10, 1996 Hubble Discovers Powerful Laser Beamed from Chaotic Star

1995



Oct 18, 1995

Hubble Discovers New Class of Gravitational Lens for Probing the Structure of the Cosmos

World's Most Powerful Telescopes Team Up With A Lens In Nature To Discover Farthest Galaxy In The Universe

An international team of astronomers has discovered the most distant galaxy in the universe to date. They found it by combining the unique sharpness of the Hubble telescope with the light-collecting power of the W. M. Keck Telescopes — with an added boost from a gravitational lens in space.

The results show the young galaxy is as far as 13 billion light-years from Earth, based on an estimated age for the universe of approximately 14 billion years. The Hubble picture at left shows the young galaxy as a red crescent to the lower right of center. The galaxy's image is brightened, magnified, and smeared into this arc-shape by the gravitational influence of an intervening galaxy cluster, which acts like a gigantic lens. The image at upper right is a close-up of the "gravitationally lensed" galaxy. In the picture at lower right, astronomers have "unsmeared" the galaxy, revealing the galaxy's normal appearance.

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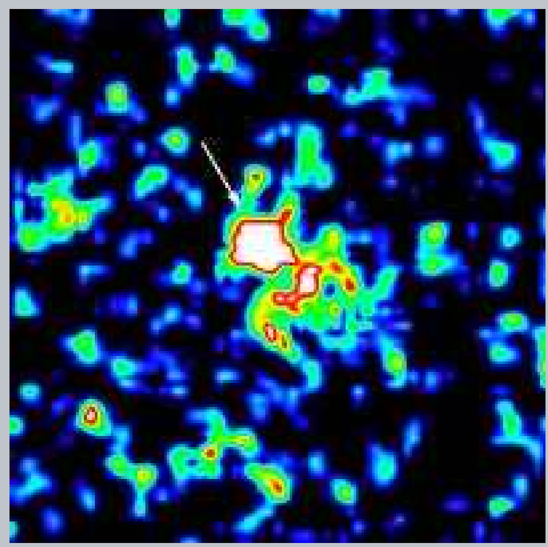
Gamma-Ray Bursts Common To Normal Galaxies? Hubble Data Offer New Clues and Puzzles



Nature's most powerful explosions, gamma-ray bursts, occur among the normal stellar population inside galaxies scattered across the universe. The energy released in such a titanic explosion, which can last from a fraction of a second to a few hundred seconds, is equal to all of the Sun's energy generated over its 10-billion-year lifetime.

Here is the visible glow from one such burst, GRB 970228. This Hubble telescope picture is the first visible-light view ever taken that links a gamma-ray burst with a potential host galaxy. This observation provides strong supporting evidence that gamma-ray bursts are cosmological- they originate in distant galaxies across the universe. The arrow points to the fireball, which is the white blob immediately to the upper left of center. Immediately to the lower right of center is an extended object (roughly resembling an "E") and interpreted to be the host galaxy where the gamma-ray burst is embedded.

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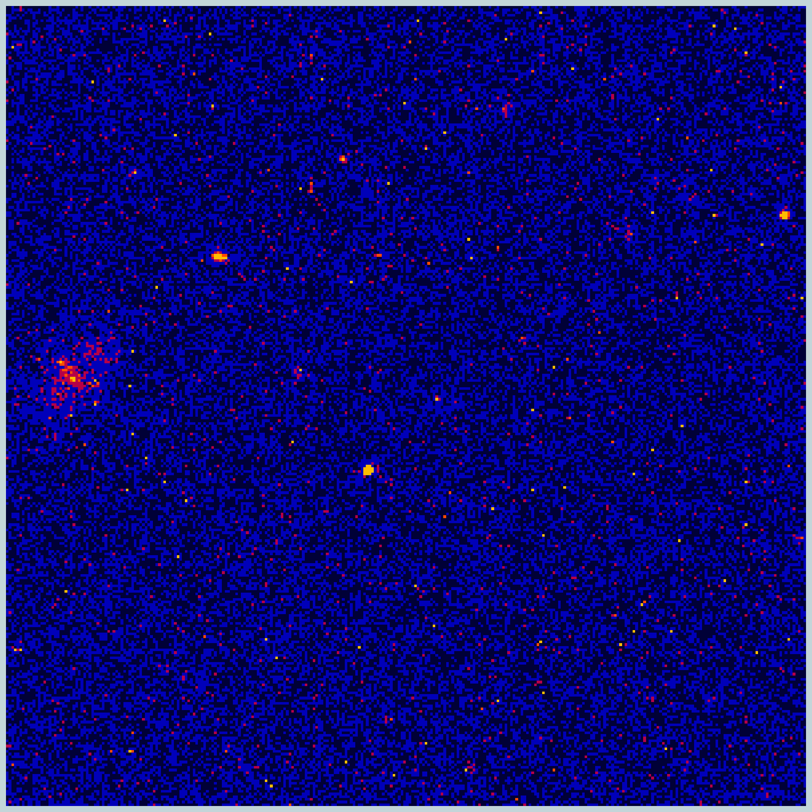
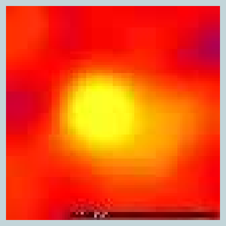
Hubble Tracks the Fading Optical Counterpart of a Gamma-Ray Burst



The Hubble telescope has made an important contribution toward solving one of astronomy's greatest enigmas by allowing astronomers to continue watching the fading visible-light counterpart of a gamma-ray burst, one of the most energetic and mysterious events in the universe.

The so-called optical counterpart is presumably a cooling fireball from the catastrophic event that triggered the massive burst of invisible gamma rays — the highest-energy radiation in the universe. This event may have unleashed as much energy in a few seconds as the Sun does in 10 billion years! The orange dot in the center of this Hubble image represents the burst's visible-light glow.



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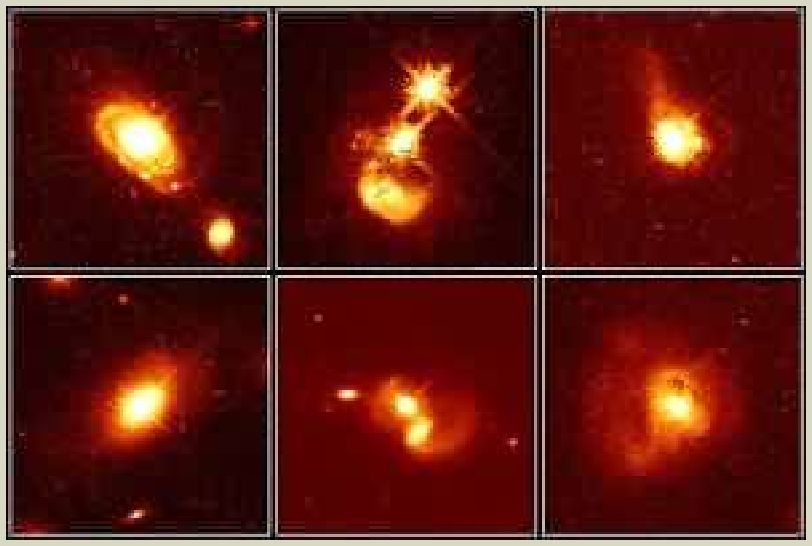
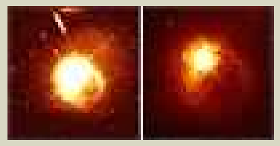
Hubble Surveys the "Homes" of Quasars



Dramatic Hubble telescope pictures reveal that quasars live in a remarkable assortment of galaxies, many of which are violently colliding. This complicated picture suggests there may be a variety of mechanisms — some quite subtle — for "turning on" quasars, the universe's most energetic objects.



When seen through ground-based telescopes, these compact, enigmatic light sources resemble stars, yet they are billions of light-years away and several hundred billion times brighter than normal stars. The following Hubble snapshots offer examples of quasar home sites. Astronomers believe that a quasar turns on when a massive black hole at the center of a galaxy feeds on gas and stars.

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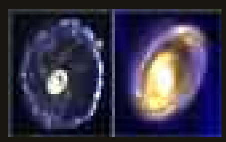
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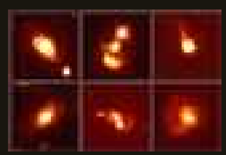
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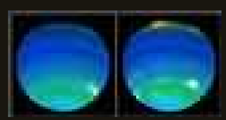
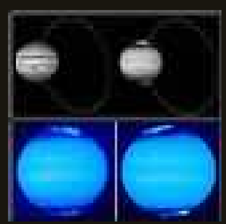
Nov 1, 1996 Springtime Dust Storm Swirls at Martian North Pole


Oct 24, 1996 Hubble Makes Movie of Neptune's Rotation and Weather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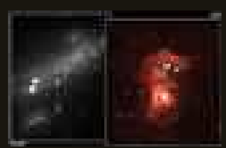
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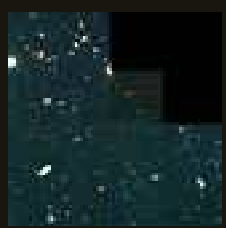
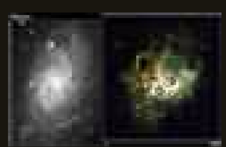
Oct 4, 1996 Rare Hubble Portrait of Io and Jupiter


Sep 4, 1996 Hubble Sees Early Building Blocks of Today's Galaxies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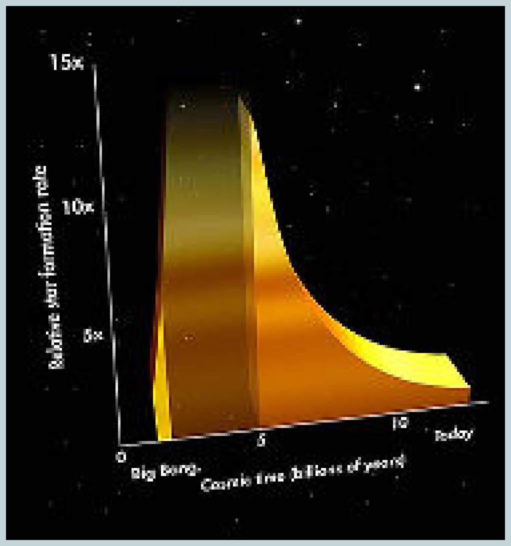

Artist's Concept

Analyzing the pictures of some of the most distant galaxies in the universe, astronomers are uncovering intriguing new evidence that the Big Bang was followed by a stellar "baby boom."

Hubble's unprecedented measurement of the rate of star birth in remote galaxies, which existed when the cosmos was less than 10 percent its current age, supports the emerging view that the early universe had an active, dynamic youth where stars formed out of dust and gas at a ferocious rate. The graph is based on observations of distant galaxies made by the Hubble telescope and ground-based observatories. Hubble shows a steep rise in star birth that happened shortly after the Big Bang. The ground-based data show a precipitous decline in the star formation rate, beginning about 9 billion years ago and continuing to the present.

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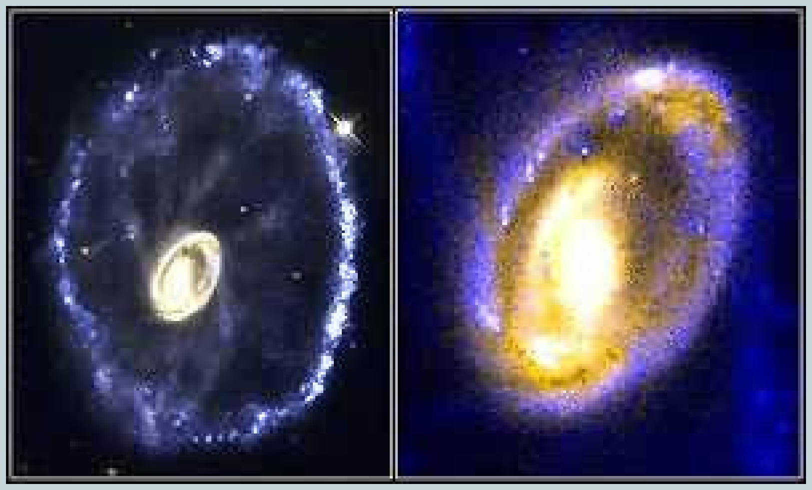
Hubble Spies Supersonic "Comet-Clouds" in Heart of Galaxy



Analysis of dramatic Hubble telescope images reveals immense comet-shaped knots of gas in the heart of the Cartwheel Galaxy. The galaxy's unusual wagon-wheel shape was created by a nearly head-on collision with a smaller galaxy about 200 million years ago.

The discovery of the knots may eventually help answer some compelling questions, such as why the center of the Cartwheel has little star formation and what causes the unusual spoke-shaped pattern between the bright outer ring of young stars and the mysterious, dusty galactic center. The galaxy's center is the bright object in the center of the left-hand picture; the spoke-like structures are wisps of material connecting the core to the outer ring of young stars. The close-up image of the galaxy's nucleus [picture on right] reveals the comet-like knots of gas. These knots are mostly confined to the core's left side and appear as white streaks inside the blue ring.

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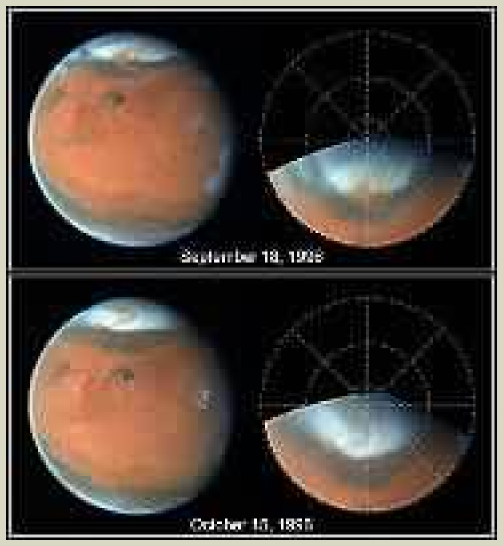
Springtime Dust Storm Swirls at Martian North Pole



Two Hubble telescope images of Mars, taken about a month apart, reveal a state-sized dust storm churning near the edge of the northern polar cap. The polar storm is probably a consequence of large temperature differences between the polar ice and the dark regions to the south, which are heated by the springtime sun. The increased sunlight also causes the dry ice in the polar cap to shrink.

Mars is famous for large, planet-wide dust storms. This is the first time that such an event has been caught near the receding northern polar cap. In the top picture, the salmon-colored notch in the white northern polar cap is a 600-mile-long (1,000 kilometer-long) storm — nearly the width of Texas. In the bottom image, taken one month later, the storm has dissipated. A distinctive dust-colored, comma-shaped feature can be seen curving across the ice cap.

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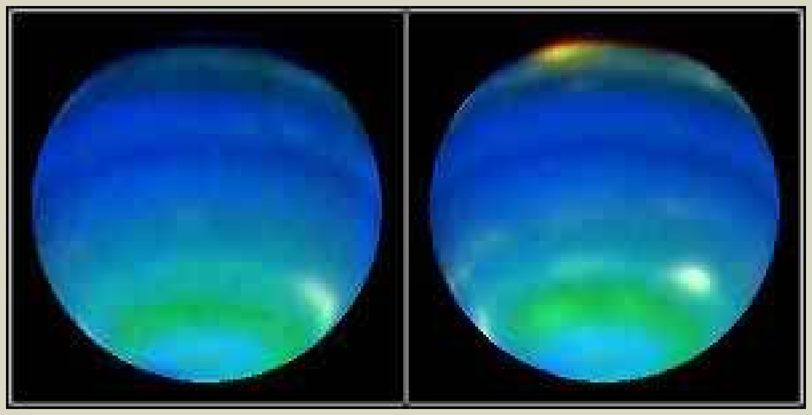
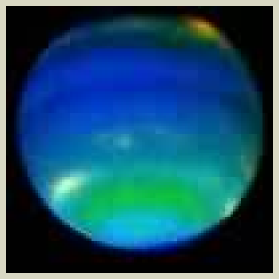
Hubble Makes Movie of Neptune's Rotation and Weather



The Hubble telescope has been used to assemble a time-lapse color movie showing a full 16-hour rotation of the distant planet Neptune. The movie, made from a series of Hubble observations over nine consecutive orbits, allows astronomers to track cloud motion on the planet. The clear pictures reveal the planet's powerful equatorial jet stream, immense storms, and dark spot in the Northern Hemisphere.

These snapshots provide views of the weather on opposite hemispheres. The photos disclose features of Neptune's blustery weather.



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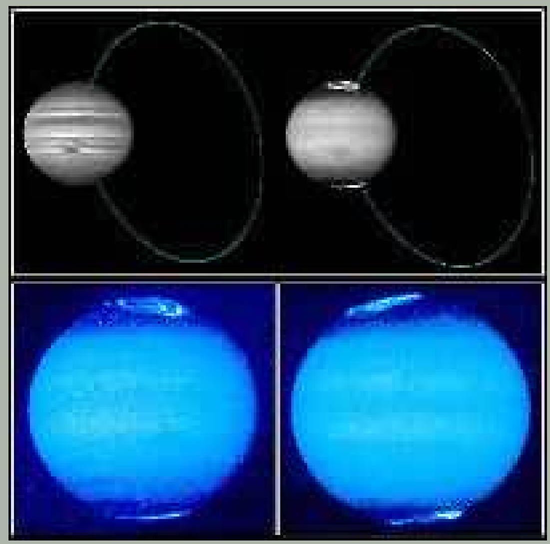

The Hubble telescope's sharp view of the rapid, spectacular dance of luminescent gases high in Jupiter's atmosphere — better known as aurora — is allowing astronomers to map Jupiter's immense magnetic field and better understand how it generates such phenomena.

The ultraviolet-light images [bottom frames] show how the auroral emissions change in brightness and shape as Jupiter rotates. The aurorae are the bright, circular features at the top and bottom of the planet. The top panel illustrates the effects of emissions from Io, one of Jupiter's moons. Io's ejects an invisible electrical current of charged particles, which flow along the planet's magnetic field lines.

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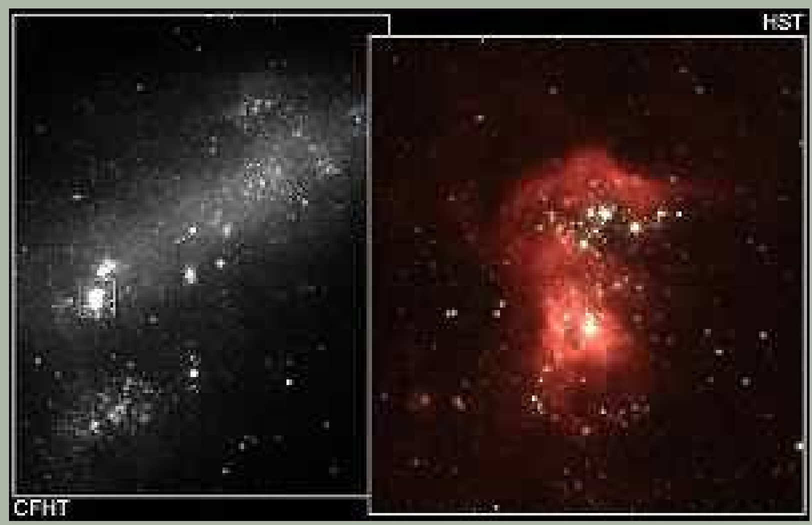
Bright Star Birth Region in a Dim Galaxy



Clusters of stars and a fishhook-shaped cloud of luminescent gases glow brilliantly in NGC 2363, a giant star-forming region in the Magellanic galaxy NGC 2366.

The brightest object visible in the Hubble telescope image [right] is a member of a rare class of stars called an erupting Luminous Blue Variable [at the tip of the fishhook]. This monstrous star (30 to 60 times as massive as the Sun) is in a very unstable, eruptive phase of its life. The Hubble telescope photo is the only one in which the star can be clearly isolated from the rest of the cluster. A view of this region from a terrestrial telescope is on the left. Only four giant eruptions of these special stars have been recorded in history, the most famous being Eta Carinae (1837-1860) and P Cygni (1600), within our own galaxy.

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Rare Hubble Portrait of Io and Jupiter

This image shows Jupiter's volcanic moon Io passing above the turbulent clouds of the giant planet. The conspicuous black spot on Jupiter is Io's shadow. This shadow is about the size of Io (2,262 miles or 3,640 kilometers across) and sweeps across the face of Jupiter at 38,000 mph (17 kilometers per second).

The smallest details seen on Io and Jupiter are about 100 miles across. Bright patches visible on Io are regions of sulfur dioxide frost. Io is roughly the size of Earth's moon but 2,000 times farther away.

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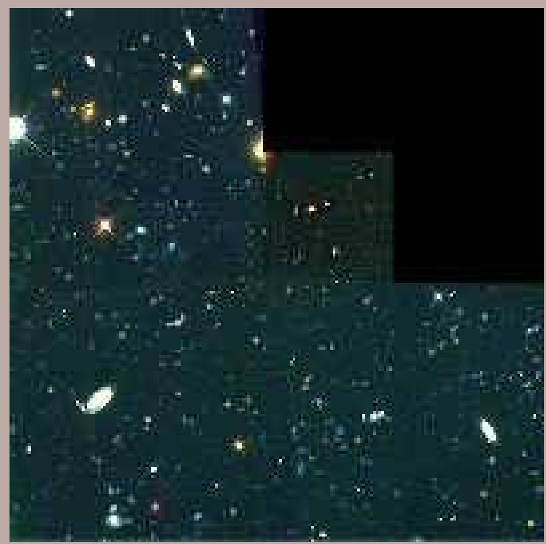
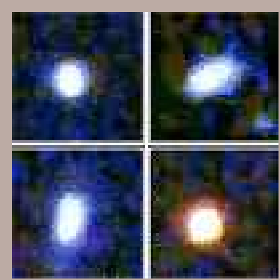
Hubble Sees Early Building Blocks of Today's Galaxies



New Hubble telescope images unveil what may be galaxies under construction in the early universe.



Hubble's detailed pictures reveal a grouping of 18 gigantic star clusters that appear to be the same distance from Earth, and close enough to each other that they will eventually merge into a few galaxy- sized objects. They are so far away, 11 billion light-years, that they existed during the epoch when it is commonly believed galaxies started to form. These results add weight to a leading theory that galaxies grew by starting out as clumps of stars, which, through a complex series of encounters, consolidated into larger assemblages that we see as fully formed galaxies.

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Giant Star Birth Region in Neighboring Galaxy

The colorful picture on the right is a Hubble telescope snapshot of a vast nebula of dust and gas called NGC 604, which lies in the neighboring spiral galaxy M33.

This region, located in the galaxy's spiral arm, is fertile ground for star birth. Though such nebulae are common in galaxies, this one is particularly large, nearly 1,500 light-years across. The image on the left, taken by a ground-based telescope, illustrates the vastness of this nebula. The galaxy resides 2.7 million light-years from Earth in the constellation Triangulum.

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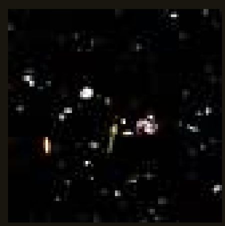

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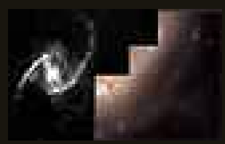
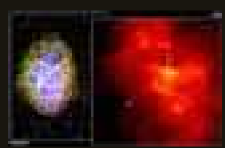
Jun 10, 1996 — Doomed Star Eta Carinae



May 30, 1996 — Hubble Space Telescope on Track for Measuring the Expansion Rate of the Universe



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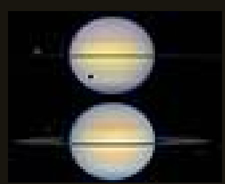
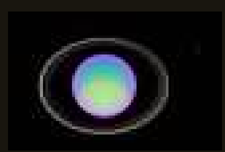
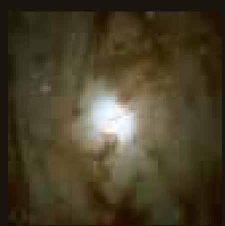


Apr 24, 1996 — Edge-On View of Saturn's Rings



Apr 24, 1996 — Hubble Captures Detailed Image of Uranus's Atmosphere



Apr 24, 1996 — Swirling Galaxy Parents Generations of Stars in Its Center

Matches 11-20 of 32 shown
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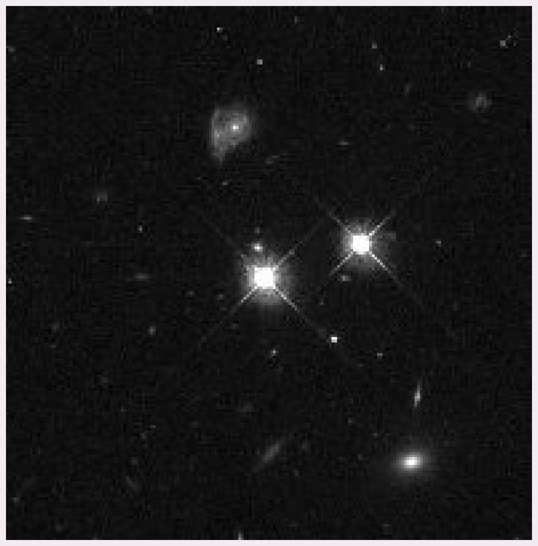
Hubble Achieves Milestone: 100,000th Exposure



The Hubble telescope reached a milestone several years sooner than scientists expected when it snapped its 100,000th exposure June 22, 1996. The six-year-old orbiting observatory has averaged 1,389 exposures a month, an amount that would make any photographer envious.

This black-and-white picture represents the telescope's 100,000th exposure: a quasar that resides about 9 billion light-years from Earth. The quasar is the bright object in the center of the photo. The fainter object just above it is an elliptical galaxy. Although the two objects appear to be close together, they are actually separated by about 2 billion light-years.

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Hubble Telescope Measures Diameters of Pulsating Stars

The Hubble telescope has been used successfully to measure the diameters of a special class of pulsating star called a Mira variable, which rhythmically change size. The results suggest these gigantic, old stars aren't round but egg-shaped.

Knowing more about these enigmatic stars is crucial to understanding how stars evolve, and may preview the fate of our Sun, five billion years from now. Due to their distance, the stars are too small for their disks to be resolved in conventional visible-light pictures, so astronomers used Hubble's Fine Guidance Sensors to measure the widths of two Mira variables, R Leonis and W. Hydrae.

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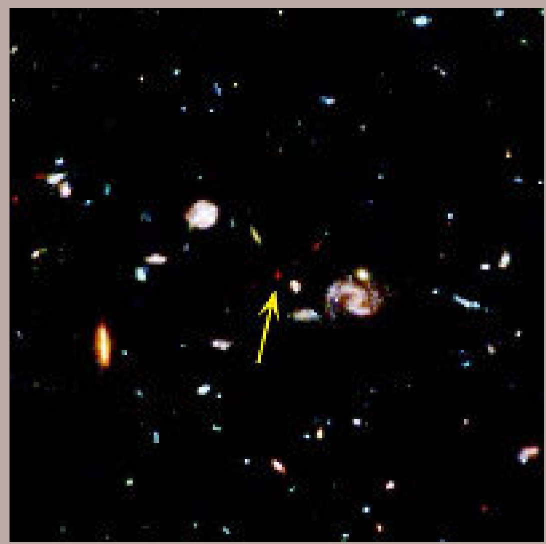
Findings from Hubble Deep Field Hone in on Distant Galaxies



Astronomers analyzing the Hubble Deep Field — the faintest view of the universe taken with the Hubble telescope — may have identified what may prove to be the most distant objects observed to date.

Scattered among the nearly 2,000 galaxies in the Hubble images, which were taken in December 1995, researchers have found several dozen galaxies they believe exhibit characteristics which make them appear to be more distant than any seen previously. Six of the galaxies appear to be more distant than the farthest quasars, the current distance record holders. The arrow pinpoints one of those six galaxies.

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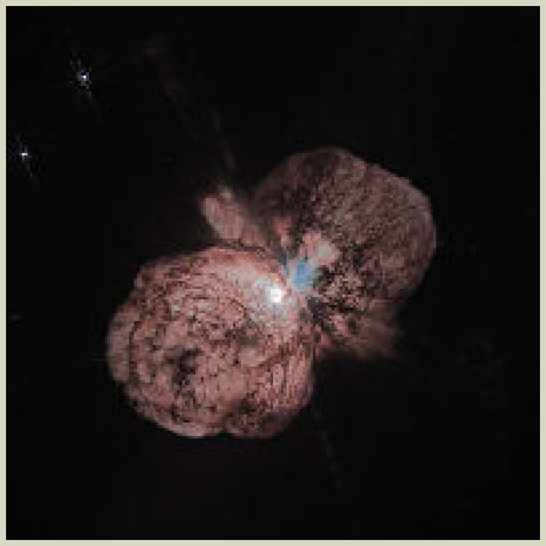
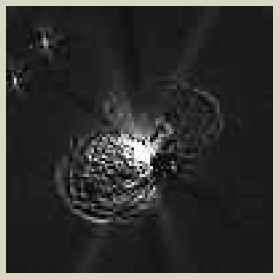
Doomed Star Eta Carinae



A huge, billowing pair of gas and dust clouds is captured in this stunning Hubble telescope picture of the super-massive star Eta Carinae.



Even though Eta Carinae is more than 8,000 light-years away, features 10 billion miles across (about the diameter of our solar system) can be distinguished. Eta Carinae suffered giant outburst about 150 years ago, when it became one of the brightest stars in the southern sky. Though the star released as much visible light as a supernova explosion, it survived the outburst. Somehow, the explosion produced two lobes and a large, thin equatorial disk, all moving outward at about 1.5 million miles per hour. Estimated to be 100 times heftier than our Sun, Eta Carinae may be one of the most massive stars in our galaxy.

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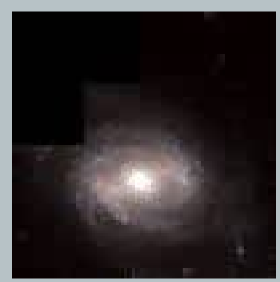
Hubble Space Telescope on Track for Measuring the Expansion Rate of the Universe

Using the Hubble telescope, two international teams of astronomers are reporting major progress in converging on an accurate measurement of the universe's rate of expansion — a value that has been debated for over half a century.



These new results yield ranges for the age of the universe from 9-12 billion years and 11-14 billion years, respectively. The black and white photograph from a ground-based telescope shows the entire galaxy. The color image from the Hubble telescope shows a region in NGC 1365, a barred spiral galaxy located in a cluster of galaxies called Fornax. A barred spiral galaxy is characterized by a "bar" of stars, dust, and gas across its center. Astronomers used Cepheid variable stars in Fornax to estimate the cluster's distance from Earth, about 60 million light-years. Cepheids are bright, young stars that are used as milepost markers to calculate distances to nearby galaxies. Galaxy distances are important in calculating the universe's expansion rate and age.

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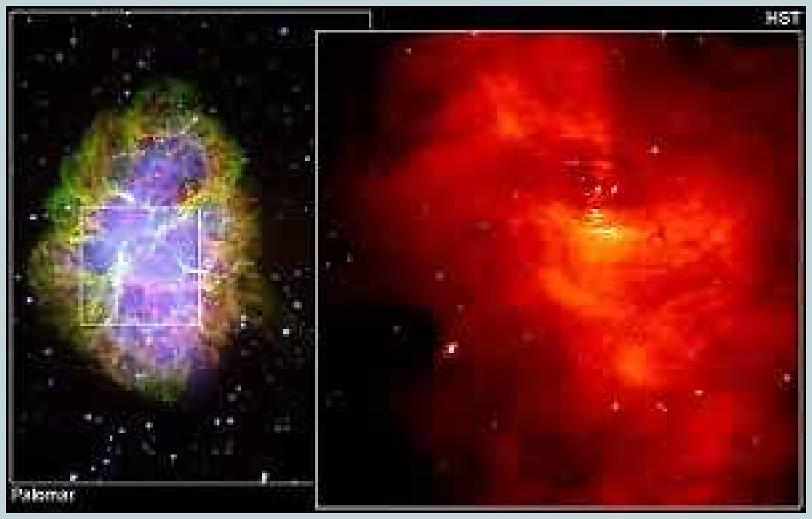
Hubble Astronomers Unveil "Crab Nebula — The Movie"



Probing the mysterious heart of the Crab Nebula, the tattered remains of an exploding star, astronomers have found this object to be even more dynamic than previously understood. These findings are based on a cosmic "movie" assembled from a series of Hubble telescope observations.

The sequence of pictures is giving astronomers a remarkable look at the dynamic relationship between the tiny Crab pulsar — the collapsed core of the exploding star — and the vast nebula of dust and gas that it powers. This picture, which reveals the inner parts of the Crab, represents one frame from the movie. The Crab pulsar is the star on the left [white dot] near the center of the frame. Surrounding the pulsar is a complex of sharp knots and wisp-like features.

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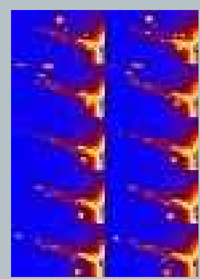
Saturn Ring-Plane Crossing, November 1995

This is a rare view of Saturn's rings seen just after the Sun has set below the ring plane.



This perspective is unusual because the Earth is slightly above Saturn's rings and the Sun is below them. Normally we see the rings fully illuminated by the Sun. The Hubble telescope photograph reveals three bright ring features [moving from the outer to the inner rings]: the F Ring, the Cassini Division, and the C Ring. The low concentration of material in these rings allows light from the Sun to shine through them. The A and B rings are much denser, which limits the amount of light that penetrates through them. Instead, they are faintly visible because they reflect light from Saturn's disk.

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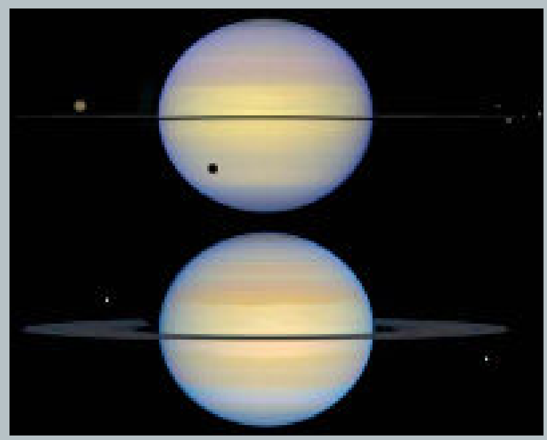
Edge-On View of Saturn's Rings



The Hubble telescope has captured snapshots of Saturn with its rings nearly edge-on to our view.

In the top image, the rings are barely visible. Saturn's largest moon, Titan, is casting a shadow on the planet. Four moons — Mimas, Tethys, Janus, and Enceladus — are clustered around the edge of Saturn's rings on the right. Two other moons — Pandora and Prometheus — appear in front of the ring plane. The rings are casting a shadow on Saturn because the Sun was above the ring plane. The bottom snapshot captures the planet with its rings slightly tilted. The moon Dione is on the lower right. The moon on Saturn's upper left is Tethys.

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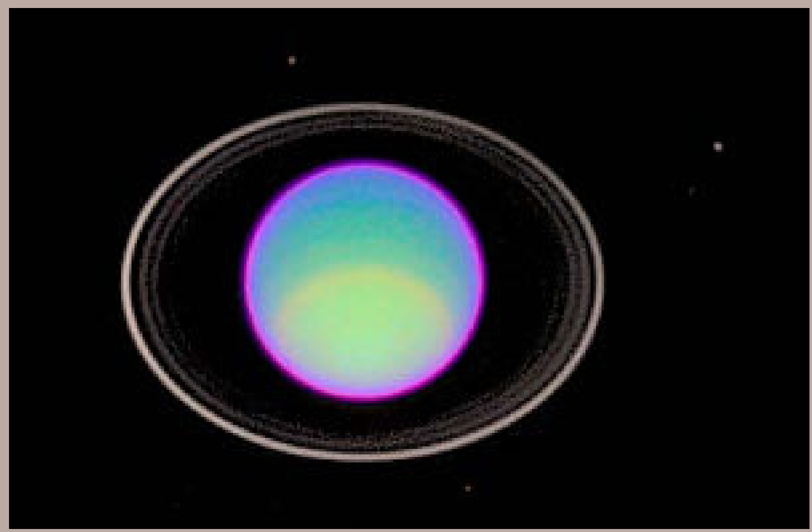
Hubble Captures Detailed Image of Uranus's Atmosphere



The Hubble telescope has peered deep into Uranus's atmosphere to see clear and hazy layers created by a mixture of gases. Using infrared filters, Hubble captured detailed features of three layers of the planet's atmosphere.

Hubble's images are different from the ones taken by the Voyager 2 spacecraft, which flew by Uranus 10 years ago. Those images — not taken in infrared light — showed a greenish-blue disk with very little detail. The infrared image allows astronomers to probe the structure of the planet's atmosphere, which consists mostly of hydrogen with traces of methane.

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Swirling Galaxy Parents Generations of Stars in Its Center

The Hubble telescope has snapped a view of several generations of stars in the central region of the Whirlpool Galaxy (M51), located 23 million light-years from Earth in the constellation Canes Venatici (the Hunting Dogs).

The spiral galaxy's massive center, the bright ball of light in the center of the photograph, is about 80 light-years across and has a brightness of about 100 million suns. Astronomers estimate that it is about 400 million years old and has a mass 40 million times larger than our Sun. The concentration of stars is about 5,000 times higher than in our solar neighborhood, the Milky Way Galaxy.

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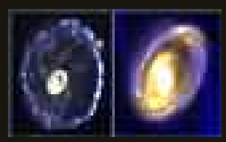
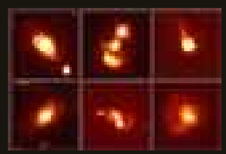
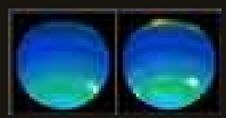
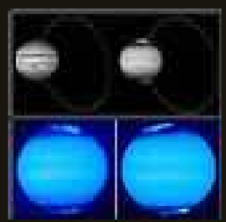
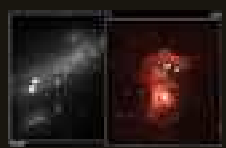

Nov 26, 1996 Hubble Spies Supersonic "Comet-Clouds" in Heart of Galaxy


Nov 19, 1996 Hubble Surveys the "Homes" of Quasars

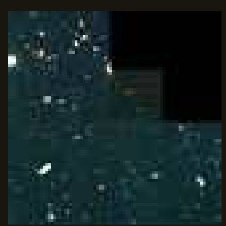

Nov 1, 1996 Springtime Dust Storm Swirls at Martian North Pole

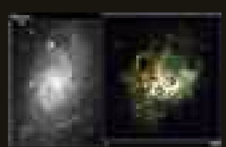

Oct 24, 1996 Hubble Makes Movie of Neptune's Rotation and Weather


Oct 17, 1996 Hubble Follows Rapid Changes in Jupiter's Aurora


Oct 11, 1996 Bright Star Birth Region in a Dim Galaxy


Oct 4, 1996 Rare Hubble Portrait of Io and Jupiter


Sep 4, 1996 Hubble Sees Early Building Blocks of Today's Galaxies


Aug 7, 1996 Giant Star Birth Region in Neighboring Galaxy

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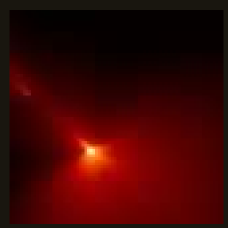
Apr 24, 1996 Hubble Space Telescope Completes Sixth Year of Exploration

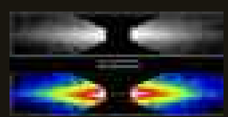
Apr 24, 1996 Hubble Spies Globular Cluster in Neighboring Galaxy

Apr 15, 1996 Hubble Finds Thousands of Gaseous Fragments Surrounding a Dying Star



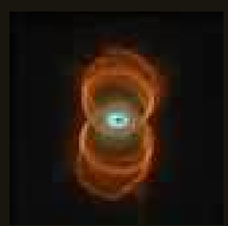
Mar 27, 1996 Hubble Probes Inner Region of Comet Hyakutake

Mar 7, 1996 Hubble Reveals Surface of Pluto for First Time

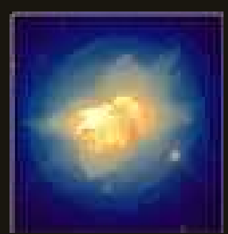


Jan 17, 1996 Disk around Star May Be Warped by Unseen Planet

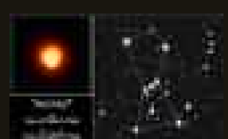
Jan 16, 1996 Hubble Finds Searchlight Beams and Multiple Arcs around a Dying Star



Jan 16, 1996 Hubble Finds an Hourglass Nebula around a Dying Star



Jan 16, 1996 Hubble Telescope Photo Reveals Stellar Death Process



Jan 15, 1996 Hubble Space Telescope Captures First Direct Image of a Star

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1996

Hubble Space Telescope Completes Sixth Year of Exploration

A new golden era of space exploration and discovery began April 24, 1990 with the launch and deployment of the Hubble telescope. Over the past six years Hubble's rapid-fire rate of unprecedented discoveries has invigorated astronomy. Not since the invention of the telescope nearly 400 years ago have astronomers' vision of the universe been so revolutionized over such a short stretch of time.

This picture, released to commemorate Hubble's sixth anniversary, shows several blue, loop-shaped objects that are actually multiple images of the same galaxy. The duplicate images were produced by a cosmic lens in space: the massive cluster of yellow elliptical and spiral galaxies near the photograph's center. This cosmic lens, called a gravitational lens, is created by the cluster's tremendous gravitational field, which bends light from a distant object and magnifies, brightens, and distorts it. How distorted the image becomes and how many copies are made depends on the alignment between the foreground cluster and the more distant galaxy.

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Hubble Spies Globular Cluster in Neighboring Galaxy

The Hubble telescope has captured a view of a globular cluster called G1, a large, bright ball of light in the center of the photograph.

G1, also known as Mayall II, orbits the Andromeda galaxy (M31), the nearest major spiral galaxy to our Milky Way. Located 130,000 light-years from Andromeda's center, G1 is the brightest globular cluster in the Local Group of galaxies, containing at least 300,000 old stars. The Local Group consists of about 20 nearby galaxies, including the Milky Way.

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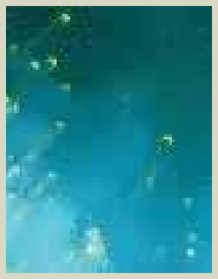
Hubble Finds Thousands of Gaseous Fragments Surrounding a Dying Star

Resembling a bizarre setting from a science fiction movie, dramatic images sent back by the Hubble telescope have surprised astronomers by uncovering thousands of gigantic, tadpole-shaped objects surrounding a dying star.



Dubbed "cometary knots" because their glowing heads and gossamer tails superficially resemble comets, they are probably the result of a dying star's final outbursts. Though ground-based telescopic observations have hinted at such objects, they have not previously been seen in such abundance, say researchers. Hubble captured thousands of these knots from a doomed star in the Helix Nebula, the closest planetary nebula to Earth — 450 light-years away in the constellation Aquarius.

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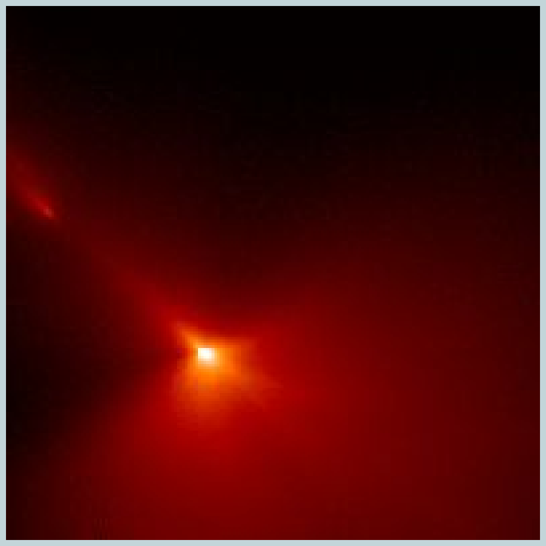
Hubble Probes Inner Region of Comet Hyakutake



The Hubble telescope snapped pictures of comet Hyakutake March 25, 1996, when the comet was just 9.3 million miles from Earth.

Unlike most of the published images of Hyakutake, the Hubble pictures focus on a very small region near the heart of the comet, the icy, solid nucleus. The images provide an exceptionally clear view of the near-nucleus region of comet Hyakutake. The image above is a complete view of the 2,070-mile-wide (3,340-kilometer-wide) comet. This picture shows that most of the dust is being produced on the comet's sunward-facing hemisphere. Also at upper left are three small pieces that have broken off the comet and are forming their own tails.

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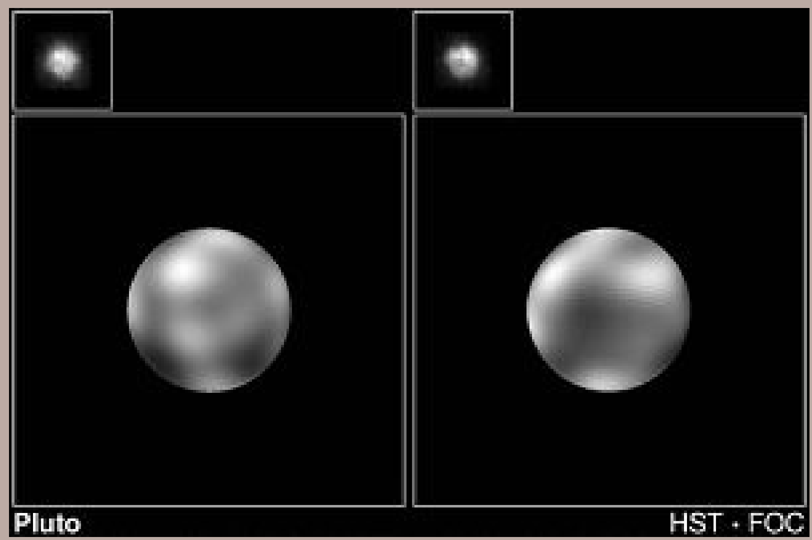
Hubble Reveals Surface of Pluto for First Time



For the first time since Pluto's discovery 66 years ago, astronomers have at last directly seen details on the surface of the solar system's farthest known planet.

The Hubble telescope's snapshots of nearly the entire surface of Pluto, taken as the planet rotated through a 6.4-day period, show that Pluto is a complex object, with more large-scale contrast than any planet, except Earth. Topographic features such as basins, or fresh impact craters may cause some of the variations across Pluto's surface.

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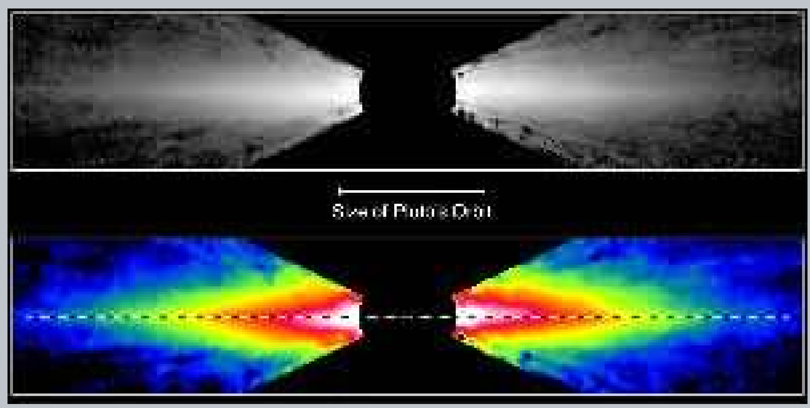
Disk around Star May Be Warped by Unseen Planet



The Hubble telescope has provided strong evidence for the existence of a roughly Jupiter-sized planet orbiting the star Beta Pictoris.

Detailed Hubble snapshots of the inner region of the 200-billion-mile-wide dust disk encircling the star reveal an unexpected warp. Researchers say the warp can be best explained as caused by the tug of an unseen planet. This is a visible-light image of the disk, which looks like a spindle because it is tilted nearly edge-on to our view. The bright star, which lies at the center of the disk, is blocked out in this image.

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Hubble Finds Searchlight Beams and Multiple Arcs around a Dying Star

This Hubble telescope picture of the Egg Nebula, also known as CRL2688, shows a pair of mysterious "searchlight" beams emerging from a hidden star and criss-crossed by numerous bright arcs. This image sheds new light on the poorly understood ejection of stellar matter that accompanies the slow death of Sun-like stars. The nebula is really a large cloud of dust and gas ejected by the star, expanding at a speed of 115,000 mph (20 km/s).

A dense cocoon of dust [the dark band in the center] enshrouds the star and hides it from our view. Starlight escapes more easily in directions where the cocoon is thinner and is reflected towards us by dust particles in the cloud, giving it its overall appearance. Objects like CRL2688 are rare because they are in a very short evolutionary phase. However, they may hold the key to our understanding of how red giant stars transform themselves into planetary nebulae, the glowing remnants of dying stars.

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Hubble Finds an Hourglass Nebula around a Dying Star

This Hubble telescope snapshot of MyCn18, a young planetary nebula, reveals that the object has an hourglass shape with an intricate pattern of "etchings" in its walls. A planetary nebula is the glowing relic of a dying, Sun-like star.

The results are of great interest because they shed new light on the poorly understood ejection of stellar matter that accompanies the slow death of Sun-like stars. According to one theory on the formation of planetary nebulae, the hourglass shape is produced by the expansion of a fast stellar wind within a slowly expanding cloud, which is denser near its equator than near its poles.

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Hubble Telescope Photo Reveals Stellar Death Process

This Hubble telescope picture of planetary nebula NGC 7027 reveals remarkable new details of the process by which a star like the Sun dies. The nebula is a glowing record of the star's final death throes.

New features include faint, blue, concentric shells surrounding the nebula; an extensive network of red dust clouds throughout the bright inner region; and the hot, central white dwarf, visible as a white dot at the center.

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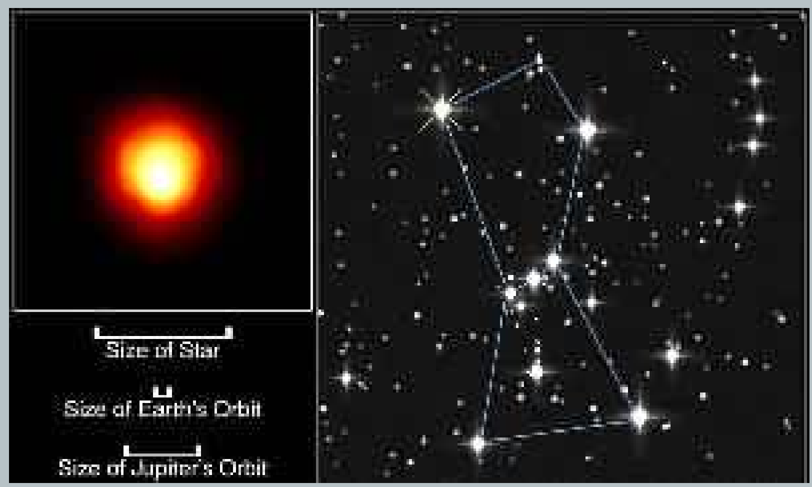
Hubble Space Telescope Captures First Direct Image of a Star



This is the first direct image of a star other than the Sun. Called Alpha Orionis, or Betelgeuse, the star is a red super giant, a Sun-like star nearing the end of its life.

The Hubble picture reveals a huge ultraviolet atmosphere with a mysterious hot spot on the stellar behemoth's surface. The enormous bright spot, more than 10 times the diameter of Earth, is at least 2,000 degrees Kelvin hotter than the star's surface.

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Jan 10, 1996 — Hubble Discovers Powerful Laser Beamed from Chaotic Star

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Hubble's Deepest View of the Universe Unveils Bewildering Galaxies across Billions of Years

One peek into a small part of the sky, one giant leap back in time. The Hubble telescope has provided mankind's deepest, most detailed visible view of the universe.

Representing a narrow "keyhole" view stretching to the visible horizon of the universe, the Hubble Deep Field image covers a speck of the sky only about the width of a dime 75 feet away. Though the field is a very small sample of the heavens, it is considered representative of the typical distribution of galaxies in space, because the universe, statistically, looks largely the same in all directions. Gazing into this small field, Hubble uncovered a bewildering assortment of at least 1,500galaxies at various stages of evolution.

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Hubble Discovers Powerful Laser Beamed from Chaotic Star

Artist's Concept

Darth Vader take heart. Astronomers have discovered a powerful ultraviolet laser beam, several times brighter than our Sun, shooting toward Earth from a super-hot "death star."

The observations, made with the Hubble telescope, have identified a gas cloud that acts as a natural ultraviolet laser near the huge, unstable star called Eta Carinae — one of the most massive and energetic stars in our Milky Way Galaxy. The interstellar laser may result from Eta Carinae's violently chaotic eruptions, in which it blasts parts of itself out into space, like an interstellar geyser. This illustration depicts a gas cloud [left], which acts as a natural ultraviolet laser near Eta Carinae [right].

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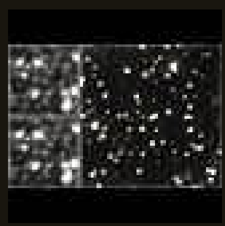
Jan 24, 2000 Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass



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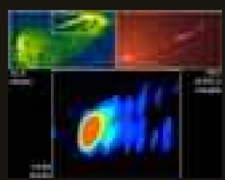
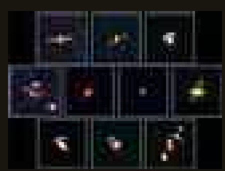
1999



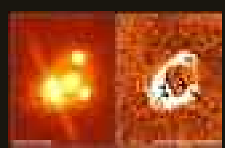
Oct 27, 1999 Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole



May 13, 1999 Natural Lenses in Space Stretch Hubble's View of the Universe

Mar 11, 1999 Hubble Views Home Galaxy of Record-Breaking Explosion

1998



Oct 26, 1998 Quasar PG1115+080 and Gravitational Lens

May 6, 1998 Gamma-Ray Burst Found to be Most Energetic Event in Universe

1997

Sep 24, 1997 Hubble Sees a Neutron Star Alone in Space

Sep 16, 1997

[Hubble Stays on Trail of Fading Gamma-Ray Burst Fireball, Results Point to Extragalactic Origin]

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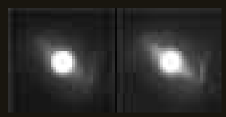
News Releases about: Exotic phenomena

1995



Jun 14, 1995 Hubble Resolves Quasars' Host Galaxies

Apr 5, 1995 Hubble Views Distant Galaxies through a Cosmic Lens

Jan 11, 1995 Surprising Hubble Images Challenge Quasar Theory

1994

Nov 15, 1994 Hubble Rules Out a Leading Explanation for Dark Matter

Matches 21-24 of 24 shown
<< Previous 1 2 3

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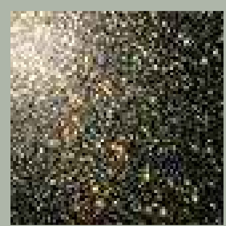
Astronomers Ponder Lack of Planets in Globular Cluster

Astronomers using the Hubble telescope made the first broad search for planets far beyond our local stellar neighborhood. They trained Hubble's "eagle eye" for eight days on a swarm of 35,000 stars in 47 Tucanae, located in the southern constellation Tucana. The researchers expected to find 17 "extrasolar" planets. To their surprise, they found none. These results may be the first evidence that conditions for planet formation and evolution are different in other regions of our Milky Way Galaxy.

You may wish to find out the answers to questions such as these:



- Why didn't astronomers find any planets?
- How did the Hubble telescope look for planets?

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2000

Hubble Peeks into a Stellar Nursery in a Nearby Galaxy

The Hubble telescope has peered deep into a neighboring galaxy to reveal details of the formation of new stars. Hubble's target was a newborn star cluster within the Small Magellanic Cloud, a small satellite galaxy of our Milky Way. The picture shows young, brilliant stars cradled within a nebula, or glowing cloud of gas, cataloged as N 81.

You may wish to find out the answers to questions such as these:

- What does Hubble's piercing view reveal to astronomers?

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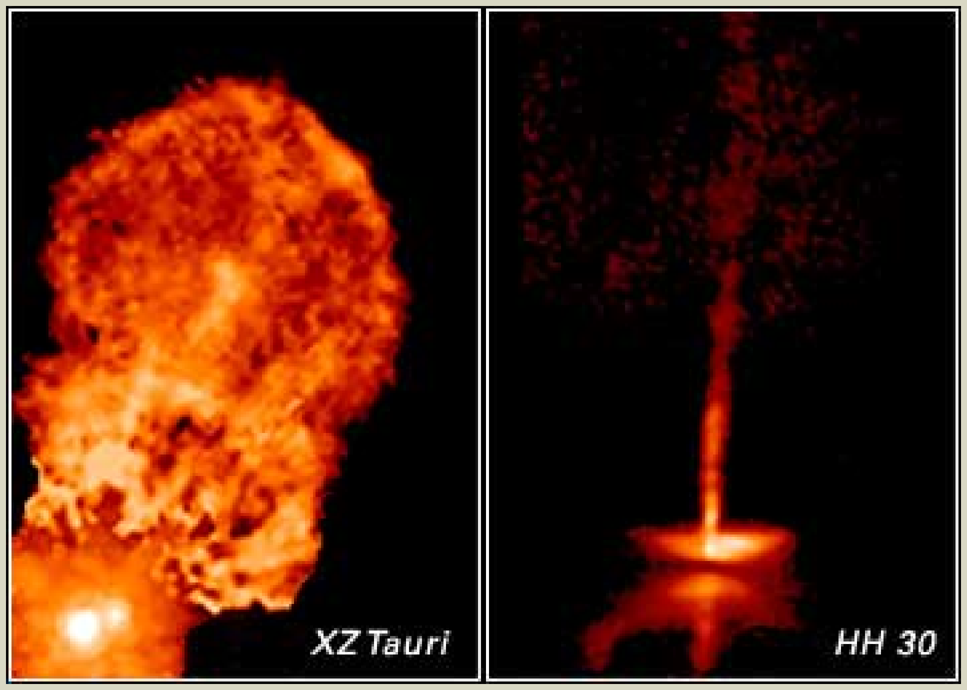
Movies from Hubble Show the Changing Faces of Infant Stars



XZ Tauri Video   HH 30 Video

Time-lapse movies made from a series of pictures taken by NASA's Hubble Space Telescope are showing astronomers that young stars and their surroundings can change dramatically in just weeks or months. As with most children, a picture of these youngsters taken today won't look the same as one snapped a few months from now. The movies show jets of gas plowing into space at hundreds of thousands of miles per hour and moving shadows billions of miles in size. The young star systems featured in the movies, XZ Tauri and HH 30, reside about 450 light-years from Earth in the Taurus-Auriga molecular cloud, one of the nearest stellar nurseries to our planet. Both systems are probably less than a million years old, making them relative newborns, given that stars typically live for billions of years.

You may wish to find out the answers to questions such as these:

- How do stars form?

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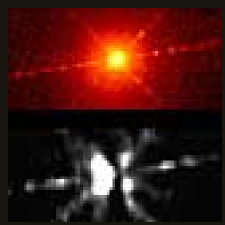
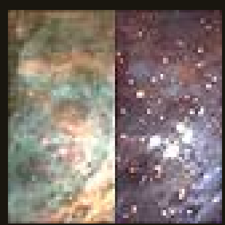
Sep 7, 2000 [IC 418: The "Spirograph" Nebula]

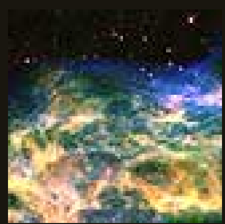


Aug 31, 2000 [He2-90's Appearance Deceives Astronomers]

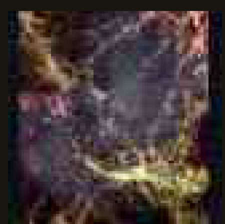
Aug 24, 2000 [Hubble Takes Census of Elusive Brown Dwarf Stars]



Aug 24, 2000 [Hubble Spies Brown Dwarfs in Nearby Stellar Nursery]



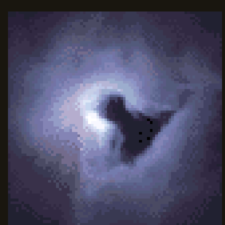
Jul 13, 2000 [Hubble Watches Star Tear Apart its Neighborhood]



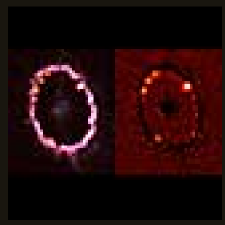
Jun 1, 2000 [Peering into the Heart of the Crab Nebula]

Mar 16, 2000 [Hubble Finds Young Stars in Cosmic Dance]

Mar 9, 2000 [Hubble Surveys Dying Stars in Nearby Galaxy]



Mar 2, 2000 [Hubble Takes a Close-up View of a Reflection Nebula in Orion]



Feb 16, 2000 Onset of Titanic Collision Lights Up Supernova Ring

IC 418: The "Spirograph" Nebula

Glowing like a multi-faceted jewel, the planetary nebula IC 418 lies about 2,000 light-years from Earth in the constellation Lepus. In this picture, the Hubble telescope reveals some remarkable textures weaving through the nebula. Their origin, however, is still uncertain.

You may wish to find out the answers to questions such as these:

- What is a planetary nebula?

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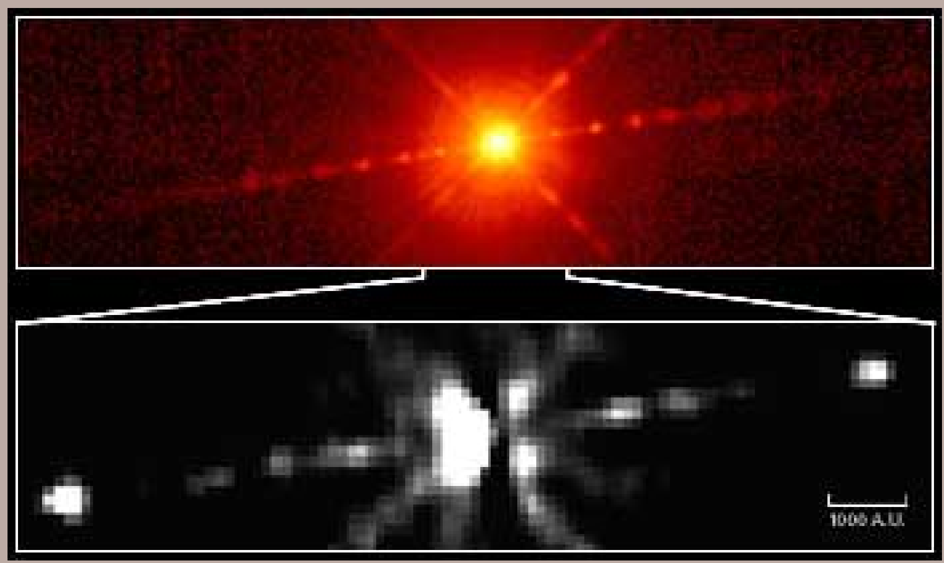
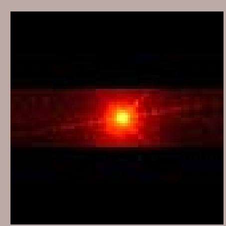
He2-90's Appearance Deceives Astronomers



Astronomers using NASA's Hubble Space Telescope have stumbled upon a mysterious object that is grudgingly yielding clues to its identity. A quick glance at the Hubble picture at top shows that this celestial body, called He2-90, looks like a young, dust-enshrouded star with narrow jets of material streaming from each side. But it's not. The object is classified as a planetary nebula, the glowing remains of a dying, lightweight star. But the Hubble observations suggest that it may not fit that classification, either. The Hubble astronomers now suspect that this enigmatic object may actually be a pair of aging stars masquerading as a single youngster. One member of the duo is a bloated red giant star shedding matter from its outer layers. This matter is then gravitationally captured in a rotating, pancake-shaped accretion disk around a compact partner, which is most likely a young white dwarf (the collapsed remnant of a sun-like star). The stars cannot be seen in the Hubble images because a lane of dust obscures them.

You may wish to find out the answers to questions such as these:



- What does the top image show?
- What does the bottom image show?

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Hubble Takes Census of Elusive Brown Dwarf Stars

Astronomers using NASA's Hubble Space Telescope have carried out the most complete inventory to date of brown dwarfs, one of the universe's most elusive types of objects, which dwell in limbo between stars and planets. The Hubble census provides new and compelling evidence that stars and planets form in different ways. Because the brown dwarfs "bridge the gap" between stars and planets, their properties reveal new and unique insights into how stars and planets form.

You may wish to find out the answers to questions such as these:

- What are brown dwarfs? What are the results of the census?

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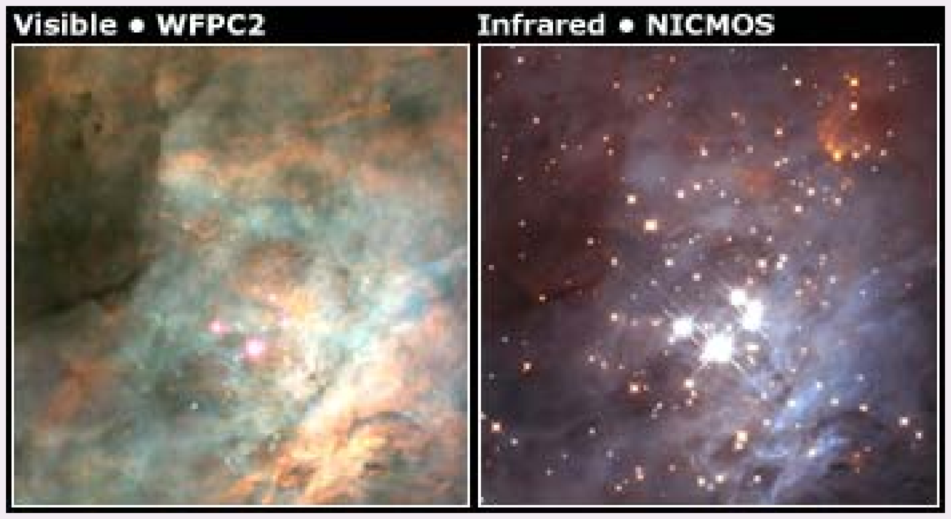
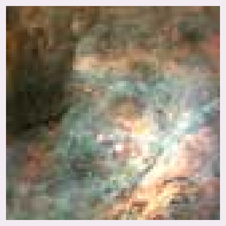
Hubble Spies Brown Dwarfs in Nearby Stellar Nursery



Probing deep within a neighborhood stellar nursery, NASA's Hubble Space Telescope uncovered a swarm of newborn brown dwarfs. The orbiting observatory's near-infrared camera revealed about 50 of these objects throughout the Orion Nebula's Trapezium cluster [image at right], about 1,500 light-years from Earth. Appearing like glistening precious stones surrounding a setting of sparkling diamonds, more than 300 fledgling stars and brown dwarfs surround the brightest, most massive stars [center of picture] in Hubble's view of the Trapezium cluster's central region. The brown dwarfs are too dim to be seen in an image taken by the Hubble telescope's visible-light camera [picture at left].

You may wish to find out the answers to questions such as these:

- What are brown dwarfs?



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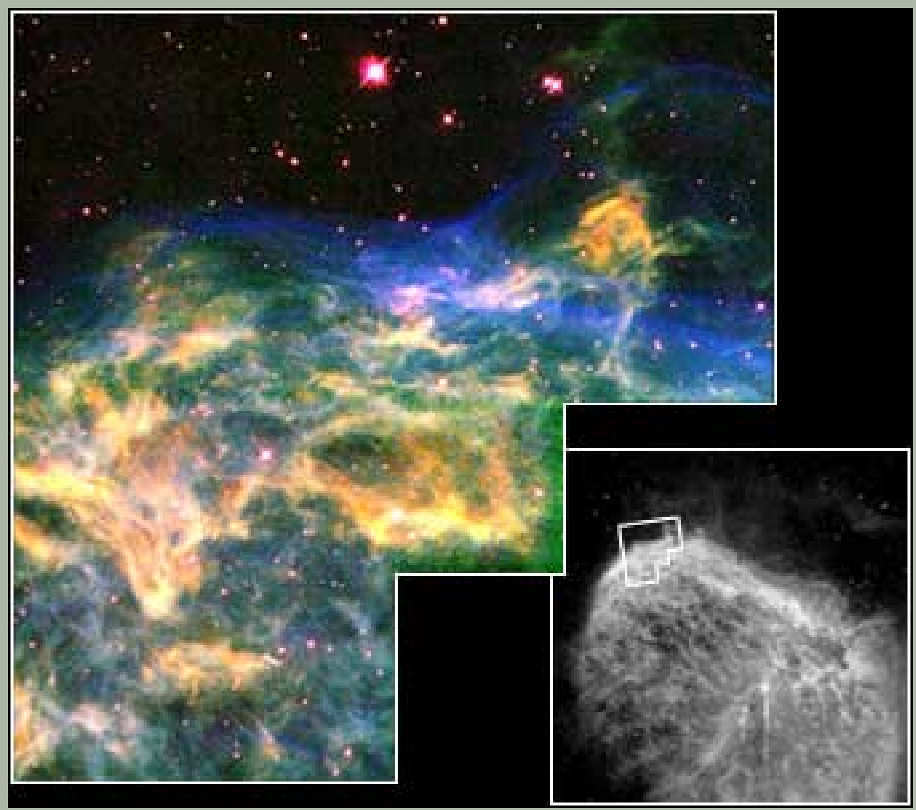
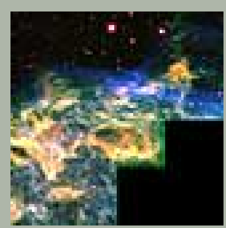
Hubble Watches Star Tear Apart its Neighborhood



The Hubble telescope has snapped a view of a stellar demolition zone in our Milky Way Galaxy: a massive star, nearing the end of its life, tearing apart the shell of surrounding material it blew off 250,000 years ago with its strong stellar wind. The shell of material, dubbed the Crescent Nebula (NGC 6888), surrounds the "hefty," aging star WR 136, an extremely rare and short-lived class of super-hot star called a Wolf-Rayet. Hubble's multicolored picture reveals with unprecedented clarity that the shell of matter is a network of filaments and dense knots, all enshrouded in a thin "skin" of gas [seen in blue]. The whole structure looks like oatmeal trapped inside a balloon. The skin is glowing because it is being blasted by ultraviolet light from WR 136.

You may wish to find out the answers to questions such as these:



- What do the images show?
- How did the star, WR 136, produce the nebula?

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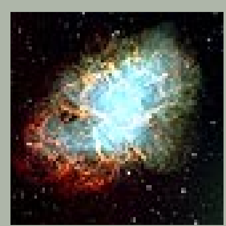
2000

Peering into the Heart of the Crab Nebula

In the year 1054 A.D., Chinese astronomers were startled by the appearance of a new star, so bright that it was visible in broad daylight for several weeks. Today, the Crab Nebula is visible at the site of that bright star. Located about 6,500 light-years from Earth, the Crab Nebula is the remnant of a star that began its life with about 10 times the mass of our Sun. Its life ended on July 4, 1054 when it exploded as a supernova. In this image, the Hubble telescope has zoomed in on the center of the Crab to reveal its structure with unprecedented detail.

You may wish to find out the answers to questions such as these:

- What does the picture reveal to astronomers?



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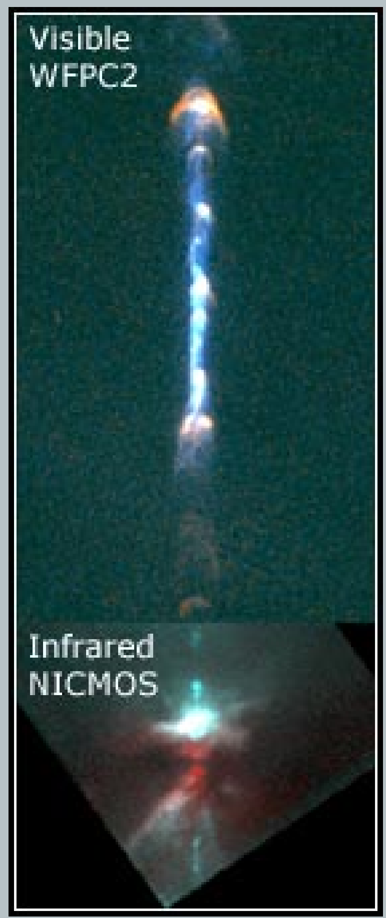
Hubble Finds Young Stars in Cosmic Dance



This composite image, made with two cameras aboard NASA's Hubble Space Telescope, shows a pair of 12 light-year-long jets of gas blasted into space from a young system of three stars. The jet is seen in visible light, and its dusty disk and stars are seen in infrared light. These stars are located near a huge torus, or donut, of gas and dust from which they formed. This torus is tilted edge-on and can be seen as a dark bar near the bottom of the picture.

You may wish to find out the answers to questions such as these:

- What does the press release picture show?
- What can scientists learn from this observation?

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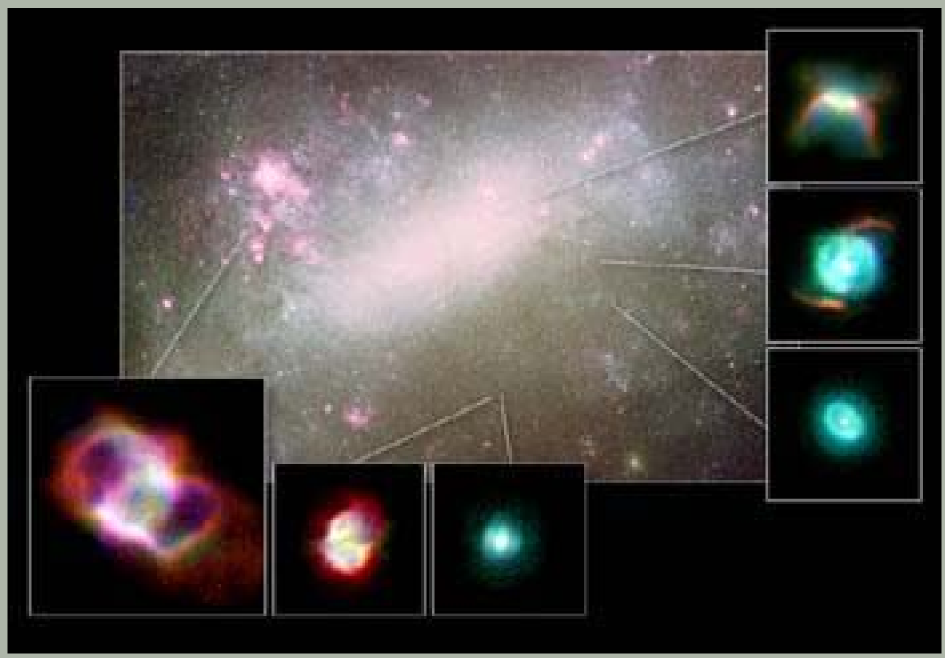
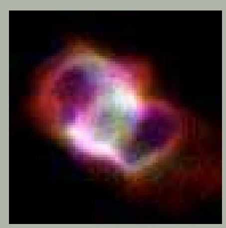
Hubble Surveys Dying Stars in Nearby Galaxy



From ground-based telescopes, the glowing gaseous debris surrounding dying, sun-like stars in a nearby galaxy, called the Large Magellanic Cloud, appear as small, shapeless dots of light. But through the "eyes" of NASA's Hubble Space Telescope, these bright dots take on a variety of shapes, from round- to pinwheel-shaped clouds of gas.

You may wish to find out the answers to questions such as these:



- What does the picture show?
- Why is this probe of dying suns in a nearby galaxy significant?
- What did scientists discover?

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Hubble Takes a Close-up View of a Reflection Nebula in Orion

Just weeks after NASA astronauts repaired the Hubble Space Telescope in December 1999, the Hubble Heritage Project snapped this picture of NGC 1999, a nebula in the constellation Orion. The Heritage astronomers, in collaboration with scientists in Texas and Ireland, used Hubble's Wide Field Planetary Camera 2 (WFPC2) to obtain the color image.

You may wish to find out the answers to questions such as these:

- What is the dark region near the center of the nebula?

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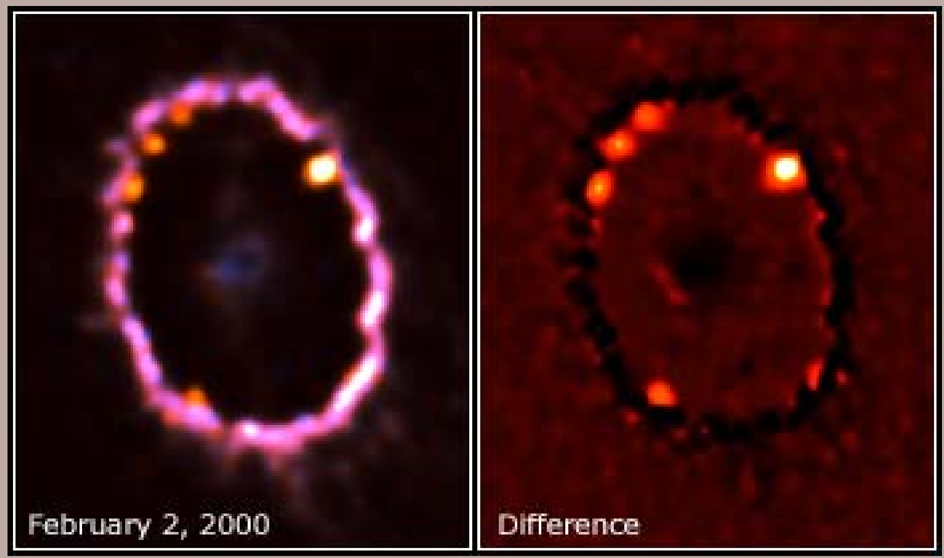
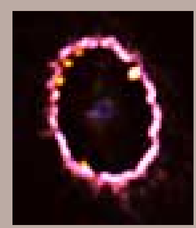
Onset of Titanic Collision Lights Up Supernova Ring



NASA's Hubble Space Telescope is giving astronomers a ringside seat to a never before seen violent celestial "main attraction" unfolding in a galaxy 169,000 light-years away. The knockout event is the collision of the fastest moving debris from an immense stellar explosion seen in Feb. 1987 with the gas ring that circles that site.

You may wish to find out the answers to questions such as these:



- What do the two pictures show?
- Did debris from the supernova explosion create the ring of material?
- Why are Hubble's observations of this supernova significant?

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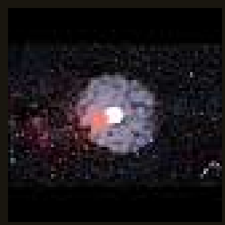
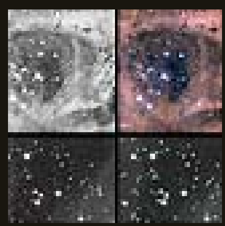
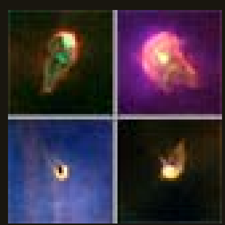
Nov 27, 2001 Hubble Makes First Direct Measurements of Atmosphere on World Around Another Star



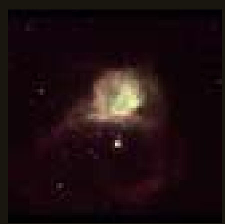
Jul 12, 2001 Magnetic Fields Weave Rings Around Stars



Jun 4, 2001 Bigger, Better Catalog Unveils Half a Billion Celestial Objects

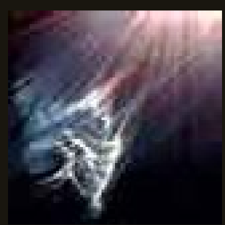


Apr 26, 2001 Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction

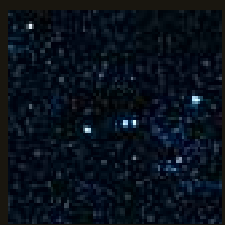


Jan 4, 2001 "X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy

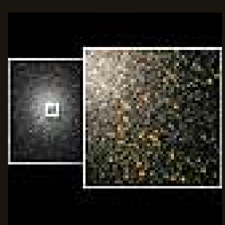
2000



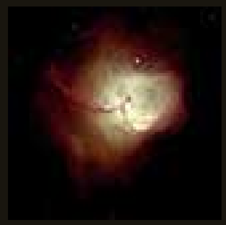
Dec 6, 2000 Ghostly Reflections in the Pleiades



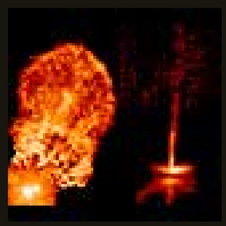
Nov 9, 2000 Hubble Sees Bare Neutron Star Streaking Across Space



Oct 31, 2000 Astronomers Ponder Lack of Planets in Globular Cluster



Oct 5, 2000 [Hubble Peeks into a Stellar Nursery in a Nearby Galaxy]



Sep 21, 2000 [Movies from Hubble Show the Changing Faces of Infant Stars]

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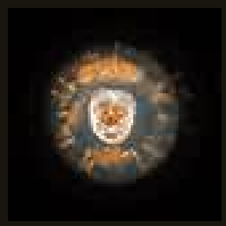
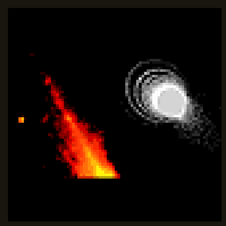
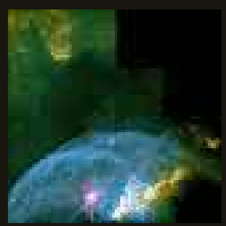
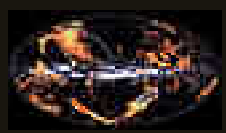

Jan 24, 2000 Hubble Reopens "Eye" on the Universe

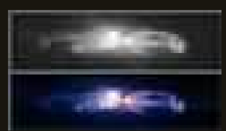

Jan 15, 2000 Beta Pictoris Disk Hides Giant Elliptical Ring System

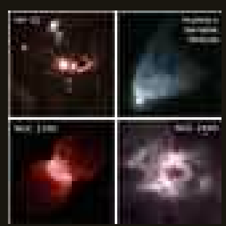

Jan 13, 2000 An Expanding Bubble in Space

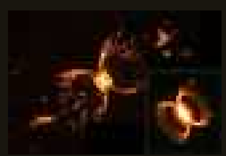
1999

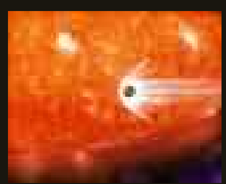

Nov 24, 1999 A Puzzle of Galactic Evolution is Solved: Massive Gas Clouds Seed the Galaxy with the Stuff of Stars

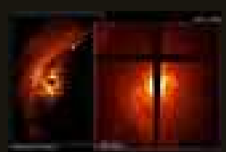

Oct 26, 1999 Hubble Identifies Source of Ultraviolet Light in an Old Galaxy


Oct 19, 1999 The "Rotten Egg" Nebula: A Planetary Nebula in the Making


Oct 7, 1999 Hubble Heritage Project's First Anniversary


Aug 24, 1999 Symbiotic Star Blows Bubbles into Space


Aug 12, 1999 Bloated Stars Swallow Giant Planets


Jun 2, 1999 Hubble Picture Adds to Planet-Making Recipe

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Hubble Reopens "Eye" on the Universe

The Hubble telescope reopened its "eye" on the universe following a successful December 1999 servicing mission by snapping a picture of the colorful death of a Sun-like star, dubbed the "Eskimo Nebula" (NGC 2392).

You may wish to find out the answers to questions such as these:

- How did the Eskimo Nebula get its name, and what are the most interesting details in the picture?

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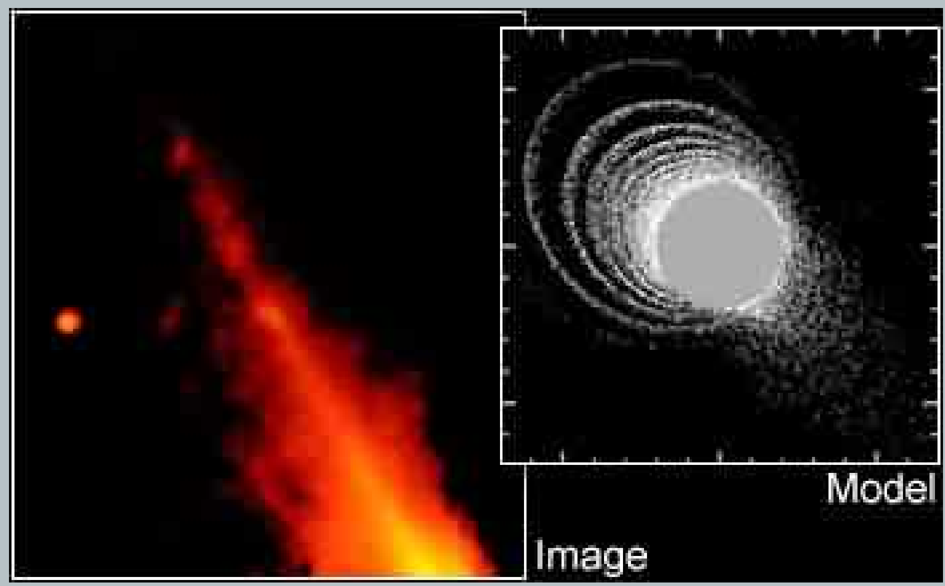
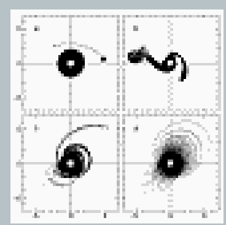
Beta Pictoris Disk Hides Giant Elliptical Ring System



The planetary dust disk around the nearby star Beta Pictoris is dynamically "ringing like a bell," say astronomers investigating Hubble telescope images. The "clapper" is the gravitational wallop of a star that passed near Beta Pictoris some 100,000 years ago. The surprising findings show that a close encounter with a neighboring star can severely disrupt the evolution and appearance of thin disks, which are the nurseries of planetary systems. Similar fly-bys of our solar system long ago may have reshuffled the comets that now populate our Oort cloud and Kuiper belt.

You may wish to find out the answers to questions such as these:

- How do the images show that Beta Pictoris was blindsided by a passing star?



These four images are from a computer simulation of a star flying by and disrupting a circumstellar disk of dust around the star Beta Pictoris.

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An Expanding Bubble in Space

A star 40 times more massive than the Sun is blowing a giant bubble of material into space. In this colorful picture, the Hubble telescope has captured a glimpse of the expanding bubble, dubbed the Bubble Nebula (NGC 7635). The beefy star [lower center] is embedded in the bright blue bubble. The stellar powerhouse is so hot that it is quickly shedding material into space. The dense gas surrounding the star is shaping the castoff material into a bubble. The bubble's surface is not smooth like a soap bubble's. Its rippled appearance is due to encounters with gases of different thickness. The nebula is 6 light-years wide and is expanding at 4 million miles per hour (7 million kilometers per hour). The nebula is 7,100 light-years from Earth in the constellation Cassiopeia.

You may wish to find out the answers to questions such as these:

- What are the yellow-colored "clouds" to the right of the star?
- What are the blobs of gas in the picture's upper left corner?

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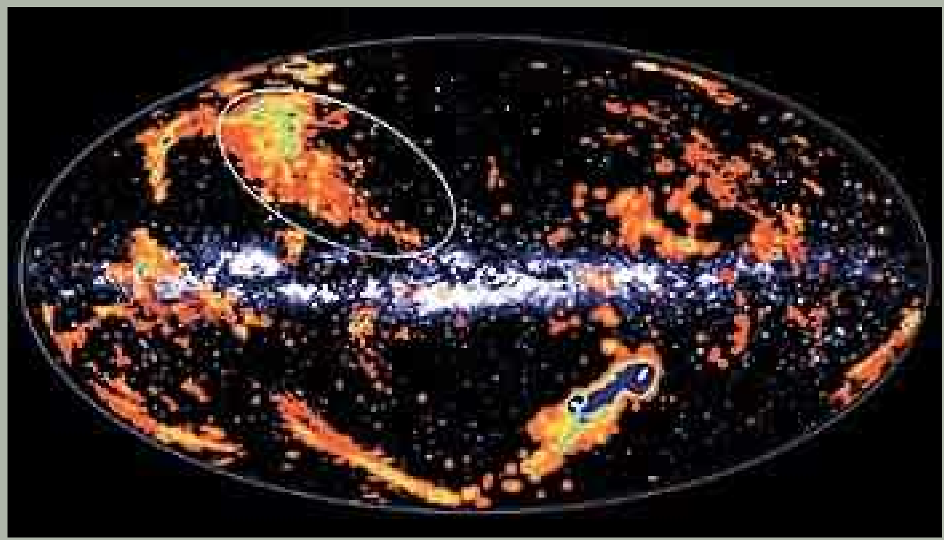
A Puzzle of Galactic Evolution is Solved: Massive Gas Clouds Seed the Galaxy with the Stuff of Stars



Massive clouds of gas, discovered long ago but only recently identified as being within the margins of the Milky Way, play a key role in the galaxy's ability to churn out new stars by raining gas onto the plane of the galaxy. Researchers have chipped away at a three-decade-old mystery about the nature and role of those massive gas clouds, called high-velocity clouds. In the process, they've discovered a mechanism by which the galaxy is seeded with the stuff of stars and solved a long-standing question of galactic evolution.

You may wish to find out the answers to questions such as these:

- What are high-velocity clouds?
- Why are these clouds so important?
- What is chemical evolution?

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Hubble Identifies Source of Ultraviolet Light in an Old Galaxy

The Hubble telescope's sharp vision has clearly seen - for the first time - hot blue stars deep inside an elliptical galaxy. Hubble confirms that the ultraviolet light emanating from this galaxy comes from a population of extremely hot, helium-burning stars at a late stage in their lives. The swarm of nearly 8,000 blue stars resembles a blizzard of snowflakes near the core of the neighboring galaxy M32, 2.5 million light-years from Earth in the constellation Andromeda.

You may wish to find out the answers to questions such as these:

- Why is this finding significant?
- What are helium-burning stars?

Illustration

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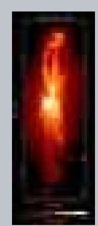
The "Rotten Egg" Nebula: A Planetary Nebula in the Making

This oddly shaped object is an aging, Sun-like star near the end of its life. The Hubble telescope's infrared camera, called the Near Infrared Camera and Multi-Object Spectrometer, captured a fleeting phase in the death march of this star. In these pictures, a red giant star is transformed into a planetary nebula, the glowing remnants of a dying star. The star is shrouded in dust and gas in the center of these pictures. The "wings" of material, called a nebula, are dust and gas cast off by the declining star.

You may wish to find out the answers to questions such as these:



Color-mapped K-band (F205W)

- What do the images of this dying star tell astronomers?
- Why do astronomers need an infrared camera to take pictures of this object?
- Why are there two pictures of the same object?
- Why is this object called the "Rotten Egg" Nebula?

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Hubble Heritage Project's First Anniversary

To mark the first anniversary of the Hubble Heritage Project, we present four Hubble telescope images of nebulae surrounding stars in our own Milky Way Galaxy.

Two of these visible-light pictures show interstellar gas and dust around young stars at the beginning of their lives, and two more show gas ejected from old stars that are nearing the end of theirs. Remarkably, in spite of the completely different evolutionary stages, the nebulae have more striking features in common, including evidence of diametrically opposed gas ejections from both the young and old stars.

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Symbiotic Star Blows Bubbles into Space

A tempestuous relationship between an unlikely pair of stars may have created an oddly shaped gaseous nebula that resembles nesting hourglasses.

Images taken with Earth-based telescopes have shown the larger, hourglass-shaped nebula. But this picture, taken with the Hubble telescope, reveals a small, bright nebula embedded in the center of the larger one [close-up of nebula in inset]. Astronomers have dubbed the entire nebula the "Southern Crab Nebula" (He2-104), because, from ground-based telescopes, it looks like the body and legs of a crab. The nebula is several light-years long. The possible creators of these shapes cannot be seen in this visible-light picture. It's a pair of aging stars buried in the glow of the tiny, central nebula. One of them is a red giant, a bloated star that is exhausting its nuclear fuel and is shedding its outer layers in a powerful stellar wind. Its companion is a hot, white dwarf, a stellar zombie of a burned-out star.

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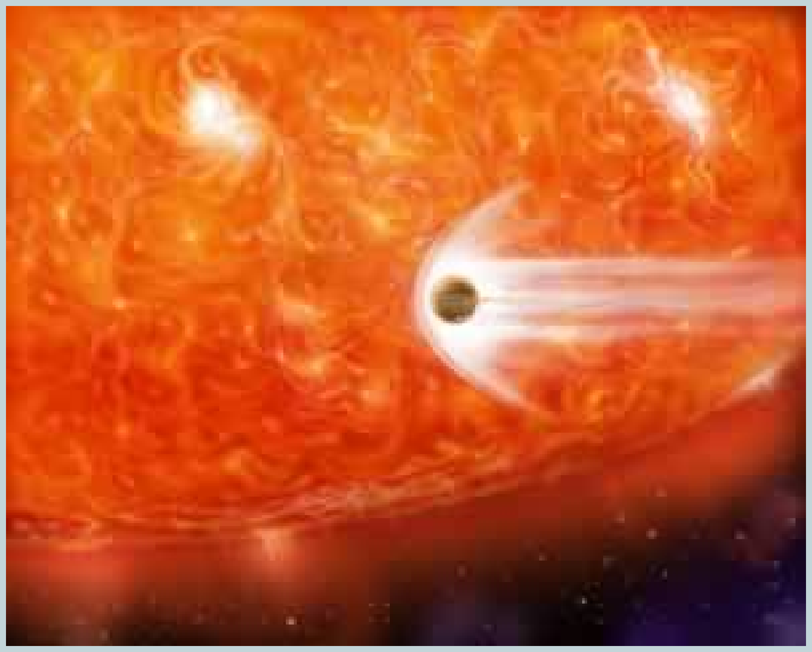
Bloated Stars Swallow Giant Planets



Artist's Concept

The phrase "big fish eat little fish" may hold true when it comes to planets and stars. Perhaps as many as 100 million of the Sun-like stars in our galaxy harbor close-orbiting gas giant planets like Jupiter, or stillborn stars known as brown dwarfs, which are doomed to be gobbled up by their parent stars.

Astronomers did not directly observe the planets, because their parent stars had already swallowed them. But the researchers did find significant telltale evidence that some giant stars once possessed giant planets that were then swallowed up. The devouring stars release excessive amounts of infrared light, spin rapidly, and are polluted with the element lithium. The illustration depicts the cosmic cannibalism.

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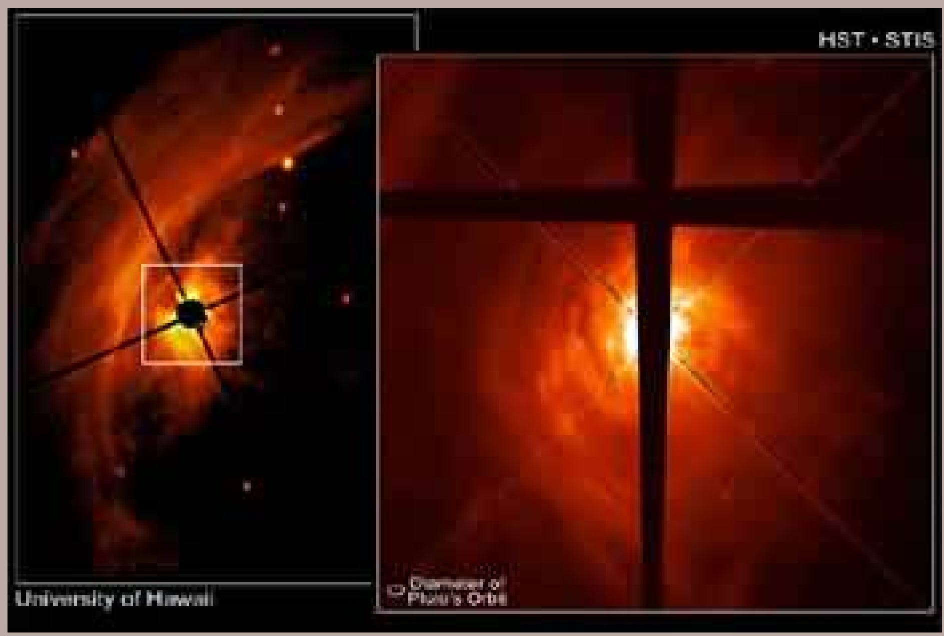
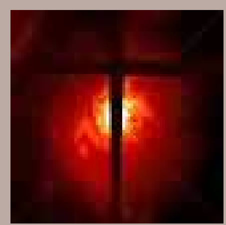
Hubble Picture Adds to Planet-Making Recipe



The Hubble telescope has snapped a nearly face-on view of a swirling disk of dust and gas surrounding a developing star called AB Aurigae. The image, taken in visible light by the Space Telescope Imaging Spectrograph, shows unprecedented detail in the disk, including clumps of dust and gas that may be the seeds of planet formation.


Hubble Telescope Image

Normally, a young star's bright light prevents astronomers from seeing material closer to it. That's why astronomers used a coronograph in these two images of AB Aurigae to block most of the star's glare. The rest of the disk material is illuminated by light reflected from the gas and dust surrounding the star. The image on the left represents the best ground-based coronographic observation of AB Aurigae. The star resides in a region of dust clouds — the semicircular-shaped material to the left of the star. The Hubble telescope image on the right shows a windowpane-shaped occulting bar. The illuminated material surrounding the star is the dust disk.

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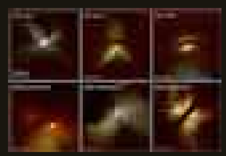

Feb 9, 1999 Vast Stellar Disks Set Stage for Planet Birth in New Hubble Images

Feb 4, 1999 SN1987A in the Large Magellanic Cloud

Jan 8, 1999 Dust Ring Around Star Offers New Clues on Planet Formation

Jan 8, 1999 Gap in Stellar Dust Disk May Be Swept Out by Planet

Jan 6, 1999 Looking Down a Barrel of Gas at a Doomed Star

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Nov 5, 1998 Great Balls of Fire! Hubble Sees Bright Knots Ejected From Brilliant Star

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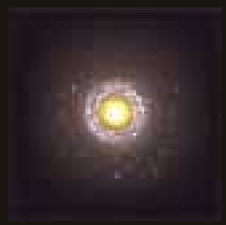

Oct 21, 1998 Astronomers Unveil Colorful Hubble Photo Gallery

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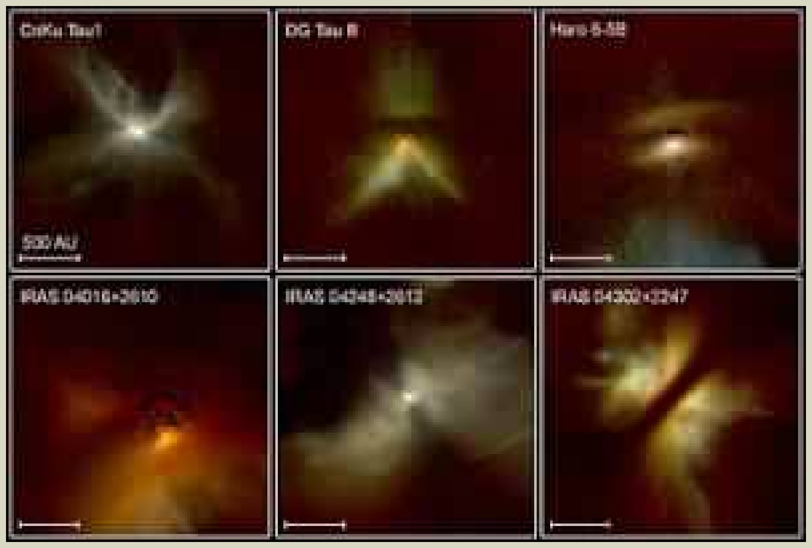
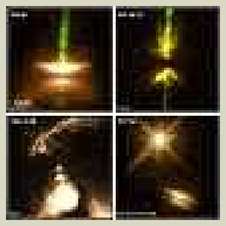
Vast Stellar Disks Set Stage for Planet Birth in New Hubble Images



Dramatic pictures of eerie disks of dust encircling young stars are giving astronomers a new look at what may be the early formative stages of planetary systems.

Although these pictures from the Hubble telescope don't show planets, the edge-on disks seen by the telescope provide some of the clearest views to date of potential planetary construction zones, say researchers. The images also offer a peek at what happened 4.5 billion years ago when the Earth and other planets in our solar system began to condense out of a pancake-shaped disk of dust and gas centered on the young Sun. These images were taken by Hubble's infrared camera. All of the objects in these pictures are extremely young stars, buried in the centers of these pictures. The wisps of material surrounding the young stars are glowing from reflected starlight.


Hubble Sees Disks Around Young Stars

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SN1987A in the Large Magellanic Cloud

Glittering stars and wisps of gas create a breathtaking backdrop for the self-destruction of a massive star, called supernova 1987A, in the Large Magellanic Cloud, a nearby galaxy. Astronomers in the Southern Hemisphere witnessed the brilliant explosion of this star on Feb. 23, 1987.

Shown in this Hubble telescope image, the supernova remnant, surrounded by inner and outer rings of material, is set in a forest of ethereal, diffuse clouds of gas.

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Dust Ring Around Star Offers New Clues on Planet Formation

The Hubble telescope has given astronomers their first view of a novel type of structure seen in space — a dust ring around a star.

Superficially resembling Saturn's rings — but on a vastly larger scale — the "hula-hoop" around the star HR 4796A offers new clues into the possible presence of young planets. All dust rings, whether around stars or planets, can only stay intact by some mechanism confining the dust. Otherwise, disruptive forces, such as those produced by particle collisions, light pressure, etc., would cause the ring to spread both inward and outward until it finally lost its identity. The HR 4796A dust ring, 6.5 billion miles from the star, is tightly confined within a relatively narrow zone

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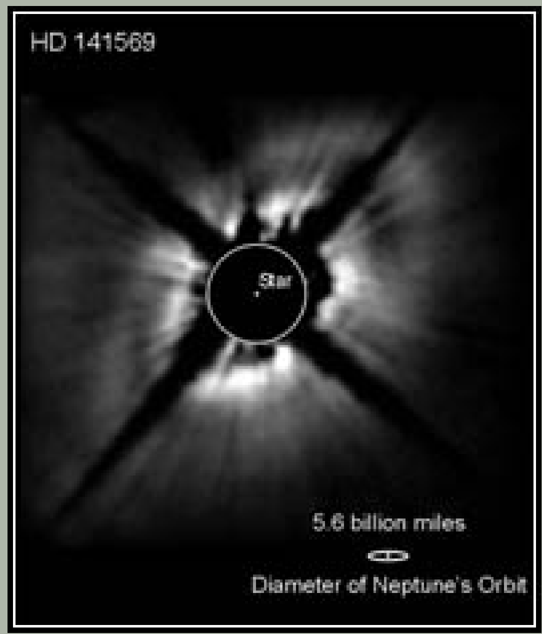
Gap in Stellar Dust Disk May Be Swept Out by Planet



Astronomers using the Hubble telescope are excited to find a dark gap dividing an immense dust disk around a young but fully formed star. An unseen planet may have gravitationally carved out the 3.7 billion mile-wide rut, which is like a wide groove in a phonograph record.

The star, known as HD 141569, lies about 320 light-years away in the constellation Libra. Hubble shows that the disk around HD 141569 appears to come in two parts: a bright inner region that is separated from a fainter outer region by a dark band. It superficially resembles the largest gap in Saturn's rings.

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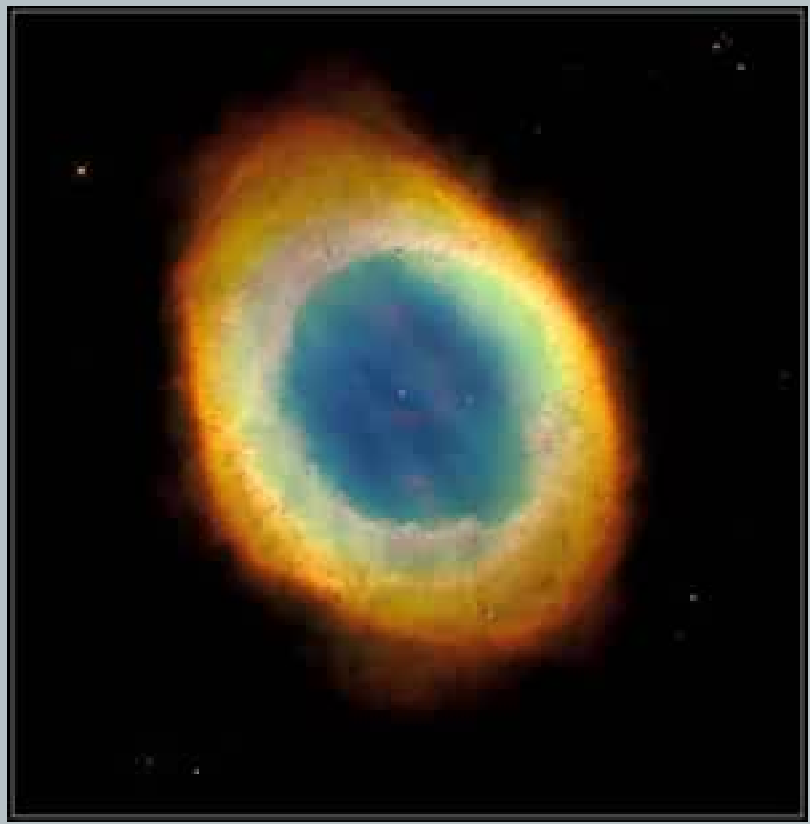
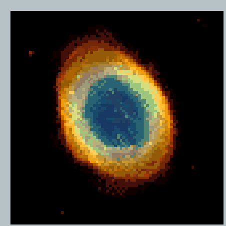
Looking Down a Barrel of Gas at a Doomed Star



Astronomers using the Hubble telescope have obtained the sharpest view yet of a glowing loop of gas called the Ring Nebula (M57), first cataloged more than 200 years ago by French astronomer Charles Messier.

The pictures reveal that the "Ring" is actually a cylinder of gas seen almost end-on. Such elongated shapes are common among other planetary nebulae, because thick disks of gas and dust form a waist around a dying star. This "waist" slows down the expansion of material ejected by the doomed object. The easiest escape route for this cast-off material is above and below the star. This photo reveals dark, elongated clumps of material embedded in the gas at the edge of the nebula; the dying central star is floating in a blue haze of hot gas.



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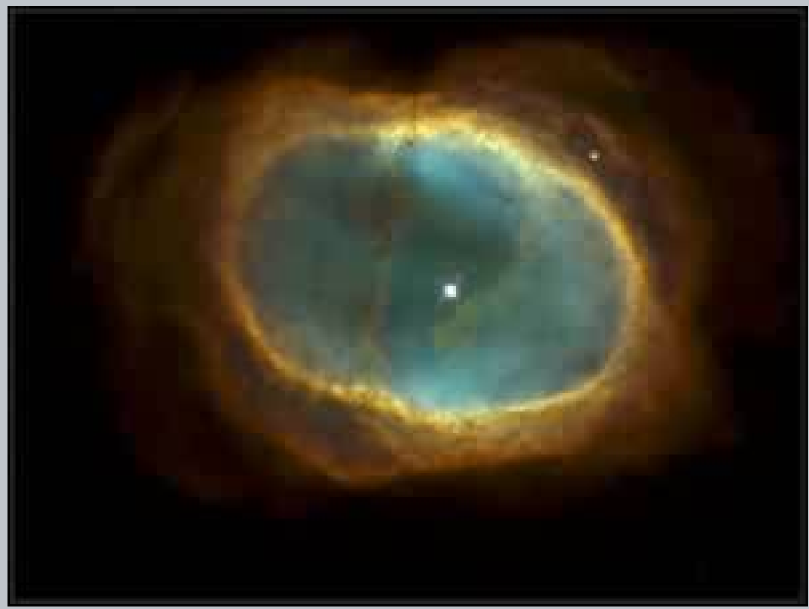
A Glowing Pool of Light



NGC 3132 is a striking example of a planetary nebula. This expanding cloud of gas surrounding a dying star is known to amateur astronomers in the Southern Hemisphere as the "Eight-Burst" or the "Southern Ring" Nebula.

The name "planetary nebula" refers only to the round shape that many of these objects show when examined through a small telescope. In reality, these nebulae have little or nothing to do with planets, but are instead huge shells of gas ejected by stars as they near the ends of their lifetimes. NGC 3132 is nearly half a light year in diameter, and at a distance of about 2,000 light-years is one of the nearest known planetary nebulae. The gases are expanding away from the central star at a speed of 9 miles per second.

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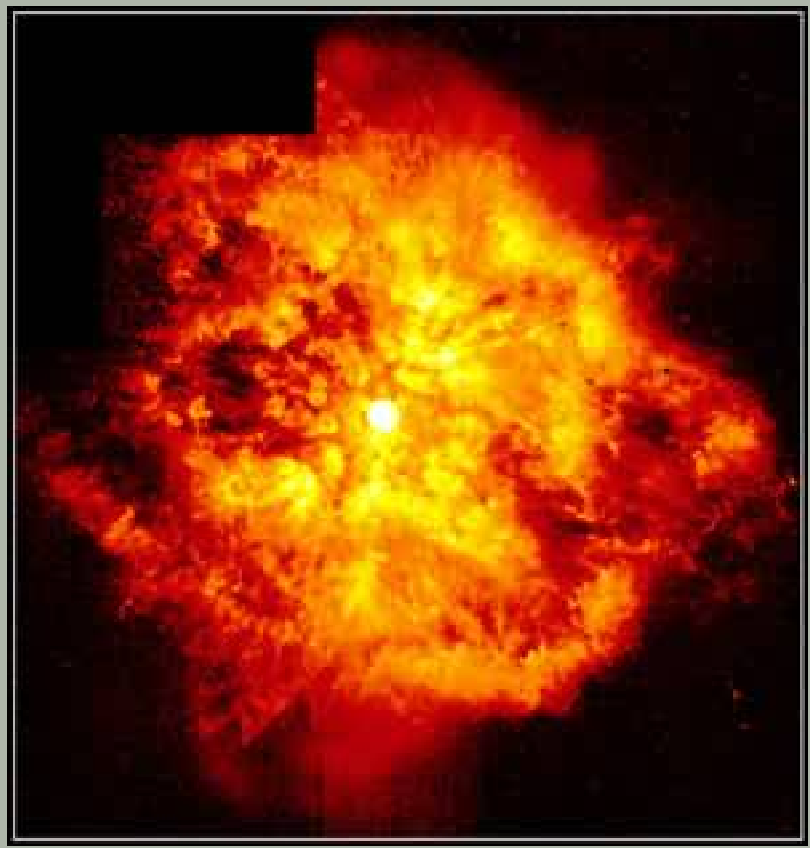
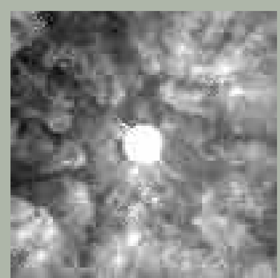
Great Balls of Fire! Hubble Sees Bright Knots Ejected From Brilliant Star



Resembling an aerial fireworks explosion, this dramatic Hubble telescope picture of the energetic star WR124 reveals that it is surrounded by hot clumps of gas being ejected into space at speeds of over 100,000 mph.

Also remarkable are vast arcs of glowing gas around the star, which are resolved into clumps, yet with no overall global shell structure. Though the existence of clumps in the winds of hot stars has been deduced through spectroscopic observations, Hubble resolves them directly in the nebula M1-67 around WR124 as 100-billion-mile-wide glowing gas blobs.



Detail of the Star WR124 And The Surrounding Nebula M1-67

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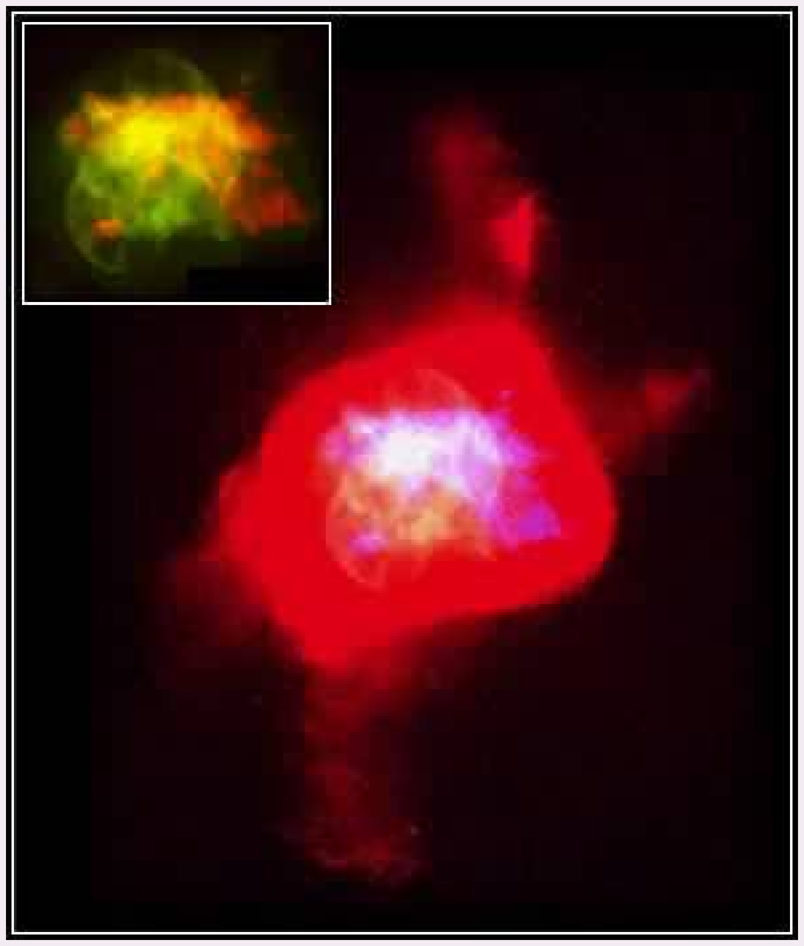
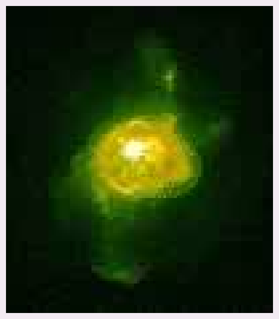
Turtle in Space Describes New Hubble Image



The Hubble telescope has shown us that the shrouds of gas surrounding dying, Sun-like stars (called planetary nebulae) come in a variety of strange shapes, from an "hourglass" to a "butterfly" to a "stingray."

With this image of NGC 6210, the Hubble telescope has added another bizarre form to the rogues' gallery of planetary nebulae: a turtle swallowing a seashell. Giving this dying star such a weird name is less of a challenge than trying to figure out how dying stars create those unusual shapes. The larger image shows the entire nebula; the inset picture captures the complicated structure surrounding the dying star.



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Astronomers Unveil Colorful Hubble Photo Gallery

A vibrant celestial photo album of some of the Hubble telescope's most stunning views of the universe is being unveiled today on the Internet. Called the Hubble Heritage Program, this technicolor gallery is being assembled by a team of astronomers at Hubble's science operations center, the Space Telescope Science Institute in Baltimore, Md.

The Hubble Heritage program is intended to provide the public with some of the very best celestial views the telescope has to offer, including this picture. The image looks like sunny-side-up egg is actually Hubble's face-on snapshot of the small spiral galaxy NGC 7742. This galaxy is not a run-of-the-mill spiral galaxy. In fact, this spiral is known to be a Seyfert 2 active galaxy, a type of galaxy that is probably powered by a black hole residing in its core.

Saturn In Natural Colors

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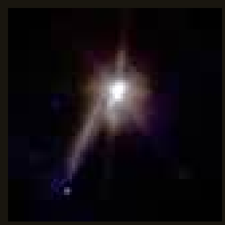
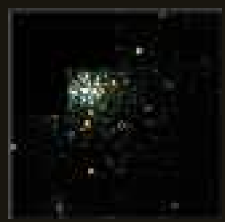
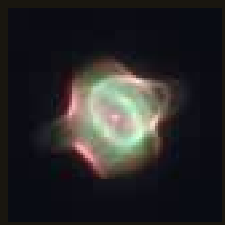


May 28, 1998 — Hubble Takes First Image of a Possible Planet around Another Star and Finds a Runaway World



Apr 9, 1998 — Hubble Finds That Even Massive Stars Just Fade Away



Apr 1, 1998 — Hubble Reveals Details of a Newly Born Planetary Nebula

Mar 19, 1998 — Hubble Captures the Shrouds of Dying Stars

Feb 10, 1998 — Shock Wave Sheds New Light on Fading Supernova

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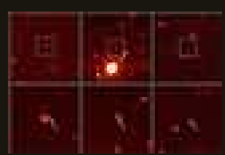
Jan 9, 1998 — A New Class of X-ray Star?



Jan 8, 1998 — Hubble Pinpoints Distant Supernovae

Jan 7, 1998 — Astronomers Have Found a New Twist in a Suspected Proto-Planetary Disk

1997

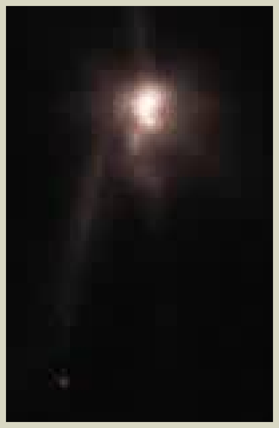
Dec 17, 1997 — Hubble Witnesses the Final Blaze of Glory of Sun-Like Stars

Dec 4, 1997 — One Star's Loss is Another's Gain: Hubble Captures Brief Moment in Life of Lively

Hubble Takes First Image of a Possible Planet around Another Star and Finds a Runaway World

The Hubble telescope has given astronomers their first direct look at what is possibly a planet outside our solar system — one apparently that has been ejected into deep space by its parent stars.

The discovery further challenges conventional theories about the birth and evolution of planets, and offers new insights into the formation of our own solar system. Located within a star-forming region in the constellation Taurus, the object, called TMR-1C, appears to lie at the end of a strange filament of light, suggesting it has apparently been flung away from the vicinity of a newly forming pair of binary stars.



Alternate view of TMR-1C showing double protostars

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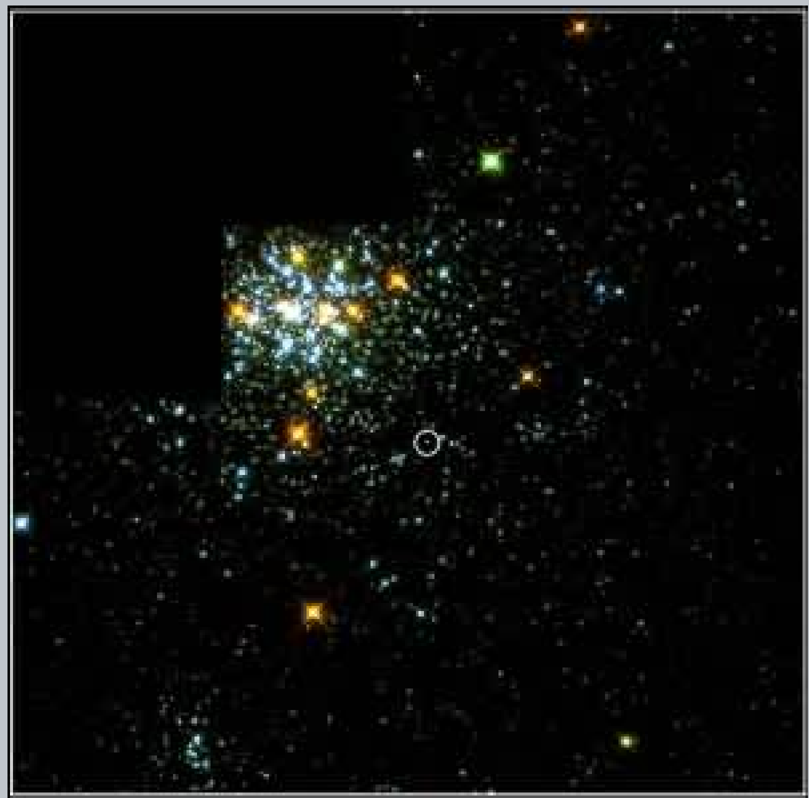
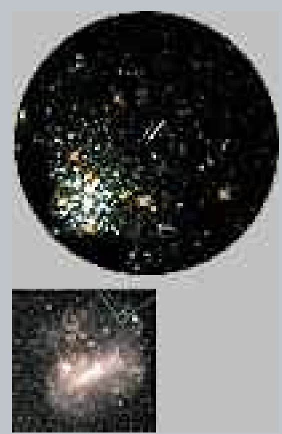
Hubble Finds That Even Massive Stars Just Fade Away



Pinpointing the rapidly fading ember of a recently burned out star, the Hubble telescope is giving astronomers a better estimate on just how big a star can be before it ultimately explodes as a supernova.

Based on Hubble's detection of a rare, young white dwarf star, astronomers conclude that its progenitor was a whopping 7.6 times the mass of our Sun. Previously, astronomers had estimated that stars anywhere from 6 to 10 solar masses would not just quietly fade away as white dwarfs, but abruptly self-destruct in torrential explosions. In this picture, Hubble can easily resolve the star [the white circle] in the crowded cluster and detect its intense blue-white glow from a sizzling surface temperature of 50,000 degrees Fahrenheit.



Ground-based image of the Large Magellanic Cloud with the location of the HST/WFPC2 field indicated.

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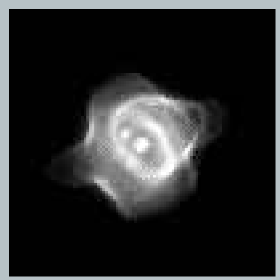
Hubble Reveals Details of a Newly Born Planetary Nebula

Astronomers have caught a peek at a rare moment in the final stages of a star's life: a ballooning shroud of gas cast off by a dying star flicking on its stellar light bulb. The Hubble telescope has captured the unveiling of the Stingray nebula (Hen-1357), the youngest known planetary nebula.

Twenty years ago, the nebulous gas entombing the dying star wasn't hot enough to glow. The Stingray nebula (Hen-1357) is so named because its shape resembles a stingray fish. Images of a planetary nebula in its formative years can yield new insights into the last gasps of ordinary stars like our Sun.



A 20 second exosure taken with the HST STIS CCD (clear) for aquisition purposes of a STIS calibration proposal.

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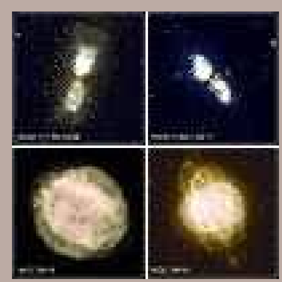
Hubble Captures the Shrouds of Dying Stars

The Hubble telescope continues to capture stunning, colorful snapshots of stellar burnout. These images reveal the beauty and complexity of planetary nebulae, the glowing relics of Sun-like stars.

This image of NGC 7027, for example, is one of the first infrared views of planetary nebulae taken with Hubble's infrared camera. In this picture, Hubble peers through the dusty core of a young planetary nebula to reveal the bright, central star. This picture also captures a young planetary nebula in a state of rapid transition.



Stellar Metamorphosis: Hubble Space Telescope Pictures of Butterfly-Shaped Nebulae Emerging from Stellar Cocoons

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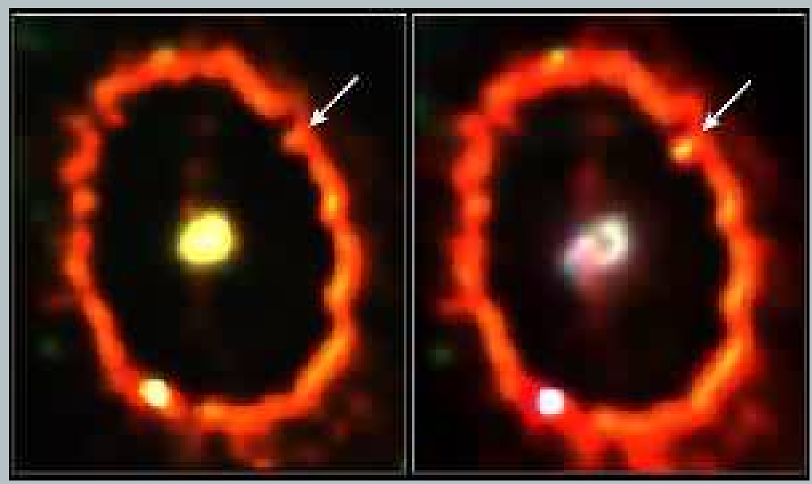
Shock Wave Sheds New Light on Fading Supernova



The Hubble telescope is giving astronomers a ringside seat to a never-before-seen titanic collision of an onrushing stellar shock wave with an eerie glowing gas ring encircling a nearby stellar explosion, called supernova 1987A.

Though the star's self-destruction was first seen nearly 11 years ago on Feb. 23, 1987, astronomers are just now beginning to witness its tidal wave of energy reaching the "shoreline" of the immense light-year-wide ring. Shocked by the 40-million-mile-per-hour sledgehammer blow, a 100-billion-mile-wide knot of gas in a piece of the ring has already begun to "light up," as its temperature surges from a few thousand degrees to a million degrees Fahrenheit. For comparison, the Hubble image on the left was taken before the collision. The picture on the right shows a glowing ball of gas [denoted by arrow].

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A New Class of X-ray Star?

Teaming up space telescopes to make simultaneous ultraviolet and X-ray observations, astronomers may have solved a 20-year-old mystery and possibly discovered a new class of X-ray star.

The unlikely suspect is a second-magnitude star 600 light-years from Earth in the constellation Cassiopeia. It turns out that the mild-mannered-looking star is ejecting 100-million-degree flares into space — 10 times hotter than typical flares ejected from our Sun. The findings are based on observations by the Hubble telescope and the Rossi X-Ray Timing Explorer.

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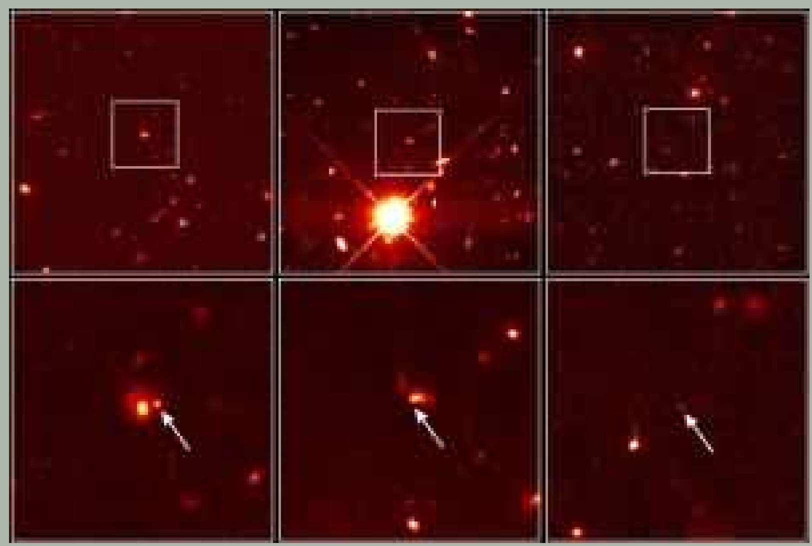
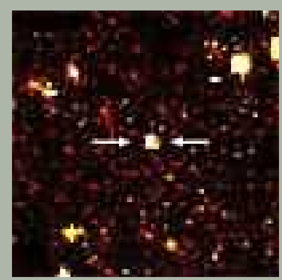
Hubble Pinpoints Distant Supernovae



Peering halfway across the universe to analyze light from exploded stars that died long before our Sun even existed, the Hubble telescope has allowed astronomers to determine that the expansion of the cosmos has not slowed since the initial impetus of the Big Bang. Thus, the universe's expansion should continue to balloon outward indefinitely.

These results are based on unprecedented distance measurements to supernovae that are so far away they allow astronomers to determine if the universe was expanding at a faster rate long ago. These images showcase three of the supernovae used in the survey. The arrows in the bottom row of pictures pinpoint these exploding stars; the top row of images shows the regions where the supernovae reside.



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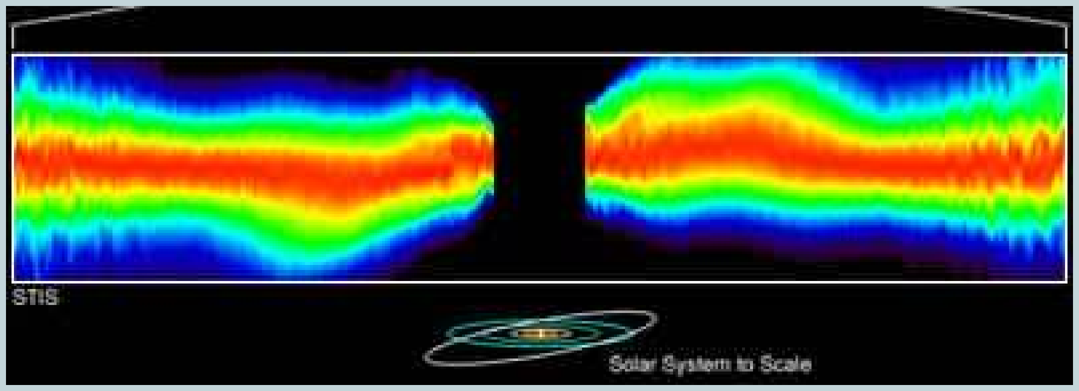
Astronomers Have Found a New Twist in a Suspected Proto-Planetary Disk



A telltale new warp uncovered in a vast, thin disk of dust encircling the star Beta Pictoris may be caused by the gravitational tug of a bypassing star or companion brown dwarf

These conclusions are based on Hubble telescope pictures that reveal the dim outermost reaches of the disk, which are 7 billion miles from the central star. The top image presents the entire disk, which spans 140 billion miles edge-to-edge. An unusual flaring at the top of the right side of the disk reveals that dust has been pulled above the dense plane of the disk beyond what is observed on the left side. A detailed close-up view of the inner region of the disk [bottom picture] shows a warp in the disk. These new details support the presence of one or more planets orbiting the star.

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One Star's Loss is Another's Gain: Hubble Captures Brief Moment in Life of Lively

Artist's Concept

Some stars in double-star systems have found a quick way to lose weight by dumping their extra pounds onto their companions. Astronomers using the Hubble telescope have discovered such a case in the double-star system Phi Persei. A "rapid diet" program has trimmed an aging, once massive star to a lean one solar mass, while the once mild-mannered, moderately massive companion has bulked up to a hefty nine solar masses and is spinning so violently that it's flinging gas from its surface.

Taken from the perspective of the Hubble telescope's observations of Phi Persei, this artist's depiction provides a taste of the double-star system's unstable existence. The star shedding pounds is represented as the white, semicircular object looming in the upper right of the illustration. The red, pancake-shaped object surrounding it is a gas disk. The gas is material the star is losing because of its rapid rotation. The small, hot sub-dwarf in the lower left of the illustration is the star that is benefiting from its companion's weight-loss program.

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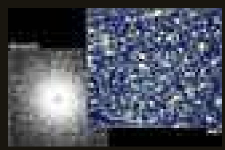
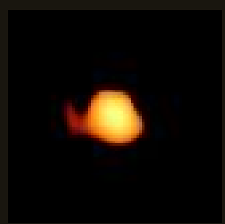

Oct 29, 1997 Hubble Catches Up with a Blue Straggler Star

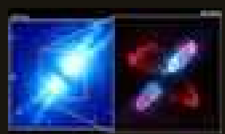

Oct 8, 1997 Hubble Identifies What May Be the Most Luminous Star Known


Sep 24, 1997 Hubble Sees a Neutron Star Alone in Space

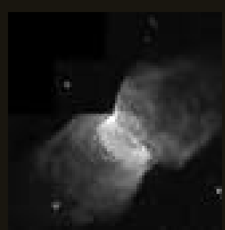

Sep 18, 1997 Blobs in Space: The Legacy of a Nova


Aug 6, 1997 Hubble Separates Stars in the Mira Binary System


Jun 9, 1997 Hubble Reveals Invisible High-Speed Collision around Supernova 1987A


May 12, 1997 Hubble Peers into Heart of Dying Star


May 12, 1997 Hubble Chemically Analyzes the Ring around Supernova 1987A


Mar 14, 1997 Hubble Camera Resumes Science Operation with Picture of "Butterfly" in Space

Jan 14, 1997 Hubble Finds Intergalactic Stars

Matches 51-60 of 86 shown
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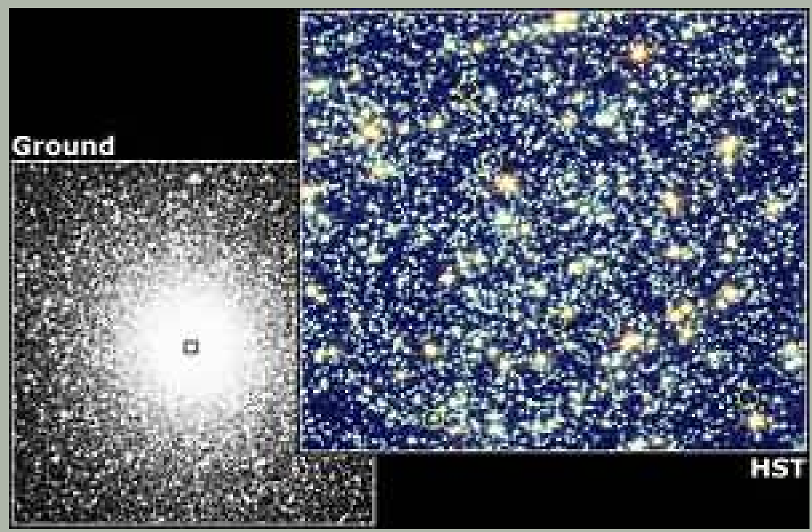
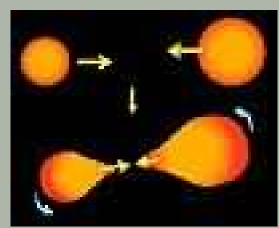
Hubble Catches Up with a Blue Straggler Star



Astronomers have long been mystified by observations of a few hot, bright, apparently young stars residing in well-established communities where most of their neighbors are much older.



With the help of the Hubble telescope, astronomers now have evidence that may eventually help solve the 45-year-old mystery of how these enigmatic stars, called blue stragglers, were formed. For the first time, astronomers have confirmed that a blue straggler in the core of a globular cluster (a very dense community of stars) is a massive, rapidly rotating star that is spinning 75 times faster than the Sun. This finding provides proof that blue stragglers are created by collisions or other intimate encounters in an overcrowded cluster core. A ground-based telescope image [left] shows the crowded core of the globular cluster 47 Tulane, which is teeming with blue stragglers. Peering into the heart of the cluster's brilliant core, Hubble separated the dense clump of stars into many individual stars [right].

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Hubble Identifies What May Be the Most Luminous Star Known

Astronomers using the Hubble telescope have identified what may be the most luminous star known — a celestial mammoth that releases up to 10 million times the power of the Sun and is big enough to fill the diameter of Earth's orbit. The star [center of image] unleashes as much energy in six seconds as our Sun does in one year.

The image, taken in infrared light, also reveals a bright nebula [magenta-colored material], created by extremely massive stellar eruptions. The nebula is so big (4 light-years) that it would nearly span the distance from the Sun to Alpha Centauri, the nearest star to Earth's solar system.

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Blobs in Space: The Legacy of a Nova

Nova eruptions by dying stars were thought to be simple, predictable acts of violence. Astronomers could point a telescope at the most recently exploded novae and see an expanding bubble of gaseous debris around each star.

Scientists using the Hubble telescope, however, were surprised to find that some nova outbursts may not produce smooth shells of gas, but thousands of gaseous blobs, each the size of our solar system. In this Hubble picture of the nova T Pyxidis, the shells of gas ejected by the star are actually more than 2,000 gaseous blobs packed into an area that is 1 light-year across.

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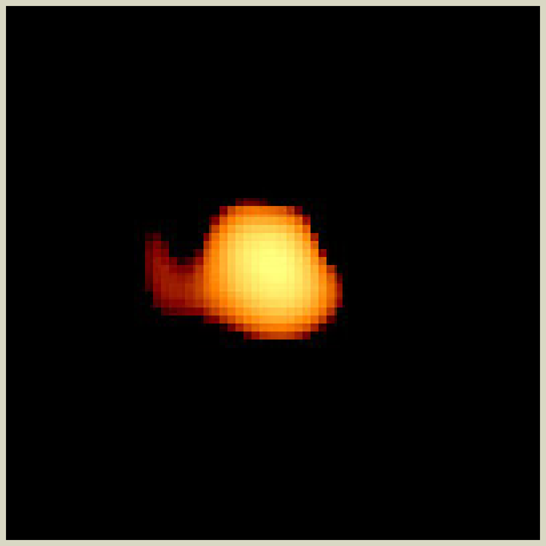
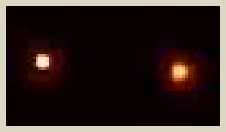
Hubble Separates Stars in the Mira Binary System



Although the giant star Mira has been known for about 400 years, astronomers have had to wait for the Hubble telescope to provide the first ultraviolet-light images of the extended atmosphere of the cool red giant star and its nearby, hot companion.



By giving astronomers a clear view of the individual members of this system, Hubble has provided valuable insights into other types of double-star systems where the stars are so close they interact with one another. In ultraviolet light, Hubble resolves a small, hook-like appendage extending from Mira and pointing towards the smaller companion. This material could be gravitationally drawn towards Mira's mate.

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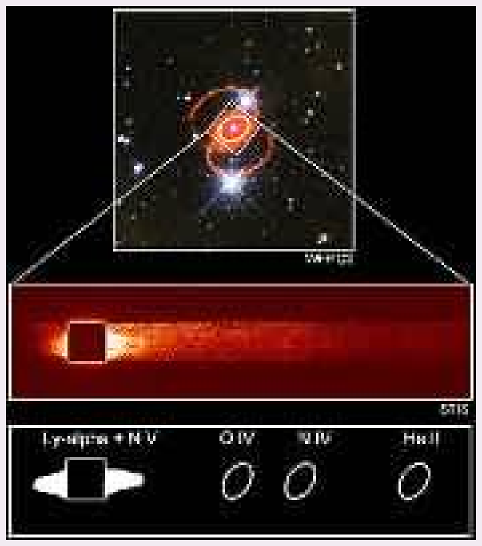
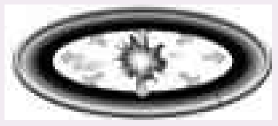
Hubble Reveals Invisible High-Speed Collision around Supernova 1987A



The highest velocity material expelled in a cataclysmic, stellar explosion 10 years ago has been detected for the first time by the Hubble telescope's imaging spectrograph.



The top image, taken with Hubble's visible-light camera, shows the orange-red rings surrounding Supernova 1987A in the Large Magellanic Cloud. The glowing debris of the supernova explosion, which occurred in February 1987, is at the center of the inner ring. The small, white square indicates the location of the imaging spectrograph aperture. The Hubble data in the middle panel [and a schematic representation in the bottom panel] shows the presence of glowing hydrogen expanding at a speed of 33 million mph (15,000 kilometers per second) coming from an extended area inside the inner ring.

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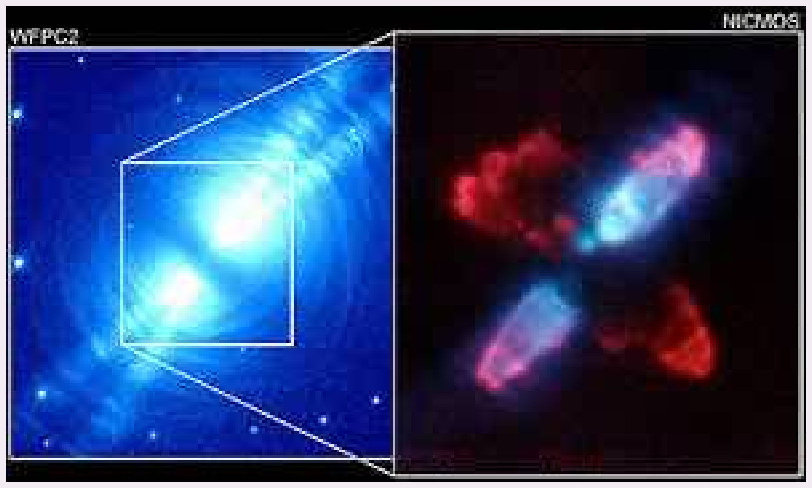
Hubble Peers into Heart of Dying Star



The Egg Nebula, also known as CRL 2688, is shown on the left as it appears in visible light and on the right as it looks in infrared light. Both Hubble views recount the last gasps of a dying, Sun-like star.

Objects like the Egg Nebula are helping astronomers understand how stars like our Sun expel carbon and nitrogen — elements crucial for life — into space. Studies on the Egg Nebula show that these dying stars eject matter at high speeds along a preferred axis and may even have multiple jet-like outflows. The signature of the collision between this fast-moving material and the slower, out-flowing shells is the glow of hydrogen molecules [the red material] captured in the right-hand image.

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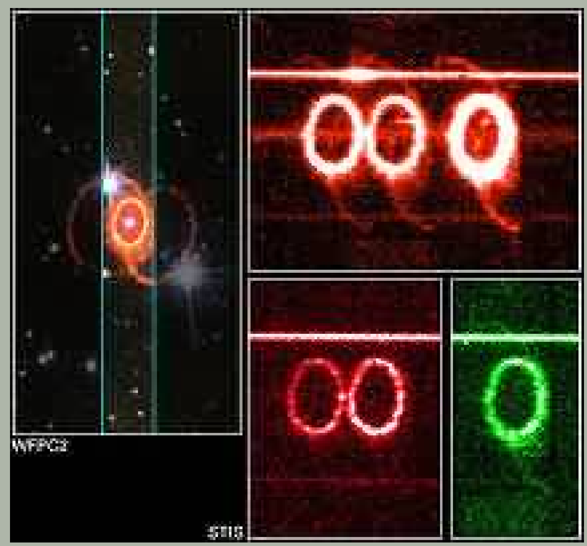
Hubble Chemically Analyzes the Ring around Supernova 1987A



These pictures from the Hubble telescope's imaging spectrograph provide a new and unprecedented look at one of the most unique and complex structures in the universe — a light-year-wide ring of glowing gas around supernova 1987A, the nearest stellar explosion in 400 years

The long-slit spectrograph viewed the entire ring system, dissecting its light and producing a detailed image of the ring in each of its component colors [the colorful loops on the right]. Each color represents light from specific elements in the ring's gases, including oxygen [single green ring], nitrogen and hydrogen [triple-orange rings], and sulfur [double-red rings]. By dismantling the ring into its different puzzle pieces — its component elements — astronomers hope to put together a picture of how the ring was created. The picture on the left is a view of the entire supernova.

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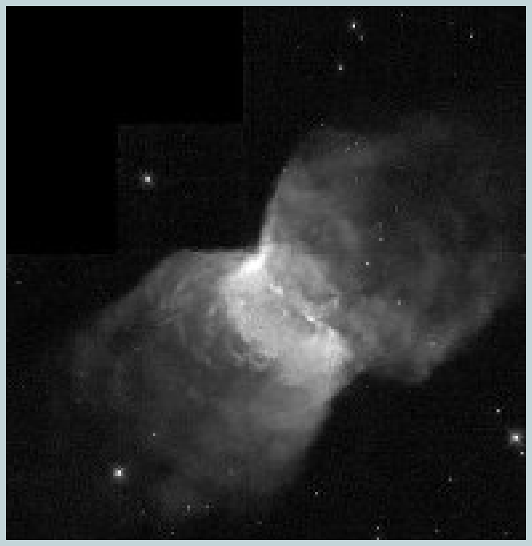
Hubble Camera Resumes Science Operation with Picture of "Butterfly" in Space



The Hubble telescope is back at work, capturing this view of the butterfly-wing-shaped nebula, NGC 2346.

The nebula is about 2,000 light-years away from Earth in the direction of the constellation Monoceros. It represents the spectacular "last gasp" of a double-star system at the nebula's center. The image was taken March 6, 1997 as part of the re-commissioning of Hubble's previously installed scientific instruments following a successful servicing mission.

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Hubble Finds Intergalactic Stars

Artist's Concept

The Hubble telescope has found a long-sought population of "stellar outcasts" — stars tossed out of their home galaxies into the dark emptiness of intergalactic space. This is the first time stars have been found more than 300,000 light-years (three Milky Way diameters) from the nearest big galaxy.

The isolated stars dwell in the Virgo cluster of galaxies, about 60 million light-years from Earth. The results suggest this population of "lone stars" accounts for 10 percent of the Virgo cluster's mass, or 1 trillion Sun-like stars adrift among the 2,500 galaxies in Virgo. This is an illustration of the view of the nighttime sky from the surface of a hypothetical planet orbiting an "outcast" star in the Virgo cluster.

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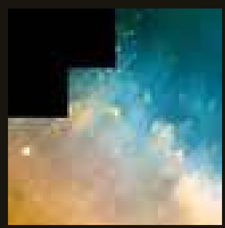
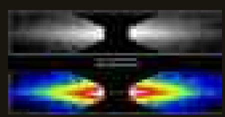
Jul 8, 1996 Hubble Telescope Measures Diameters of Pulsating Stars

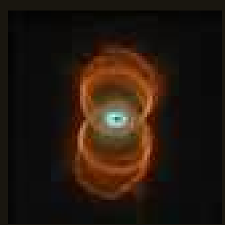
Jun 10, 1996 Doomed Star Eta Carinae



Apr 15, 1996 Hubble Finds Thousands of Gaseous Fragments Surrounding a Dying Star



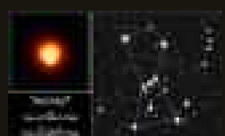
Jan 17, 1996 Disk around Star May Be Warped by Unseen Planet



Jan 16, 1996 Hubble Finds an Hourglass Nebula around a Dying Star

Jan 16, 1996 Hubble Telescope Photo Reveals Stellar Death Process

Jan 16, 1996 Hubble Finds Searchlight Beams and Multiple Arcs around a Dying Star



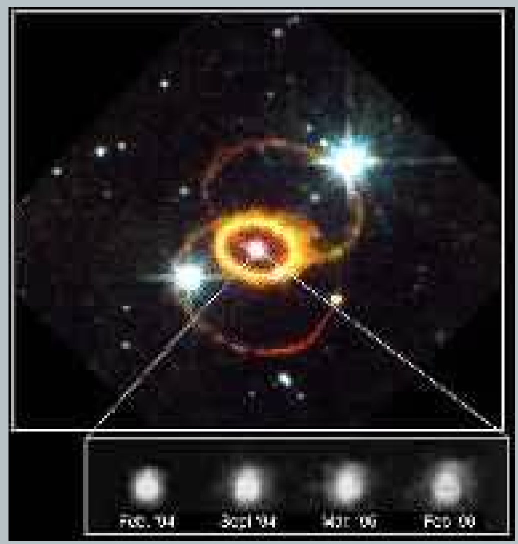
Jan 15, 1996 Hubble Space Telescope Captures First Direct Image of a Star

Jan 10, 1996

Hubble Discovers Powerful Laser Beamed from Chaotic Star

1997

Supernova Blast Begins Taking Shape



Though the brightest supernova in four centuries lit up the southern sky almost exactly 10 years ago on Feb. 23, 1987, astronomers have waited a decade for the ballooning fireball to become large enough — about one-sixth of a light-year — to be resolved from Earth's orbit with the Hubble telescope.

Hubble's sharp "eyes" have resolved a dumbbell-shaped structure — one-tenth of a light-year long — that consists of two blobs of debris expanding apart at nearly 6 million mph from each other. This Hubble picture shows the supernova, designated 1987A, and its neighborhood. The four frames follow the evolution of the supernova debris.

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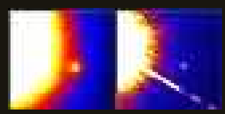
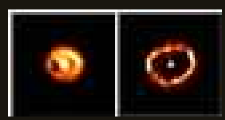
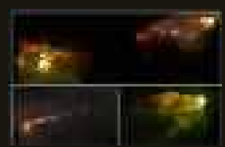

Nov 29, 1995 Astronomers Announce First Clear Evidence of a Brown Dwarf


Nov 2, 1995 Embryonic Stars Emerge from Interstellar "Eggs"


Oct 10, 1995 Hubble Sees Thin Disk Around the Star Beta Pictoris


Sep 14, 1995 Hubble Spies a Really Cool Star

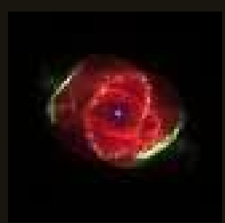

Jul 7, 1995 Hubble Sees Changes in Gas Shell around Nova Cygni 1992


Jun 6, 1995 Hubble Observes the Fire and Fury of a Stellar Birth


May 22, 1995 Hubble Probes the Workings of a Stellar Hydrogen Bomb


Apr 10, 1995 Oxygen-Rich Supernova Remnant in the Large Magellanic Cloud


Feb 20, 1995 Hubble's Close-Up View of a Shock Wave from a Stellar Explosion


Jan 11, 1995 Hubble Probes the Complex History of a Dying Star

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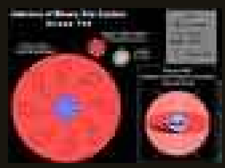
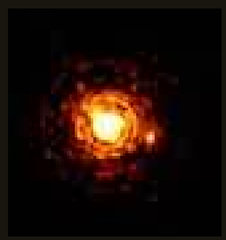


Jan 10, 1995 Red Dwarf Dynamo Raises Puzzle over Interiors of Lowest Mass Stars

1994



Dec 21, 1994 Hubble Finds One of the Smallest Stars in the Universe

Nov 15, 1994 Hubble Rules Out a Leading Explanation for Dark Matter

Jun 13, 1994 Hubble Confirms Abundance of Protoplanetary Disks around Newborn Stars

May 20, 1994 Hubble Observes the Supernova in the Whirlpool Galaxy

May 19, 1994 Hubble Finds Mysterious Ring Structure around Supernova 1987a

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Behind a Dusty Veil Lies a Cradle of Star Birth

NGC 253 is a large, almost edge-on spiral galaxy, and is one of the nearest galaxies beyond our local neighborhood of galaxies.

This dramatic galaxy shows complex structures such as clumpy gas clouds, darkened dust lanes, and young, luminous central star clusters. These elements are typical of spiral galaxies. Caroline Herschel discovered NGC 253 in 1783 while looking for comets. The galaxy's closeness to Earth makes it an ideal target for amateur astronomers who can see the southern sky and for astronomers interested in learning more about the makeup of these stunning cities of stars.

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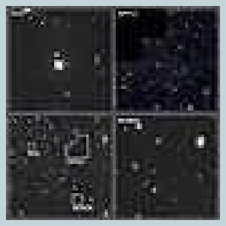
The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View

Turning its penetrating vision toward southern skies, the Hubble telescope has peered down a 12- billion-light-year-long corridor loaded with a dazzling assortment of thousands of never-before-seen galaxies. The observation, called the Hubble Deep Field South, doubles the number of far-flung galaxies available to astronomers for deciphering the history of the universe.

This new far-look complements the original Hubble "deep field" taken in late 1995, when Hubble was aimed at a small patch of space near the Big Dipper. Hubble's sharp vision allows astronomers to sort galaxy shapes. The image is dominated by beautiful pinwheel-shaped disk galaxies, which are like our Milky Way.



Hubble Deep Field South— Multiple Windows On The Universe

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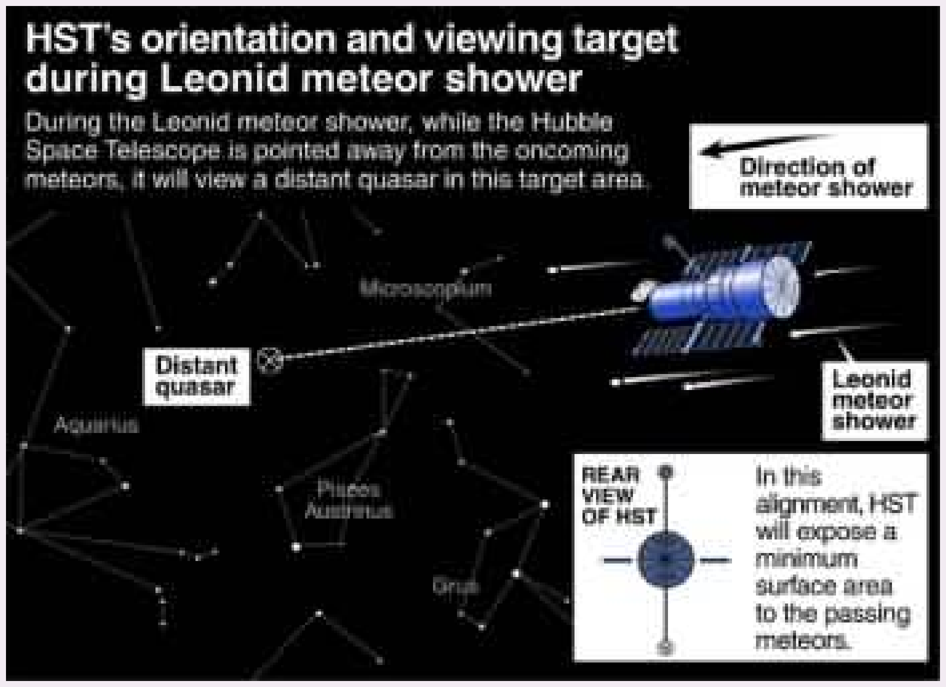
Leonid Meteor Storm Won't Deter Hubble from Space Observations



Artist's Concept

The anticipated celestial bombardment called the Leonid meteor storm on the afternoon of November 17th, 1998 won't deter the Hubble telescope from its key mission of gazing far across the universe — as long as the view is in the opposite direction of the incoming meteor swarm.

Using the brilliant glow of a distant quasar located near the southern boundary of the constellation Aquarius, Hubble will probe galaxy formation and the distribution of matter in space. The Hubble data will become immediately available to the astronomical community.

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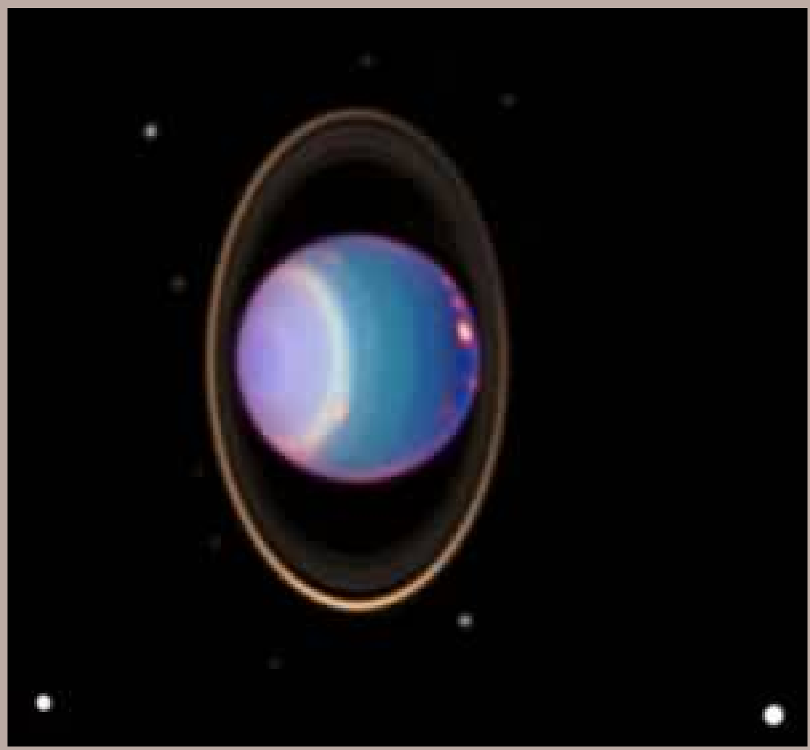
Hubble Finds Many Bright Clouds on Uranus



A Hubble telescope infrared view of Uranus reveals that the planet is surrounded by its four major rings and by 10 of its 17 known satellites.

Hubble recently found about 20 clouds — nearly as many clouds on Uranus as the previous total in the history of modern observations. The orange-colored clouds near the prominent bright band circle the planet at more than 300 mph (500 km/h). One of the clouds on the right-hand side is brighter than any other cloud ever seen on Uranus.

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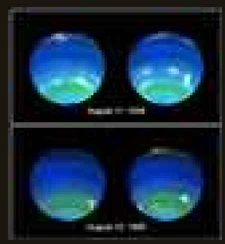

Oct 14, 1998 — Hubble Provides a Moving Look at Neptune's Stormy Disposition

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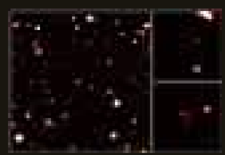
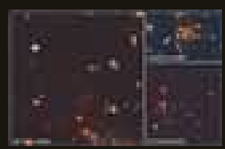
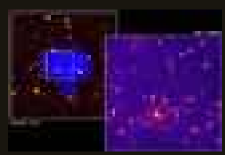
Oct 9, 1998 — Second Hubble Web Simulcast Takes Listeners on a Tour of the Cosmos



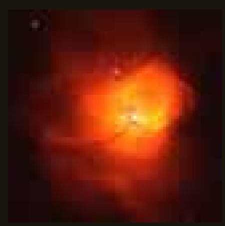
Oct 8, 1998 — Hubble Goes to the Limit In Search Of Farthest Galaxies



Aug 27, 1998 — Far-Flung Galaxy Clusters May Reveal Fate of Universe



Aug 19, 1998 — Distant Heavyweight Galaxy Cluster Clobbers Dense-Universe Theory



Jul 23, 1998 — Nearby Massive Star Cluster Yields Insights into Early Universe

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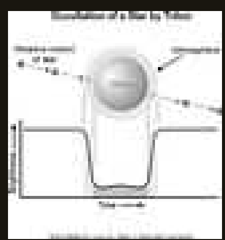
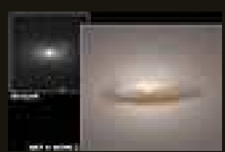
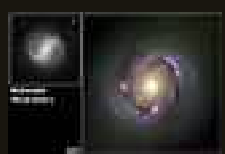
Jul 1, 1998 — Hubble Simulcast Links Outer Space to Cyberspace



Jun 24, 1998 — Hubble Space Telescope Helps Find Evidence that Neptune's Largest Moon Is Warming Up



Jun 18, 1998 — Hubble Uncovers Dust Disk around a Massive Black Hole



Jun 10, 1998 — A Bright Ring of Star Birth around a Galaxy's Core

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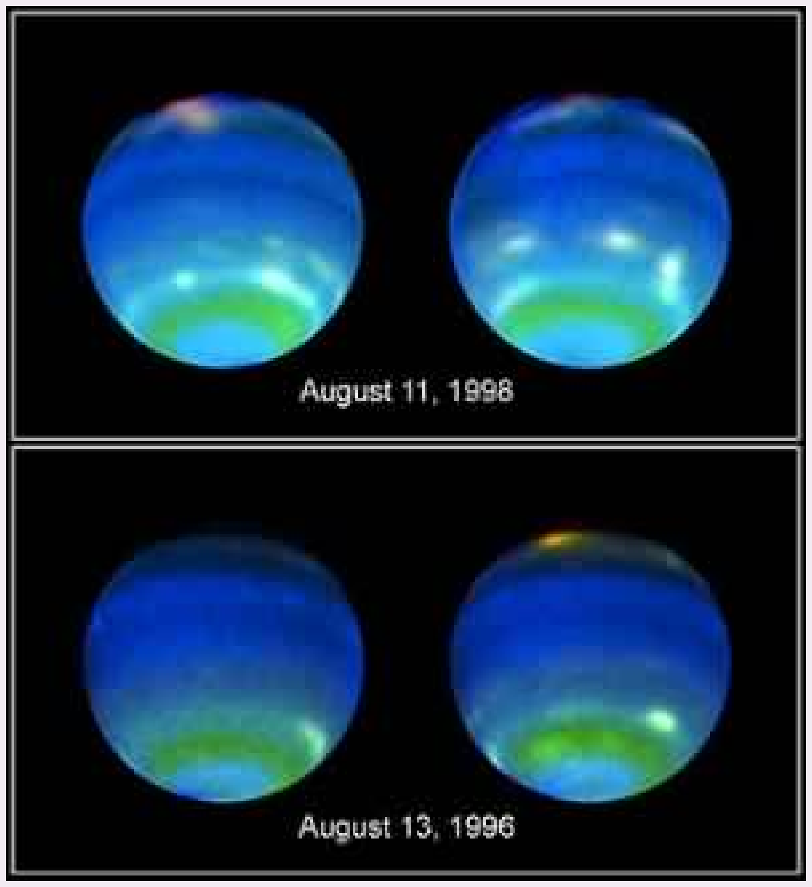
Hubble Provides a Moving Look at Neptune's Stormy Disposition



Using powerful ground- and space-based telescopes, scientists have obtained a moving look at some of the wildest, weirdest weather in the solar system.

Combining simultaneous observations of Neptune made with the Hubble telescope and NASA's Infrared Telescope Facility on Mauna Kea, Hawaii, a team of scientists has captured the most insightful images to date of a planet whose blustery weather bewilders scientists. On Neptune, winds blow at 900 miles per hour and huge storms — some the sizes of Earth itself — come and go with regularity.

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Second Hubble Web Simulcast Takes Listeners on a Tour of the Cosmos

The popular National Public Radio program "The Marc Steiner Show" (WJHU, FM 88.1) and the Space Telescope Science Institute in Baltimore, Md., will again team up to take listeners on a tour of the cosmos via the Internet on October 14, 1998.

This is the second in a series of programs in which host Marc Steiner's discussion and interview with his guests will be made available on the World Wide Web, courtesy of the institute's Office of Public Outreach. This is also the first time the institute will utilize multimedia technology to stream video of the science images along with real-time audio from the radio show.

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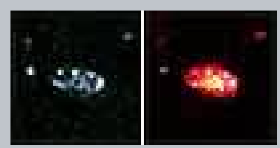
Hubble Goes to the Limit In Search Of Farthest Galaxies

Stretching the Hubble telescope's vision farther across space and further back into time than ever before, astronomers have peered into a previously unseen realm of the universe.



Comparative View Of Galaxy's Stellar Populations

A "long-exposure" infrared image has uncovered the faintest galaxies ever seen. Astronomers believe some of these galaxies could be the farthest objects ever seen. A powerful new generation of telescopes will be needed to confirm the suspected distances. The picture on the left contains over 300 galaxies, which have spiral, elliptical, and irregular shapes. The two images on the right represent close-up views of objects that may be over 12 billion light-years away, the farthest galaxies ever seen. Each faraway galaxy is centered in the frame.

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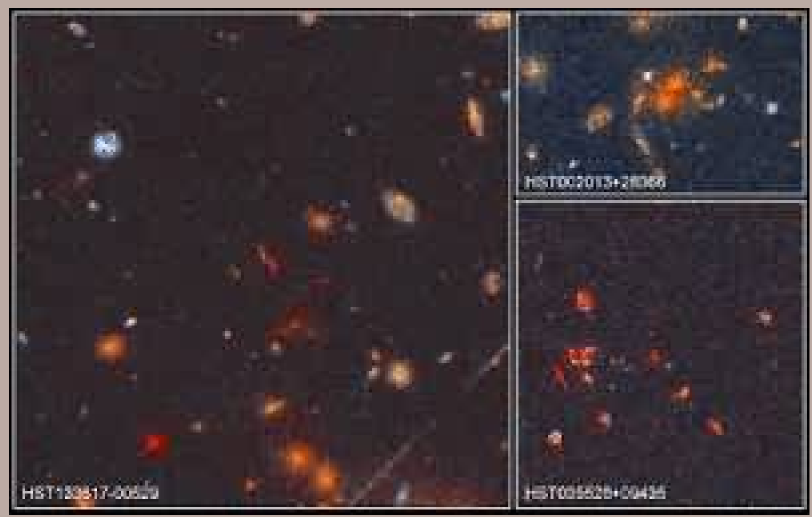
Far-Flung Galaxy Clusters May Reveal Fate of Universe



A survey of galaxy clusters by the Hubble telescope has found what could be some of the most distant clusters ever seen. If ground-based telescopes confirm the distances and masses of the clusters, the survey may hold clues to how galaxies quickly formed into massive, large-scale structures after the Big Bang, which could provide answers for the universe's eventual fate.

According to theoretical models, if the clusters turn out to be massive and very distant, it could imply that the cosmos does not contain enough matter for gravity to stop the expansion of the universe. These models predict that such a low-density universe would have built most of its galaxy clusters long ago. These images represent three of the faraway clusters of galaxies. These galaxies were selected from a catalog of 92 new clusters uncovered during a six-year Hubble observing program known as the Medium Deep Survey.

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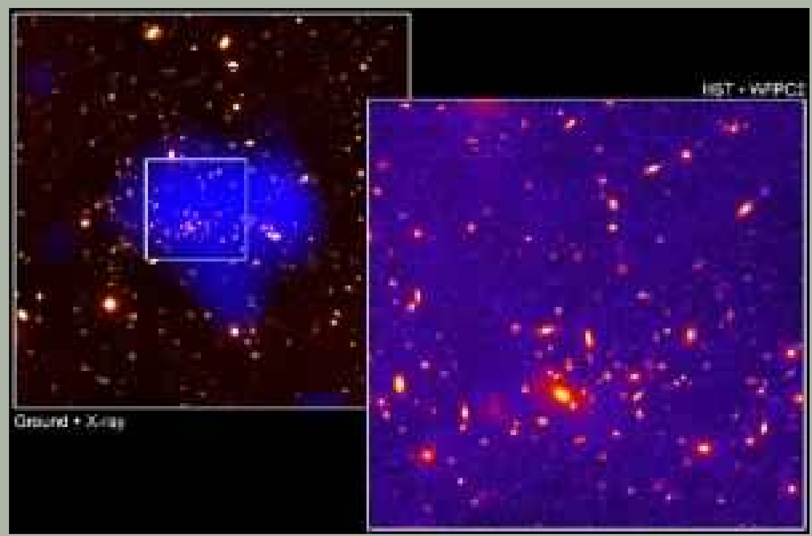
Distant Heavyweight Galaxy Cluster Clobbers Dense-Universe Theory



A Space Telescope Science Institute astronomer has found the equivalent of the proverbial 900-pound gorilla in deep space. The "gorilla" is an extremely massive cluster of galaxies — the weight of several thousand of our Milky Ways — that existed when the universe was half its present age.

Hubble Captures View Of Supernova Blast In Remote Galaxy Cluster

Paradoxically, the unexpected discovery of this ancient, heavyweight cluster is one of the strongest pieces of evidence yet that we live in a lightweight universe, one that doesn't have enough bulk to provide the gravity necessary to halt the expansion of space. Using X-ray satellites and ground-based telescopes to probe the remote regions of space, the Institute astronomer discovered MS1054-0321, a hefty galaxy cluster containing thousands of galaxies and many trillions of stars. The image on the left, taken by ground-based and X-ray observatories, shows the entire galaxy cluster surrounded by background and foreground galaxies. The image on the right, taken by Hubble's visible-light camera, provides a clearer view of the galaxies in the heart of the cluster.

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Hubble Simulcast Links Outer Space to Cyberspace

Expanding its broadcast universe far beyond the Baltimore area and into cyberspace, the popular WJHU radio program "The Marc Steiner Show" (WJHU, FM 88.1) has teamed up with the Space Telescope Science Institute to take listeners on a Hubble Space Telescope tour of the cosmos via the Internet.

For the show's first time, host Marc Steiner's discussion and interview with his guests will be available on the World Wide Web, courtesy of the institute's Office of Public Outreach.

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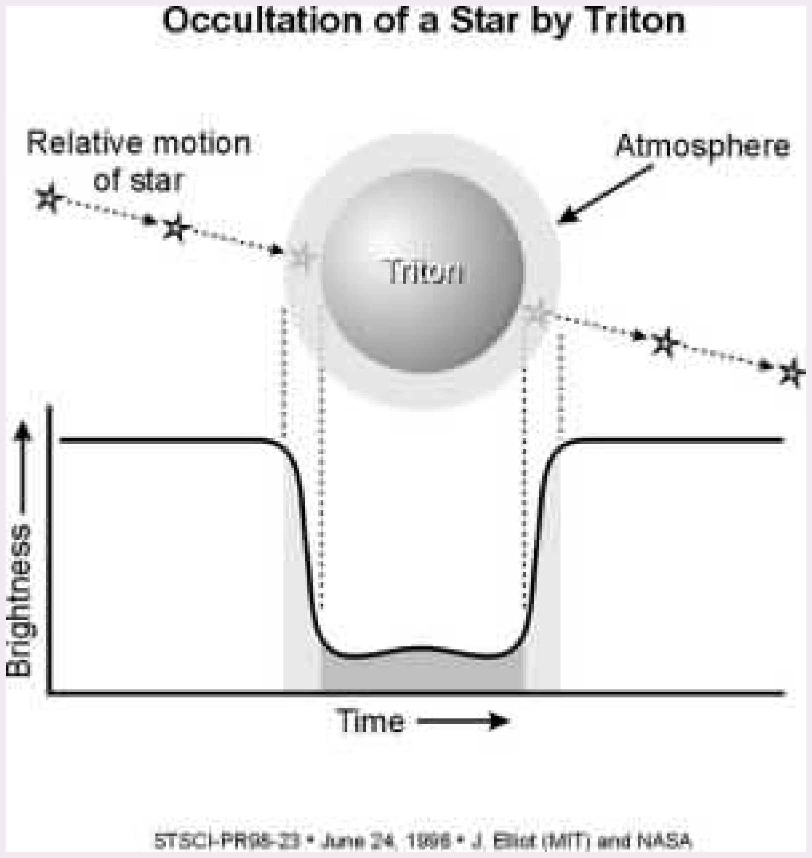
Hubble Space Telescope Helps Find Evidence that Neptune's Largest Moon Is Warming Up



Observations obtained by the Hubble telescope and ground-based instruments reveal that Neptune's largest moon, Triton, seems to have heated up significantly since the Voyager spacecraft visited it in 1989.

Even with the warming, no one is likely to plan a summer vacation on Triton, which is a bit smaller than Earth's moon. Since 1989 Triton's temperature has risen from about 37 on the absolute (Kelvin) temperature scale (-392 degrees Fahrenheit) to about 39 Kelvin (-389 degrees Fahrenheit). The scientists are basing a rise in Triton's surface temperature on the Hubble telescope's detection of an increase in the moon's atmospheric pressure, which has at least doubled in bulk since the time of the Voyager encounter. When Triton passed in front of a star known as "Tr180" in the constellation Sagittarius, Hubble measured the star's gradual decrease in brightness. The starlight became fainter as it traveled through Triton's thicker atmosphere, alerting astronomers to changes in the moon's air pressure.

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A Bright Ring of Star Birth around a Galaxy's Core

This Hubble telescope snapshot reveals clusters of infant stars that formed in a ring around the core of the barred-spiral galaxy NGC 4314. This stellar nursery, whose inhabitants were created within the past 5 million years, is the only place in the entire galaxy where new stars are being born.

This close-up view also illustrates other interesting details in the galaxy's core: dust lanes, a smaller bar of stars, dust and gas embedded in the stellar ring, and an extra pair of spiral arms packed with young stars. These details make the center resemble a miniature version of a spiral galaxy. The black-and-white image on the left, taken by a ground-based telescope, shows the entire galaxy.

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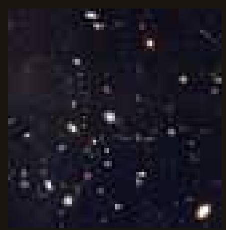

Nov 23, 1998 [The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View]

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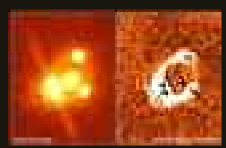

Oct 26, 1998 [Quasar PG1115+080 and Gravitational Lens]

Oct 22, 1998 [Turtle in Space Describes New Hubble Image]

Oct 21, 1998 [Astronomers Unveil Colorful Hubble Photo Gallery]

Oct 14, 1998 Hubble Finds Many Bright Clouds on Uranus

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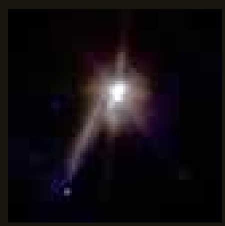
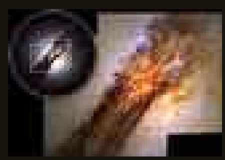


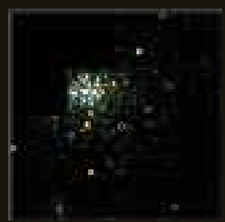
May 28, 1998 Hubble Takes First Image of a Possible Planet around Another Star and Finds a Runaway World



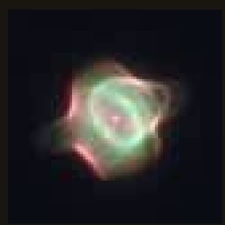
May 14, 1998 Hubble Provides Multiple Views of How to Feed a Black Hole

May 6, 1998 Gamma-Ray Burst Found to be Most Energetic Event in Universe

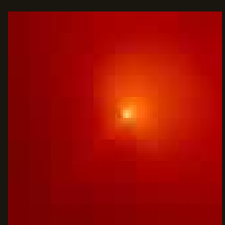
Apr 23, 1998 Hubble Space Telescope Completes Eighth Year Of Exploration



Apr 9, 1998 Hubble Finds That Even Massive Stars Just Fade Away

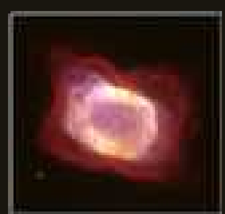


Apr 1, 1998 Hubble Reveals Details of a Newly Born Planetary Nebula



Mar 27, 1998 Comet Hyakutake

Mar 22, 1998 Hubble Captures the Heart of Star Birth



Mar 19, 1998 Hubble Captures the Shrouds of Dying Stars

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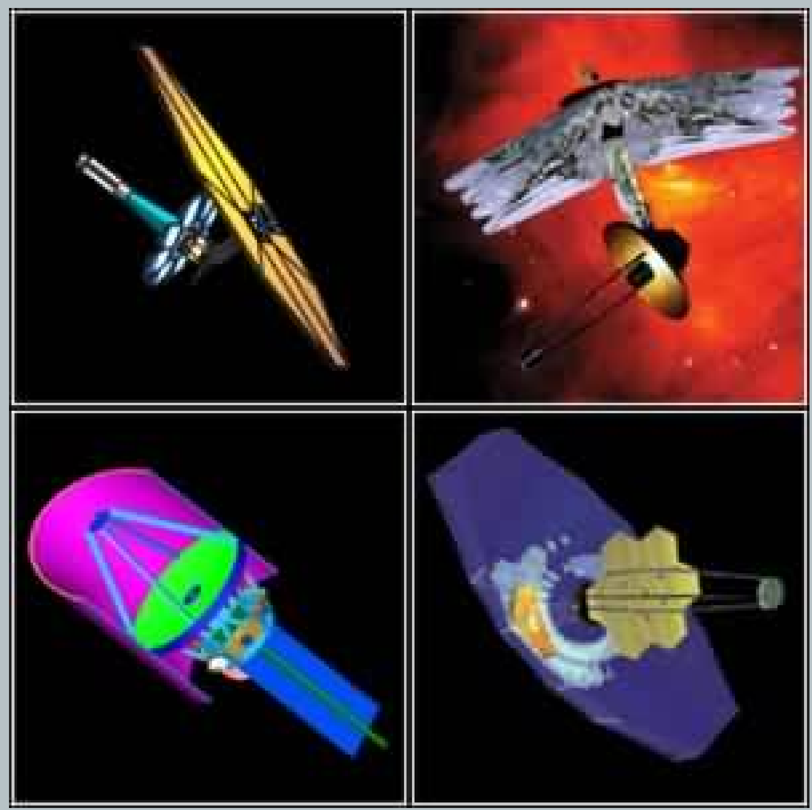
NASA Selects Home for Next Generation Space Telescope



Artist's Concept

The duties of the Space Telescope Science Institute in Baltimore, Md., will be expanded to include the management of science operations for the Next Generation Space Telescope (NGST), NASA officials announced today.

The Space Telescope Science Institute, located at the Johns Hopkins University, has been operating the science program for the Hubble telescope since 1983. The illustration represents the four designs NASA is considering for NGST.

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Hubble Space Telescope Completes Eighth Year Of Exploration

In honor of NASA Hubble Space Telescope's eighth anniversary, we have gift-wrapped Saturn in vivid colors. Actually, this image is courtesy of Hubble's infrared camera, which has taken its first peek at Saturn.

This view provides detailed information on the clouds and hazes in Saturn's atmosphere. The blue colors indicate a clear atmosphere down to the main cloud layer. Most of the Northern Hemisphere that is visible above the rings is relatively clear. The dark region around the South Pole indicates a big hole in the main cloud layer. The green and yellow colors indicate a haze above the main cloud layer. The red and orange colors indicate clouds reaching up high into the atmosphere. The rings, made up of chunks of ice, are as white as images taken in visible light.

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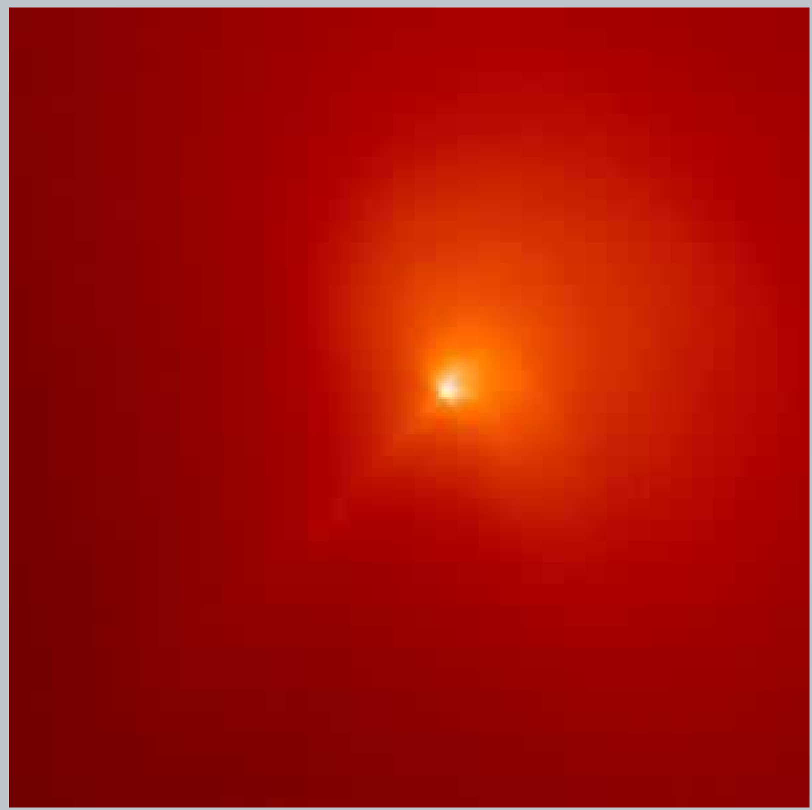
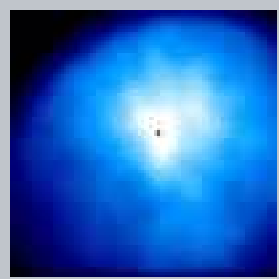


The Hubble telescope has probed the inner regions of Comet Hyakutake. This picture captures sunlight scattered by dust particles in the comet's inner coma.

The coma is the head or dusty-gas atmosphere surrounding a comet's icy nucleus. This image will help astronomers understand the effects of sunlight on the comet's icy central region.



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Hubble Captures the Heart of Star Birth

The Hubble telescope has captured a flurry of star birth near the heart of the barred spiral galaxy NGC 1808.

This is a close-up view of the galaxy's center, the hotbed of vigorous star formation. The yellow color pinpoints older stars; the blue color reveals areas of star birth. NGC 1808 is called a barred spiral galaxy because of the straight lines of star formation on both sides of the bright nucleus. The bar may be the catalyst for this intense star formation. The rotation of the bar may have triggered the star birth, or matter streaming along the bar towards the central region may be feeding the stellar breeding ground.

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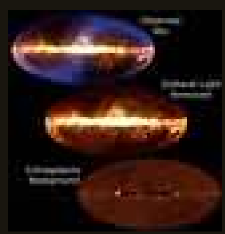
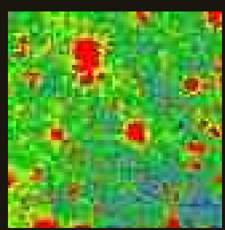
Jan 9, 1998 A New Class of X-ray Star?

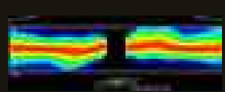

Jan 9, 1998 Astronomers Discover an Infrared Background Glow in the Universe


Jan 8, 1998 Hubble Pinpoints Distant Supernovae


Jan 7, 1998 Hubble Finds Most of Visible Light in the Universe


Jan 7, 1998 Hubble Provides Clear Images of Saturn's Aurora


Jan 7, 1998 Hubble Provide Complete View of Jupiter's Auroras


Jan 7, 1998 Astronomers Have Found a New Twist in a Suspected Proto-Planetary Disk

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Astronomers Track Down Asteroids in Hubble Archive

Astronomers have stumbled on an unusual asteroid hunting ground: the thousands of Hubble telescope images stored in the orbiting observatory's archive.

The hunt has yielded a sizable catch of small asteroids — about 100. A preliminary analysis suggests that a total population of 300,000 small asteroids — essentially rocks just over 1 to 3 kilometers wide (equal to half a mile to two miles) — are orbiting between Mars and Jupiter in a band of space debris known as the main belt. Currently, there are 8,319 confirmed main belt asteroids whose orbits have been measured, and about the same number have been sighted but not confirmed. These pictures are a sampling of what astronomers have found. The blue, curved lines mark an asteroid's trail.

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Space Telescope Science Institute Gets New Director

An agreement has been reached in principle to appoint Dr. Steven V. W. Beckwith director of the Space Telescope Science Institute (STScI), in Baltimore. The agreement is under negotiation and will be finalized in the near future. The appointment becomes effective on Sept. 1, 1998. Dr. Beckwith is currently the managing director of the Max-Planck Institute for Astronomy in Heidelberg, Germany.

The STScI carries out the scientific mission of the Hubble Space Telescope. The Association of Universities for Research in Astronomy, Inc., manages STScI for NASA. The European Space Agency participates in the Hubble Project under a long-term arrangement with NASA.

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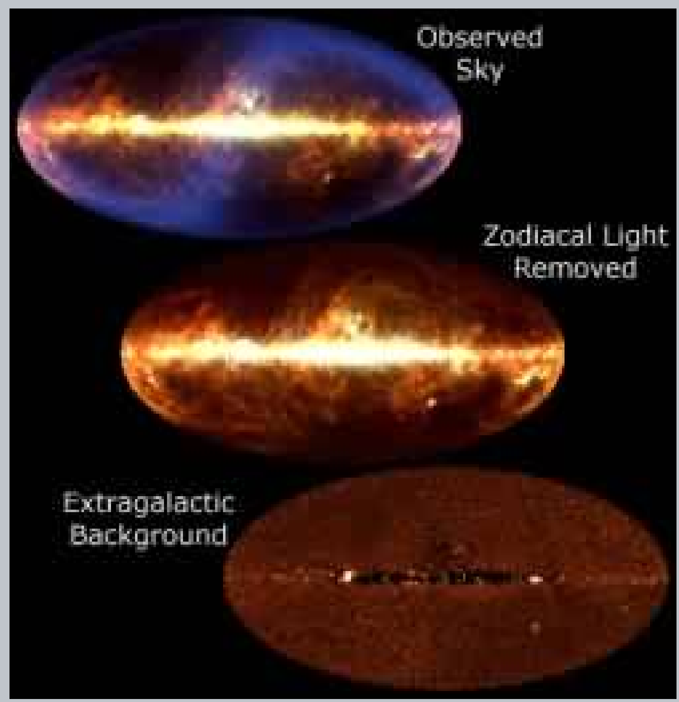
Astronomers Discover an Infrared Background Glow in the Universe



Astronomers have assembled the first definitive detection of a background infrared glow across the sky produced by dust warmed by all the stars that have existed since the beginning of time. For scientists, the discovery of this "fossil radiation" is akin to turning out all the lights in a bedroom only to find the walls, floor, and ceiling aglow with an eerie luminescence.

The telltale infrared radiation puts a limit on the total amount of energy released by all the stars in the universe. Astronomers say this will greatly improve development of models explaining how stars and galaxies were born and evolved after the Big Bang. These three pictures are maps of the full sky as seen in infrared light. The top picture represents the brightness of the full sky as seen in infrared light. The middle picture is a view of the sky after the foreground glow of the solar system dust has been extracted. After the infrared light from our solar system and galaxy has been removed, what remains is a uniform, cosmic, infrared background.

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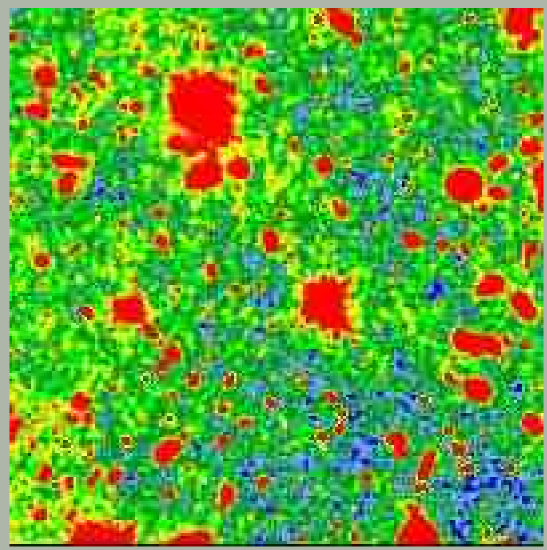
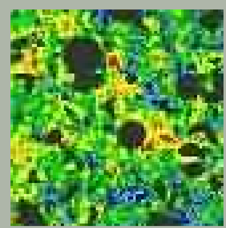
Hubble Finds Most of Visible Light in the Universe



A closer look at the Hubble telescope's most detailed image, the Hubble Deep Field, reveals that the faint galaxies seen by Hubble could account for most of the visible light in the cosmos.



The Hubble Deep Field, an image obtained in 1995 when Hubble observed one location on the sky for two weeks, revealed galaxies that are billions of times fainter than could be seen with the naked eye. Astronomers probed apparently blank patches that lie between the faint galaxies, searching for tiny ripples in the sky brightness that would indicate the presence of even more galaxies. They found very little variation in brightness, indicating that most of the visible light filling the universe comes from galaxies like those in the Hubble Deep Field and not from still fainter galaxies.

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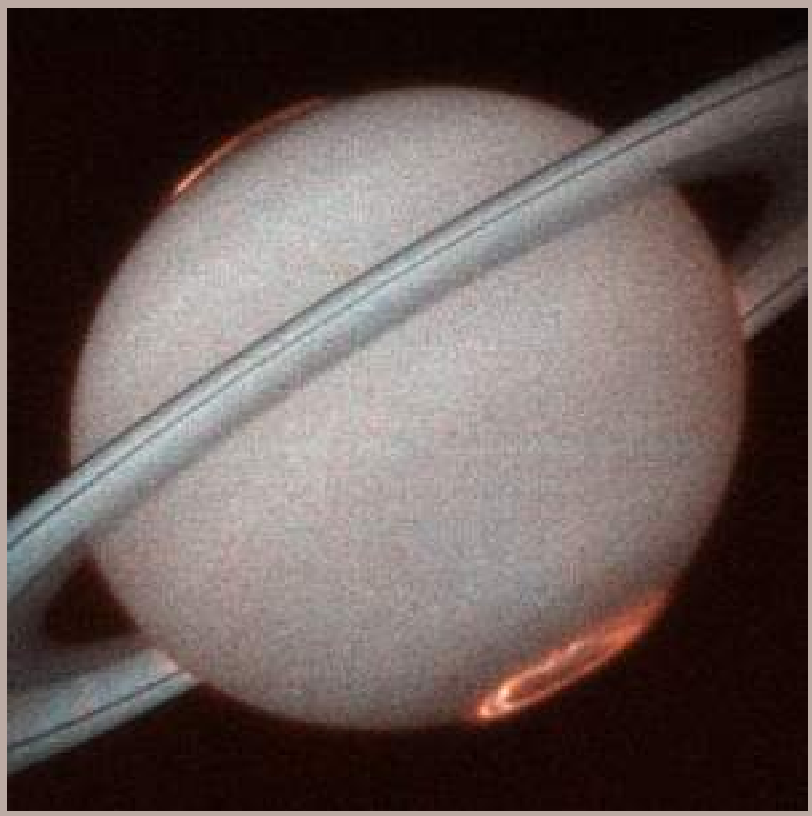
Hubble Provides Clear Images of Saturn's Aurora



Here is the picture of Saturn taken by the Hubble telescope in ultraviolet light. The glowing, swirling material at Saturn's poles is its auroral "curtains," rising more than a thousand miles above the cloud tops.

Saturn's auroral displays are caused by an energetic wind from the Sun that sweeps over the planet, much like Earth's aurora, which is occasionally seen in the nighttime sky. The process that triggers these auroras is similar to the phenomenon that causes fluorescent lamps to glow.

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Hubble Provide Complete View of Jupiter's Auroras

The Hubble telescope has captured a complete view of Jupiter's northern and southern auroras. Images taken in ultraviolet light show both auroras, the oval-shaped objects in the inset photos.

STIS image of the southern aurora

The "curtains" of auroral light extend several hundred miles above the edge of Jupiter. Images of Earth's auroral curtains, taken from the space shuttle, have a similar appearance. Jupiter's auroras are viewed against a backdrop of the entire planet. The auroras are brilliant curtains of light in Jupiter's upper atmosphere. Jovian auroral storms, like Earth's, develop when electrically charged particles trapped in the magnetic field surrounding the planet spiral inward at high energies toward the north and south magnetic poles. When these particles hit the upper atmosphere, they excite atoms and molecules there, causing them to glow (the same process acting in street lights).

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Hubble Snaps "Family Portrait"

The Hubble telescope's infrared camera has peered into the Cone Nebula, revealing a stunning picture of six babies, Sun-like stars surrounding their mother, a bright, massive star. Known as NGC 2264 IRS, the massive star triggered the creation of these baby stars by releasing high-speed particles of dust and gas during its formative years.

The image on the left, taken in visible light by a terrestrial telescope, shows the Cone Nebula, located 2,500 light-years away in the constellation Monoceros. The white box pinpoints the location of the star nursery, which cannot be seen in this image because dust and gas obscure it. The infrared image on the right shows the massive star — the brightest source in the region — and the stars formed by its outflow.

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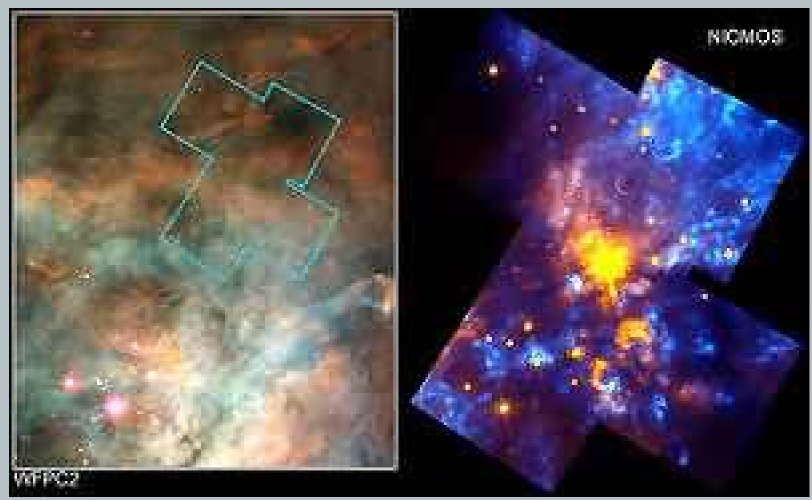
Hubble Captures the Heart of the Orion Nebula



The Hubble telescope's infrared vision is providing a dramatic new look at the beautiful Orion Nebula, which contains the nearest nursery for massive stars.

For comparison, Hubble's visible-light view of the nebula is on the left. The heart of the giant Orion molecular cloud, OMC-1, is included in the relatively dim and featureless area inside the blue outline near the top of the image. Light from a few foreground stars provides only a hint of the many other stars embedded in this dense cloud. Hubble's infrared camera reveals a chaotic, active star birth region [as seen in the right-hand picture]. Here, stars and glowing interstellar dust, heated by and scattering the intense starlight, appear yellow-orange.

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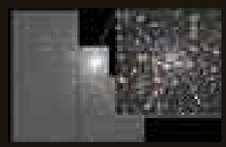
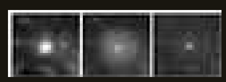
News Releases about: Star clusters

1995

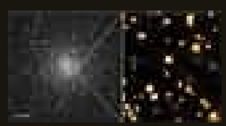
Nov 20, 1995 [Panoramic Hubble Picture Surveys Star Birth, Proto-Planetary Systems in the Great Orion Nebula]



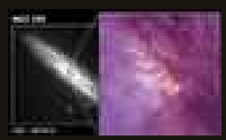
Nov 8, 1995 [Hubble Peers Deep into the Crowded Heart of the Densest Known Star Cluster]



Oct 9, 1995 [Hubble Space Telescope Images of a Bright Star in the Large Magellanic Cloud]



Aug 28, 1995 [Hubble Space Telescope Finds Stellar Graveyard]



Feb 20, 1995 [Hubble Probes the Violent Birth of Stars in Galaxy NGC 253]

1994

Oct 17, 1994 [Tale Of Two Clusters Yields Secrets of Star Birth in the Early Universe]

Matches 31-36 of 36 shown
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news & views

2001

By Popular Demand: Hubble Observes the Horsehead Nebula

Rising from a sea of dust and gas like a giant seahorse, the Horsehead nebula is one of the most photographed objects in the sky. The Hubble telescope took a close-up look at this heavenly icon, revealing the cloud's intricate structure. This detailed view of the horse's head is being released to celebrate the orbiting observatory's eleventh anniversary. Hubble was launched by the Space Shuttle Discovery on April 24, 1990 and deployed into a 360-mile-high Earth orbit on April 25. Produced by the Hubble Heritage Project, this picture is a testament to the Horsehead's popularity. Internet voters selected this object for the orbiting telescope to view.

You may wish to find out the answers to questions such as these:

- What does the picture show?

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2001

Astro-Entomology? Ant-like Space Structure Previews Death of Our Sun

From ground-based telescopes, this cosmic object -- the glowing remains of a dying, Sun-like star -- resembles the head and thorax of a garden-variety ant. But this dramatic Hubble telescope image of the so-called "ant nebula" (Menzel 3, or Mz 3) shows even more detail, revealing the "ant's" body as a pair of fiery lobes protruding from the dying star.

You may wish to find out the answers to questions such as these:

- What can astronomers learn from this picture?

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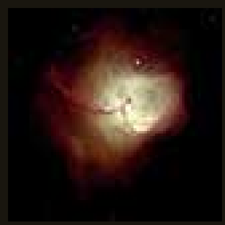
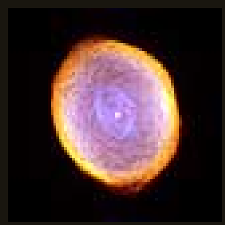
News Releases about: Nebulae

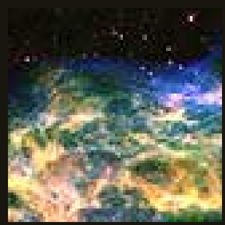
2000



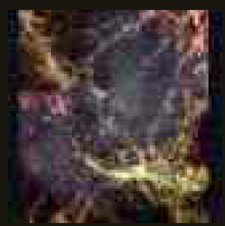
Oct 5, 2000 Hubble Peeks into a Stellar Nursery in a Nearby Galaxy



Sep 7, 2000 IC 418: The "Spirograph" Nebula

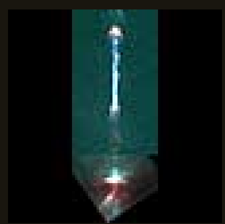


Jul 13, 2000 Hubble Watches Star Tear Apart its Neighborhood



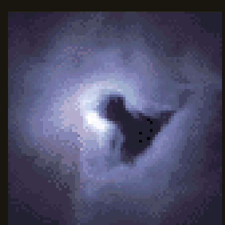
Jun 1, 2000 Peering into the Heart of the Crab Nebula

Apr 6, 2000 The Glowing Eye of NGC 6751

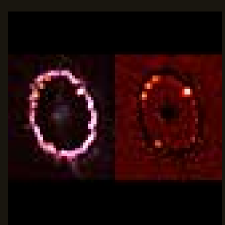


Mar 16, 2000 Hubble Finds Young Stars in Cosmic Dance

Mar 9, 2000 Hubble Surveys Dying Stars in Nearby Galaxy



Mar 2, 2000 Hubble Takes a Close-up View of a Reflection Nebula in Orion



Feb 16, 2000 Onset of Titanic Collision Lights Up Supernova Ring

Feb 3, 2000 Light and Shadow in the Carina Nebula

Matches 11-20 of 56 shown

The Glowing Eye of NGC 6751

The Hubble telescope has spied a giant celestial "eye," known as planetary nebula NGC 6751. The Hubble Heritage Project is releasing this picture to commemorate the Hubble telescope's tenth anniversary. Glowing in the constellation Aquila, the nebula is a cloud of gas ejected several thousand years ago from the hot star visible in its center. Planetary nebulae have nothing to do with planets. They are shells of gas thrown off by Sun-like stars nearing the ends of their lives. The star's loss of its outer, gaseous layers exposes the hot stellar core, whose strong ultraviolet radiation then causes the ejected gas to fluoresce as the planetary nebula.

You may wish to find out the answers to questions such as these:

- Why does this nebula resemble an eyeball?

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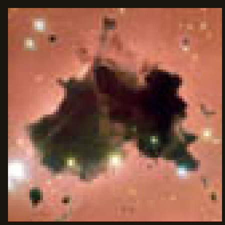
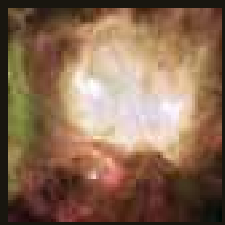
2002



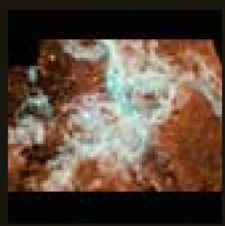
Jan 3, 2002 Thackeray's Globules in IC 2944

2001

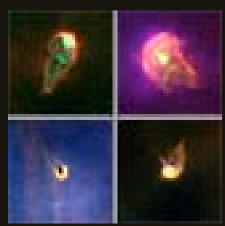


Dec 19, 2001 Hubble Sends Season's Greetings from the Cosmos to Earth

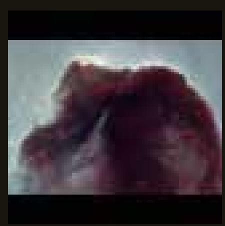
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822



Jul 26, 2001 Hubble's Panoramic Portrait of a Vast Star-forming Region



Apr 26, 2001 Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction



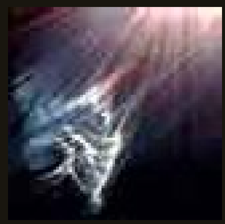
Apr 24, 2001 By Popular Demand: Hubble Observes the Horsehead Nebula

Mar 28, 2001 Massive Infant Stars Rock their Cradle

Feb 1, 2001 Astro-Entomology? Ant-like Space Structure Previews Death of Our Sun

Jan 4, 2001 ["X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy]

2000



Dec 6, 2000 [Ghostly Reflections in the Pleiades]

Matches 1-10 of 56 shown
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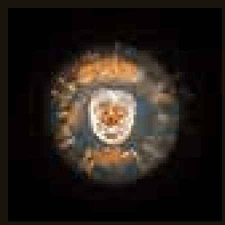
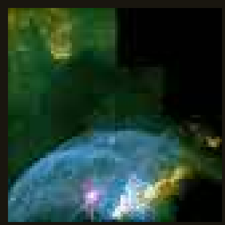
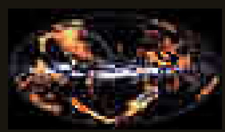
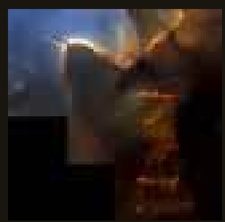
2000


Jan 24, 2000 Hubble Reopens "Eye" on the Universe

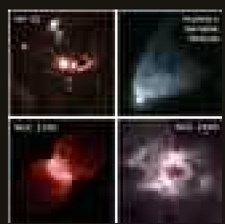

Jan 13, 2000 An Expanding Bubble in Space

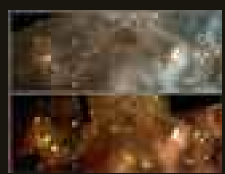
1999

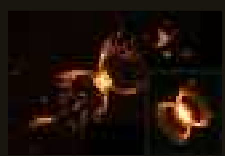

Nov 24, 1999 A Puzzle of Galactic Evolution is Solved: Massive Gas Clouds Seed the Galaxy with the Stuff of Stars

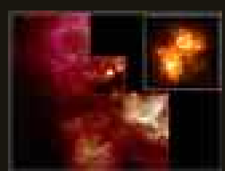

Nov 9, 1999 The Trifid Nebula: Stella Sibling Rivalry

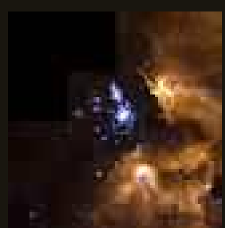

Oct 19, 1999 The "Rotten Egg" Nebula: A Planetary Nebula in the Making


Oct 7, 1999 Hubble Heritage Project's First Anniversary


Sep 29, 1999 Hubble Captures a Grand View of the Birth of "Hefty" Stars


Aug 24, 1999 Symbiotic Star Blows Bubbles into Space


Jun 10, 1999 A Butterfly-Shaped "Papillon" Nebula Yields Secrets of Massive Star Birth


Jun 1, 1999 Hubble Snapshot Captures Life Cycle of Stars

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News Releases about: Nebulae

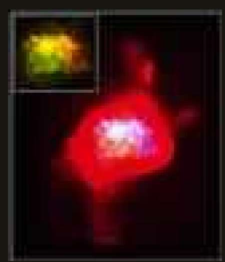
1999

Apr 1, 1999 [Multiple Generations of Stars in the Tarantula Nebula]

Jan 6, 1999 [Looking Down a Barrel of Gas at a Doomed Star]

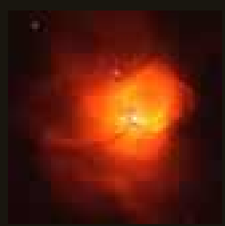
1998

Nov 5, 1998 [A Glowing Pool of Light]

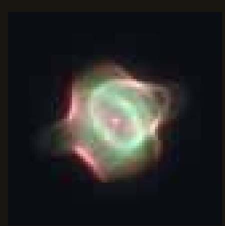


Oct 22, 1998 [Turtle in Space Describes New Hubble Image]

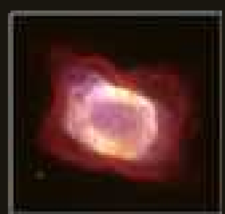
Oct 21, 1998 [Astronomers Unveil Colorful Hubble Photo Gallery]



Jul 23, 1998 [Nearby Massive Star Cluster Yields Insights into Early Universe]

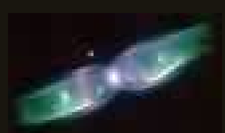


Apr 1, 1998 [Hubble Reveals Details of a Newly Born Planetary Nebula]

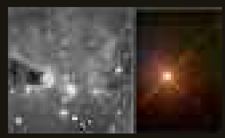


Mar 19, 1998 [Hubble Captures the Shrouds of Dying Stars]

1997



Dec 17, 1997 [Hubble Witnesses the Final Blaze of Glory of Sun-Like Stars]



Jun 9, 1997 Hubble Snaps "Family Portrait"

Matches 31-40 of 56 shown
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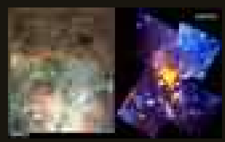
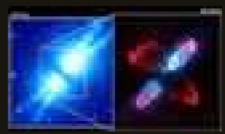
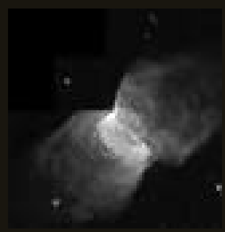
News Releases about: Nebulae

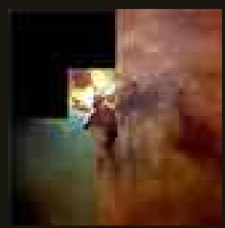
1997


May 12, 1997 [Hubble Chemically Analyzes the Ring around Supernova 1987A]

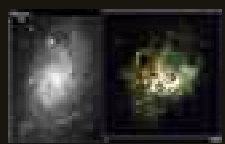

May 12, 1997 [Hubble Captures the Heart of the Orion Nebula]

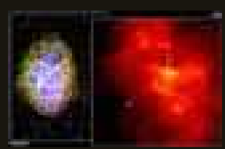

May 12, 1997 [Hubble Peers into Heart of Dying Star]

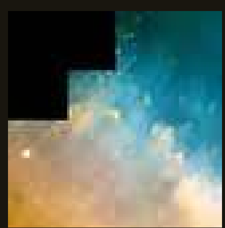

Mar 14, 1997 [Hubble Camera Resumes Science Operation with Picture of "Butterfly" in Space]


Jan 22, 1997 [Giant "Twisters" and Star Wisps in the Lagoon Nebula]

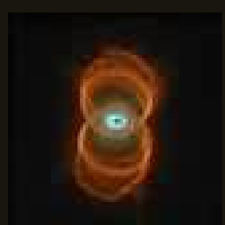
1996


Aug 7, 1996 [Giant Star Birth Region in Neighboring Galaxy]


May 9, 1996 [Hubble Astronomers Unveil "Crab Nebula — The Movie"]


Apr 15, 1996 [Hubble Finds Thousands of Gaseous Fragments Surrounding a Dying Star]

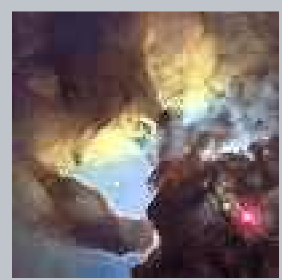

Jan 16, 1996 [Hubble Finds Searchlight Beams and Multiple Arcs around a Dying Star]


Jan 16, 1996 [Hubble Finds an Hourglass Nebula around a Dying Star]

news & views

Giant "Twisters" and Star Wisps in the Lagoon Nebula

This Hubble telescope snapshot unveils a pair of one-half, light-year-long interstellar "twisters" — eerie funnels and twisted-rope structures [upper left] — in the heart of the Lagoon Nebula (M8) which lies 5,000 light-years from Earth in the direction of the constellation Sagittarius.



The hot, central star, O Herschel 36 [upper left], is the primary source of the illuminating light for the brightest region in the nebula, called the Hourglass. The glare from this hot star is eroding the clouds by heating the hydrogen gas in them [seen as a blue "mist" at the right of the image]. This activity drives away violent stellar winds that are tearing into the cool clouds.

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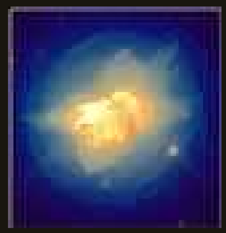
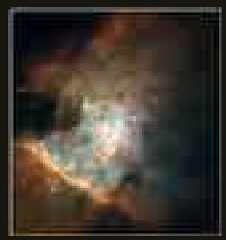
1996



Jan 16, 1996 — Hubble Telescope Photo Reveals Stellar Death Process

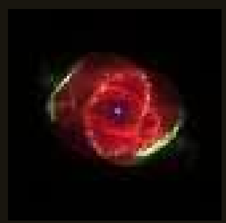
1995



Nov 20, 1995 — Panoramic Hubble Picture Surveys Star Birth, Proto-Planetary Systems in the Great Orion Nebula

Apr 10, 1995 — Oxygen-Rich Supernova Remnant in the Large Magellanic Cloud

Feb 20, 1995 — Hubble's Close-Up View of a Shock Wave from a Stellar Explosion



Jan 11, 1995 — Hubble Probes the Complex History of a Dying Star

1994

Jun 13, 1994 — Hubble Confirms Abundance of Protoplanetary Disks around Newborn Stars

Matches 51-56 of 56 shown
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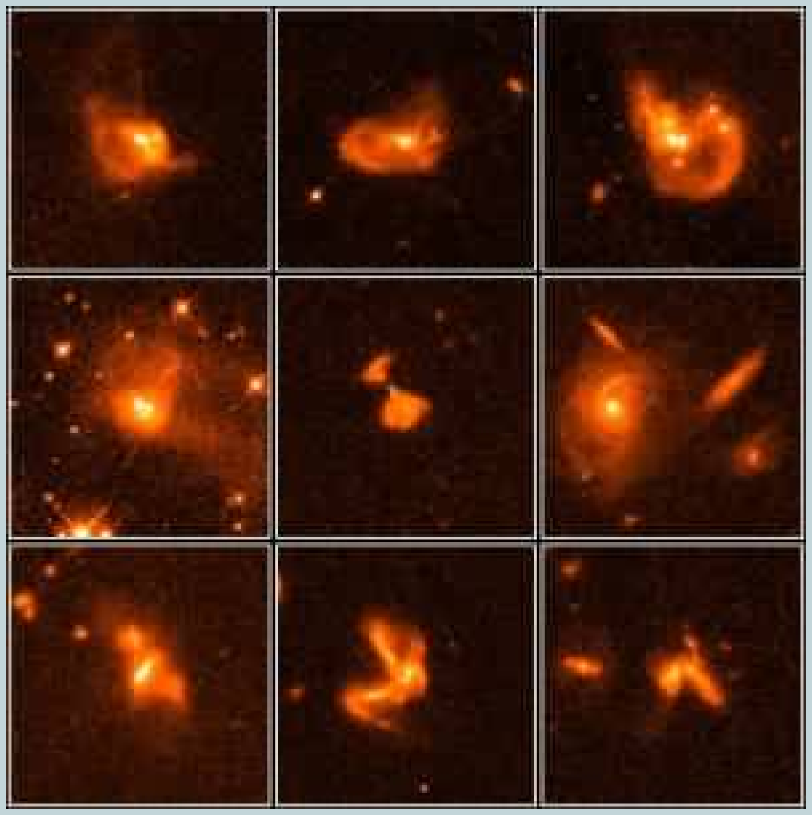
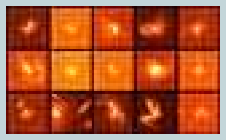
Multiple Galaxy Collisions Surprise Hubble Astronomers



Wrecks between two galaxies were a common occurrence in the early cosmos. But pileups among several galaxies? Astronomers conducting a three-year survey of ultra-luminous infrared galaxies (ULIRGs) have discovered more than 24 of them involved in three-, four-, or even five-galaxy smashups. Astronomers have made this discovery by analyzing Hubble telescope pictures of these pileups, including the nine presented here. These results offer a snapshot of what conditions were like in the early universe, when galaxy collisions were commonplace.

You may wish to find out the answers to questions such as these:

- How can astronomers look at the images and tell that multiple galaxies are colliding?
- What are ULIRGs?



Here is a sampling of 15 ultraluminous infrared galaxies viewed by NASA's Hubble Space Telescope.

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A Grazing Encounter between Two Spiral Galaxies

The Hubble telescope has caught a cosmic dance between two spiral galaxies. The larger galaxy, NGC 2207, is on the left; the smaller one, IC 2163, is on the right. Their dance has already caused quite a stir. Strong gravitational forces from NGC 2207 have distorted the shape of its smaller dance partner, flinging out stars and gas into long streamers that extend 100,000 light-years toward the right-hand edge of the picture. Eventually this dance will end. Billions of years from now the two galaxies will become one.

You may wish to find out the answers to questions such as these:

- How do galaxies meet?
- What happens after they merge?

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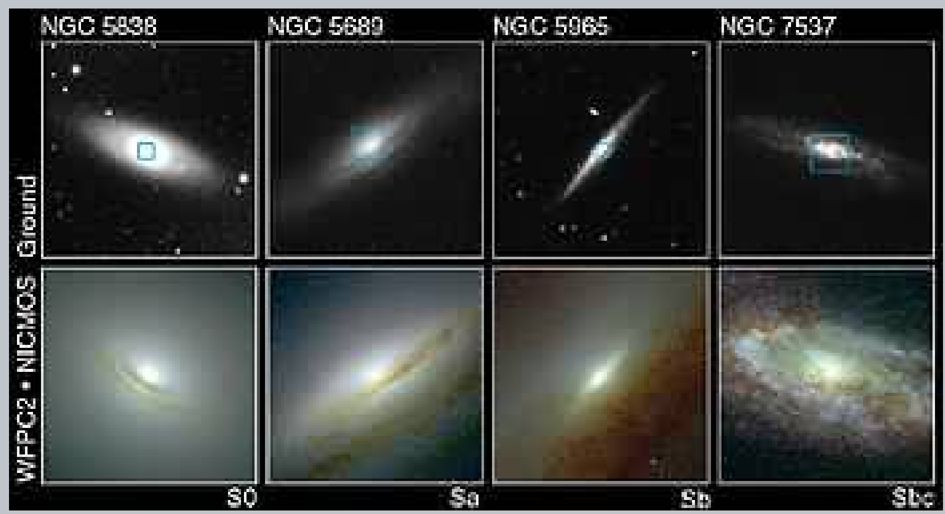
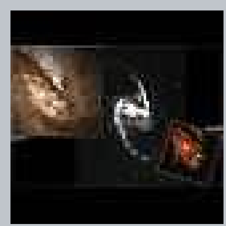
Starry Bulges Yield Secrets to Galaxy Growth



The Hubble telescope is uncovering important new clues to a galaxy's birth and growth by peering into its heart — a bulge of millions of stars resembling a bulbous center yolk in the middle of a disk of egg white.

Astronomers have combined information from the Hubble telescope's visible- and infrared-light cameras to show the heart of four spiral galaxies peppered with ancient populations of stars. The top row of pictures, taken by a ground-based telescope, represents complete views of each galaxy. The blue boxes outline the regions observed by the Hubble telescope. The bottom row represents composite pictures from Hubble's visible- and infrared-light cameras. Astronomers combined views from both cameras to obtain the true ages of the stars surrounding each galaxy's bulge. The Hubble telescope's sharper resolution allows astronomers to study the intricate structure of a galaxy's central region.



Getting to the Heart of a Galaxy

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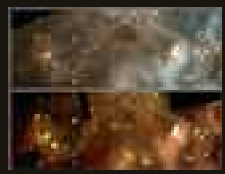
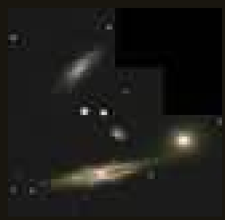
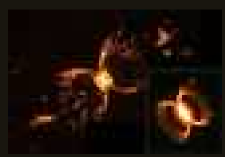

Sep 29, 1999 Hubble Captures a Grand View of the Birth of "Hefty" Stars


Sep 16, 1999 Hubble Spies Giant Star Clusters Near Galactic Center

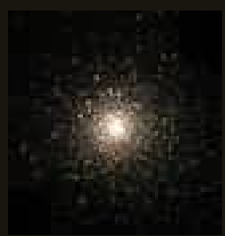

Sep 2, 1999 A Minuet of Galaxies

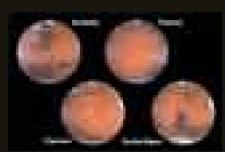

Aug 24, 1999 Symbiotic Star Blows Bubbles into Space

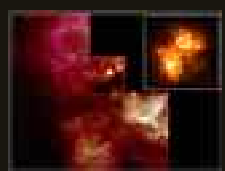

Aug 12, 1999 Bloated Stars Swallow Giant Planets


Aug 5, 1999 Hubble Views Ancient Storm in the Atmosphere of Jupiter


Jul 15, 1999 Cosmic Collisions: European HST Scientists Catch Merging Galaxies in the Act


Jul 1, 1999 Hubble Images a Swarm of Ancient Stars


Jun 30, 1999 A Closer Encounter with Mars


Jun 10, 1999 A Butterfly-Shaped "Papillon" Nebula Yields Secrets of Massive Star Birth

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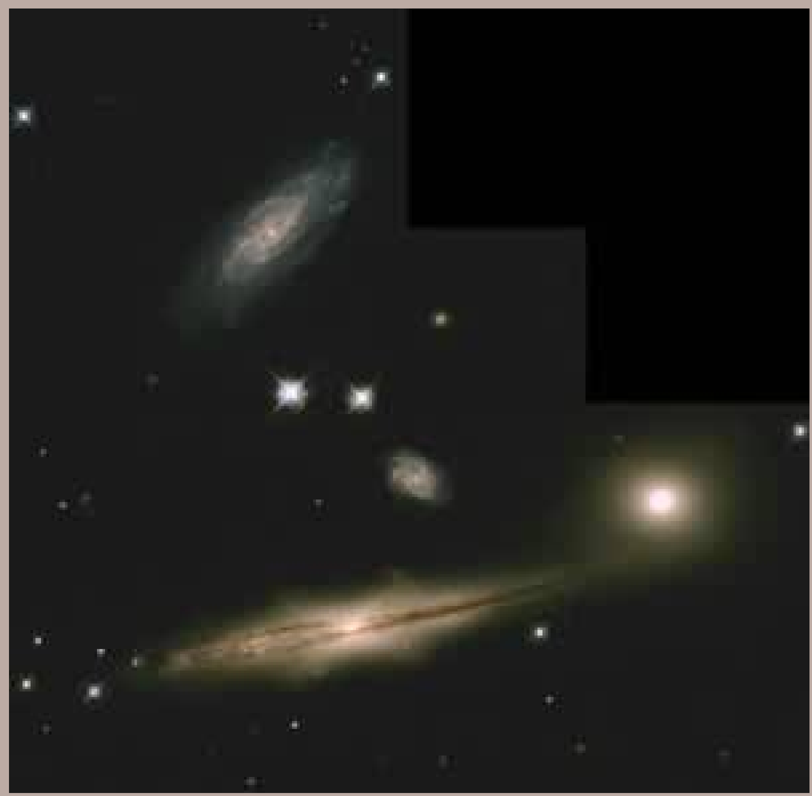
A Minuet of Galaxies



This troupe of four galaxies, known as Hickson Compact Group 87 (HCG 87), is performing an intricate dance orchestrated by the mutual gravitational forces acting between them. The dance is a slow, graceful minuet, occurring over a time span of hundreds of millions of years.

This Hubble telescope image reveals complex details in the dust lanes of the group's largest galaxy member (HCG 87a), which is actually disk-shaped, but tilted so that we see it nearly edge-on. Both 87a and its elliptically shaped nearest neighbor (87b) have active galactic nuclei, which are believed to harbor black holes that are consuming gas. A third group member, the nearby spiral galaxy 87c, may be undergoing a burst of active star formation. The three galaxies are so close to each other that gravitational forces disrupt their structure and alter their evolution.

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Cosmic Collisions: European HST Scientists Catch Merging Galaxies in the Act

Exciting Hubble telescope images of more than a dozen very distant colliding galaxies indicate that, at least in some cases, big massive galaxies form through collisions between smaller ones, in a "generation after generation" story.

Hubble studied 81 galaxies in the galaxy cluster MS1054-03 and found that 13 are remnants of recent collisions or pairs of colliding galaxies. The large picture on the left shows this galaxy cluster. The eight smaller images on the right are close-ups of some of the colliding galaxies. The snapshots show the paired galaxies very close together with streams of stars being pulled out of them. The colliding "parent" galaxies lose their shape and smoother galaxies are formed. The whole merging process can take less than a billion years.

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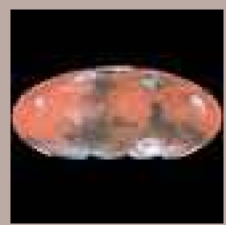
A Closer Encounter with Mars

Taking advantage of Mars's closest approach to Earth in eight years, astronomers using the Hubble telescope have taken the space-based observatory's sharpest views yet of the Red Planet. NASA is releasing these images to commemorate the second anniversary of the Mars Pathfinder landing.

The telescope snapped these pictures between April 27 and May 6, 1999, when Mars was 54 million miles (87 million kilometers) from Earth. From this distance the telescope could see Martian features as small as 12 miles (19 kilometers) wide. The telescope obtained four images, which, together, show the entire planet. Each view depicts the planet as it completes one quarter of its daily rotation.


A Global Mars Map

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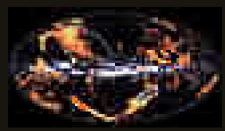
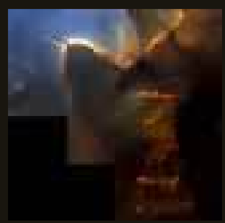
News Releases in 1999

Dec 2, 1999 [Hubble Telescope Reveals Swarm of Glittering Stars in Nearby Galaxy]

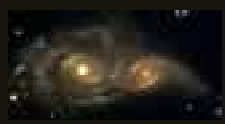


Nov 24, 1999 [A Puzzle of Galactic Evolution is Solved: Massive Gas Clouds Seed the Galaxy with the Stuff of Stars]

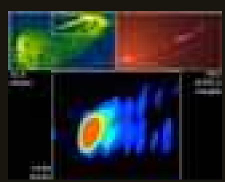
Nov 22, 1999 [Multiple Galaxy Collisions Surprise Hubble Astronomers]



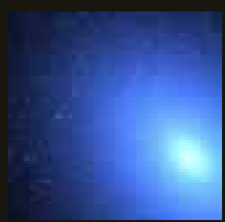
Nov 9, 1999 [The Trifid Nebula: Stella Sibling Rivalry]



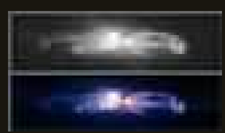
Nov 4, 1999 [A Grazing Encounter between Two Spiral Galaxies]



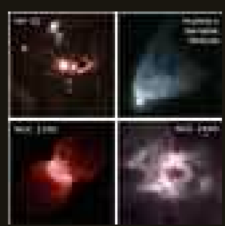
Oct 27, 1999 [Very Long Baseline Array Reveals Formation Region of Giant Cosmic Jet Near a Black Hole]



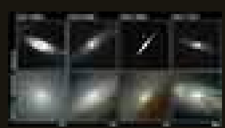
Oct 26, 1999 [Hubble Identifies Source of Ultraviolet Light in an Old Galaxy]



Oct 19, 1999 [The "Rotten Egg" Nebula: A Planetary Nebula in the Making]



Oct 7, 1999 [Hubble Heritage Project's First Anniversary]



Oct 6, 1999 [Starry Bulges Yield Secrets to Galaxy Growth]

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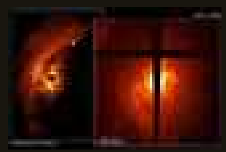
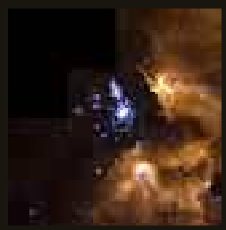
News Releases in 1999

Jun 3, 1999 [Magnificent Details in a Dusty Spiral Galaxy]

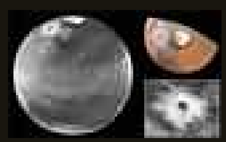


Jun 2, 1999 Hubble Picture Adds to Planet-Making Recipe



Jun 1, 1999 Hubble Snapshot Captures Life Cycle of Stars

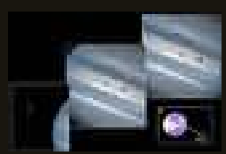
May 25, 1999 Hubble Completes Eight-Year Effort to Measure Expanding Universe



May 19, 1999 Colossal Cyclone Swirls near Martian North Pole

May 13, 1999 Natural Lenses in Space Stretch Hubble's View of the Universe

Apr 20, 1999 Ring Around a Galaxy



Apr 20, 1999 Hubble Clicks Images of Io Sweeping across Jupiter

Apr 19, 1999 Maryland Science Center's "Space Place" Showcases Hubble Discoveries

Apr 16, 1999 Hubble Shoots the Moon

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1999

Magnificent Details in a Dusty Spiral Galaxy

The Key Project team used this Hubble telescope view of the magnificent spiral galaxy, NGC 4414, to help calculate the expansion rate of the universe.

Based on their discovery and careful brightness measurements of variable stars in this galaxy, the Key Project astronomers were able to make an accurate determination of the distance to the galaxy. The resulting distance to NGC 4414, about 60 million light-years, along with similarly determined distances to other nearby galaxies, contributes to astronomers' overall knowledge of the expansion rate of the cosmos, and helps them determine the age of the universe.

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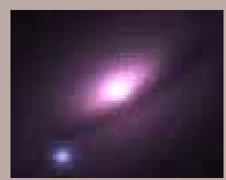
1999

Hubble Completes Eight-Year Effort to Measure Expanding Universe

The Hubble Space Telescope Key Project team today announced that it has completed efforts to measure precise distances to far-flung galaxies, an essential ingredient needed to determine the age, size and fate of the universe.

The team used the Hubble telescope to observe 19 galaxies out to 108 million light-years. They discovered almost 800 Cepheid variable stars, a special class of pulsating star used for accurate distance measurements. Here is a picture of one of those galaxies. It is the spiral galaxy NGC 4603, the most distant galaxy in which Cepheid variables have been found. It is associated with the Centaurus cluster, one of the most massive assemblages of galaxies in the nearby universe.



Ground-based image of supernova 1994D in Galaxy NGC 4526

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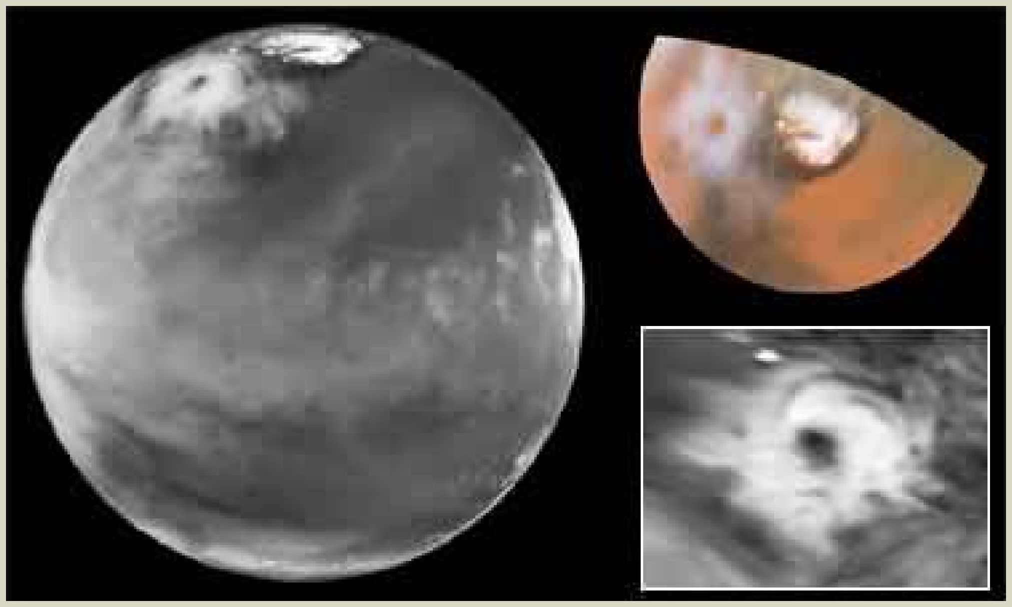
Colossal Cyclone Swirls near Martian North Pole



Astronomers using the Hubble telescope have discovered an enormous cyclonic storm system raging in the northern polar regions of the planet Mars. Nearly four times the size of the state of Texas, the storm is composed of water ice clouds like storm systems on Earth, rather than dust typically found in Martian storms.

The system is similar to so-called "spiral" storms observed more than 20 years ago by NASA's Viking Orbiter spacecraft, but it is nearly three times as gigantic as the largest previously detected Martian spiral storm system. The storm is nearly 1,100 miles across in the east-west direction and 900 miles in the north-south direction. The eye of the storm is nearly 200 miles in diameter. Each of these pictures illustrates the breadth of this immense storm.

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Ring Around a Galaxy

Located about 130 million light-years away, NGC 4650A is one of only 100 known polar-ring galaxies. Their unusual disk-ring structure is not yet understood fully. One possibility is that polar rings are the remnants of colossal collisions between two galaxies sometime in the distant past, probably at least 1 billion years ago. What is left of one galaxy has become the rotating inner disk of old red stars in the center.

Meanwhile, another smaller galaxy, which ventured too close, was probably severely damaged or destroyed. During the collision the gas from the smaller galaxy would have been stripped off and captured by the larger galaxy, forming a new ring of dust, gas, and stars, which orbit around the inner galaxy almost at right angles to the old disk. This is the polar ring that we see almost edge-on in this Hubble telescope view.

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Hubble Clicks Images of Io Sweeping across Jupiter

While hunting for volcanic plumes on Io, the Hubble telescope captured these images of the volatile moon sweeping across the giant face of Jupiter. Only a few weeks before these dramatic pictures were taken, the orbiting telescope snapped a portrait of one of Io's volcanoes spewing sulfur dioxide "snow."

These stunning images of the planetary duo are being released to commemorate the ninth anniversary of the Hubble telescope's launch on April 24, 1990. The three overlapping snapshots show in crisp detail Io passing above Jupiter's turbulent clouds. The close-up picture of Io [bottom right] reveal a 120-mile-high (200-kilometer) plume of sulfur dioxide "snow" emanating from Pillan, one of the moon's active volcanoes.

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Maryland Science Center's "Space Place" Showcases Hubble Discoveries

The Maryland Science Center's new Outer Space Place offers visitors a chance to explore the wonders of the universe as seen through the eyes of the Hubble telescope. In collaboration with the Space Telescope Science Institute, the latest findings from Hubble are colorfully showcased and explained in a permanent exhibit gallery and high-tech space information center.

The Maryland Science Center first established a permanent Hubble exhibit in 1990. Hubble has made many discoveries since then, and the science center has now upgraded its Hubble exhibit to display and interpret the very latest Hubble telescope findings.

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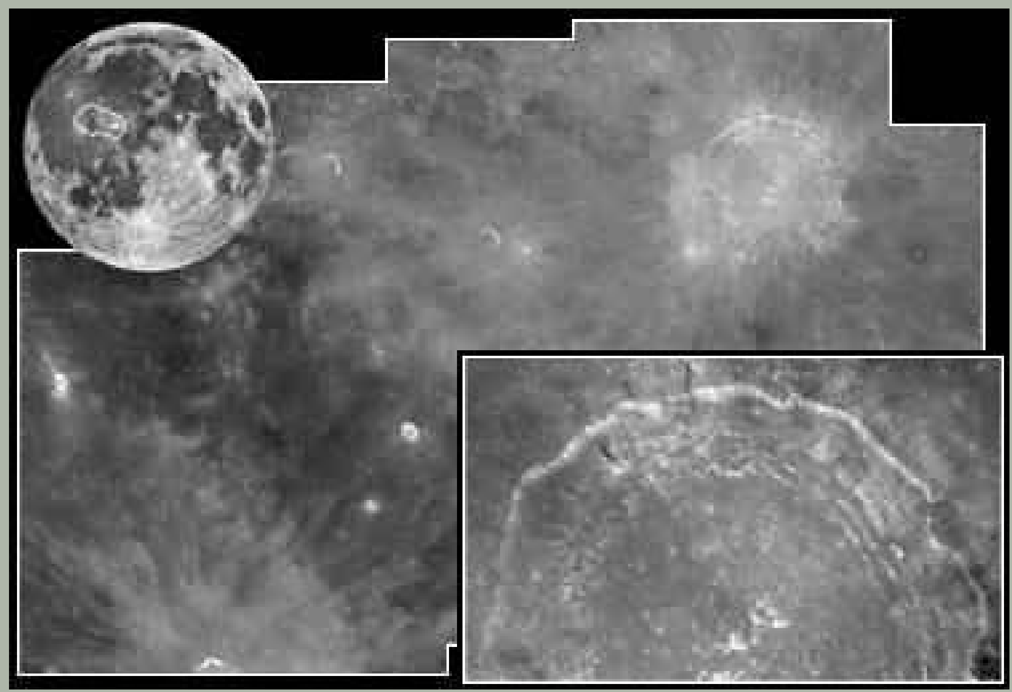
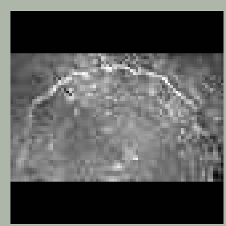
Hubble Shoots the Moon



In a change of venue from peering at the distant universe, the Hubble telescope has taken a look at Earth's closest neighbor in space, the Moon. Hubble was aimed at one of the Moon's most dramatic and photogenic targets, the 58-mile-wide (93-kilometer) impact crater Copernicus.

The image was taken while the Space Telescope Imaging Spectrograph was aimed at a different part of the moon to measure the colors of sunlight reflected off the Moon. The picture at upper left is a full view of the moon taken by a terrestrial telescope. The wide, central image is Hubble's crisp, bird's-eye view, which clearly shows the ray pattern of bright dust ejected out of the crater over one billion years ago when an asteroid larger than a mile across slammed into the Moon. A close-up view of Copernicus's terraced walls is shown at lower right.



A closeup view of Copernicus' terraced walls. Hubble can resolve features as small as 280 feet across.

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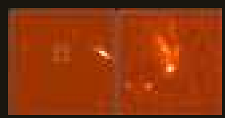
News Releases in 1999

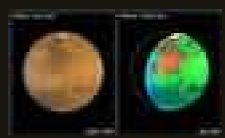

Apr 1, 1999 [Multiple Generations of Stars in the Tarantula Nebula]

Mar 29, 1999 [Huge Spring Storms Rouse Uranus from Winter Hibernation]

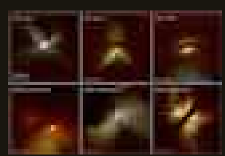

Mar 18, 1999 [Hubble's Infrared Galaxy Gallery]

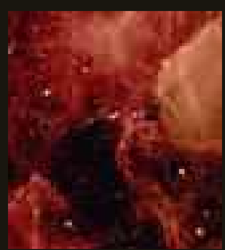

Mar 11, 1999 [Hubble Views Home Galaxy of Record-Breaking Explosion]


Mar 4, 1999 [A Mote in Hubble's Eye]


Feb 25, 1999 [Martian Colors Provide Clues about Martian Water]


Feb 18, 1999 [Hubble Finds More Evidence of Galactic Cannibalism]


Feb 9, 1999 [Vast Stellar Disks Set Stage for Planet Birth in New Hubble Images]


Feb 4, 1999 [SN1987A in the Large Magellanic Cloud]

Jan 8, 1999 [Dust Ring Around Star Offers New Clues on Planet Formation]

Matches 31-40 of 43 shown

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1999

Huge Spring Storms Rouse Uranus from Winter Hibernation

If springtime on Earth were anything like it will be on Uranus, we would be experiencing waves of massive storms, each one covering the country from Kansas to New York, with temperatures of 300 degrees below zero.

A dramatic new time-lapse movie by the Hubble telescope shows for the first time seasonal changes on the planet. Once considered one of the blander-looking planets, Uranus is now revealed as a dynamic world with the brightest clouds in the outer solar system and a fragile ring system that wobbles like an unbalanced wagon wheel. The clouds are probably made of crystals of methane, which condense as warm bubbles of gas well up from deep in the planet's atmosphere.

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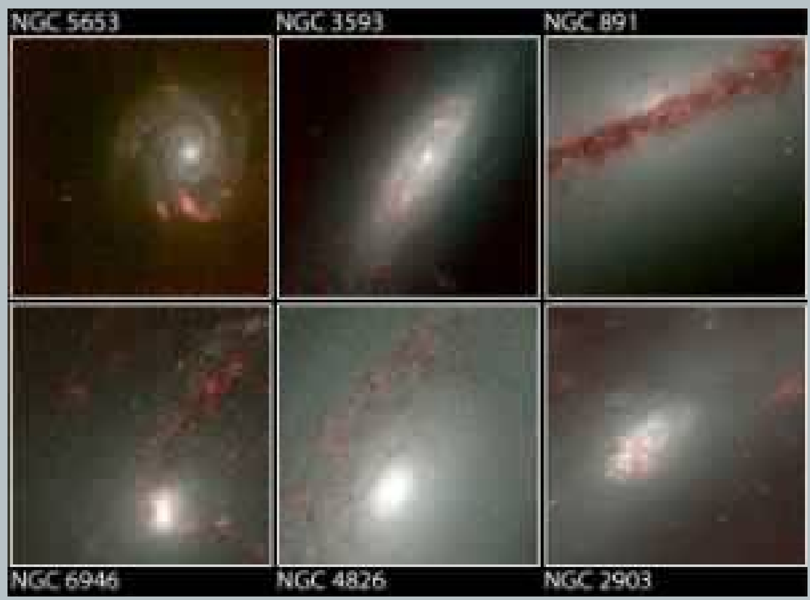
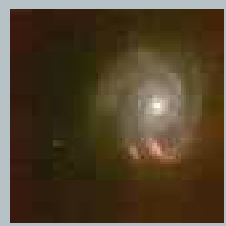
1999

Hubble's Infrared Galaxy Gallery



Astronomers have used the Hubble telescope to produce an infrared "photo essay" of spiral galaxies. By penetrating the dust clouds swirling around the centers of these galaxies, the telescope's infrared vision is offering fresh views of star birth.

These six images, taken with Hubble's infrared camera, showcase different views of spiral galaxies, from a face-on picture of an entire galaxy to a close-up of a core. The top row shows spirals at diverse angles, from face-on, [left]; to slightly tilted, [center]; to edge-on, [right]. The bottom row shows close-ups of the hubs of three galaxies.



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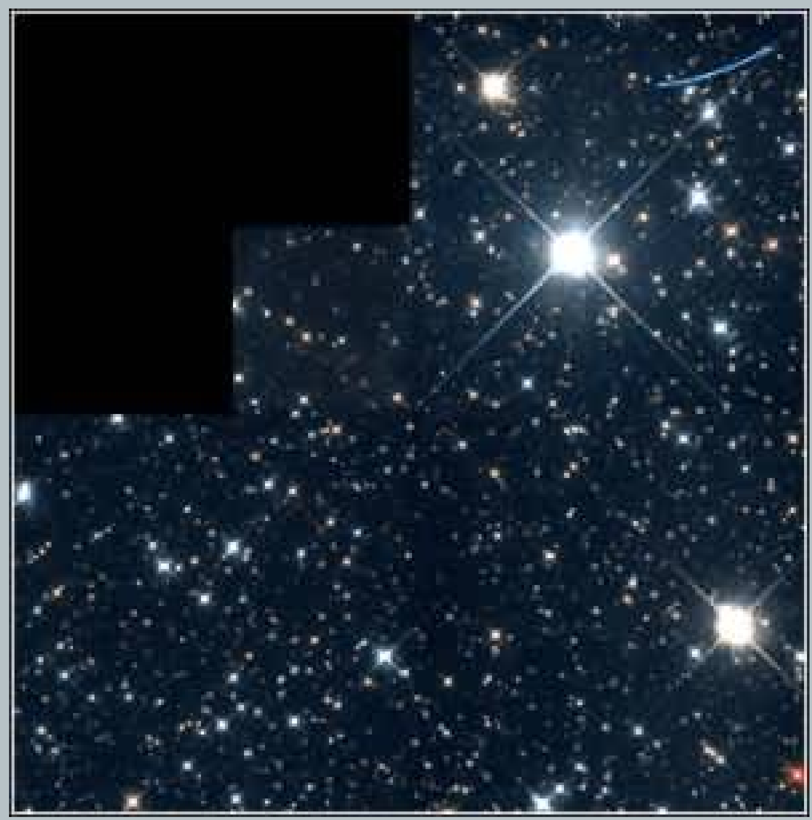
A Mote in Hubble's Eye



The Hubble telescope image is a typical Milky Way star field in the constellation Centaurus. Such snapshots can be used to study the evolution of stars that make up our galaxy.

Most of the stars in this image lie near the center of our galaxy some 25,000 light-years distant. But one object, the blue curved streak [top right], is something much closer. An uncatalogued, mile-wide bit of rocky debris — an asteroid — orbiting the Sun only light-minutes away strayed into Hubble's field of view. An analysis of this asteroid indicates this asteroid's orbit could cross Mars's path.

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Martian Colors Provide Clues about Martian Water

Hubble telescope images of Mars detail a rich geologic history and provide further evidence for water-bearing minerals on the planet's surface.

These pictures showcase the planet in both visible and infrared light. In the image on the left, taken in visible light, Mars appears in natural color or as we would see it close-up. The multicolor picture on the right was taken in infrared light, which is invisible to the eye. Therefore, astronomers have assigned false colors to highlight important features that cannot be seen in visible light. Hubble's unique infrared view illustrates variations in the abundance and distribution of unknown water-bearing minerals on the planet. While it has been known for decades that small amounts of water-bearing minerals exist on the planet's surface, the reddish regions in this image indicate areas of enhanced concentrations of these as-yet-unidentified deposits.

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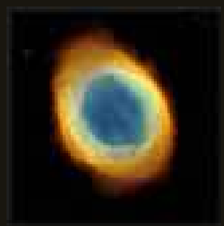
	*Jan 8, 1999*	Gap in Stellar Dust Disk May Be Swept Out by Planet
	*Jan 7, 1999*	Combined Deep View of Infrared- and Visible-Light Galaxies
	*Jan 6, 1999*	Looking Down a Barrel of Gas at a Doomed Star

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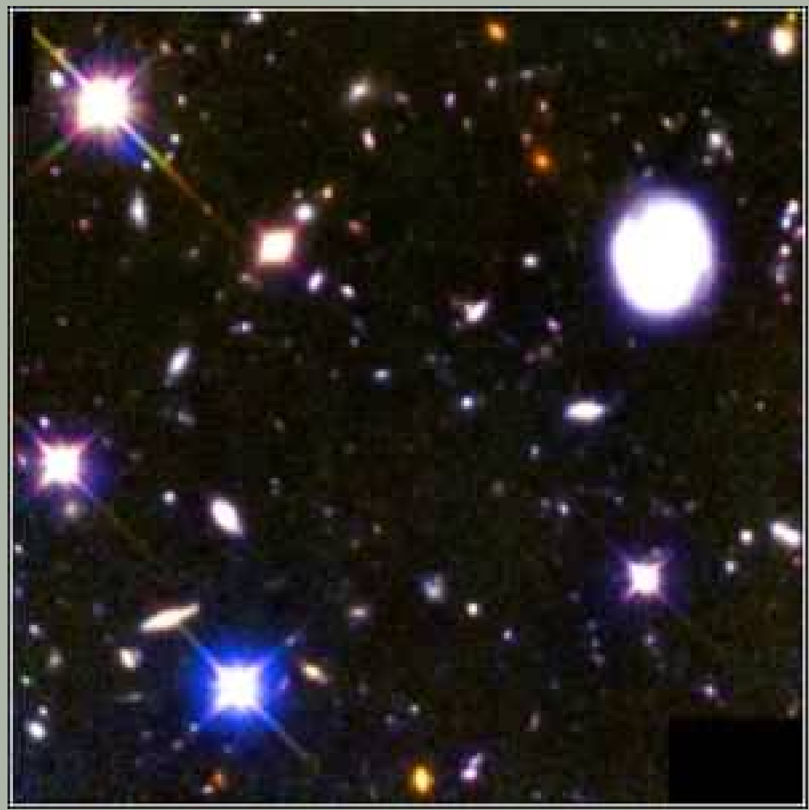
1999

Combined Deep View of Infrared- and Visible-Light Galaxies



This narrow, deep view of the universe reveals a plethora of faint galaxies, as seen in visible and infrared light by the Hubble telescope.

The reddish galaxies are glowing in infrared light; the bluish galaxies are glowing in visible light. Several distinctive types of galaxies can be seen in these views: blue dwarf galaxies, disk galaxies, and very red elliptical galaxies. A bright, nearby, face-on spiral galaxy appears at upper right. Some of the brightest objects in the field are foreground stars in the halo of our own Milky Way Galaxy. By combining views in infrared and visible light, astronomers have a better idea of the shapes of galaxies in the remote universe and of the fraction of galaxies that are old or dust-obscured at early epochs.

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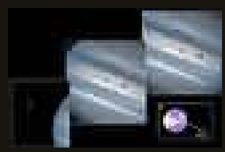
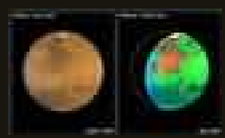


Apr 20, 1999 Hubble Clicks Images of Io Sweeping across Jupiter

Apr 16, 1999 Hubble Shoots the Moon

Mar 29, 1999 Huge Spring Storms Rouse Uranus from Winter Hibernation

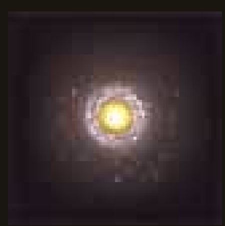
Mar 4, 1999 A Mote in Hubble's Eye



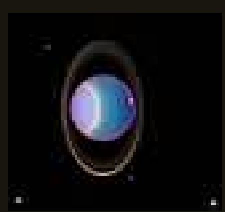
Feb 25, 1999 Martian Colors Provide Clues about Martian Water

1998

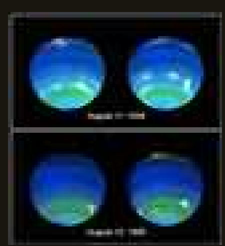
Nov 10, 1998 Leonid Meteor Storm Won't Deter Hubble from Space Observations



Oct 21, 1998 Astronomers Unveil Colorful Hubble Photo Gallery



Oct 14, 1998 Hubble Finds Many Bright Clouds on Uranus



Oct 14, 1998 Hubble Provides a Moving Look at Neptune's Stormy Disposition

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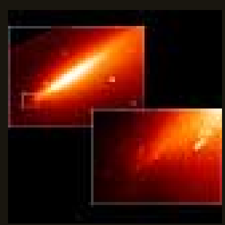
2001

Oct 11, 2001 Scientists Track "Perfect Storm" on Mars

Jul 5, 2001 Hubble Captures Best View of Mars Ever Obtained From Earth

Jun 7, 2001 A Change of Seasons on Saturn



May 17, 2001 Astronomers Puzzled over Comet LINEAR's Missing Pieces

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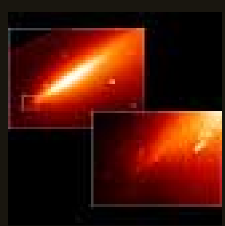
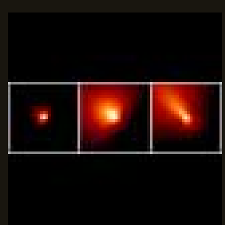
Dec 14, 2000 Satellite Footprints Seen in Jupiter Aurora

Sep 14, 2000 Centaur's Bright Surface Spot Could be Crater of Fresh Ice



Aug 7, 2000 Hubble Discovers Missing Pieces of Comet Linear



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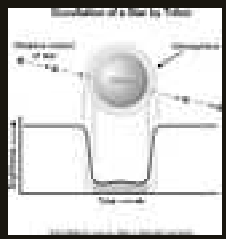
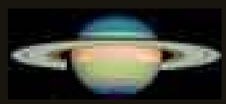
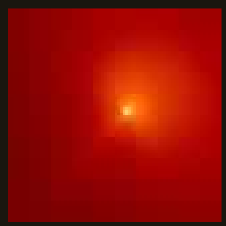


Jun 24, 1998 — Hubble Space Telescope Helps Find Evidence that Neptune's Largest Moon Is Warming Up



Apr 23, 1998 — Hubble Space Telescope Completes Eighth Year Of Exploration



Mar 27, 1998 — Comet Hyakutake

Mar 9, 1998 — Astronomers Track Down Asteroids in Hubble Archive

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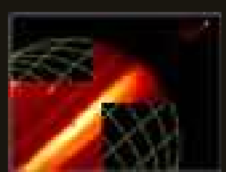
Nov 20, 1997 — Hubble Watches Uranus



Nov 20, 1997 — Hubble Provides Infrared View of Moon, Ring, and Clouds

Sep 17, 1997 Hubble Watches the Red Planet as Mars Global Surveyor Begins Aerobraking

Sep 4, 1997 Hubble Reveals Huge Crater on the Surface of the Asteroid Vesta

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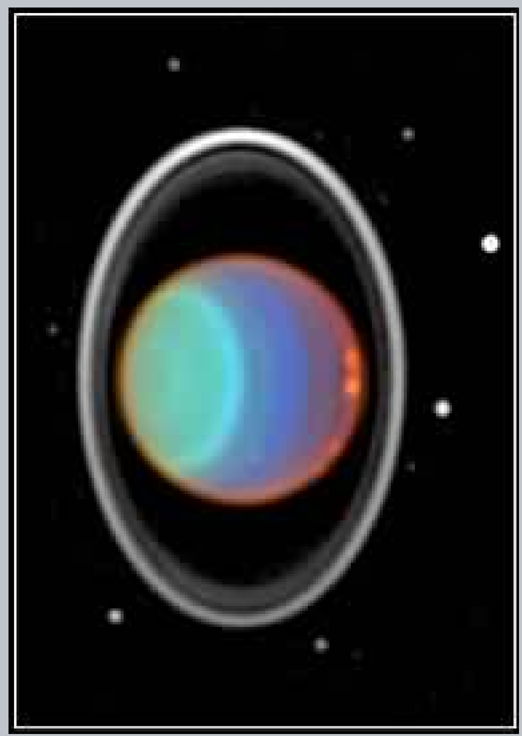
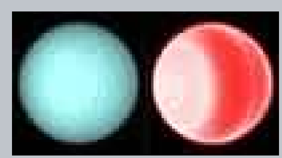


Using the Hubble telescope's visible-light camera, astronomers for the first time this century have detected clouds in the Northern Hemisphere of Uranus. The snapshots show banded structure and multiple clouds. Using these images, astronomers plan to measure the wind speeds in the Northern Hemisphere for the first time.

The clouds can be seen along the planet's right edge [the bright dots]. Another cloud [faint white dot] is barely visible near the bottom of the blue band. The clouds are almost as large as continents on Earth, such as Europe.



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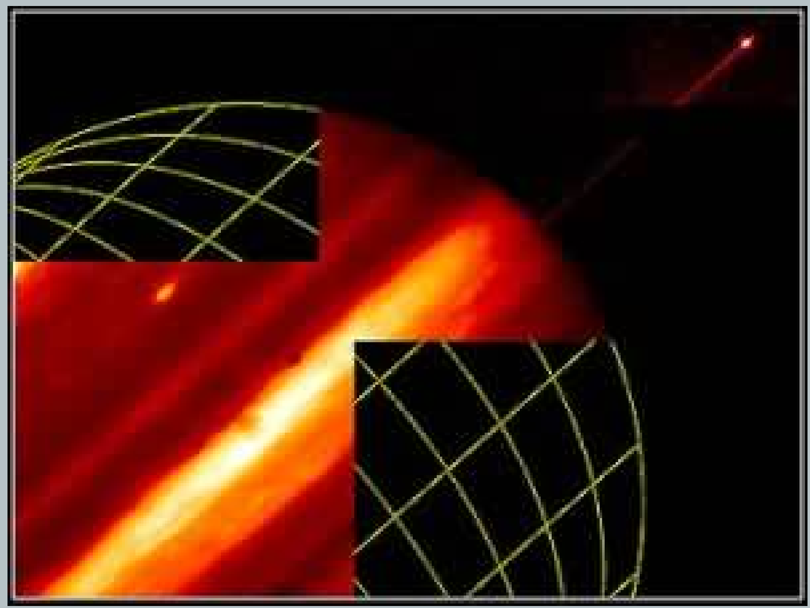
Hubble Provides Infrared View of Moon, Ring, and Clouds



Probing Jupiter's atmosphere for the first time, the Hubble telescope's infrared camera is providing a sharp glimpse of the planet's ring, moon, and high-altitude clouds.

The presence of methane in Jupiter's hydrogen- and helium-rich atmosphere has allowed Hubble to plumb Jupiter's atmosphere, revealing bands of high-altitude clouds. Visible-light observations cannot provide a clear view of these high clouds because the underlying clouds reflect so much visible light that the higher-level clouds are indistinguishable from the lower layer.

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Hubble Watches the Red Planet as Mars Global Surveyor Begins Aerobraking

This Hubble telescope picture of Mars was taken Sept. 12, 1997, one day after the arrival of the Mars Global Surveyor (MGS) spacecraft and only five hours before the beginning of autumn in the Martian Northern Hemisphere.

This Hubble picture was taken in support of the MGS mission. Hubble is monitoring Martian weather conditions, such as large dust storms, during the early phases of the spacecraft's aerobraking.

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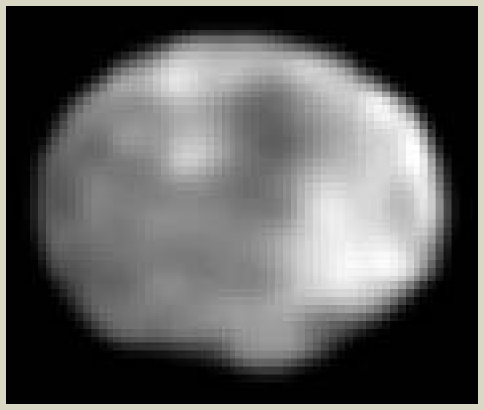
Hubble Reveals Huge Crater on the Surface of the Asteroid Vesta



Astronomers have used the Hubble Space telescope to discover a giant impact crater on the asteroid Vesta. The crater is a link in a chain of events thought responsible for forming a distinctive class of tiny asteroids as well as some meteorites that have reached the Earth.

The giant crater is 285 miles across, which is nearly equal to Vesta's 330-mile diameter. If Earth had a crater of proportional size, it would fill the Pacific Ocean basin. Astronomers had predicted the existence of one or more large craters, reasoning that if Vesta is the true "parent body" of some smaller asteroids then it should have the wound of a major impact that was catastrophic enough to knock off big chunks. In this Hubble picture of Vesta, a "nub" at the bottom of the asteroid is suggestive of a catastrophic impact.

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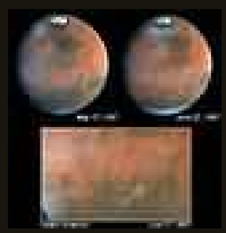
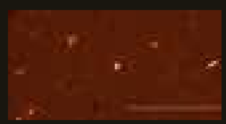
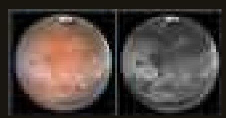
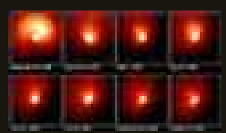
Jul 15, 1997 Hubble Sees Rapid Weather Changes On Mars, New Dust Activity

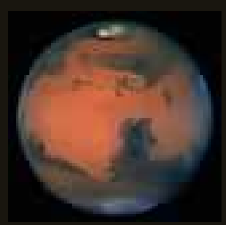

Jul 1, 1997 Hubble's Look At Mars Shows Canyon Dust Storm, Cloudy Conditions For Pathfinder Landing


Jun 19, 1997 Hubble Captures Volcanic Eruption Plume From Io


Jun 10, 1997 Mysterious Fireball From A Cataclysmic Explosion


May 20, 1997 Hubble Finds Cloudy, Cold Weather Conditions for Mars-Bound Spacecraft


Mar 27, 1997 Hale-Bopp Observations with Hubble and IUE Surprise Astronomers


Mar 20, 1997 Hubble's Sharpest View of Mars

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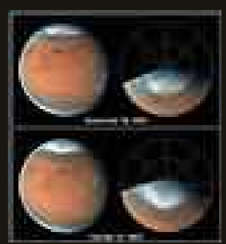
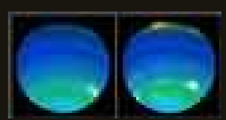
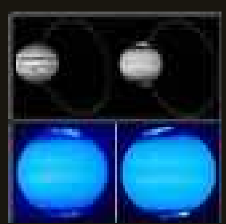

Nov 1, 1996 Springtime Dust Storm Swirls at Martian North Pole


Oct 24, 1996 Hubble Makes Movie of Neptune's Rotation and Weather


Oct 17, 1996 Hubble Follows Rapid Changes in Jupiter's Aurora

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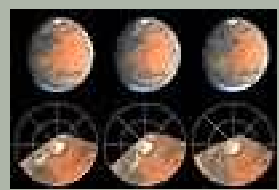
Hubble Sees Rapid Weather Changes On Mars, New Dust Activity

Astronomers using the Hubble telescope to track weather on Mars and how it might affect the Pathfinder landing site in Ares Vallis report that a large dust storm seen south of the site only 12 days earlier has dissipated. However, a new dust storm has appeared in the polar region, about 1,200 miles (2,000 kilometers) due north of the landing site.

The Hubble researchers conclude that Pathfinder landed during a period when large changes in the regional distributions of dust and clouds were taking place on Mars. The green cross on the bottom picture identifies the Pathfinder landing site.



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Hubble's Look At Mars Shows Canyon Dust Storm, Cloudy Conditions For Pathfinder Landing

Hubble telescope pictures of Mars, taken June 27, 1997 in preparation for the July 4 landing of the Pathfinder spacecraft, show a dust storm churning through the deep canyons of Valles Marineris, just 600 miles (1,000 kilometers) south of the Pathfinder spacecraft landing site.

Astronomers also report the presence of patchy cirrus clouds over the landing site and very thick clouds to the north. Because there are so many clouds (related to low temperatures in the atmosphere causing water vapor to freeze), the dust will probably stay confined to the canyons, they conclude. The green cross on the bottom picture identifies the Pathfinder landing site.

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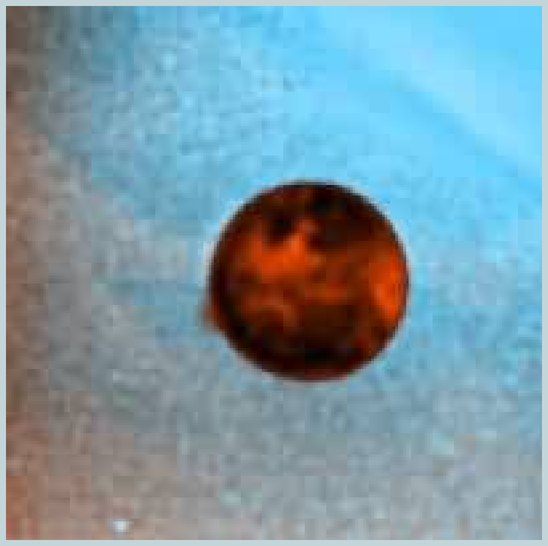
Hubble Captures Volcanic Eruption Plume From Io



The Hubble telescope has snapped a picture of a 400-kilometer-high (250-mile-high) plume of gas and dust from a volcanic eruption on Io, Jupiter's large, innermost moon.

Io was passing in front of Jupiter when Hubble took this image. The plume appears as an orange patch just off the edge of Io [at eight o'clock], against the blue background of Jupiter's clouds. Io's volcanic eruptions blast material hundreds of kilometers into space in giant plumes of gas and dust. In this image, material must have been blown out of the volcano at more than 2,000 mph to form a plume of this size, which is the largest yet seen on Io.

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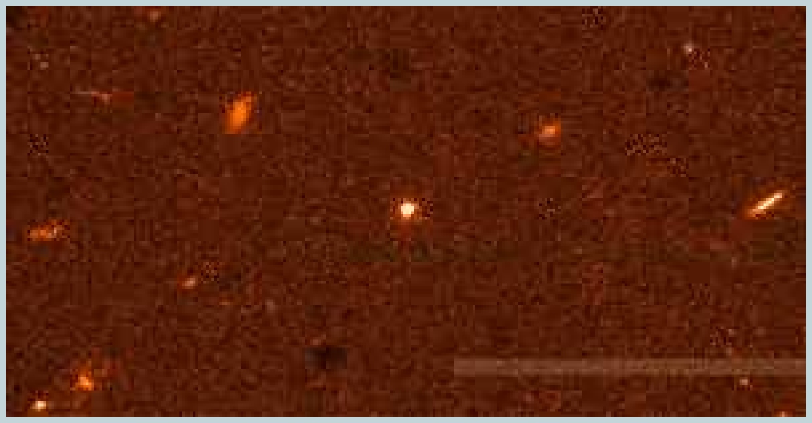
Mysterious Fireball From A Cataclysmic Explosion



The visible fireball from a titanic explosion in deep space, called a gamma-ray burst, blazes in the center of this image, taken with the Hubble telescope's imaging spectrograph.

The burst occurred on May 8, 1997, and Hubble observations to acquire the fading fireball were made on June 2. No accompanying object, such as a host galaxy, can be found near the burst. This result adds to the puzzlement over the source of these enigmatic explosions, because a previous Hubble picture of the visible glow from another gamma-ray burst identified a potential host galaxy.

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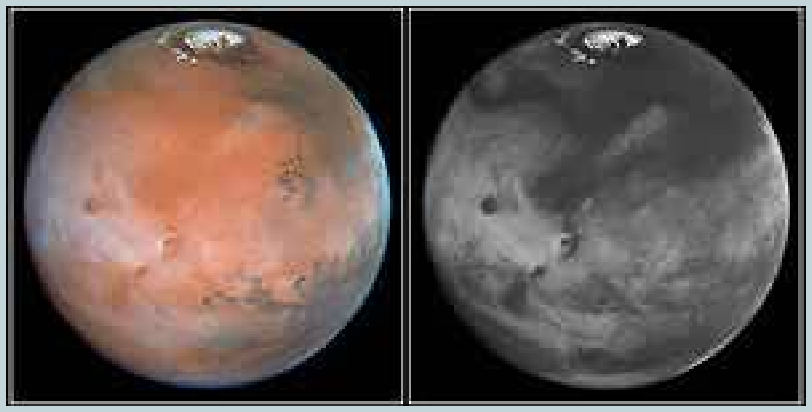
Hubble Finds Cloudy, Cold Weather Conditions for Mars-Bound Spacecraft



As two NASA spacecraft speed toward a mid-year rendezvous with Mars, astronomers using the Hubble telescope are providing updated planetary weather reports to help plan the missions.

Hubble's new images show that the "Martian invasion" of spacecraft will experience considerably different weather conditions than seen by the last U.S. spacecraft to land on Mars 21 years ago. Martian atmospheric conditions will affect the operation of both the Mars Pathfinder landing on July 4, 1997 and the September 11 arrival of the Mars Global Surveyor, which will map the planet from orbit. These two Hubble snapshots were taken barely three weeks after another Hubble observations of the Red Planet. The differences in the two sets of images are striking, revealing dramatic changes in some local conditions and show overall cloudier and colder conditions than the Viking orbiter encountered two decades ago.

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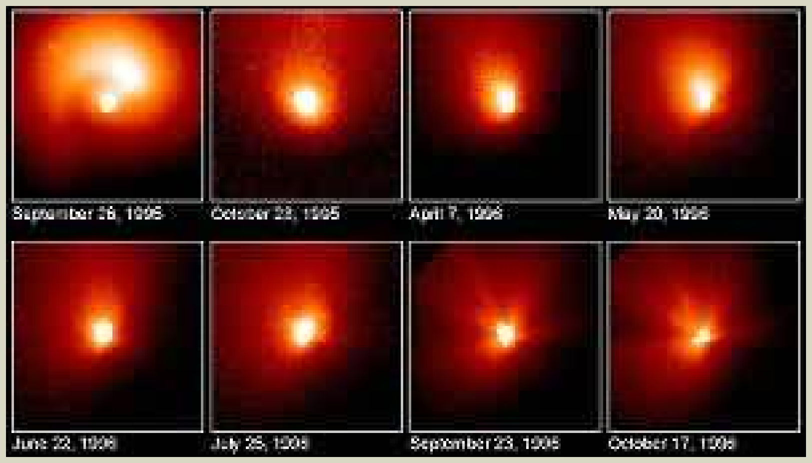
Hale-Bopp Observations with Hubble and IUE Surprise Astronomers



Completing an unprecedented yearlong study of Comet Hale-Bopp with two NASA observatories, including the Hubble telescope, astronomers report that they are surprised to find that the different ices in the nucleus seem to be isolated from each other. They also have seen unexpectedly brief and intense bursts of activity from the nucleus during the monitoring period. The Hubble observations suggest that the nucleus is huge, 19 to 25 miles (30 to 40 kilometers) across.

Here are a series of Hubble telescope observations of the region around the nucleus of Hale-Bopp, taken on eight different dates since September 1995. They chronicle changes in the evolution of the nucleus as it moves ever closer to, and is warmed by, the Sun.

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Hubble's Sharpest View of Mars

The recently refurbished Hubble telescope obtained the sharpest view of Mars ever taken from Earth. This stunning portrait was taken with March 10, 1997, just before the Red Planet made one of its closest passes to Earth (about 60 million miles or 100 million kilometers).

The Martian North Pole is at the top [near the center of the bright polar cap] and east is to the right. This view of Mars was taken on the last day of Martian spring in the Northern Hemisphere.

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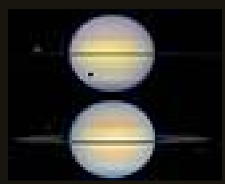
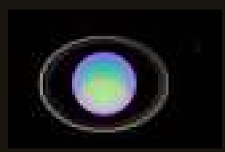
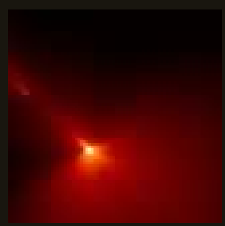
Apr 26, 1996 Saturn Ring-Plane Crossing, November 1995


Apr 24, 1996 Edge-On View of Saturn's Rings


Apr 24, 1996 Hubble Captures Detailed Image of Uranus's Atmosphere


Mar 27, 1996 Hubble Probes Inner Region of Comet Hyakutake


Mar 7, 1996 Hubble Reveals Surface of Pluto for First Time

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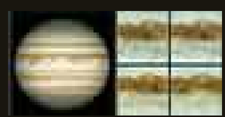
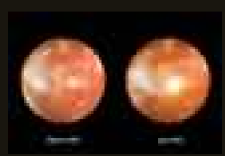

Nov 9, 1995 Hubble Views the Galileo Probe Entry Site on Jupiter


Oct 10, 1995 Hubble Discovers Bright New Spot on Io


Oct 10, 1995 Hubble Provides the First Images of Saturn's Aurorae


Oct 10, 1995 Hubble Maps the Asteroid Vesta

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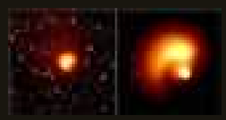
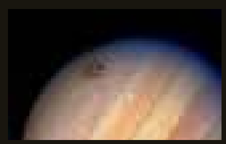
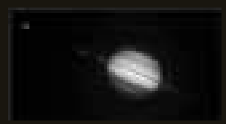


Oct 10, 1995 — Hubble Sees Material Ejected from Comet Hale-Bopp

Oct 10, 1995 — Hubble Photo Gallery of Jupiter's Galilean Satellites



Oct 9, 1995 — Color Hubble Image of Large Comet Impact on Jupiter

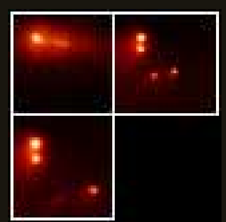


Aug 11, 1995 — Hubble Again Views Saturn's Rings Edge-On

Aug 1, 1995 — Hubble Discovers New Moons Orbiting Saturn

Jul 14, 1995 — Hubble Maps Surface Features of Titan

Jun 26, 1995 — Hubble Monitors Weather on Neighboring Planets



Jun 14, 1995 — Comet P/Shoemaker-Levy 9 "Gang Of Four"

Jun 14, 1995 — Hubble Space Telescope Resolves Volcanoes on Io

Jun 14, 1995 — Hubble Portrait of the "Double Planet" Pluto & Charon

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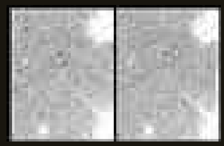
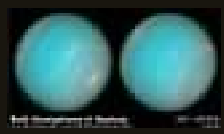
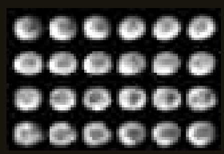
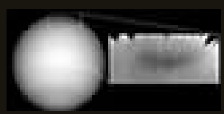

Jun 14, 1995 [Hubble Identifies a Long-Sought Population of Comets Beyond Neptune]


Jun 14, 1995 [Hubble Space Telescope Observations of Neptune]

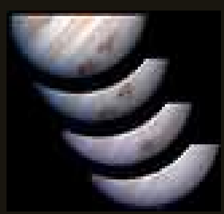

Jun 5, 1995 [Hubble Views Saturn Ring-Plane Crossing]


Apr 19, 1995 [Asteroid or Mini-Planet? Hubble Maps the Ancient Surface of Vesta]


Apr 19, 1995 [Hubble Discovers New Dark Spot on Neptune]


Mar 31, 1995 [Hubble Tracks Jupiter Storms]


Mar 21, 1995 [Venus in Ultraviolet Light]


Mar 3, 1995 [Comet Fragment Slams into Jupiter]

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Dec 20, 1994 [Hubble Observes A New Saturn Storm]

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Sep 29, 1994 Hubble Observations Shed New Light on Jupiter Collision

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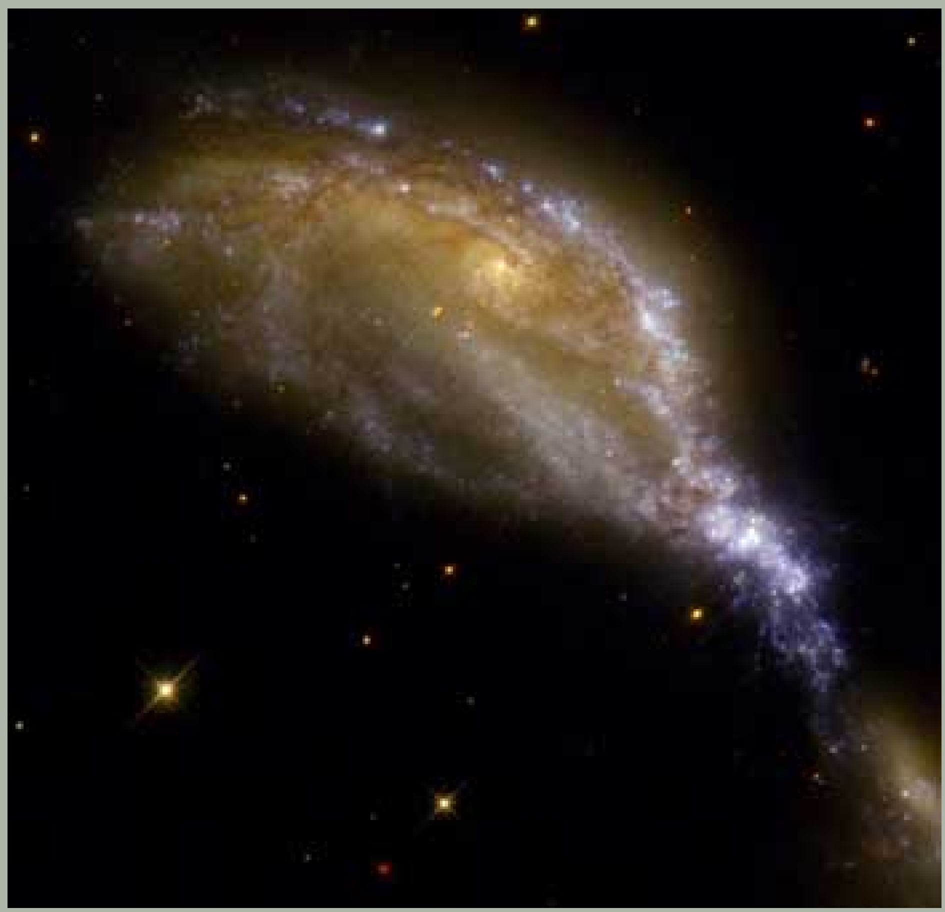
A Bird's Eye View of a Galaxy Collision



What appears as a bird's head, leaning over to snatch up a tasty meal, is a striking example of a galaxy collision in NGC 6745. The "bird" is a large spiral galaxy, with its core still intact. It is peering at its "prey," a smaller passing galaxy (nearly out of the field of view at lower right). The bright blue beak and bright, whitish-blue top feathers show the distinct path taken during the smaller galaxy's journey. These galaxies did not merely interact gravitationally as they passed one another; they actually collided.

You may wish to find out the answers to questions such as these:

- What happens when galaxies collide?

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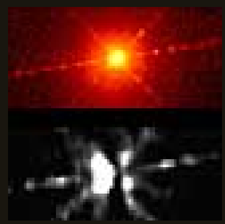
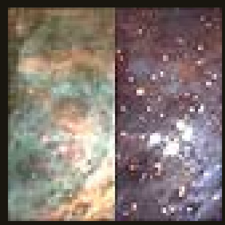
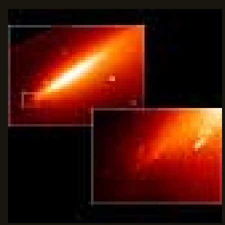


Aug 31, 2000 [He2-90's Appearance Deceives Astronomers]

Aug 24, 2000 Hubble Takes Census of Elusive Brown Dwarf Stars

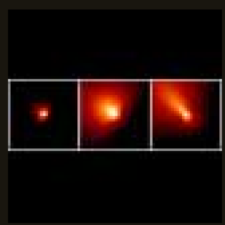


Aug 24, 2000 Hubble Spies Brown Dwarfs in Nearby Stellar Nursery



Aug 7, 2000 Hubble Discovers Missing Pieces of Comet Linear

Aug 3, 2000 A Dying Star in Globular Cluster M15



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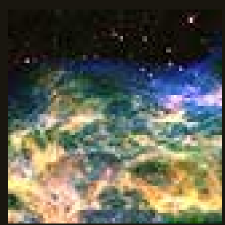
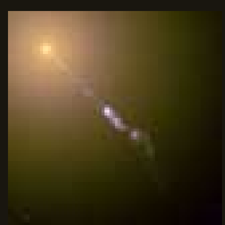
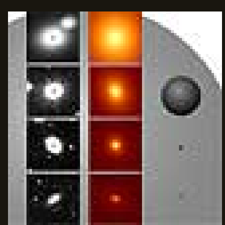


Jul 13, 2000 Hubble Watches Star Tear Apart its Neighborhood



Jul 6, 2000 A Cosmic Searchlight



Jun 5, 2000 Black Holes Shed Light on Galaxy Formation

Jun 5, 2000 [Feasting Black Hole Blows Bubbles]

Matches 11-20 of 35 shown
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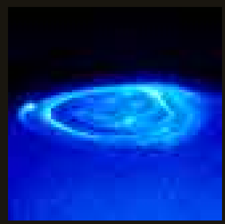
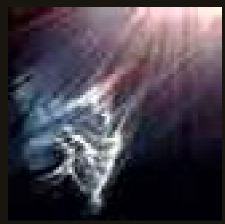


Dec 14, 2000 Satellite Footprints Seen in Jupiter Aurora



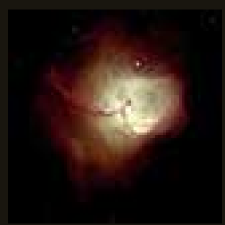
Dec 6, 2000 Ghostly Reflections in the Pleiades

Nov 30, 2000 Hubble Captures an Extraordinary and Powerful Active Galaxy

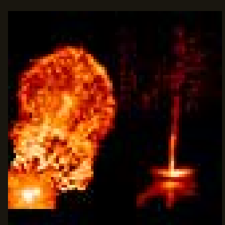
Nov 9, 2000 Hubble Sees Bare Neutron Star Streaking Across Space

Nov 2, 2000 A Bird's Eye View of a Galaxy Collision

Oct 31, 2000 Astronomers Ponder Lack of Planets in Globular Cluster



Oct 5, 2000 Hubble Peeks into a Stellar Nursery in a Nearby Galaxy



Sep 21, 2000 Movies from Hubble Show the Changing Faces of Infant Stars

Sep 14, 2000 Centaur's Bright Surface Spot Could be Crater of Fresh Ice

Sep 7, 2000 IC 418: The "Spirograph" Nebula

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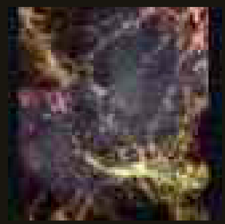
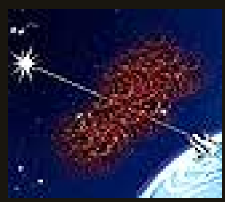
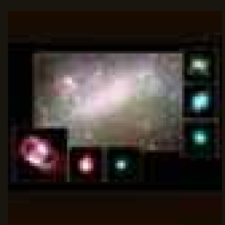

Jun 1, 2000 Peering into the Heart of the Crab Nebula

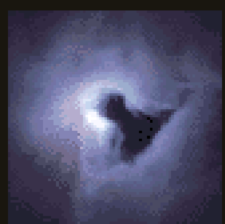

May 11, 2000 Galactic Silhouettes

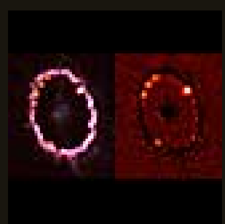

May 3, 2000 Lost and Found: Hubble Finds Much of the Universe's Missing Hydrogen

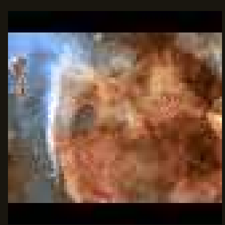

Apr 6, 2000 The Glowing Eye of NGC 6751


Mar 16, 2000 Hubble Finds Young Stars in Cosmic Dance


Mar 9, 2000 Hubble Surveys Dying Stars in Nearby Galaxy


Mar 2, 2000 Hubble Takes a Close-up View of a Reflection Nebula in Orion


Feb 16, 2000 Onset of Titanic Collision Lights Up Supernova Ring


Feb 3, 2000 Light and Shadow in the Carina Nebula

Jan 24, 2000

Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass

Galactic Silhouettes

Through an extraordinary chance alignment, the Hubble telescope has captured a view of a face-on spiral galaxy lying precisely in front of another larger spiral. The unique pair is called NGC 3314. This line-up provides astronomers with the rare chance to see the dark material within the foreground galaxy, seen only because it is silhouetted against the light from the object behind it. NGC 3314 lies about 140 million light-years from Earth in the direction of the southern hemisphere constellation Hydra. This picture is one of many produced by the Hubble Heritage Program, created 1-1/2 years ago to publicly release some of the best celestial views taken by the telescope's visible-light camera. Now, the International Center of Photography in New York City has rewarded the program for its work with the annual Infinity Award for Applied Photography.

You may wish to find out the answers to questions such as these:

- What are the interesting features in this picture?

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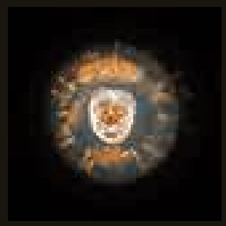
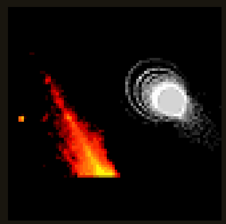
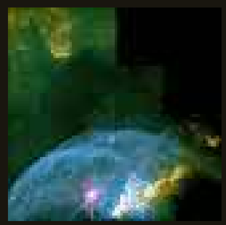


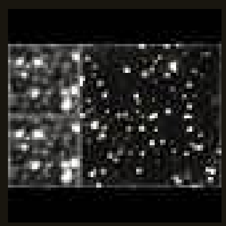
Jan 24, 2000 — Hubble Reopens "Eye" on the Universe



Jan 15, 2000 — Beta Pictoris Disk Hides Giant Elliptical Ring System



Jan 13, 2000 — An Expanding Bubble in Space



Jan 13, 2000 — Lone Black Holes Discovered Adrift in the Galaxy

Jan 6, 2000 — Fireworks of Star Formation Light up a Galaxy

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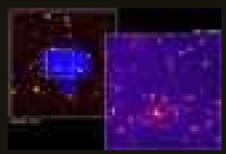
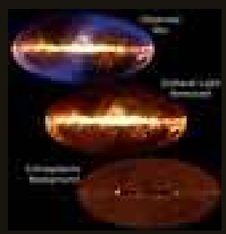
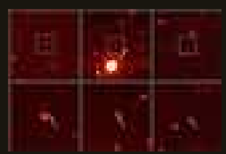


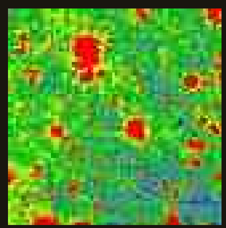
Aug 19, 1998 Distant Heavyweight Galaxy Cluster Clobbers Dense-Universe Theory



Jan 9, 1998 Astronomers Discover an Infrared Background Glow in the Universe



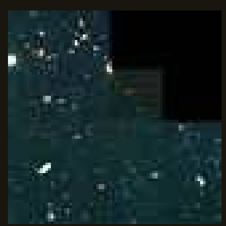
Jan 8, 1998 Hubble Pinpoints Distant Supernovae



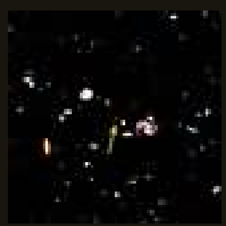
Jan 7, 1998 Hubble Finds Most of Visible Light in the Universe

1996

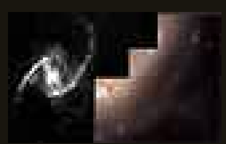
Dec 17, 1996 Hubble Census Tracks a Stellar "Baby Boom"



Sep 4, 1996 Hubble Sees Early Building Blocks of Today's Galaxies



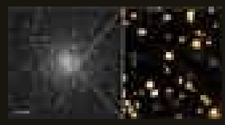
Jun 26, 1996 Findings from Hubble Deep Field Hone in on Distant Galaxies



May 30, 1996 Hubble Space Telescope on Track for Measuring the Expansion Rate of the Universe

Jan 15, 1996 Hubble's Deepest View of the Universe Unveils Bewildering Galaxies across Billions of Years

1995



Aug 28, 1995 Hubble Space Telescope Finds Stellar Graveyard

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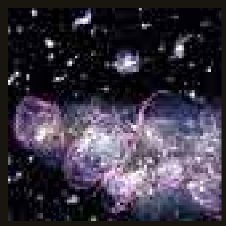
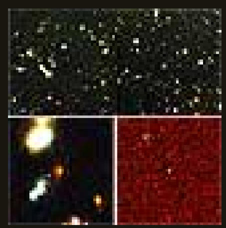


Jan 8, 2002 Stellar 'Fireworks Finale' Came First in the Young Universe

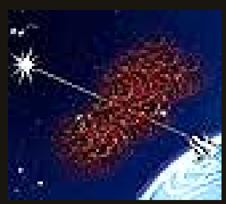
2001

Oct 5, 2001 Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block



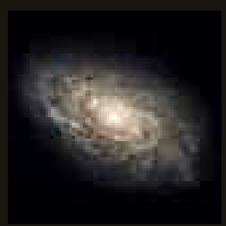
Apr 2, 2001 Blast from the Past: Farthest Supernova Ever Seen Sheds Light on Dark Universe

2000



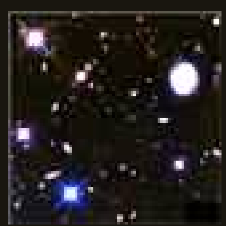
May 3, 2000 Lost and Found: Hubble Finds Much of the Universe's Missing Hydrogen

1999



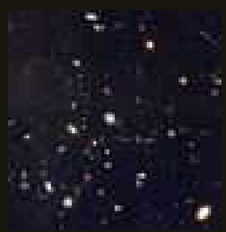
Jun 3, 1999 Magnificent Details in a Dusty Spiral Galaxy

May 25, 1999 Hubble Completes Eight-Year Effort to Measure Expanding Universe

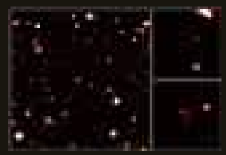


Jan 7, 1999 Combined Deep View of Infrared- and Visible-Light Galaxies

1998



Nov 23, 1998 The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View



Oct 8, 1998 Hubble Goes to the Limit In Search Of Farthest Galaxies

Aug 27, 1998 Far-Flung Galaxy Clusters May Reveal Fate of Universe

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1995

Jun 14, 1995 Galaxy NGC 4881 and the Coma Cluster

1994

Dec 6, 1994 Hubble Identifies Primeval Galaxies, Uncovers New Clues to the Universe's Evolution

Oct 26, 1994 Hubble Space Telescope Measures Precise Distance to the Most Remote Galaxy Yet

Matches 21-23 of 23 shown

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A Galaxy Blazes With Star Formation

Most galaxies form new stars at a fairly slow rate, but members of a rare class known as "starburst" galaxies blaze with extremely active star formation. The galaxy NGC 3310 is one such starburst galaxy that is forming clusters of new stars at a prodigious rate. Scientists using NASA's Hubble Space Telescope are perfecting a technique to determine the history of starburst activity in NGC 3310 by studying the colors of its star clusters.

You may wish to find out the answers to questions such as these:

- How is the color of the star clusters linked to their age?
- What does this tell us about starburst activity in general?

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New View of Primordial Helium Traces the Structure of Early Universe

Artist's Concept

NASA's Far Ultraviolet Spectroscopic Explorer (FUSE) satellite has given astronomers their best glimpse yet at the ghostly cobweb of helium gas left over from the big bang, which underlies the universe's structure. The helium is not found in galaxies or stars but spread thinly through the vastness of space. The helium traces the architecture of the universe back to very early times. This structure arose from small gravitational instabilities seeded in the chaos just after the big bang. These FUSE observations help confirm theoretical models of how matter in the expanding universe condensed into a web-like structure pervading all of the space between galaxies.

You may wish to find out the answers to questions such as these:

- How were these observations made?
- What does this tell us about the early universe?

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Hubble Photographs Warped Galaxy as Camera Passes Milestone

The Hubble telescope has captured an image of an unusual edge-on galaxy, revealing remarkable details of its warped dusty disk and showing how colliding galaxies spawn the formation of new generations of stars. The dust and spiral arms of normal spiral galaxies, like our own Milky Way, appear flat when viewed edge-on. This Hubble Heritage image of ESO 510-G13 shows a galaxy that, by contrast, has an unusual twisted disk structure, first seen in ground-based photographs.

You may wish to find out the answers to questions such as these:

- Why does the galaxy have a warped shape?

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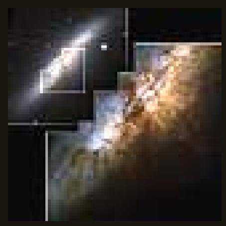
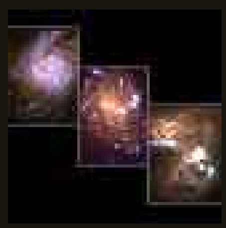
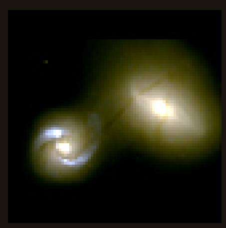


Mar 7, 2001 Hubble Spies Huge Clusters of Stars Formed by Ancient Encounter

Mar 1, 2001 NGC 4013: A Galaxy on the Edge

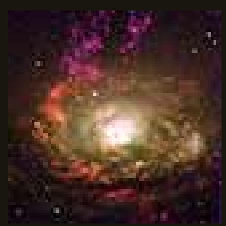


Jan 11, 2001 Hubble's Ultraviolet Views of Nearby Galaxies Yield Clues to Early Universe

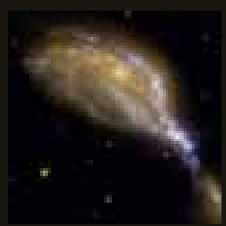


Jan 9, 2001 Intergalactic 'Pipeline' Funnels Matter Between Colliding Galaxies

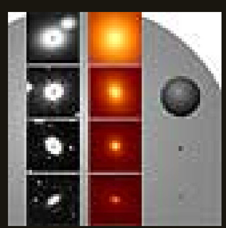
2000



Nov 30, 2000 Hubble Captures an Extraordinary and Powerful Active Galaxy



Nov 2, 2000 A Bird's Eye View of a Galaxy Collision



Jun 5, 2000 Black Holes Shed Light on Galaxy Formation

Jun 5, 2000 Feasting Black Hole Blows Bubbles

Jan 24, 2000 [Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass]

Jan 6, 2000 [Fireworks of Star Formation Light up a Galaxy]

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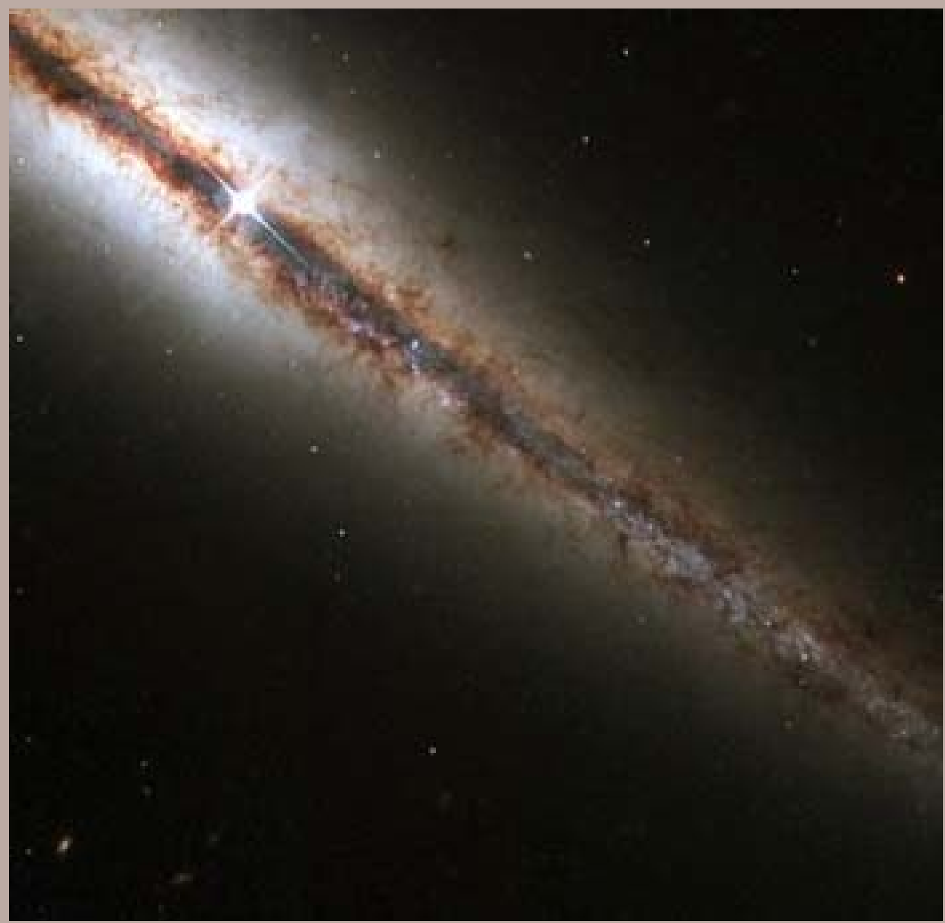
NGC 4013: A Galaxy on the Edge



The Hubble telescope has snapped this remarkable view of a perfectly "edge-on" galaxy, NGC 4013. This new Hubble picture reveals with exquisite detail huge clouds of dust and gas extending along, as well as far above, the galaxy's main disk. NGC 4013 is a spiral galaxy, similar to our Milky Way, lying some 55 million light-years from Earth in the direction of the constellation Ursa Major. Viewed face-on, it would look like a nearly circular pinwheel, but NGC 4013 happens to be seen edge-on from our vantage point. Even at 55 million light-years, the galaxy is larger than Hubble's field of view, and the image shows only a little more than half of the object, albeit with unprecedented detail.

You may wish to find out the answers to questions such as these:

- Why is the galaxy so dark and so thin?
- Why are there so many clouds?

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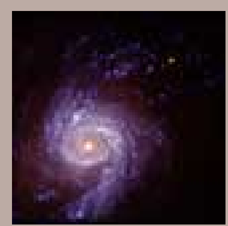
Hubble's Ultraviolet Views of Nearby Galaxies Yield Clues to Early Universe

Astronomers are using these three Hubble telescope images of nearby galaxies to help tackle the question of why their distant relatives have such odd shapes, appearing markedly different from the typical "ellipticals" and "spirals" seen in the nearby universe. By viewing these galaxies in ultraviolet light, astronomers can compare their shapes with those of their distant relatives. The results of their survey support the idea that astronomers are detecting the "tip of the iceberg" of very distant galaxies. Based on these Hubble ultraviolet images, not all the faraway galaxies necessarily possess intrinsically odd shapes.

You may wish to find out the answers to questions such as these:



- What do the three pictures show?
- Why did astronomers look at the nearby galaxies in ultraviolet light?

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Intergalactic 'Pipeline' Funnels Matter Between Colliding Galaxies

This visible-light picture, taken by the Hubble telescope, reveals an intergalactic "pipeline" of material flowing between two battered galaxies that bumped into each other about 100 million years ago. The pipeline [the dark string of matter] begins in NGC 1410 [the galaxy at left], crosses over 20,000 light-years of intergalactic space, and wraps around NGC 1409 [the companion galaxy at right] like a ribbon around a package. The galaxies reside about 300 million light-years from Earth in the constellation Taurus.

You may wish to find out the answers to questions such as these:

- How was the pipeline created?

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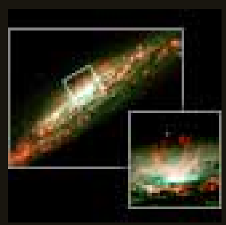
Feb 7, 2002 Hubble Reveals "Backwards" Spiral Galaxy

2001

Nov 1, 2001 Hubble Reveals Ultraviolet Galactic Ring

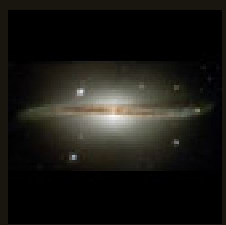
Oct 5, 2001 Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block

Sep 6, 2001 A Galaxy Blazes With Star Formation

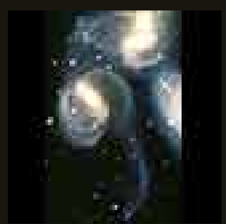


Aug 16, 2001 Burst of Star Formation Drives Bubble in Galaxy's Core

Aug 9, 2001 New View of Primordial Helium Traces the Structure of Early Universe

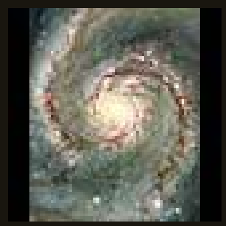


Aug 2, 2001 Hubble Photographs Warped Galaxy as Camera Passes Milestone



Jul 19, 2001 Star Clusters Born in the Wreckage of Cosmic Collisions

May 31, 2001 Hubble Unveils a Galaxy in Living Color



Apr 5, 2001 Hubble Reveals the Heart of the Whirlpool Galaxy

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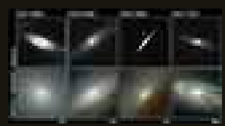
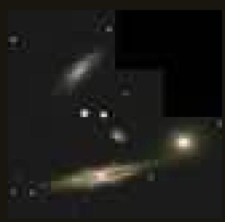
1999

Nov 22, 1999 Multiple Galaxy Collisions Surprise Hubble Astronomers

Nov 4, 1999 A Grazing Encounter between Two Spiral Galaxies

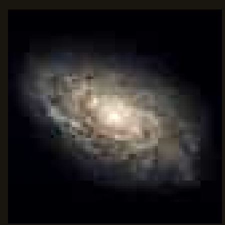


Oct 6, 1999 Starry Bulges Yield Secrets to Galaxy Growth



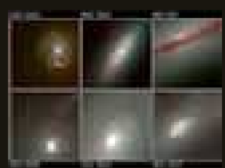
Sep 2, 1999 A Minuet of Galaxies

Jul 15, 1999 Cosmic Collisions: European HST Scientists Catch Merging Galaxies in the Act



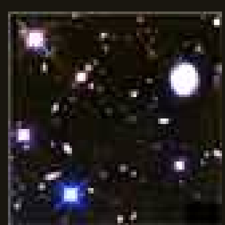
Jun 3, 1999 Magnificent Details in a Dusty Spiral Galaxy

Apr 20, 1999 Ring Around a Galaxy



Mar 18, 1999 Hubble's Infrared Galaxy Gallery

Feb 18, 1999 Hubble Finds More Evidence of Galactic Cannibalism



Jan 7, 1999 Combined Deep View of Infrared- and Visible-Light Galaxies

Matches 21-30 of 55 shown

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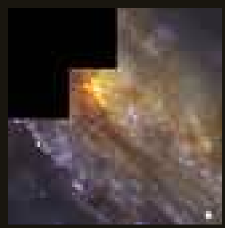
News Releases about: Galaxies

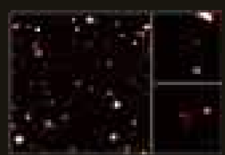
1998



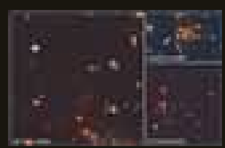
Dec 3, 1998 Behind a Dusty Veil Lies a Cradle of Star Birth

Nov 23, 1998 The Universe "Down Under" Is the Latest Target for Hubble's Latest Deep-View

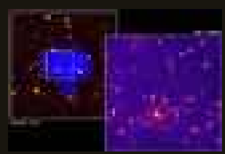
Oct 21, 1998 Astronomers Unveil Colorful Hubble Photo Gallery



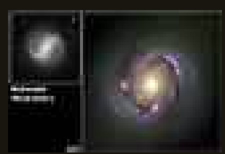
Oct 8, 1998 Hubble Goes to the Limit In Search Of Farthest Galaxies



Aug 27, 1998 Far-Flung Galaxy Clusters May Reveal Fate of Universe



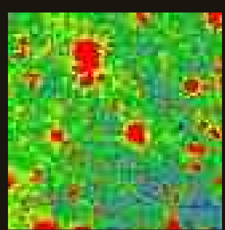
Aug 19, 1998 Distant Heavyweight Galaxy Cluster Clobbers Dense-Universe Theory



Jun 10, 1998 A Bright Ring of Star Birth around a Galaxy's Core

May 14, 1998 Hubble Provides Multiple Views of How to Feed a Black Hole

Mar 22, 1998 Hubble Captures the Heart of Star Birth



Jan 7, 1998 Hubble Finds Most of Visible Light in the Universe

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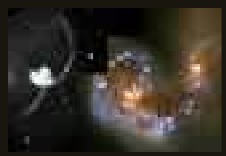
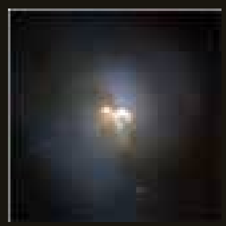
1997



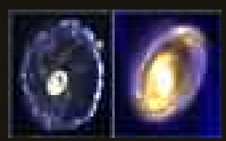
Oct 21, 1997 Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions

Jul 30, 1997 World's Most Powerful Telescopes Team Up With A Lens In Nature To Discover Farthest Galaxy In The Universe

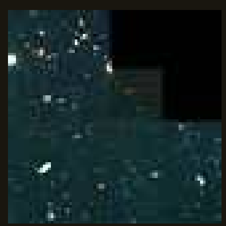


Jun 9, 1997 A Collision In The Heart Of A Galaxy

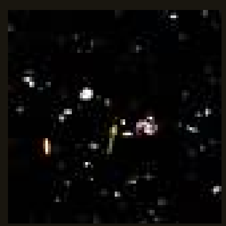
1996



Nov 26, 1996 Hubble Spies Supersonic "Comet-Clouds" in Heart of Galaxy



Sep 4, 1996 Hubble Sees Early Building Blocks of Today's Galaxies

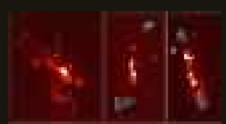


Jun 26, 1996 Findings from Hubble Deep Field Hone in on Distant Galaxies

Apr 24, 1996 Hubble Spies Globular Cluster in Neighboring Galaxy

Jan 15, 1996 Hubble's Deepest View of the Universe Unveils Bewildering Galaxies across Billions of Years

1995



Aug 7, 1995 Hubble Uncovers Surprisingly Complex Structures in Radio Galaxies

Jul 24, 1995 [Hubble Sheds Light on the "Faint Blue Galaxy" Mystery]

Matches 41-50 of 55 shown
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1997

A Collision In The Heart Of A Galaxy

The Hubble telescope's infrared camera has uncovered a collision between two spiral galaxies in the heart of the peculiar galaxy called Arp 220. The collision has provided the spark for a burst of star formation.

Hubble's infrared vision has captured bright knots of stars forming in the heart of Arp 220. The bright, crescent, moon-shaped object is a remnant core of one of the colliding galaxies. The core is a cluster of 1 billion stars. The core's half-moon shape suggests that its bottom half is obscured by a disk of dust about 300 light-years across. This disk is embedded in the core and may be swirling around a black hole. The core of the other colliding galaxy is the bright round object to the left of the crescent, moon-shaped object. Both cores are about 1,200 light-years apart and are orbiting each other.

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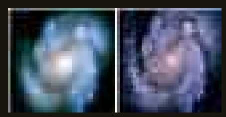
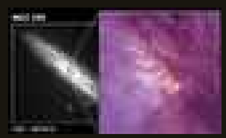


Jul 7, 1995 Picture Perfect: Hubble's New Improved Optics Probe the Core of a Distant Galaxy

Jun 14, 1995 Galaxy NGC 4881 and the Coma Cluster



Feb 20, 1995 Hubble Probes the Violent Birth of Stars in Galaxy NGC 253

Jan 10, 1995 Hubble Views a Starry Ring World Born in a Head-On Collision

1994

Dec 6, 1994 Hubble Identifies Primeval Galaxies, Uncovers New Clues to the Universe's Evolution

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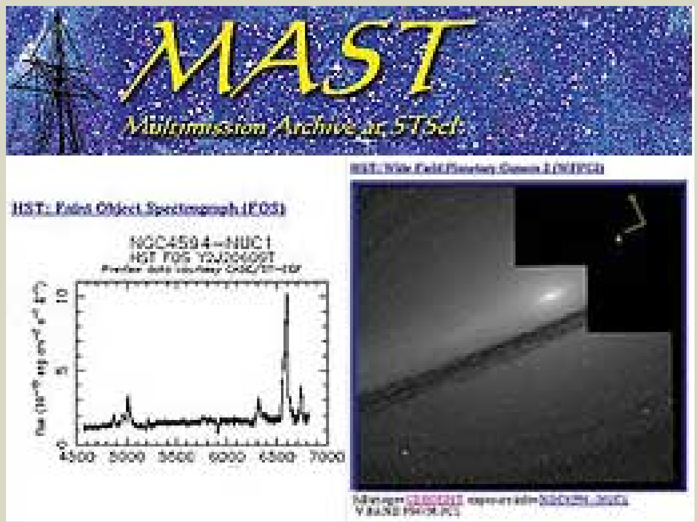
2001

Build Your Own Space Scrapbook



Want to learn more about your favorite star or galaxy? NASA Hubble Space Telescope pictures and other information about thousands of stars and galaxies beyond our solar system are just a mouse click away by visiting the "Spectral/Image Scrapbook." The "scrapbook" was developed by the Multi-Mission Archive at the Space Telescope Science Institute (MAST) team in Baltimore, MD. This new astronomy Web resource provides easy access to the rich repository of black-and-white images and spectra of stars and galaxies stored in the MAST digital archives. While a picture shows astronomers what a celestial object looks like, a spectrum provides information about its physical nature and its motion toward or away from Earth. Astronomers analyze spectra and images of a celestial body to get a complete picture.

You may wish to find out the answers to questions such as these:

- How much information is contained in the MAST archives?
- Can anyone use the scrapbook?

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New Web Site Brings Popular Hubble Exhibition to Millions

Artist's Concept

How old is the universe? How big is it? What is its fate? Where did the planets, stars, and galaxies come from? Are we alone here? Scientists seeking answers to these age-old questions—which have eluded humankind for centuries—have made astounding progress using NASA's orbiting Hubble Space Telescope. Now anyone with access to the World Wide Web can go online to visit Hubble Space Telescope: New Views of the Universe, a popular Smithsonian exhibition highlighting Hubble's unique contributions to our understanding of the universe. The new Web site seeks to simulate the experience of visiting the actual exhibition, which is now touring the United States.

Hubble Space Telescope: New Views of the Universe is a special feature of HubbleSite (http://hubble.stsci.edu), Hubble's official online home and the Web's most comprehensive source of Hubble news, pictures, information, and educational resources.

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May 11, 2000 Galactic Silhouettes

1999

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Apr 19, 1999 Maryland Science Center's "Space Place" Showcases Hubble Discoveries

1998

Nov 10, 1998 Leonid Meteor Storm Won't Deter Hubble from Space Observations

Oct 21, 1998 Astronomers Unveil Colorful Hubble Photo Gallery

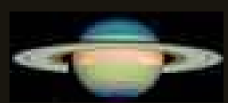
NO IMAGE AVAILABLE

Oct 9, 1998 Second Hubble Web Simulcast Takes Listeners on a Tour of the Cosmos

NO IMAGE AVAILABLE

Jul 1, 1998 Hubble Simulcast Links Outer Space to Cyberspace

Jun 8, 1998 NASA Selects Home for Next Generation Space Telescope



Apr 23, 1998 Hubble Space Telescope Completes Eighth Year Of Exploration

NO IMAGE AVAILABLE

Jan 27, 1998 Space Telescope Science Institute Gets New Director

Jul 18, 1996 Hubble Achieves Milestone: 100,000th Exposure

Matches 11-20 of 23 shown
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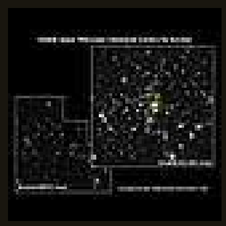
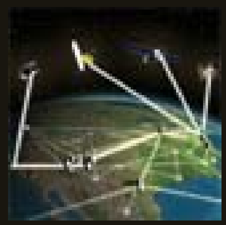
News Releases about: Miscellaneous

2002

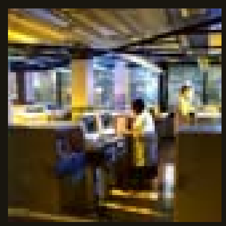


Feb 15, 2002 New Instrument Package to Expand Space Telescope's Vision

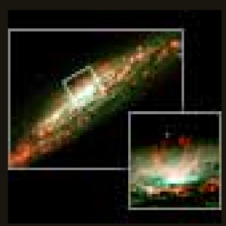
2001



Oct 29, 2001 $10 Million NSF Grant to Fund "National Virtual Observatory"

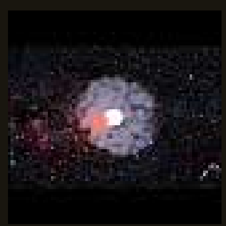


Oct 23, 2001 AURA's OPUS Software Licensed to Celera Genomics

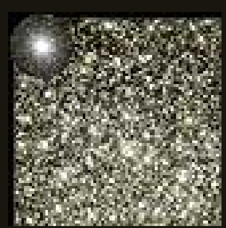


Aug 16, 2001 Burst of Star Formation Drives Bubble in Galaxy's Core

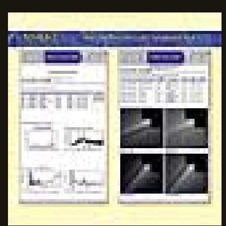
Aug 9, 2001 New View of Primordial Helium Traces the Structure of Early Universe



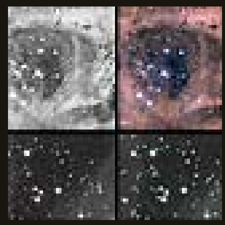
Jul 12, 2001 Magnetic Fields Weave Rings Around Stars



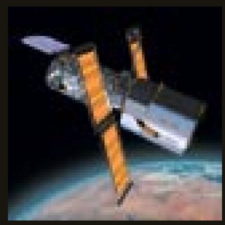
Jun 27, 2001 Hint of Planet-Sized Drifters Bewilders Hubble Scientists



Jun 4, 2001 Build Your Own Space Scrapbook



Jun 4, 2001 [Bigger, Better Catalog Unveils Half a Billion Celestial Objects]



Feb 8, 2001 [New Web Site Brings Popular Hubble Exhibition to Millions]

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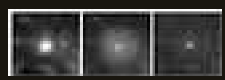
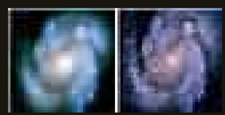
1996

Apr 24, 1996 — Hubble Space Telescope Completes Sixth Year of Exploration

1995



Oct 9, 1995 — Hubble Space Telescope Images of a Bright Star in the Large Magellanic Cloud



Jul 7, 1995 — Picture Perfect: Hubble's New Improved Optics Probe the Core of a Distant Galaxy

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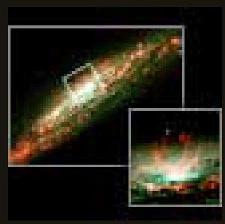
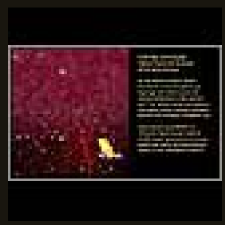
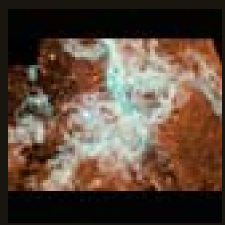
News Releases in 2001

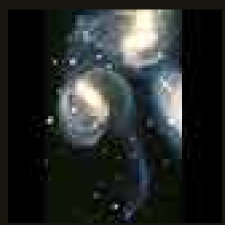

Sep 6, 2001 A Galaxy Blazes With Star Formation

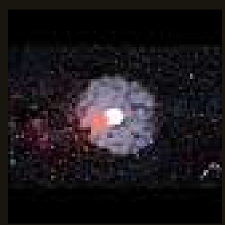

Aug 16, 2001 Burst of Star Formation Drives Bubble in Galaxy's Core

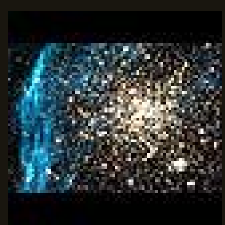

Aug 9, 2001 New View of Primordial Helium Traces the Structure of Early Universe

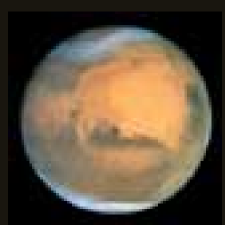

Aug 2, 2001 Hubble Photographs Warped Galaxy as Camera Passes Milestone

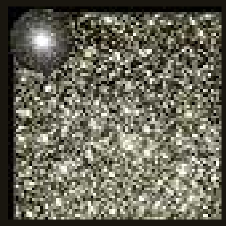

Jul 26, 2001 Hubble's Panoramic Portrait of a Vast Star-forming Region


Jul 19, 2001 Star Clusters Born in the Wreckage of Cosmic Collisions


Jul 12, 2001 Magnetic Fields Weave Rings Around Stars


Jul 10, 2001 Hubble Snaps Picture of Remarkable Double Cluster


Jul 5, 2001 Hubble Captures Best View of Mars Ever Obtained From Earth



Jun 27, 2001

[Hint of Planet-Sized Drifters Bewilders Hubble Scientists]

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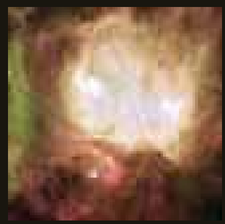
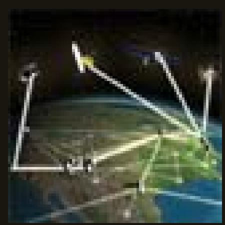


Dec 19, 2001 Hubble Sends Season's Greetings from the Cosmos to Earth

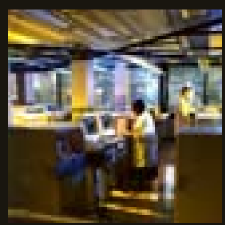
Dec 6, 2001 A Giant Star Factory in Neighboring Galaxy NGC 6822

Nov 27, 2001 Hubble Makes First Direct Measurements of Atmosphere on World Around Another Star

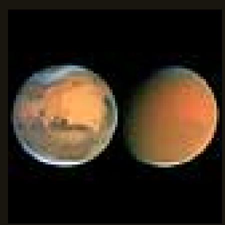
Nov 1, 2001 Hubble Reveals Ultraviolet Galactic Ring



Oct 29, 2001 $10 Million NSF Grant to Fund "National Virtual Observatory"



Oct 23, 2001 AURA's OPUS Software Licensed to Celera Genomics



Oct 11, 2001 Scientists Track "Perfect Storm" on Mars

Oct 5, 2001 Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block

Oct 4, 2001 Peering into the Core of a Globular Cluster

Sep 12, 2001

Ancient Black Hole Speeds Through Sun's Galactic Neighborhood, Devouring Companion Star

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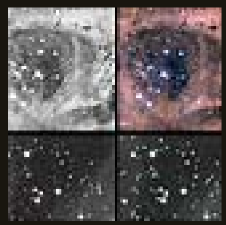
News Releases in 2001

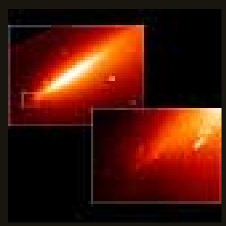
Jun 7, 2001 [A Change of Seasons on Saturn]

Jun 4, 2001 Build Your Own Space Scrapbook

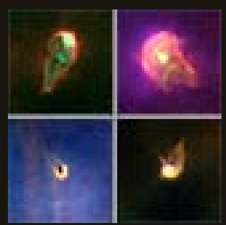


Jun 4, 2001 Bigger, Better Catalog Unveils Half a Billion Celestial Objects

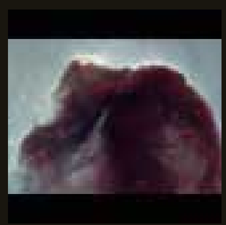
May 31, 2001 Hubble Unveils a Galaxy in Living Color



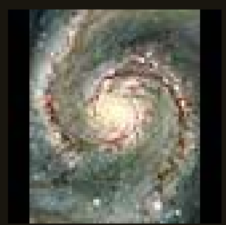
May 17, 2001 Astronomers Puzzled over Comet LINEAR's Missing Pieces



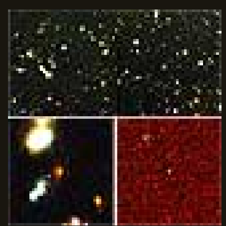
Apr 26, 2001 Planet 'Survivor': Astronomers Witness First Steps of Planet Growth - And Destruction



Apr 24, 2001 By Popular Demand: Hubble Observes the Horsehead Nebula



Apr 5, 2001 Hubble Reveals the Heart of the Whirlpool Galaxy



Apr 2, 2001 Blast from the Past: Farthest Supernova Ever Seen Sheds Light on Dark Universe

Mar 28, 2001 Massive Infant Stars Rock their Cradle

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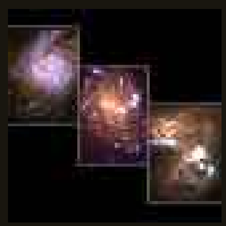
News Releases in 2001

Mar 7, 2001 Hubble Spies Huge Clusters of Stars Formed by Ancient Encounter

Mar 1, 2001 NGC 4013: A Galaxy on the Edge

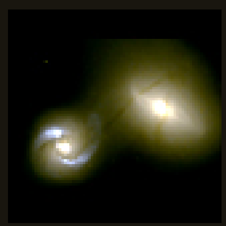
Feb 8, 2001 New Web Site Brings Popular Hubble Exhibition to Millions

Feb 1, 2001 Astro-Entomology? Ant-like Space Structure Previews Death of Our Sun

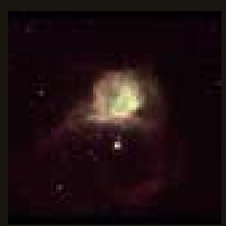


Jan 11, 2001 Hubble's Ultraviolet Views of Nearby Galaxies Yield Clues to Early Universe

Jan 11, 2001 'Death Spiral' Around a Black Hole Yields Tantalizing Evidence of an Event Horizon



Jan 9, 2001 Intergalactic 'Pipeline' Funnels Matter Between Colliding Galaxies



Jan 4, 2001 "X" Marks the Spot: Hubble Sees the Glow of Star Formation in a Neighbor Galaxy

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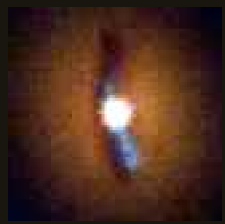
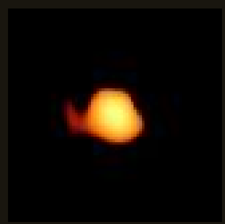
News Releases in 1997

Sep 16, 1997 Hubble Stays on Trail of Fading Gamma-Ray Burst Fireball, Results Point to Extragalactic Origin



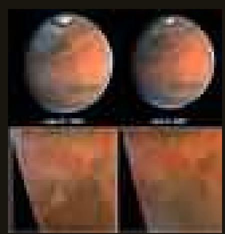
Sep 10, 1997 Hubble Finds a Bare Black Hole Pouring Out Light

Sep 4, 1997 Hubble Reveals Huge Crater on the Surface of the Asteroid Vesta



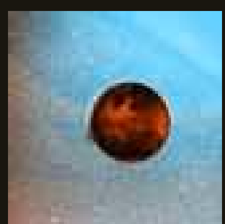
Aug 6, 1997 Hubble Separates Stars in the Mira Binary System

Jul 30, 1997 World's Most Powerful Telescopes Team Up With A Lens In Nature To Discover Farthest Galaxy In The Universe



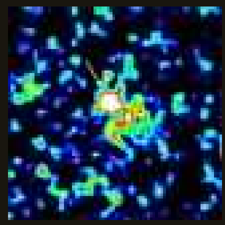
Jul 15, 1997 Hubble Sees Rapid Weather Changes On Mars, New Dust Activity

Jul 1, 1997 Hubble's Look At Mars Shows Canyon Dust Storm, Cloudy Conditions For Pathfinder Landing



Jun 19, 1997 Hubble Captures Volcanic Eruption Plume From Io

Jun 10, 1997 Mysterious Fireball From A Cataclysmic Explosion



Jun 10, 1997

Gamma-Ray Bursts Common To Normal Galaxies? Hubble Data Offer New Clues and Puzzles

HUBBLESITE

news & views

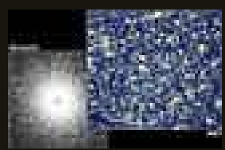
News Releases in 1997

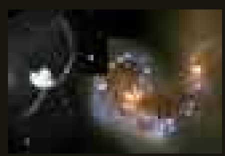

Dec 17, 1997 [Hubble Witnesses the Final Blaze of Glory of Sun-Like Stars]


Dec 4, 1997 One Star's Loss is Another's Gain: Hubble Captures Brief Moment in Life of Lively


Nov 20, 1997 Hubble Provides Infrared View of Moon, Ring, and Clouds


Nov 20, 1997 Hubble Watches Uranus

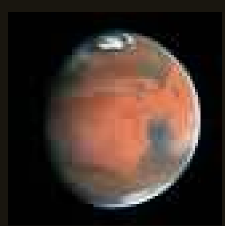

Oct 29, 1997 Hubble Catches Up with a Blue Straggler Star


Oct 21, 1997 Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions


Oct 8, 1997 Hubble Identifies What May Be the Most Luminous Star Known


Sep 24, 1997 Hubble Sees a Neutron Star Alone in Space


Sep 18, 1997 Blobs in Space: The Legacy of a Nova


Sep 17, 1997 Hubble Watches the Red Planet as Mars Global Surveyor Begins Aerobraking

news & views

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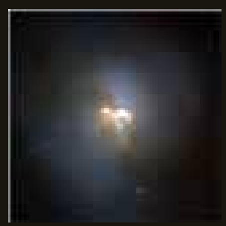
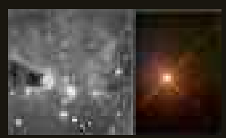
News Releases in 1997

Jun 9, 1997 Hubble Reveals Invisible High-Speed Collision around Supernova 1987A

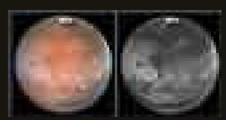
Jun 9, 1997 Fireworks Near a Black Hole in the Core of Seyfert Galaxy NGC 4151



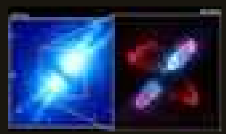
Jun 9, 1997 A Collision In The Heart Of A Galaxy



Jun 9, 1997 Hubble Snaps "Family Portrait"

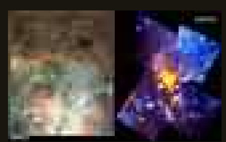


May 20, 1997 Hubble Finds Cloudy, Cold Weather Conditions for Mars-Bound Spacecraft

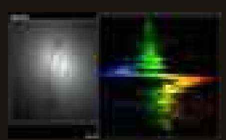


May 12, 1997 Hubble Peers into Heart of Dying Star

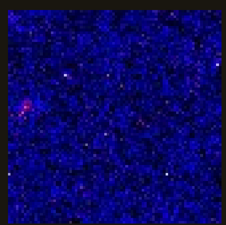
May 12, 1997 Hubble Chemically Analyzes the Ring around Supernova 1987A



May 12, 1997 Hubble Captures the Heart of the Orion Nebula



May 12, 1997 Hubble Records a Black Hole's Signature



Apr 1, 1997 Hubble Tracks the Fading Optical Counterpart of a Gamma-Ray Burst

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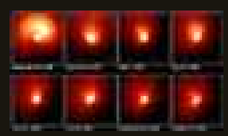
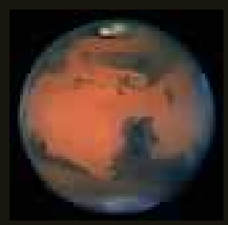
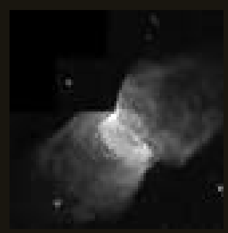
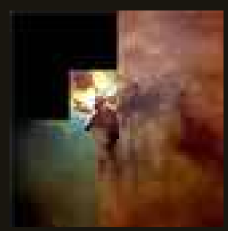
News Releases in 1997


Mar 27, 1997 Hale-Bopp Observations with Hubble and IUE Surprise Astronomers

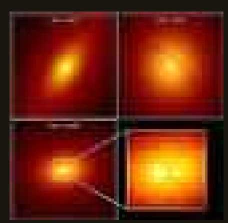

Mar 20, 1997 Hubble's Sharpest View of Mars


Mar 14, 1997 Hubble Camera Resumes Science Operation with Picture of "Butterfly" in Space


Jan 22, 1997 Giant "Twisters" and Star Wisps in the Lagoon Nebula


Jan 14, 1997 Supernova Blast Begins Taking Shape


Jan 14, 1997 Hubble Finds Intergalactic Stars


Jan 13, 1997 Massive Black Holes Dwell in Most Galaxies, According to Hubble Census

HUBBLESITE

... MORE ON WFPC2

WFPC2 SMILE!

THE SCIENCE INSTRUMENTS

Advanced Camera for Surveys

Wide Field and Planetary Camera 2: Introduction

More on WFPC2

Near Infrared Camera and Multi-Object Spectrometer

Space Telescope Imaging Spectrograph

Faint Object Camera

Fine Guidance Sensors

NEED MORE BACKGROUND?

Spectrum 101

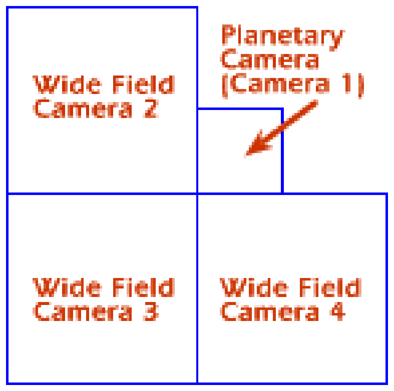
Resolution 101

More on the funny shape

FOCUS FURTHER

Space Telescope Science Institute

PIECE IT TOGETHER
(Click on squares)



Papillon Nebula

RESET

Installation of WFPC2

Why Do the Pictures Look So Funny?

The unique WFPC2 design results in the stair-step appearance of many of its images. The "heart" of WFPC2 is a trio of wide-field detectors and a high-resolution "planetary" camera. Although the planetary camera can see only a small region of the sky, it packs a punch — compacting the same number of pixels into a smaller area results in finer-detailed images. The difference between the wide-field detectors and the planetary camera is like the difference between a wide-angle lens and a telephoto lens.

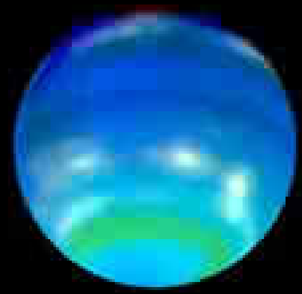
Hubble's original Wide Field and Planetary Camera was replaced with WFPC2 during the First Servicing Mission in December 1993. WFPC2 was built by the Jet Propulsion Laboratory in Pasadena, California.

TOP

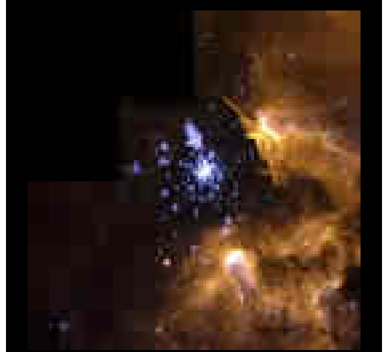
MORE COOL VIEWS FROM WFPC2

Lagoon Nebula

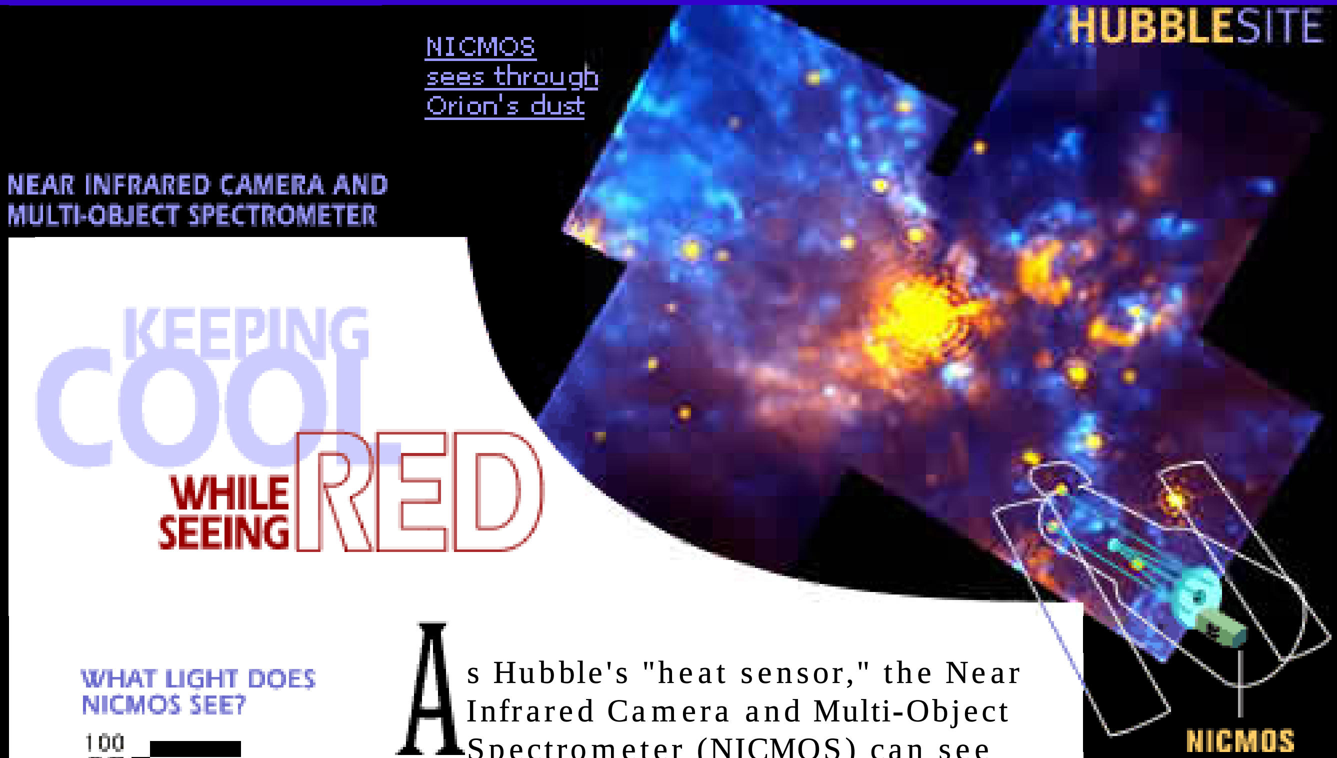
Storms on Neptune (below) and other planets



Star lifestages



NICMOS sees through Orion's dust



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Advanced Camera for Surveys

Wide Field and Planetary Camera 2

Near Infrared Camera and Multi-Object Spectrometer

Space Telescope Imaging Spectrograph

Faint Object Camera

Fine Guidance Sensors

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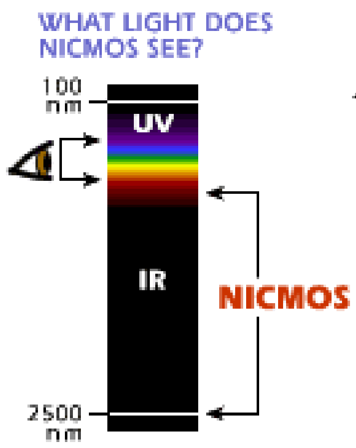
Ball Aerospace NICMOS page



As Hubble's "heat sensor," the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) can see objects in deepest space — objects whose light takes billions of years to reach us here on Earth. NICMOS allows astronomers to use Hubble's exquisite detail to open an important window of the electromagnetic spectrum.

Making the Invisible Visible

The instrument's three "cameras" — each with different fields of view — are specially designed to see objects in the near-infrared wavelengths, which are slightly longer than the wavelengths of visible light (human eyes cannot see infrared light).

Many secrets about the birth of stars, solar systems, and galaxies are revealed in infrared light, which can penetrate the interstellar gas and dust that block visible light. In addition, light from the most distant objects in the universe "shifts" into the infrared wavelengths. By studying objects and phenomena in this spectral region, astronomers probe our universe's past, present, and future, learn how galaxies, stars, and planetary systems form, and reveal a great deal about our universe's basic nature.

TOP

NICMOS's infrared detectors sit inside this chilled "thermos"

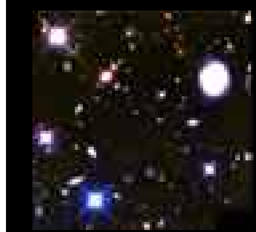
A Cool Customer

As a camera for recording visible light must be dark inside to avoid exposure to unwanted light, a camera for recording infrared light must be cold inside to avoid exposure to unwanted light in the form of heat. To make sure that NICMOS is recording infrared light from space (as opposed to heat created by its own electronics), the sensitive infrared detectors in NICMOS must operate at very cold temperatures — below –321

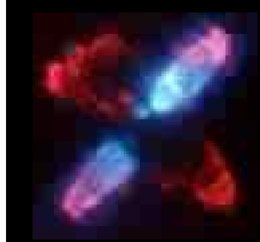
COOL VIEWS FROM NICMOS

Nebula burnout

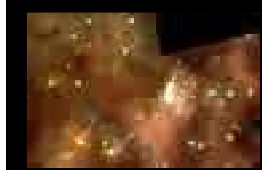
Faraway galaxies



Objects obscured by gas and dust



Newly forming stars



Uranus with actual tilt of rings

degrees Fahrenheit, or 77 degrees Kelvin.

The instrument's detectors used to be cooled inside a cryogenic dewar (a thermally insulated container much like a thermos bottle). When NICMOS was installed in 1997, the dewar contained a 230-pound block of nitrogen ice. The dewar, which successfully cooled the detectors for about two years, ran out of coolant prematurely. NICMOS will be rechilled during Servicing Mission 3B with a "cryocooler," a machine that operates much like a household refrigerator.

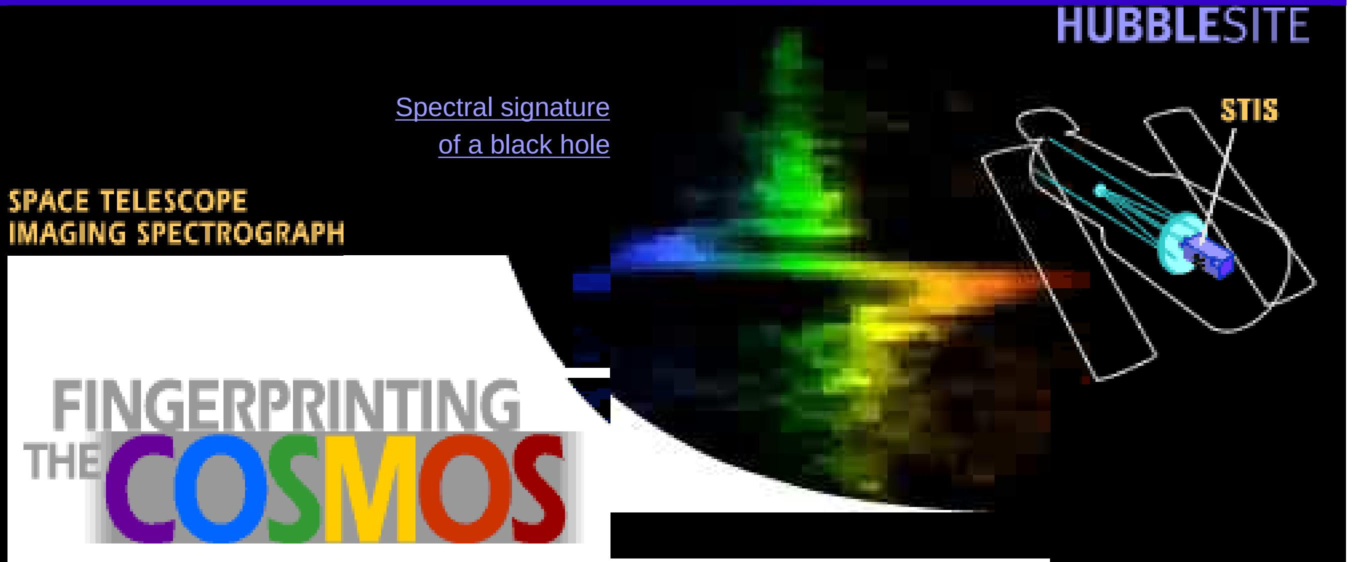
NICMOS, which was built by Ball Aerospace, was installed in the Hubble Space Telescope during the 1997 Second Servicing Mission.

Cool Views from NICMOS

• Faraway galaxies
• Objects obscured by dust and gas
• Newly forming stars and clusters
• Planetary atmospheric changes over time

TOP

Spectral signature
of a black hole



THE SCIENCE INSTRUMENTS

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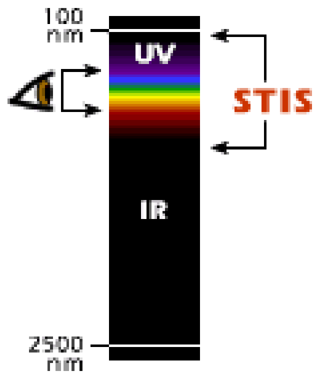
Ball Aerospace

NASA/Goddard

WHAT LIGHT DOES STIS SEE?



In addition to taking detailed pictures of celestial objects, Hubble's versatile and efficient Space Telescope Imaging Spectrograph (STIS) acts like a prism to separate light from the cosmos into its component colors. This provides a wavelength "fingerprint" of the object being observed, which tells us about its temperature, chemical composition, density, and motion. Spectrographic observations also reveal changes in celestial objects as the universe evolves. STIS spans ultraviolet, visible, and near-infrared wavelengths.

The Great Black Hole Hunter

Astronomers can use STIS to hunt for black holes. The light emitted by stars and gas orbiting the center of a galaxy appears redder when moving away from us (redshift), and bluer when coming toward us (blueshift). STIS is looking for redshifted material on one side of the suspected black hole and blueshifted material on the other, indicating that this material is orbiting an object at very high speeds.

STIS can sample 500 points along a celestial object simultaneously. This means that many regions in a planet's atmosphere or many stars within a galaxy can be recorded in one exposure, vastly improving Hubble's speed and efficiency.

STIS, which was built by Ball Aerospace, was installed in the Hubble Space Telescope during the 1997 Second Servicing Mission.

SPECTROSCOPY AT WORK

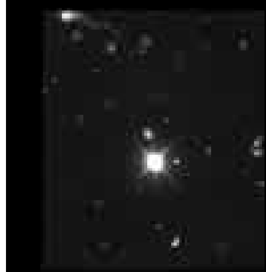
An example: Figuring out what's between here and there

TOP

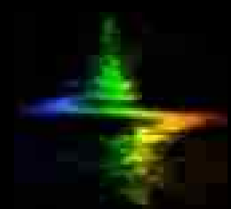
COOL VIEWS FROM STIS

Saturn's auroras

Quasar among distant galaxies



Black hole alert



THE SCIENCE INSTRUMENTS

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NEED MORE BACKGROUND?

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Resolution 101

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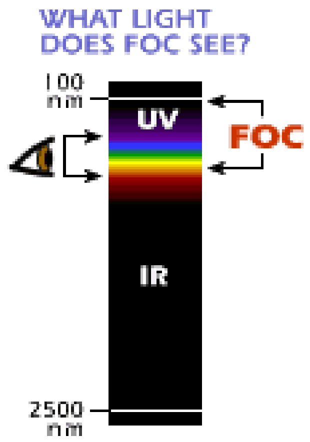
European Space Agenc

The surface of Betelgeuse

FAINT OBJECT CAMERA



The Faint Object Camera (FOC) records high-resolution images of faint celestial objects in deep space. The FOC has the sharpest vision of all the science instruments. It serves as Hubble's "telephoto lens" — recording the most detailed images over a small field of view. The FOC will be replaced with the Advanced Camera for Surveys in early 2002.

Pinpoint Accuracy

The FOC's resolution allows Hubble to single out individual stars in distant star clusters. Resolution is the ability to distinguish two points of light as separate and distinct. In space, the instrument can distinguish between objects that are 0.05 arcseconds apart — which is roughly the width of a human hair viewed from a distance of 1 kilometer. If human eyes had this ability, we would be able to distinguish between a pair of automobile headlights 5,000 miles away!

Winnowing Wavelengths

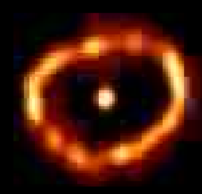
The FOC directs light down one of two optical pathways. The light enters a detector after passing through one or more filters, which permit only specific wavelengths of light to pass through. By selecting very specific wavelength ranges, scientists can look for specific features, such as the hottest stars in a particular cluster.

The detector intensifies the image and then records it, much like a video camera. Images of faint objects can be built up over long exposure times. The total image is converted into digital data, transmitted to Earth, and then reconstructed.

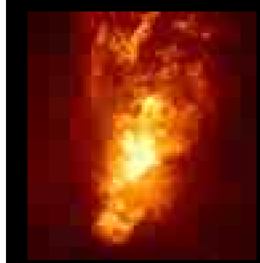
Since FOC can make high-resolution observations of faint sources at ultraviolet and visible wavelengths, in can study star clusters, examine

COOL VIEWS FROM FOC:

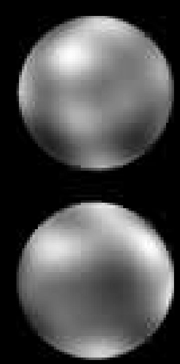
Nova



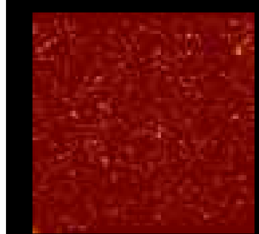
Active galaxy's core



Opposite hemispheres of Pluto



Globular Cluster



galaxies and faint objects (such as quasars), and look for small details of celestial objects. The FOC was built by the European Space Agency.

Cool Views from FOC

• Gravitationally lensed quasars
• The actual surface of a star, such as Betelgeuse
• Globular clusters
• Pluto/Charon system

TOP

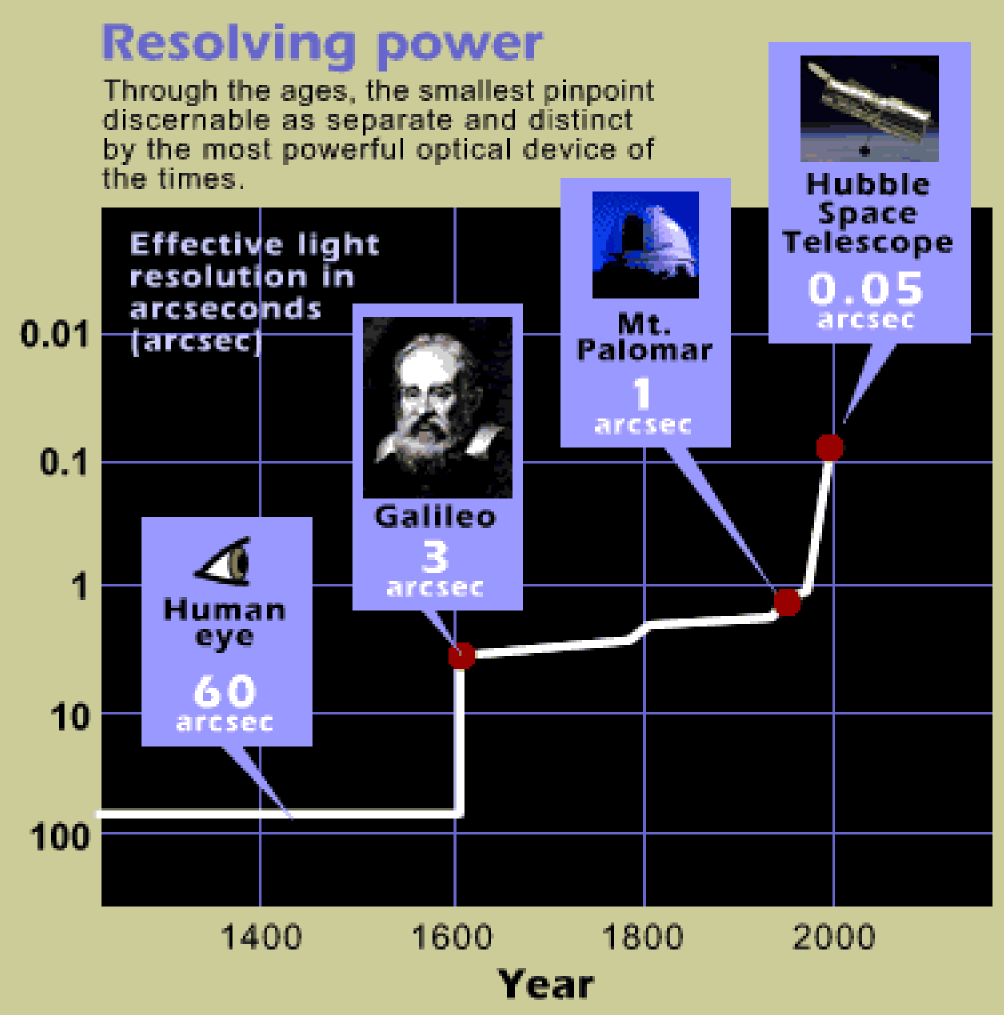
RESOLUTION 101

When astronomers talk about how clearly a telescope "sees," they are referring to its resolving power, or resolution — how fine a detail it can see or how close together two objects (such as stars) can be and still be seen as two distinct objects. Astronomers measure the resolving power of a telescope in terms of degrees. Degrees are further divided into arcminutes and arcseconds.

1 degree = 60 arcminutes = 3600 arcseconds

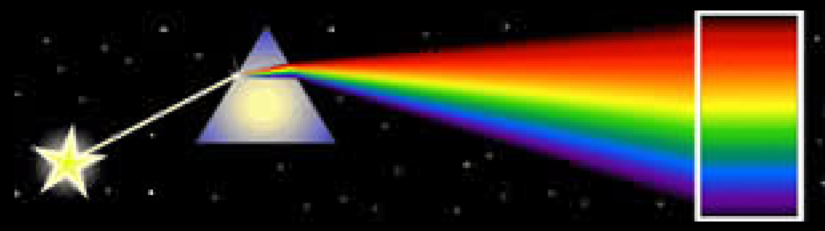
The best telescopes on the ground can rarely see detail that is less than 1 arcsecond wide or differentiate between two stars that are less than 1 arcsecond apart in the sky. This is because turbulence in Earth's atmosphere causes images to ripple and shimmer. By comparison, Hubble can see detail down to less than 0.1 arcsecond across — more than 10 times clearer. This is one of the main reasons astronomers like to use Hubble.

The full moon extends roughly 0.5 degrees (or 1,800 arcsec) across one's view of the night sky.



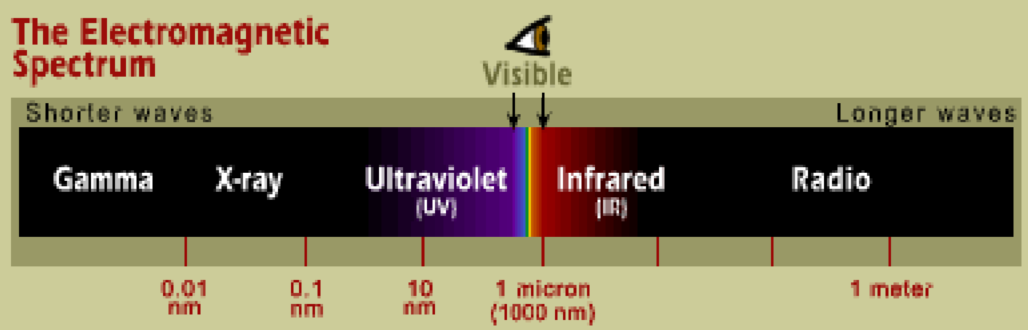
TOP

Go back



SPECTRUM 101

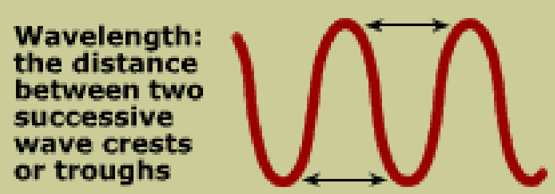
Wavelengths in nanometers
(One meter equals 1,000,000,000 nanometers. One nanometer is about the length of ten atoms in a row.)



All the information we have from the universe comes from light. White light such as starlight is made up of the individual colors of the rainbow — the visible light spectrum.

Each color of the spectrum represents a different wavelength. For example, an object that we see as red reflects the "red" wavelength of light and absorbs all the other colors of the spectrum.

TOP



Visible light is a form of electromagnetic radiation — along with radio waves, microwaves, infrared radiation, ultraviolet rays, X-rays, and gamma rays. All electromagnetic radiation travels through space at the speed of light, or 186,000 miles (300,000 km) per second.

The light we can see represents only a very small portion of the electromagnetic spectrum. On one end of the spectrum are radio waves having wavelengths billions of times longer than those of visible light. On the other end of the spectrum are gamma rays, with wavelengths millions of times smaller than those of visible light. Wavelength is directly related to the amount of energy the waves carry. The shorter

Filters

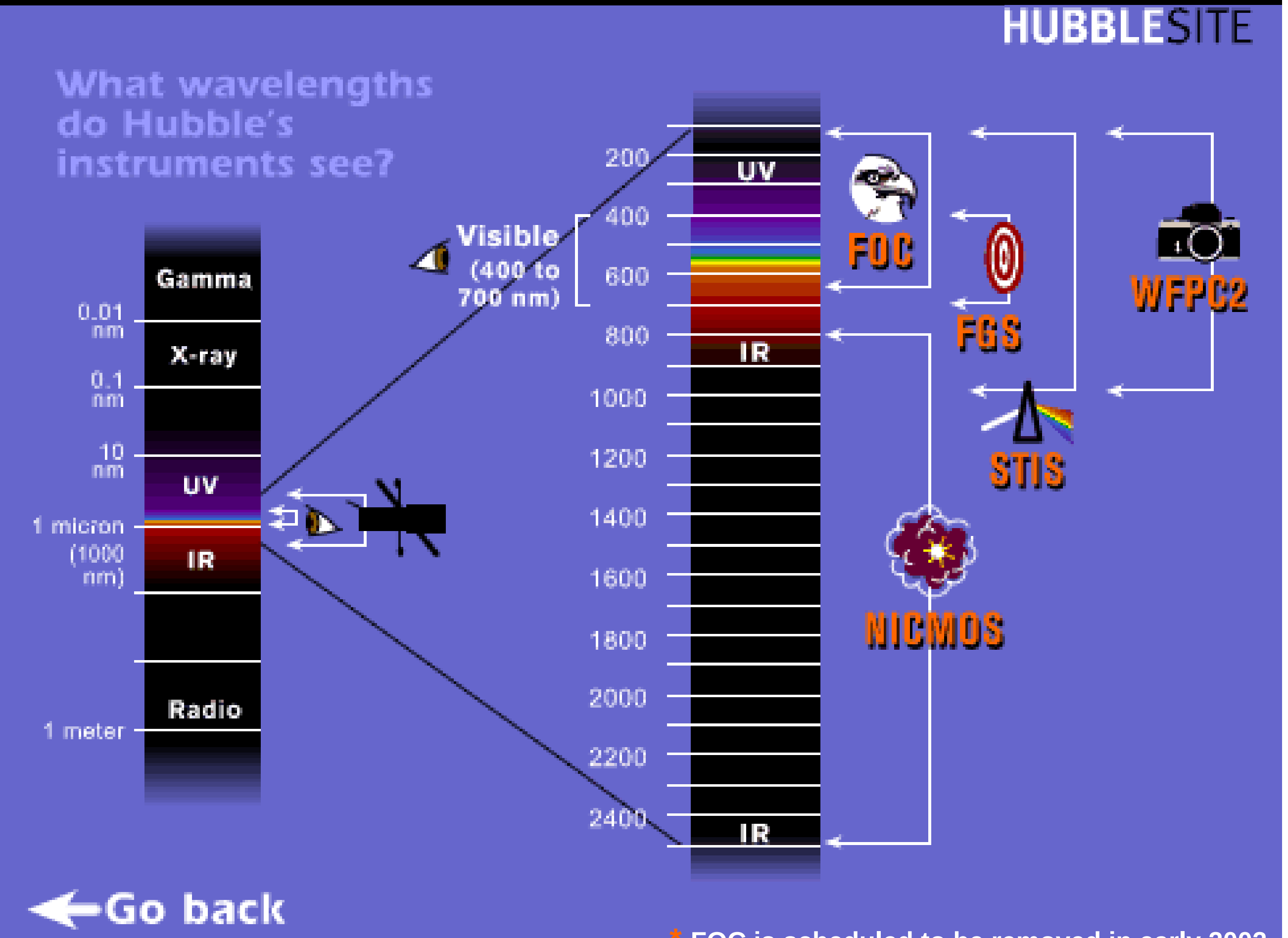
There are different ways to isolate different types of light. For example, although our eyes cannot see ultraviolet light from a star, one way to gain a record of it is to let the star's light pass through a filter and then fall on a special detector.

Hubble uses special filters to "screen out" the types of light from an object that astronomers are not currently studying. These filters allow only a certain range of light wavelengths through. Once the unwanted light has been filtered out, the resulting light is allowed to fall onto one or more light-sensitive detectors.

This produces a "picture" of the star in the selected wavelength. Since the detectors can detect light outside the visible light spectrum, the use of filters allows scientists to see "invisible" objects — those only visible in ultraviolet and infrared wavelengths.

the radiation's wavelength, the higher its energy.

Wavelengths in nanometers
(One meter equals 1,000,000,000 nanometers. One nanometer is about the length of ten atoms in a row.)

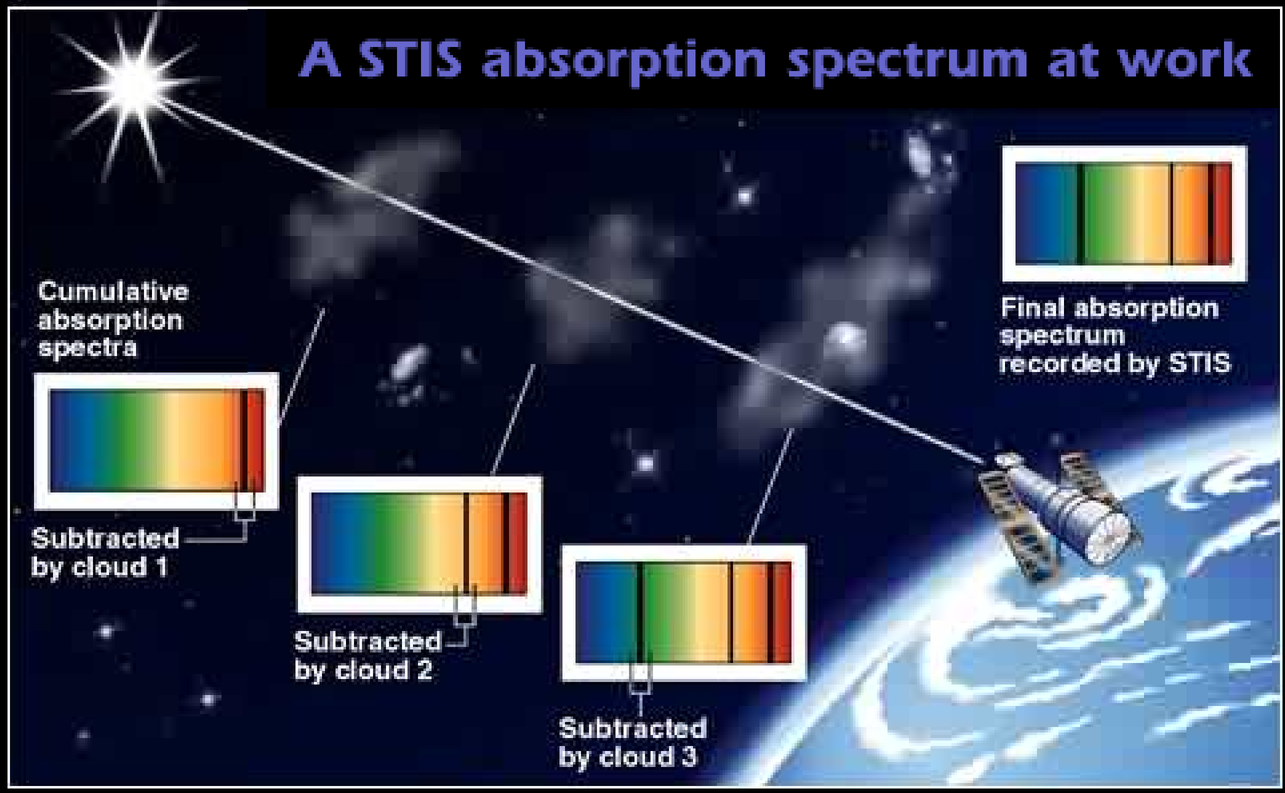


* FOC is scheduled to be removed in early 2002.

NEED MORE BACKGROUND?

Spectrum 101

The Instruments Defined



Go back

A beam of light coming to Earth from a distant quasar passes through numerous intervening gas clouds in galaxies and in intergalactic space. These clouds subtract specific colors from the beam. The resulting composite "absorption spectrum" is used to determine the distances and chemical composition of the invisible clouds.

TEAM Hubble

Servicing Mission 2

Operations

Servicing Missions

Servicing Mission 1

Servicing Mission 2

Servicing Mission 3A

Servicing Mission 3B

Duty Roster

The crew of STS-82

Expanding Hubble's Universe

There is no question that Hubble's "first generation" cameras gave us remarkable views of very distant galaxies. But the light from the most distant galaxies is shifted to infrared wavelengths by the expanding universe. To see these galaxies, Hubble needed to be fitted with an instrument that could observe infrared light.


The Hubble Space Telescope is temporarily latched to space shuttle Discovery's payload bay.


Astronaut Mark Lee (top) performs a patching task on Hubble's worn insulation material.

During the 10-day Second Servicing Mission (STS-82) in February 1997, the seven astronauts aboard the space shuttle Discovery installed two technologically advanced instruments. The Near Infrared Camera and Multi-Object Spectrometer (NICMOS) would be able to observe the universe in the infrared wavelengths. The second instrument—the versatile Space Telescope Imaging Spectrograph (STIS)—would be used to take detailed pictures of celestial objects and to hunt for black holes.

Both instruments had optics that corrected for the flawed primary mirror. In addition, they featured technology that wasn't available when scientists designed and built the original Hubble instruments in the late 1970s—and opened up a broader viewing window for Hubble.

The new instruments replaced the Goddard High Resolution Spectrograph and the Faint Object Spectrograph.

See Also:

Spectrum 101

NICMOS

STIS

top


Astronaut Steve Smith picks up a power ratchet tool as he prepares to join astronaut Mark Lee on the first spacewalk.

Also installed during the Second Servicing Mission were:

- A refurbished Fine Guidance Sensor—one of three essential instruments used to provide pointing information for the spacecraft, to keep it pointing on target, and to calculate celestial distances
- A Solid State Recorder (SSR) to replace one of Hubble's data recorders (An SSR is more flexible and can store 10 times more data)
- A refurbished, spare Reaction Wheel Assembly—part of the Pointing Control Subsystem.


Astronauts Mark Lee (in foreground) and Steve Smith setting up a spacewalk.

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NEXT:
Servicing Mission 3A >>

HUBBLESITE

TEAM Hubble

Operations

Servicing Missions

Duty Roster


STScI employees review the observation schedule. (Photo by John Dean)

THE HUBBLE PROJECT GODDARD SPACE FLIGHT CENTER
World Class Teamwork

Behind the Scenes: Team Hubble

Gathering images from space is more than a "point and shoot" proposition. The Hubble Space Telescope explores our universe 24 hours a day, 365 days a year. Operating and maintaining such a tireless observatory and converting its raw data (digital signals) into images requires considerable effort from the people on the ground.

NEXT>>

Now Featured:

Find out who's in the driver's seat with this peek behind the scenes at **Hubble's Operations**

Find out how Team Hubble pulls it all together to bring you those unprecedented views of the cosmos.

TEAM Hubble Operations

Operations

Hubble Ground Control

Astronomers Compete for a Peek at the Cosmos

Ready, Aim... Observe!

The Data Dance

Servicing Missions

Duty Roster

"Taking" a Hubble image is a complex process ranging from choosing who will observe what to making pictures out of digital data.

Operating Hubble

Goddard headquarters in Greenbelt, MD

Hundreds of scientists, engineers, and technicians—at both NASA's Goddard Space Flight Center and the Space Telescope Science Institute (STScI)—bear the collective responsibility for operating the Hubble Space Telescope and for monitoring its health, safety, and performance. Specific tasks range from choosing targets to performing on-orbit upgrades.

Space Telescope Science Institute in Baltimore, MD

Hubble mission operations fall into two categories:

Engineering operations, which test and maintain the Hubble spacecraft's overall performance.

Science operations, which select and schedule observing programs, prepare and conduct observations, calibrate the science instruments, translate raw data into usable form, and archive and distribute data.

top

NEXT: Hubble Ground Control >>

HUBBLESITE

TEAM Hubble

Hubble Ground Control

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Hubble Control Room

All of the Hubble Space Telescope's activities are controlled by people on the ground. The focal point of all Hubble operations is the Flight Operations Team, which is located at the Space Telescope Science Institute in Baltimore, Maryland. Here Hubble's controllers monitor the telescope's health while they direct its movements and science activities. The controllers direct Hubble's movements by sending commands via satellite to the telescope's onboard computer. They interact in real time with the spacecraft, telling it what to do and when to do it.

Flight Operations Tasks

- Establish the status of systems (mechanical, electrical, and data management) and subsystems
- Look for unusual things in Hubble's behavior
- Route commands generated onboard or received from the ground
- Manage communications
- Perform guide star acquisitions (point the telescope)

Hubble's flight operations facility operates 24 hours a day, 7 days a week. The specially trained engineers and technicians who comprise the Flight Operations Team work rotating shifts, with 3 to 4 people on each shift. A typical day involves commanding and pointing the telescope, monitoring its behavior on consoles, and looking for anything unusual in the technical sense.

The ground controllers become even busier than usual during Hubble servicing missions. Shortly after the shuttle is launched, the controllers instruct Hubble to stop normal science operations. To prepare the huge telescope for rendezvous and capture, they command Hubble's aperture door to close and its high gain antennas to be stowed. After capture, as the astronauts install new equipment on Hubble, the controllers immediately test the updates. Later, while the crew sleeps, controllers perform more detailed checkouts. At the end of each servicing mission, the Flight Operations Team deploys Hubble's high gain antennas and opens its aperture door. They then reactivate all Hubble equipment powered off during the servicing call.

See Also:

Pointing Hubble

Hubble's Instruments

top

NEXT: Astronomers Compete >>

Team Hubble Astronomers Compete...

Operations

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Astronomers Compete for a Peek at the Cosmos

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STScI employees review the observation schedule
(Photo by John Dean)

... for a Peek at the Cosmos

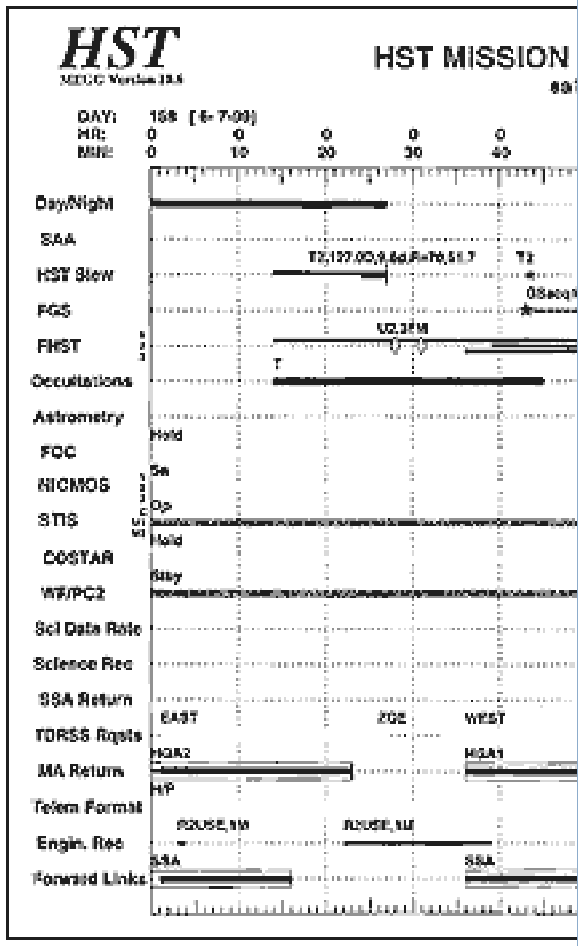
Each year astronomers from dozens of countries vie for precious minutes of Hubble's unrivaled view of the cosmos. Scheduling of the viewing time falls to staff at the Space Telescope Science Institute (STScI) in Baltimore, Maryland.

Astronomers from around the world submit observing proposals to the STScI. A review committee made up of experts from the astronomical community then determines which proposed observations address pressing scientific questions and make the best use of the telescope's capabilities. Each year more than 1,000 proposals are reviewed and approximately 200 to 300 are selected, which represents roughly 20,000 individual observations.

Each year more than 1,000 proposals are reviewed and 300 are selected, which represents roughly 20,000 individual observations.

top

Once a proposal is accepted, the observation is carefully planned—along with thousands of others—for the most appropriate viewing time. Planning viewing time is tricky because there are certain times of the year during which the Earth's revolution around the Sun causes a "geometry" in which the target is too close to the Sun to be observable.



Consequently, technicians must schedule each observation down to a fraction of a second. Observation information

See Also:

The Duty Roster

Hubble's Instruments

such as which instrument to use, what filter to use, and how long the exposure should be must be converted into a detailed technical list of second-by-second instructions. These instructions are loaded onto the telescope's computers a few days before the scheduled observation.

A miniscule portion of the HST schedule

top

Next: Ready, Aim...Observe! >>

TEAM Hubble

Ready, Aim...Observe!

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The Data Dance

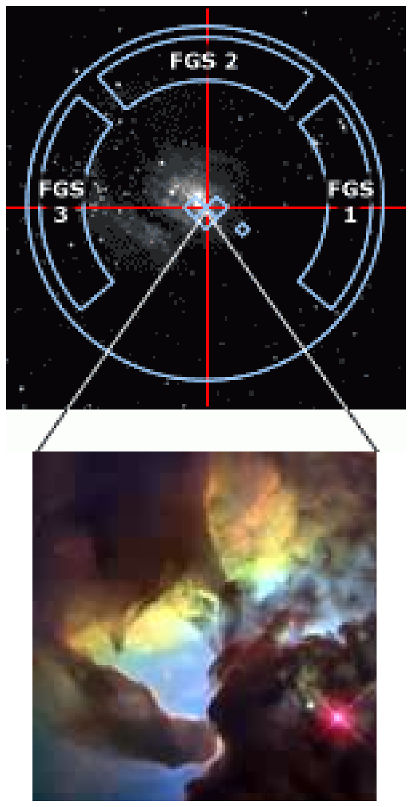
Servicing Missions

Duty Roster

Imagine trying to take a picture of someone from a seat on a moving Ferris wheel. You'd have a hard time keeping that person in the camera's field of view. Astronomers using Hubble have to take this concept to the extreme. Their "camera" is revolving around Earth at 17,500 mph... and the Earth is moving around the Sun at 67,000 mph. First they must pinpoint a tiny target's exact location in the vast sky... and then keep the object within the telescope's field of view.

HST orbits above Earth's atmosphere.

Pointing the Hubble and locking on to distant celestial targets is like holding a laser light steady on a dime that is 200 miles away.



The stars that fall within the three FGS "pickles" (curved boxes) helped aim the telescope when it took this picture of the Lagoon Nebula

To do this, a pair of "guide stars" are selected whose apparent positions are near the science target. The guide stars are selected from the Space Telescope Science Institute's Guide Star Catalog, which lists the brightness and positions of 15 million stars. These guide stars help center the target in the telescope's field of view.

Guide star information is combined with the detailed observation instructions and transmitted to Hubble's onboard computers via satellite. The telescope's computers send the data to the Fine Guidance Sensors, which search for the guide stars—"lock on" to them—and maintain the precise pointing and alignment needed for a Hubble observation.

The images and data that Hubble gather during an observation are usually stored on an onboard data recorder, or occasionally are beamed directly back to Earth. Information from the data recorder is transmitted back to Earth several times a day.

See Also:

Pointing Hubble

FGS

Team Hubble — The Data Dance

Hubble's Operations

Hubble Ground Control

Astronomers Compete for a Peek at the Cosmos

Ready, Aim... Observe!

The Data Dance

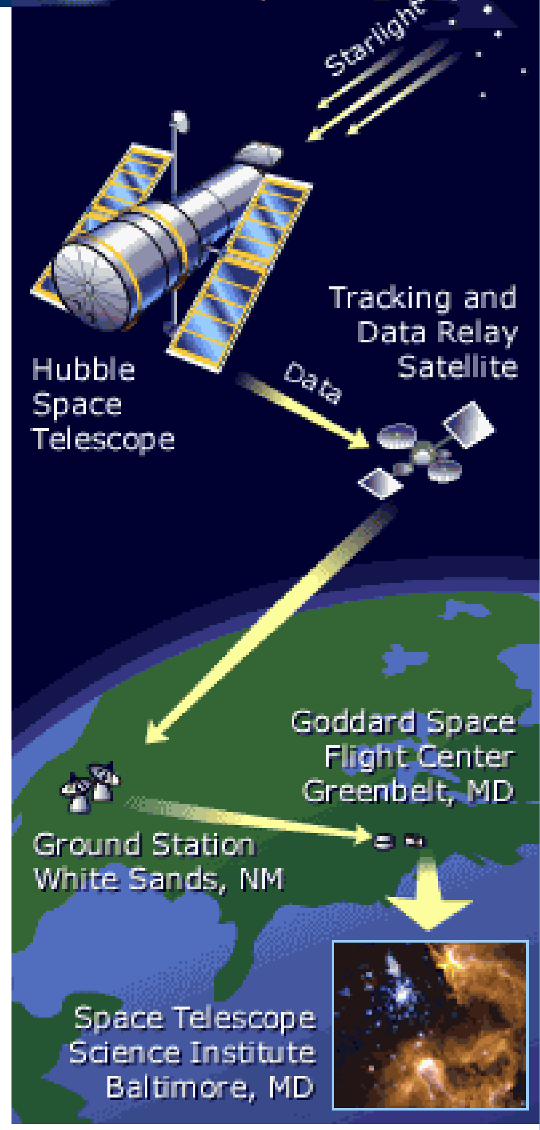
Servicing Missions

Duty Roster

Images and data collected by the orbiting Hubble Space Telescope travel 90,000 miles over satellite and ground links before they finally reach the Institute in Baltimore, Maryland.

The raw data collected by the telescope have a long way to go before they become actual Hubble images. As Hubble completes a particular observation, it converts the starlight into digital signals. The digital signals are then relayed down to a ground station at White Sands, New Mexico through one of five orbiting Tracking and Data Relay Satellites (TDRS). The ground station then relays the data to Goddard Space Flight Center's ground control system, where staff ensure its completeness and accuracy.

top



Path that Hubble data must travel before becoming an image

Optical disk
(Photo by John Dean)

Goddard then sends the data via data lines to the Space Telescope Science Institute for processing and calibration. Institute personnel translate the data into scientifically meaningful units—such as wavelength or brightness—and archive the information on 12-inch optical disks. The archive makes available for retrieval over 100,000 observations of more than 20,000 celestial targets. Astronomers can download archived data via Internet and analyze it from anywhere in the world.

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NEXT: Servicing Missions Make Hubble Even Better >>

TEAM Hubble Servicing Missions

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Servicing Missions

Servicing Mission 1

Servicing Mission 2

Servicing Mission 3A

Servicing Mission 3B

Duty Roster

Astronauts Smith (left) and Lee (right) try out the Remote Manipulator System (RMS) arm.

Crew of the space shuttle Endeavour (STS-61)

Making Hubble Even Better

The Hubble Space Telescope is both a national asset and a complex machine, so NASA astronauts visit it regularly to keep it running smoothly and extend its life. On-orbit servicing ensures that this unique scientific resource will continue making exciting discoveries in our exploration of the universe.

Shuttle astronauts visit the Hubble Space Telescope approximately every three years. During these service calls they replace gyroscopes, electronic boxes, and other limited-life items and install state-of-the-art science instruments—creating, essentially, a more capable observatory.

Because the Hubble Space Telescope was designed for periodic servicing, the items to be replaced are easily accessible. Ranging in size from a shoebox to a telephone booth, most of these items can be removed or installed using special wrenches and power tools.

Additional servicing missions will ensure Hubble's health and productivity into the 21st century.

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Next:
Servicing Mission 1 >>

Shuttle flights enable on-orbit repairs and instrument upgrades.

THE HUBBLE PROJECT
GODDARD SPACE FLIGHT CENTER

Team Hubble Duty Roster

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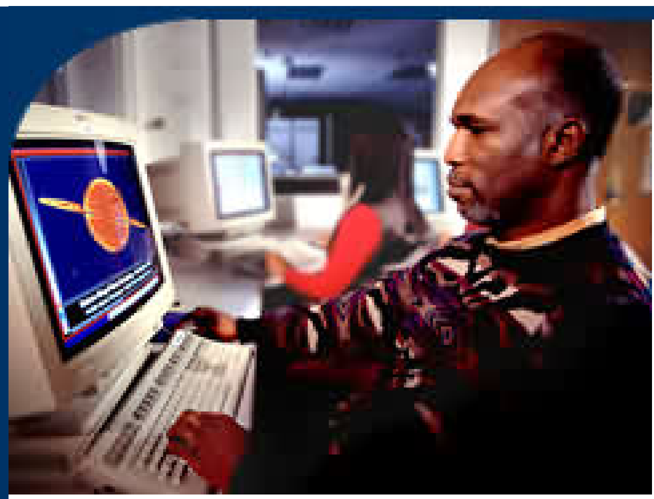


Many people are involved in making Hubble work.
(Photo by John Dean)

Team Hubble is an international collaboration of scientists, engineers, technicians, instrument builders and designers, and computer experts. These dedicated people come from universities and other academic organizations, national space agencies, government, and private industry.

See Also:

STScI

AURA

ESA

CSC

Lockheed Martin

Allied Signal

Hubble's engineering operations—the testing and maintenance of the spacecraft's overall performance—are conducted by NASA's Goddard Space Flight Center in Greenbelt, MD.

Hubble's flight and science operations, which include steering, conducting observations, and translating raw data into the telescope's images, are led by staff at the Space Telescope Science Institute (STScI) in Baltimore, MD. STScI's work is managed for NASA by the Association of Universities for Research in Astronomy, Inc. (AURA), an international group of 31 educational and nonprofit organizations.

STScI's 400-member Hubble team represents a collaboration between AURA and the European Space Agency (ESA), as well as several industry collaborators such as Computer Sciences Corporation (CSC), Lockheed Martin, and Honeywell.

top

Additional Team Hubble Players

Acton Research Corporation

Aliant Tech Systems

Applied Aerospace Structure

Ball Aerospace

BARR Associates

BDM International

Boeing

BP Chemicals

Crystal Systems

Global Science & Technology

Goddard Space Flight Center

Jet Propulsion Laboratories

Johns Hopkins University

Mantech Engineering Systems

Marlow Industries

Mega Engineering

OPTOVAC

Orbital Sciences

Paramax

Raytheon Optical Systems

Richardson Grating Labs

THE HUBBLE PROJECT GODDARD SPACE FLIGHT CENTER
The Engineering Team

Scientific Imaging Technologies

Speedring, Inc.

Sterling Optics

Swales & Associates

Tifco, Inc.

Tinsley Laboratory

Unisys

University of Arizona

University of Colorado

University of Wisconsin

Vanley-Fisher

Vermitron, Inc.

(Photo by John Dean)

Team Hubble Servicing Mission 1

Operations

Servicing Missions

Servicing Mission 1

Servicing Mission 2

Servicing Mission 3A

Servicing Mission 3B

Duty Roster

The crew of STS-61.

See Also:

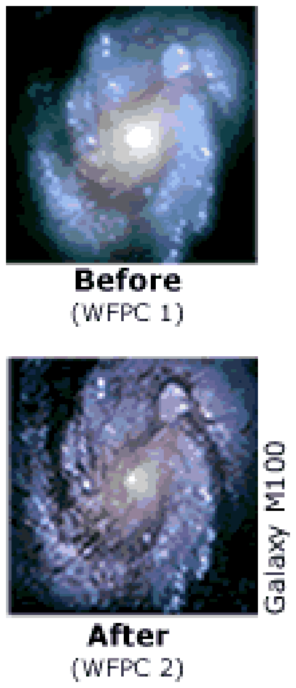
WFPC2

COSTAR

Restoring Hubble's Vision

Astronaut Kathryn Thornton lifts COSTAR prior to its installation.

As the first in a series of planned visits to the orbiting Hubble Space Telescope, the First Servicing Mission (STS-61) in December 1993 had a lot to prove and a lot to do. The mission's most important objective was to install two devices to fix Hubble's vision problem. Because Hubble's primary mirror was incorrectly shaped, the telescope could not focus all the light from an object to a single sharp point. Instead, it saw a fuzzy halo around objects it observed.



Once astronauts from the space shuttle Endeavour caught up with the orbiting telescope, they hauled it into the shuttle's cargo bay and spent five days tuning it up. They installed two new devices—the Wide Field and Planetary Camera 2 (WFPC2) and the Corrective Optics Space Telescope Axial Replacement (COSTAR). Both WFPC2 and the COSTAR apparatus were designed to compensate for the primary mirror's incorrect shape.

Once Hubble received its corrective "eyeglasses," it began seeing more clearly.

top

Astronaut Jeffrey Hoffman removing WFPC1 during changeout operations.

Also installed during the First Servicing Mission were:

- New solar arrays to reduce the "jitter" caused by excessive flexing of the solar panels during the telescope's orbital transition from cold darkness into warm daylight
- New gyroscopes to help point and track the telescope, along with fuse plugs and electronic units.

Astronaut Hoffman (right), anchored on the end of the RMS arm, holds onto WFPC1 during the third spacewalk.

This successful mission not only improved Hubble's vision — which led to a string of remarkable discoveries in a very short time — but it also validated the effectiveness of on-orbit servicing.

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NEXT:
Servicing Mission 2 >>

TEAM Hubble

Servicing Mission 3A

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Servicing Mission 3A

Servicing Mission 3B

Duty Roster

The crew of STS-103

Long Distance House Call

On December 19, 1999, seven astronauts boarded the space shuttle Discovery to pay the Hubble Space Telescope a special holiday visit. After a successful launch and several trips around Earth, the crew caught up with Hubble and hauled it into the shuttle's cargo bay. Six days and three 6-hour spacewalks later, the crew had successfully completed Part A of the two-part Third Servicing Mission, which had them replacing worn or outdated equipment and performing several critical maintenance upgrades.

Astronauts Smith and Grunsfeld on the shuttle's robotic arm.

NASA had originally planned 4 days of spacewalks, but condensed the mission to 3 days because of a weather-delayed launch. The deorbit (return to Earth) time was fixed for this mission in order to avoid any possible Y2K problems.

One of the three spacewalks.

Servicing Mission 3A (STS-103) was a busy one. The most pressing task was the replacement of gyroscopes, which accurately point the telescope at celestial targets. The crew, two of whom were Hubble repair veterans, replaced all six gyroscopes-as well as one of Hubble's three fine guidance sensors (which allow fine pointing and keep Hubble stable during observations) and a transmitter.

See Also:

Gyroscopes

Hubble's Computers

Fine Guidance Sensors

Servicing Mission 3A

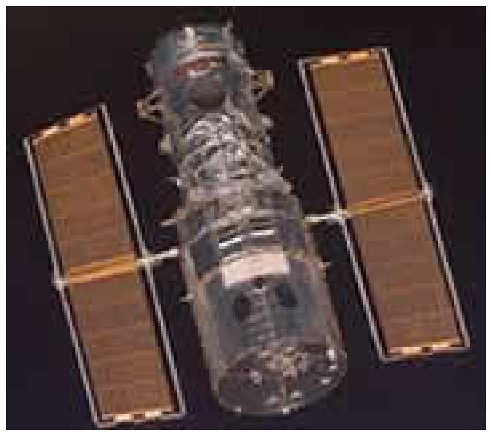

A successful mission!

The astronauts also installed an advanced central computer, a digital data recorder, an electronics enhancement kit, battery improvement kits, and new outer layers of thermal protection. Hubble was as good as new.


Replacing Hardware is tricky at zero gravity.

The Discovery crew deployed Hubble back into orbit on Christmas Day and returned to Earth, landing safely on December 27. Once the mission ended, scientists "turned on" the telescope's science instruments, which were taken offline during the servicing mission, and took "test" pictures to make sure the instruments were functioning properly.

top


Overall view of Hubble

Why the Rush?
NASA decided to split the Third Servicing Mission (SM3) into two parts, SM3A and SM3B, after the third of Hubble's six gyroscopes failed (Hubble needs three gyroscopes to observe a target). The second part of the mission, SM3B, is tentatively scheduled for mid-2001.

On November 13, 1999, the Hubble Space Telescope was placed into "safe-mode" after the failure of a fourth gyroscope. In safe-mode Hubble could not observe targets, but its safety was preserved. This protective mode allows ground control of the telescope, but with only two gyros working, Hubble cannot be aimed with the precision necessary for scientific observations of the sky. Controllers closed the aperture door to protect the optics and aligned the spacecraft to ensure that Hubble's solar panels would receive adequate power from the sun.

NEXT:
Servicing Mission 3B >>

Team Hubble Servicing Mission 3B

Operations

Servicing Missions

Servicing Mission 1

Servicing Mission 2

Servicing Mission 3A

Servicing Mission 3B

Duty Roster

Better Than Ever

On February 28, 2002, NASA will launch the space shuttle Columbia into an orbit 360 miles above Earth, where its seven-member crew will rendezvous with the Hubble Space Telescope and perform a series of upgrades. Servicing Mission 3B, also known as STS-109, will be the fourth visit to Hubble. NASA split the original Servicing Mission 3 into two parts and conducted the first part – Servicing Mission 3A – in December 1999.

The crew of Servicing Mission 3B and an artist's rendition of Hubble with its new solar panels installed.

Advanced Camera for Surveys
This technologically-advanced science instrument will produce larger, more detailed images of our universe.

A Bigger, Sharper View

The highly-trained astronauts will perform five spacewalks over 11 days. Their principal task is to install a new science instrument called the Advanced Camera for Surveys, or ACS. The first new instrument to be installed in Hubble since 1997, ACS will bring the nearly 12-year-old telescope into the 21st century. With its wide field of view, sharp image quality, and enhanced sensitivity, ACS will double Hubble's field of view and collect data ten times faster than the Wide Field and Planetary Camera 2, which is the telescope's current surveying instrument.

See Also:

Servicing Mission 3A

Solar Arrays

WFPC2

NICMOS

Reaction Wheels

Pointing Control System

A More Efficient Power System

Hubble gets its power from four large flexible solar array panels. The current 8-year-old panels will be replaced by smaller rigid ones that produce 30 percent more power. Astronauts will also replace the outdated Power Control Unit, which distributes electricity from the solar arrays and batteries to other parts of the telescope. Replacing the original unit, which has been on the job for nearly 12 years, will require the telescope to be completely powered down for the first time since its launch in 1990.

top

Restoring Hubble's Infrared Vision


NICMOS Cooling System
An experimental refrigeration technology will make it possible to restore Hubble's infrared vision.

During the last spacewalk astronauts will install a new cooling system for the Near Infrared Camera and Multi-Object Spectrometer, or NICMOS, which became inactive three years ago when it depleted the 230-pound block of nitrogen ice that had cooled it since 1997. The new refrigeration system, which works much like a household refrigerator, will chill NICMOS's infrared detectors to below –315° F (–193° C). Technicians on the ground will then reactivate the instrument.


Reaction Wheel Assembly
Four Reaction Wheel Assemblies like this one are needed to point the telescope. Astronauts will replace one of them.

New Steering Equipment

Astronauts will replace one of the four reaction wheel assemblies that make up Hubble's pointing control system. Flight software commands the reaction wheels "steer" the telescope by spinning in one direction, which causes Hubble to spin in the other direction.

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NEXT: Duty Roster >>

Team Hubble

Duty Roster

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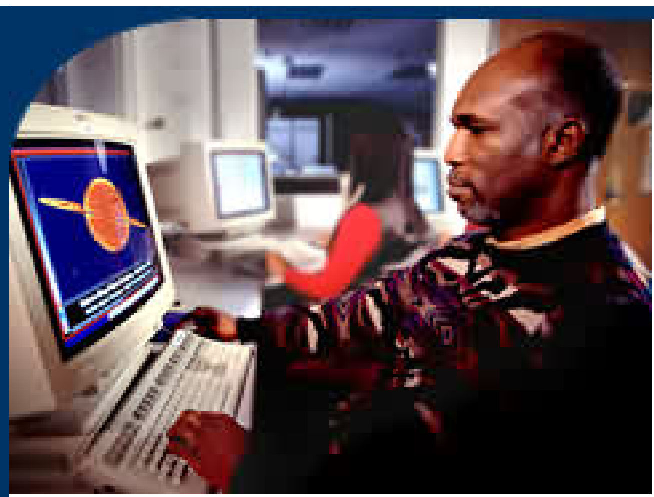
Duty Roster



Many people are involved in making Hubble work.
(Photo by John Dean)

Team Hubble is an international collaboration of scientists, engineers, technicians, instrument builders and designers, and computer experts. These dedicated people come from universities and other academic organizations, national space agencies, government, and private industry.

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top

See Also:

STScI

AURA

ESA

CSC

Lockheed Martin

Allied Signal

THE HUBBLE PROJECT GODDARD SPACE FLIGHT CENTER

The Engineering Team

Additional Team Hubble Players

- Acton Research Corporation
- Aliant Tech Systems
- Applied Aerospace Structure
- Ball Aerospace
- BARR Associates
- BDM International
- Boeing
- BP Chemicals
- Crystal Systems
- Global Science & Technology
- Goddard Space Flight Center
- Jet Propulsion Laboratories
- Johns Hopkins University
- Mantech Engineering Systems
- Marlow Industries
- Mega Engineering
- OPTOVAC
- Orbital Sciences
- Paramax
- Raytheon Optical Systems
- Richardson Grating Labs

(Photo by John Dean)

Scientific Imaging Technologies

Speedring, Inc.

Sterling Optics

Swales & Associates

Tifco, Inc.

Tinsley Laboratory

Unisys

University of Arizona

University of Colorado

University of Wisconsin

Vanley-Fisher

Vermitron, Inc.

EYEGLASSES FOR HUBBLE

COSTAR being installed

Hubble's Amazing Optics

The Optical Telescope Assembly

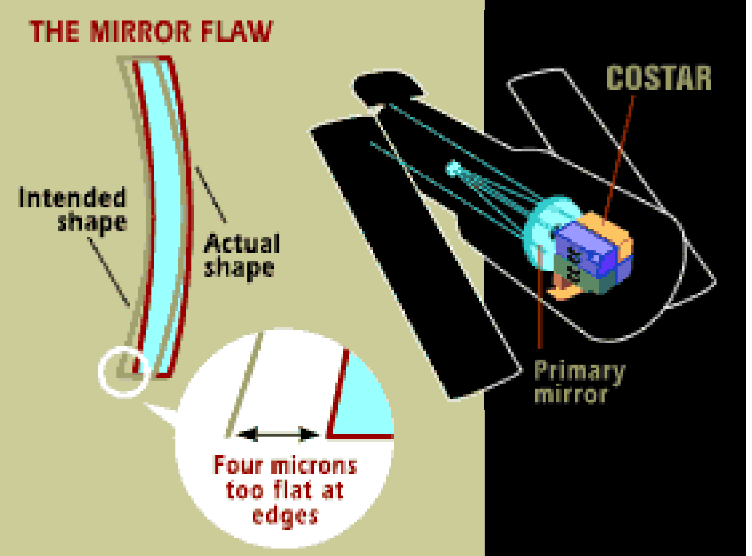
COSTAR: Glasses for Hubble

BEFORE AND AFTER COSTAR

FOCUS FURTHER

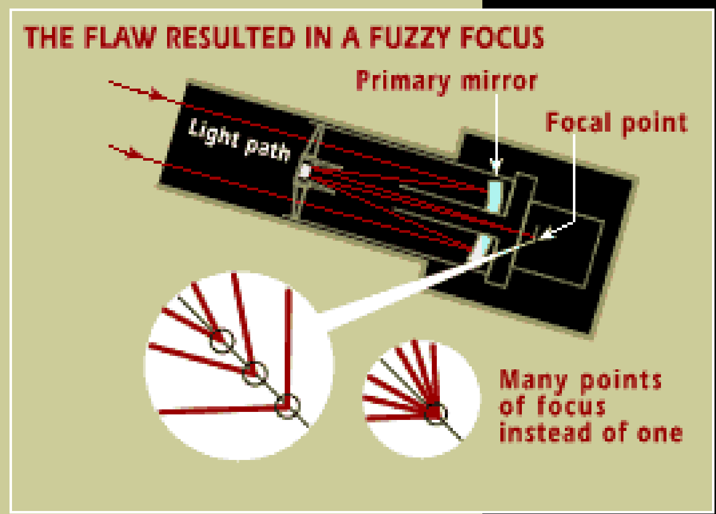
Ball Aerospace

Soon after Hubble began sending images from space, scientists discovered that the telescope's primary mirror had a flaw called spherical aberration. The outer edge of the mirror was ground too flat by a depth of 4 microns (roughly equal to one fiftieth the thickness of a human hair). The flaw resulted in images that were fuzzy because some of the light from the objects being studied was being scattered.



After this discovery, scientists and engineers developed corrective optics that functioned like eyeglasses to restore Hubble's vision. The optics of the Wide Field and Planetary Camera 2, which was already under construction when the problem was discovered, were changed to correct for spherical aberration.

The original science instruments on Hubble were fixed using the Corrective Optics Space Telescope Axial Replacement (COSTAR) apparatus, which was installed during the 1993 First Servicing Mission. By placing small and carefully designed mirrors in front of these instruments, COSTAR successfully improved their vision to their original design goals.

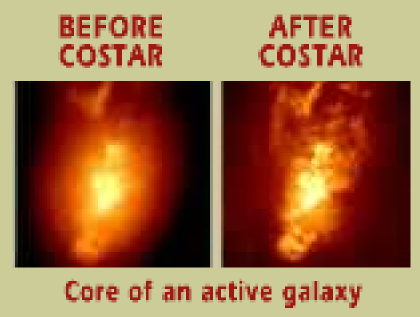


All the instruments installed during the Second Servicing Mission have internal corrections for spherical aberration, as will all instruments installed in the future. Once COSTAR is no longer needed (after Servicing Mission 3B in early 2002), it will be removed from

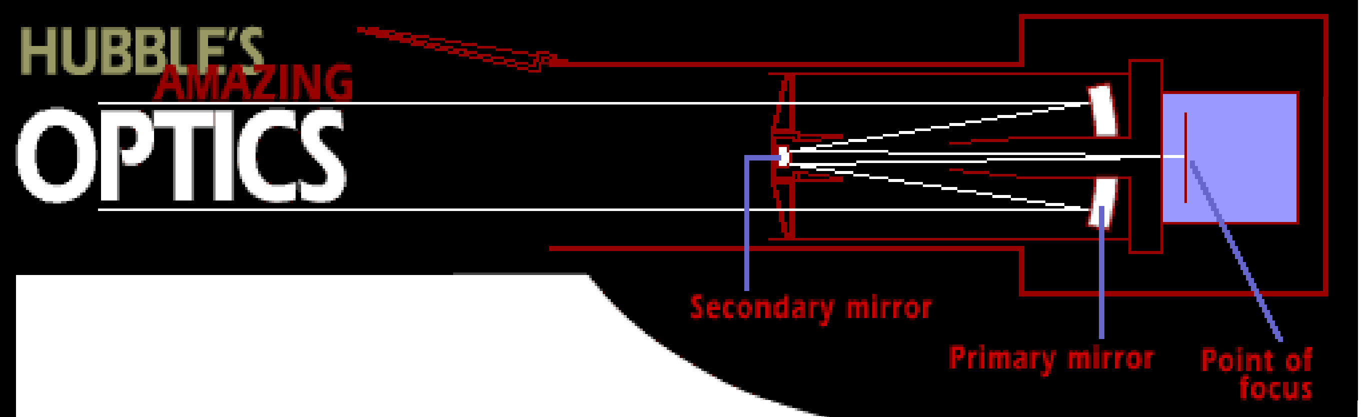
Hubble.

The COSTAR apparatus was built by Ball Aerospace.

TOP



HUBBLESITE



Hubble's Amazing Optics

The Optical Telescope Assembly

COSTAR: Glasses for Hubble

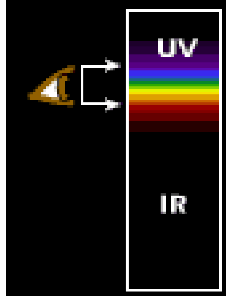
Primary mirror before installation

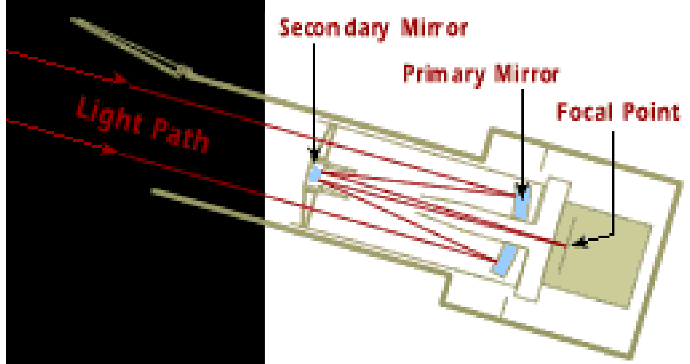
What gives Hubble such remarkable eyesight? What makes its pictures of distant objects so sharp? Its position above Earth's atmosphere — although clearly advantageous — is only part of the answer. Without powerful eyesight, Hubble would not be able to take full advantage of its unique location.

Hubble's "eyes" are actually a system called the Optical Telescope Assembly. That system consists of two mirrors, support trusses, and the apertures (openings) of the instruments. Hubble's optical system is a straightforward design known as Ritchey-Chretien Cassegrain, in which two special mirrors form focused images over the largest possible field of view.

Resolution 101

What light does Hubble see?





Light Path

Incoming light travels down a tube fitted with baffles that keep out stray light. The light is collected by the concave (curved inward, like a bowl) primary mirror and reflected toward the smaller, convex (curved outward, like a dome) secondary mirror. The secondary mirror bounces the light back toward the primary mirror and through a hole in its center. The light is then focused on a small area called the focal plane, where it is picked up by the various science instruments.

TOP

Cleanroom inspection of primary mirror

Mirror Quality

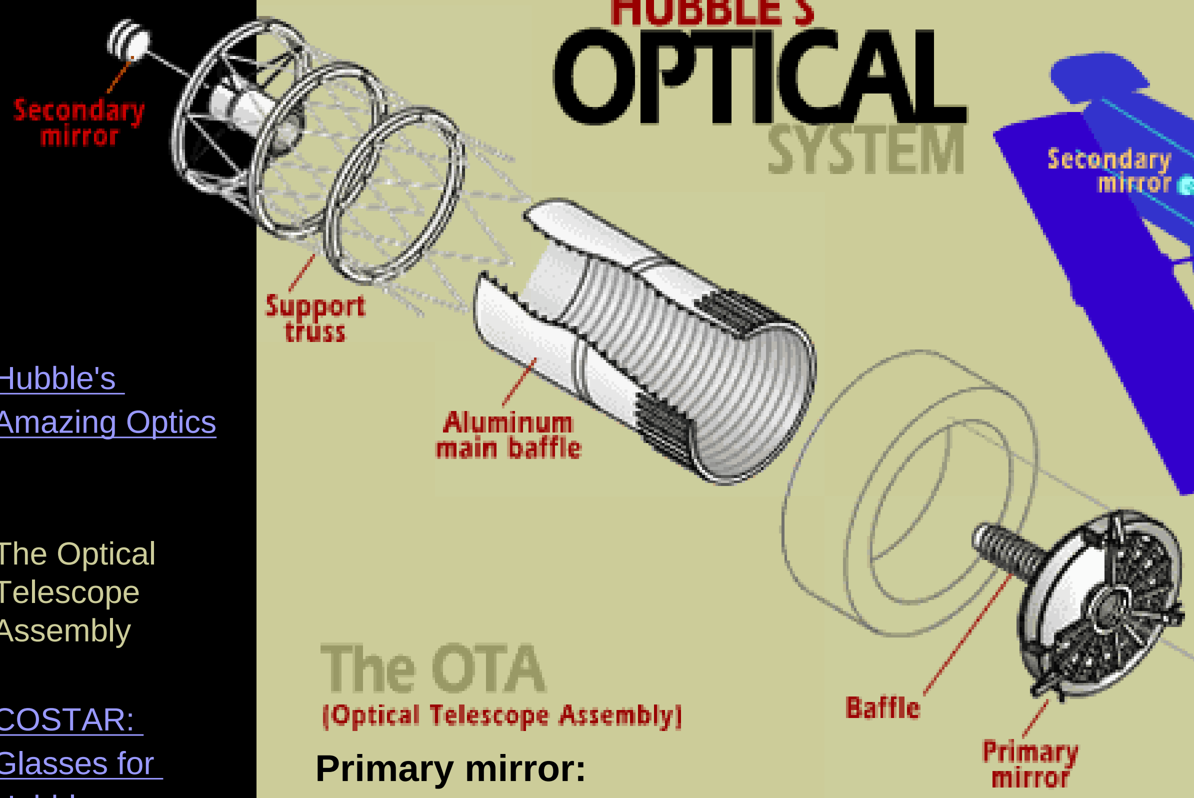
Hubble's mirrors are very smooth and have precisely shaped reflecting surfaces. They were ground (shaped by removing glass with abrasives) so that their surfaces do not deviate from a perfect curve by more than 1/800,000ths of an inch. If Hubble's primary mirror were scaled up to the diameter of the Earth, the biggest bump would be only six inches tall.

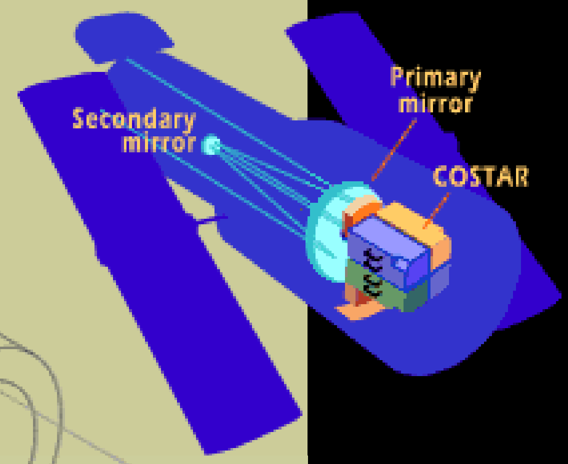
Shortly after Hubble's deployment in 1990, scientists found that the curve to which the primary mirror was ground was incorrect, causing "spherical aberration." Fortunately, corrective optics were able to solve this problem.

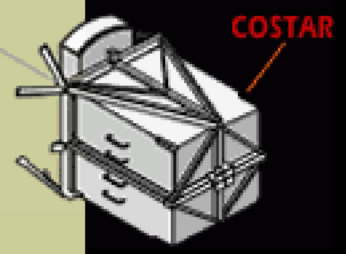
Hubble's mirrors are made of ultra-low expansion glass and kept at a nearly constant room temperature (about 70 degrees Fahrenheit) to avoid warping. The reflecting surfaces are coated with a 3/1,000,000th-inch layer of pure aluminum and protected by a 1/1,000,000th-inch layer of magnesium fluoride. The magnesium fluoride makes the mirrors more reflective of ultraviolet light.

TOP

HUBBLE'S OPTICAL SYSTEM







Hubble's Amazing Optics

The Optical Telescope Assembly

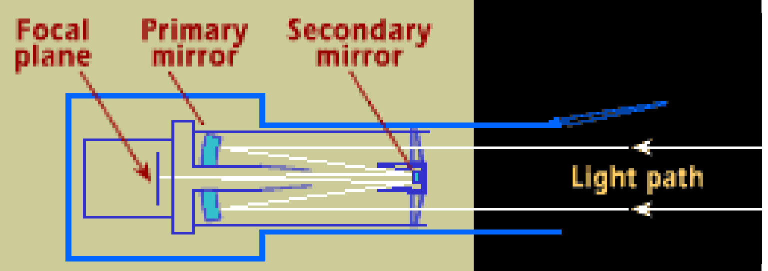
COSTAR: Glasses for Hubble

The OTA
(Optical Telescope Assembly)

Primary mirror:
The main mirror of the Hubble Space Telescope, measuring 2.4 meters (94.5 inches) in diameter. The primary mirror captures light from objects in space and focuses it toward the secondary mirror.

Secondary mirror:
A smaller mirror (0.3 meters, or 12.2 inches) that redirects the light coming from the primary mirror through a hole in the center of the primary mirror and onward to the science instruments.

Focal plane:
Where Hubble's images are formed. The mirrors focus the starlight onto the focal plane, which is roughly the size of a dinner plate. The light is then picked up by the science instruments.



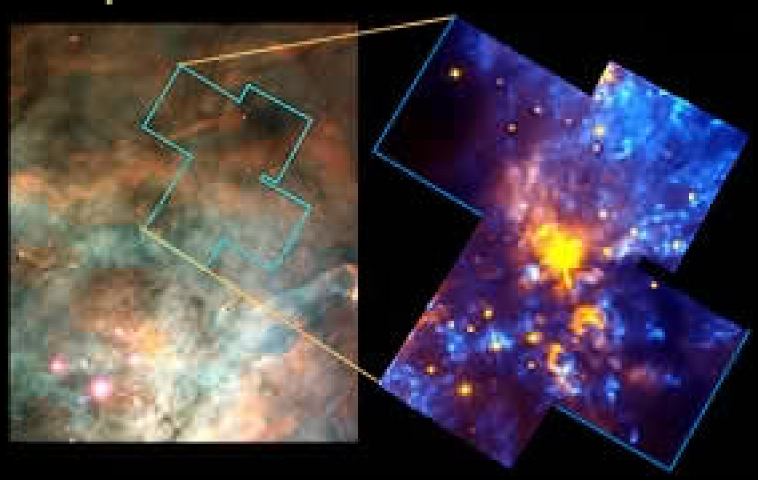
Corrective optics: Corrective apparatus "worn" by each science instrument to compensate for the imperfect shape of the primary mirror. COSTAR provided the corrective optics for the original science instruments.

TOP

HUBBLESITE

NICMOS sees through gas and dust

Example 1: The heart of Orion

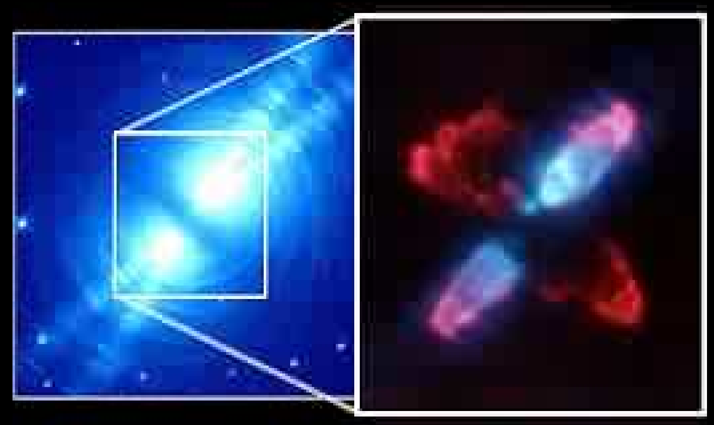


WFPC2's visible light image

NICMOS's infrared image

NICMOS's infrared eyes reveal OMC-1, the giant molecular cloud at the heart of the Orion Nebula. For comparison, the same area in the WFPC2 image on the left appears relatively dim and featureless.

Example 2: The Egg Nebula



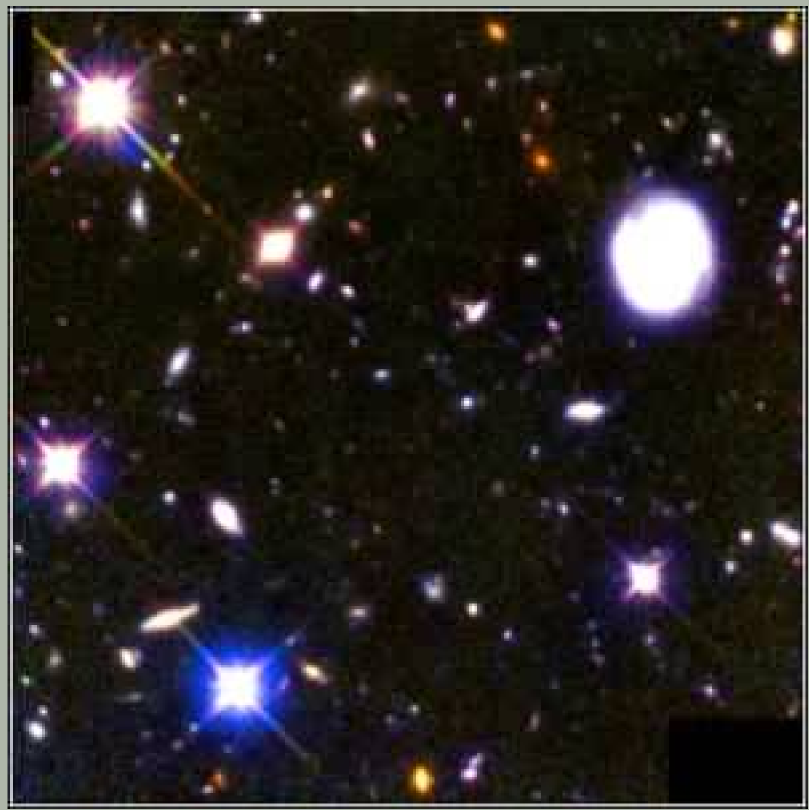
WFPC2's visible light image

NICMOS's infrared image

The dust-obscured heart of the Egg Nebula is shown on the left as it appears in visible light with WFPC2, and on the right as it appears in infrared light with NICMOS.

Go back

Combined Deep View of Infrared- and Visible-Light Galaxies



This narrow, deep view of the universe reveals a plethora of faint galaxies, as seen in visible and infrared light by the Hubble telescope.

The reddish galaxies are glowing in infrared light; the bluish galaxies are glowing in visible light. Several distinctive types of galaxies can be seen in these views: blue dwarf galaxies, disk galaxies, and very red elliptical galaxies. A bright, nearby, face-on spiral galaxy appears at upper right. Some of the brightest objects in the field are foreground stars in the halo of our own Milky Way Galaxy. By combining views in infrared and visible light, astronomers have a better idea of the shapes of galaxies in the remote universe and of the fraction of galaxies that are old or dust-obscured at early epochs.

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Galaxies, Cosmology

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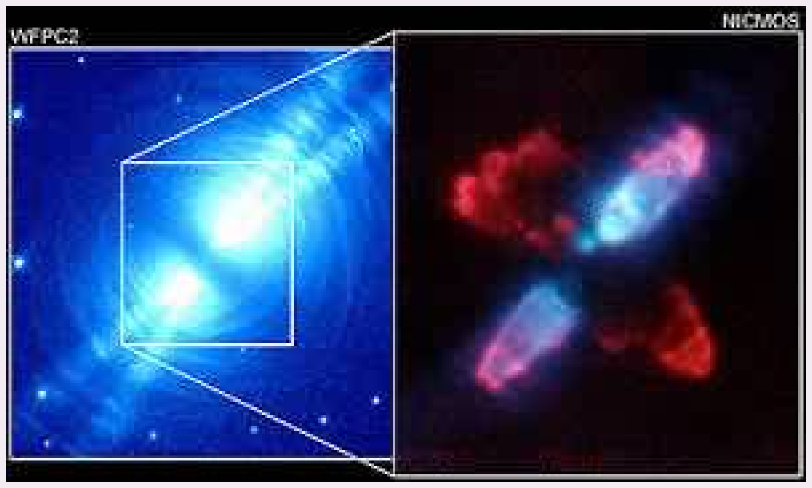
HUBBLESITE

1997

Hubble Peers into Heart of Dying Star



The Egg Nebula, also known as CRL 2688, is shown on the left as it appears in visible light and on the right as it looks in infrared light. Both Hubble views recount the last gasps of a dying, Sun-like star.

Objects like the Egg Nebula are helping astronomers understand how stars like our Sun expel carbon and nitrogen — elements crucial for life — into space. Studies on the Egg Nebula show that these dying stars eject matter at high speeds along a preferred axis and may even have multiple jet-like outflows. The signature of the collision between this fast-moving material and the slower, out-flowing shells is the glow of hydrogen molecules [the red material] captured in the right-hand image.

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Stars, Nebulae

1999

Hubble Captures a Grand View of the Birth of "Hefty" Stars

Pictures taken in infrared and visible light by the Hubble telescope recount a vivid story of the turbulent birthing process of massive stars.

The images show that powerful radiation and high-speed material unleashed by "hefty" adult stars residing in the hub of the 30 Doradus Nebula are triggering a new burst of star birth in the surrounding suburbs. Like their adult relatives, the fledgling stars are creating all sorts of havoc in their environment. Nascent stars embedded in columns of gas and dust, for example, are blowing away the tops of their nurseries, like a volcano blasting material into the sky. Jets of material streaming from another developing star are slamming into surrounding dust and gas in opposite directions, causing it to glow in moving patterns. These views [the top panel taken in visible light, the bottom in infrared] represent part of the highly active region of star birth.

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HUBBLESITE

1999

Hubble Snapshot Captures Life Cycle of Stars

In this stunning picture of the giant galactic nebula NGC 3603, the Hubble telescope's crisp resolution captures various stages of the life cycle of stars in one single view.

This picture nicely illustrates the entire stellar life cycle of stars, starting with the Bok globules and giant gaseous pillars (evidence of embryonic stars), followed by circumstellar disks around young stars, and progressing to aging, massive stars in a young starburst cluster. The blue super-giant with its ring and bipolar outflow [upper left of center] marks the end of the life cycle.

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HUBBLESITE

1996

Hubble's Deepest View of the Universe Unveils Bewildering Galaxies across Billions of Years

One peek into a small part of the sky, one giant leap back in time. The Hubble telescope has provided mankind's deepest, most detailed visible view of the universe.

Representing a narrow "keyhole" view stretching to the visible horizon of the universe, the Hubble Deep Field image covers a speck of the sky only about the width of a dime 75 feet away. Though the field is a very small sample of the heavens, it is considered representative of the typical distribution of galaxies in space, because the universe, statistically, looks largely the same in all directions. Gazing into this small field, Hubble uncovered a bewildering assortment of at least 1,500galaxies at various stages of evolution.

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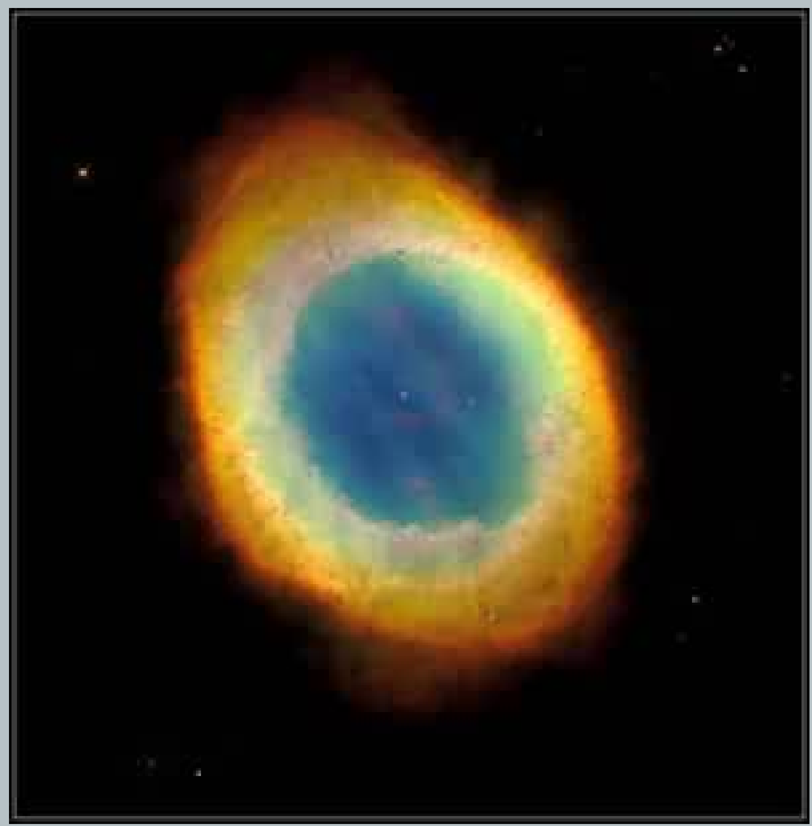
HUBBLESITE

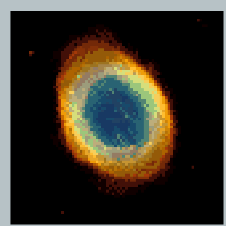
1999

Looking Down a Barrel of Gas at a Doomed Star



Astronomers using the Hubble telescope have obtained the sharpest view yet of a glowing loop of gas called the Ring Nebula (M57), first cataloged more than 200 years ago by French astronomer Charles Messier.

The pictures reveal that the "Ring" is actually a cylinder of gas seen almost end-on. Such elongated shapes are common among other planetary nebulae, because thick disks of gas and dust form a waist around a dying star. This "waist" slows down the expansion of material ejected by the doomed object. The easiest escape route for this cast-off material is above and below the star. This photo reveals dark, elongated clumps of material embedded in the gas at the edge of the nebula; the dying central star is floating in a blue haze of hot gas.


PR99-01

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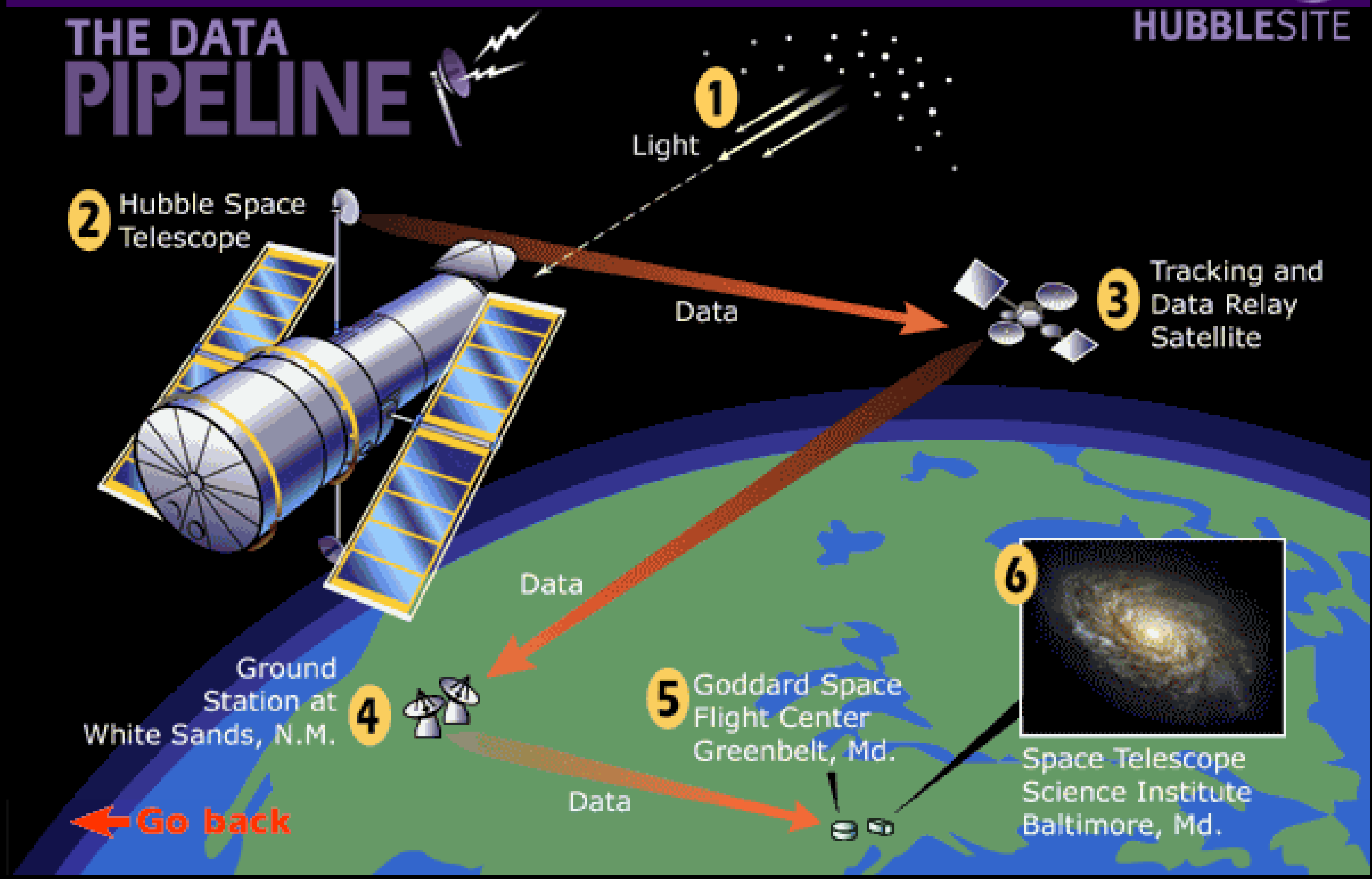
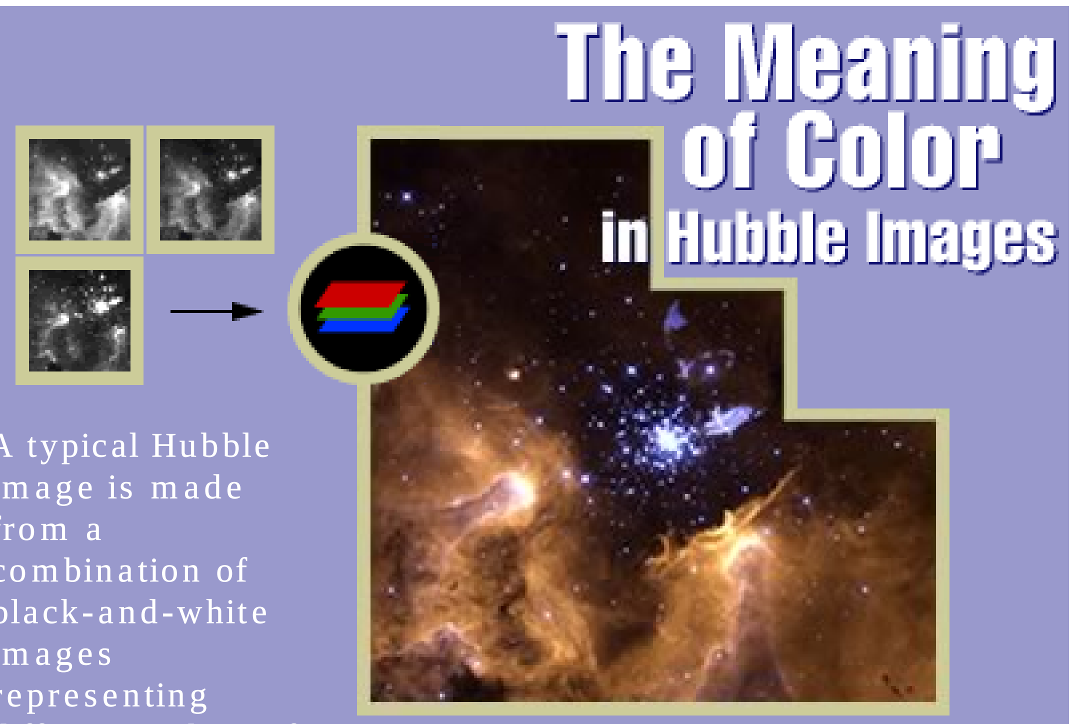

HUBBLESITE
THE DATA
PIPELINE
1
Light
2 Hubble Space Telescope
Data
3 Tracking and Data Relay Satellite
Data
6
Ground Station at White Sands, N.M.
4
5 Goddard Space Flight Center Greenbelt, Md.
Space Telescope Science Institute Baltimore, Md.
Data
Go back



A typical Hubble image is made from a combination of black-and-white images representing different colors of light. Click on the circle to see colorized versions of the black-and-white images.

Taking color pictures with the Hubble Space Telescope is much more complex than taking color pictures with a traditional camera. For one thing, Hubble doesn't use color film — in fact, it doesn't use film at all. Rather, its cameras record light from the universe with special electronic detectors. These detectors produce images of the cosmos not in color, but in shades of black and white.

Finished color images are actually combinations of two or more black-and-white exposures to which color has been added during image processing.

The colors in Hubble images, which are assigned for various reasons, aren't always what we'd see if we were able to visit the imaged objects in a spacecraft. We often use color as a tool, whether it is to enhance an object's detail or to visualize what ordinarily could never be seen by the human eye.

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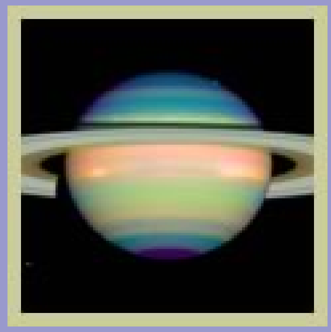
Color as a Tool

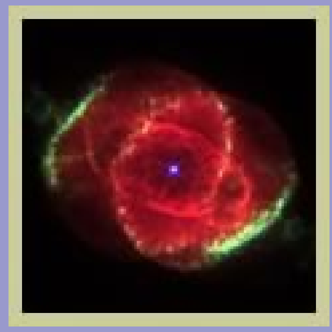
Natural Color

The colors in this image of a galaxy were chosen to simulate the colors that our eyes might see if we were able to visit it in a spacecraft.



Representative Color

Representative color helps scientists visualize what would otherwise be invisible, such as the appearance of an object in infrared light.



Enhanced Color

Enhancing the visible colors in an image often brings out an object's subtle structural detail.

Color in Hubble images is used to highlight interesting features of the celestial object being studied. It is added to the separate black-and-white exposures that are combined to make the final image.

Creating color images out of the original black-and-white exposures is equal parts art and science.

We use color:

- To depict how an object might look to us if our eyes were as powerful as Hubble
- To visualize features of an object that would ordinarily be invisible to the human eye
- To bring out an object's subtle details.

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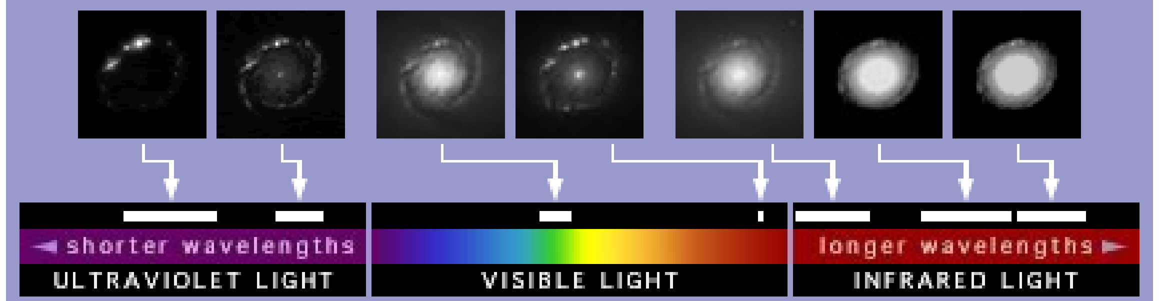
HUBBLESITE

Light and Wavelength

Light & Filters

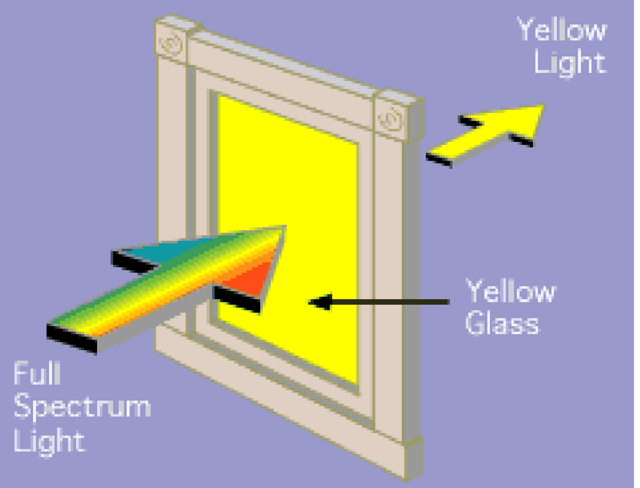
The seven pictures below depict galaxy NGC 1512 in different kinds of light. Note how the individual images differ in appearance.



About Filters

Colored-Glass Window

A colored-glass window allows only its particular color of light to pass through — it filters out the other colors of the spectrum. Hubble's filters work the same way, allowing only a specific color of light to pass through.



Light from astronomical objects comes in a wide range of colors, each corresponding to a particular kind of electromagnetic wave. Hubble can detect all the visible wavelengths of light plus many more that are invisible to human eyes, such as ultraviolet and infrared light.

Astronomical objects often look different in these different wavelengths of light. To record what an object looks like at a certain wavelength, Hubble uses special filters that allow only a certain range of light wavelengths through. Once the unwanted light has been filtered out, the remaining light is recorded.

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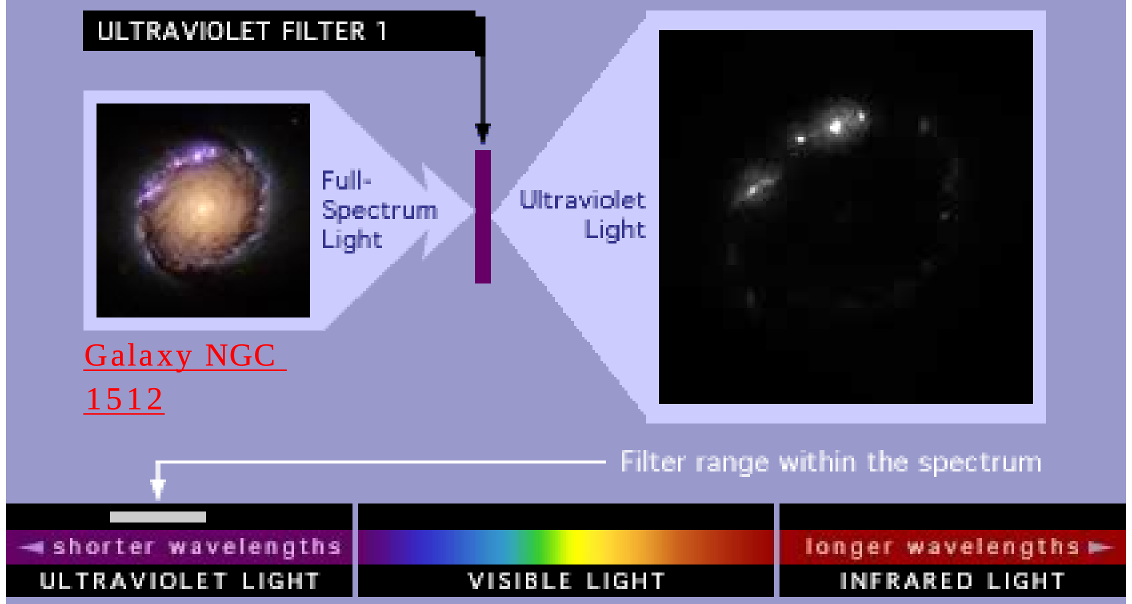
HUBBLESITE

Hubble's Filters at Work

Click on each of the "Choose a Filter" buttons to see how galaxy NGC 1512 looks in seven different wavelength ranges.

CHOOSE A FILTER: Ultraviolet 1 | Ultraviolet 2 | Green | Red | Infrared 1 | Infrared 2 | Infrared 3



Hubble's many filters allow it to record images in a variety of wavelengths of light. Since the cameras can detect light outside the visible light spectrum, the use of filters allows scientists to study "invisible" features of objects — those only visible in ultraviolet and infrared wavelengths.

In the example to the left, galaxy NGC 1512 is represented in several different wavelengths. Hubble isolates these specific wavelengths using special filters. Choosing a particular filter reveals an image of the galaxy taken through that filter — that is, in a specific wavelength range. The finished image at the far left is actually a combination of all the filtered images.

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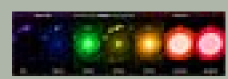
Hubble Unveils a Galaxy in Living Color

In this view of the center of the magnificent barred spiral galaxy NGC 1512, the Hubble telescope reveals a stunning 2,400 light-year-wide circle of infant star clusters. Astronomers generally believe that the giant bar, which is too faint to be seen in this image, funnels the gas to the inner ring, where massive stars are formed within numerous star clusters. Located 30 million light-years away, NGC 1512 is a neighbor of our Milky Way galaxy.

You may wish to find out the answers to questions such as these:



- What is a barred spiral galaxy?
- Why is this picture so colorful?

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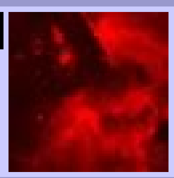
Star clusters, Galaxies

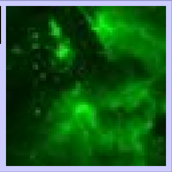
HUBBLESITE

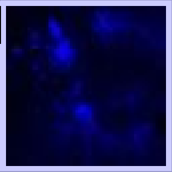
Red + Green + Blue

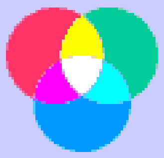
Most of the popular Hubble images are made by combining a red image, a green image, and a blue image.

See how this image looks in different combinations of light! For each color, select either "on" or "off" to control the color(s) used to make the final image.

RED
ON OFF


GREEN
ON OFF


BLUE
ON OFF




Because of the way our eyes work, almost any color can be simulated by combining red, green, and blue light. All the colors combined make white light.

Many full-color Hubble images are combinations of three separate exposures — one each taken in red, green, and blue light. When mixed together, these three colors of light can simulate almost any color of light that is visible to human eyes. That's how televisions, computer monitors, and video cameras recreate colors.

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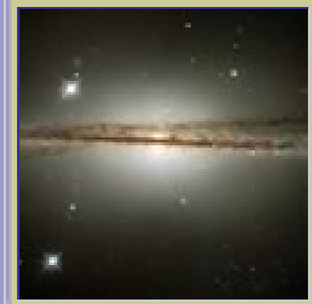
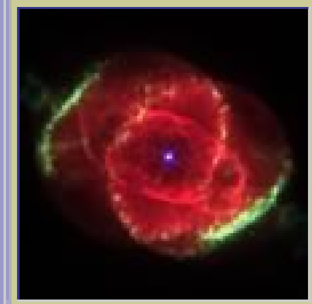
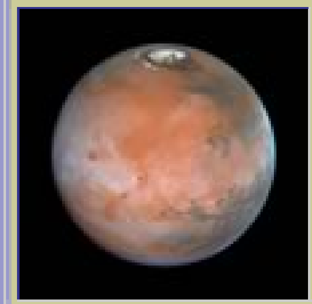
Hubble's Color Toolbox

GALAXY ESO 510-G13

NATURAL

INFRARED SATURN

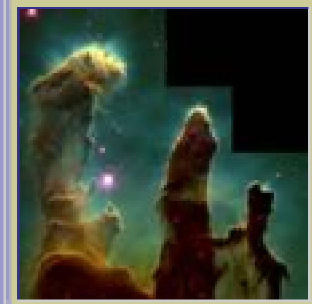
REPRESENTATIVE

CAT'S EYE NEBULA

ENHANCED

MARS

NATURAL

EGG NEBULA

REPRESENTATIVE

EAGLE NEBULA

ENHANCED

See some of the ways we use color by exploring a few of Hubble's most famous images.

Click on one or more of the images at left to explore their color secrets.

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SATURN
CAT'S EYE NEBULA
MARS
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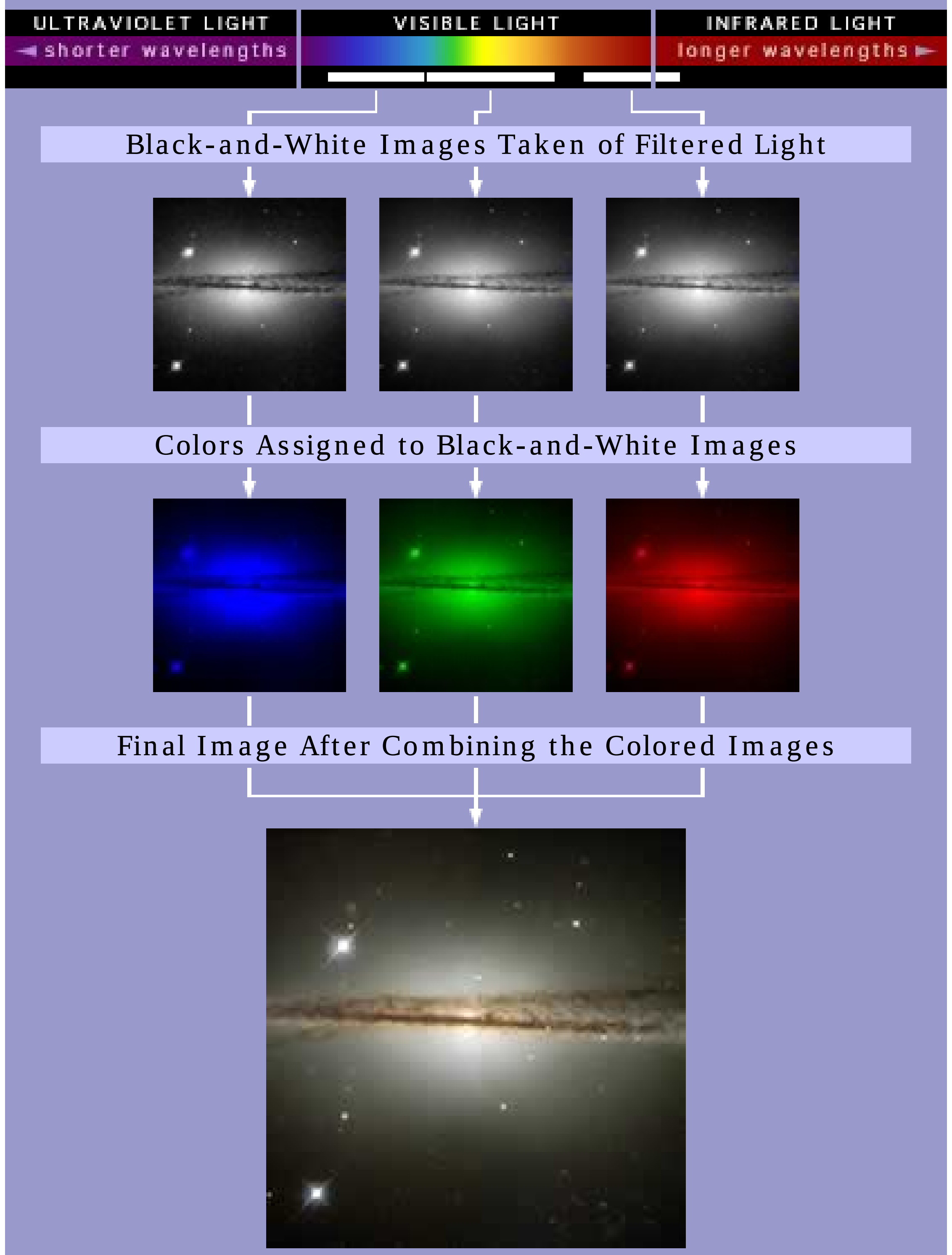
EAGLE NEBULA

Hubble's Color Toolbox

Galaxy ESO 510-G13

Natural Color



LEARN MORE ABOUT THIS IMAGE

Natural Color: Galaxy ESO 510-G13

We constructed this image of the galaxy ESO 510-G13 from three different black-and-white images representing red light, green light, and blue light from the galaxy. The colors assigned to each of these images were chosen to simulate the actual colors of the galaxy.

Much of the galaxy appears whitish because it contains stars of many different colors, which combine to create a white appearance in the final image.

However, near the dark band of dusty gas slicing through the middle of this galaxy, the starlight appears redder because the dusty gas blocks blue light more effectively than red light.

This effect is even clearer in the individual black-and-white images. Note that the dust band appears darkest in the leftmost black-and-white image, which was taken through a blue filter.

next >>

EAGLE NEBULA

2001

Hubble Photographs Warped Galaxy as Camera Passes Milestone

The Hubble telescope has captured an image of an unusual edge-on galaxy, revealing remarkable details of its warped dusty disk and showing how colliding galaxies spawn the formation of new generations of stars. The dust and spiral arms of normal spiral galaxies, like our own Milky Way, appear flat when viewed edge-on. This Hubble Heritage image of ESO 510-G13 shows a galaxy that, by contrast, has an unusual twisted disk structure, first seen in ground-based photographs.

You may wish to find out the answers to questions such as these:

- Why does the galaxy have a warped shape?

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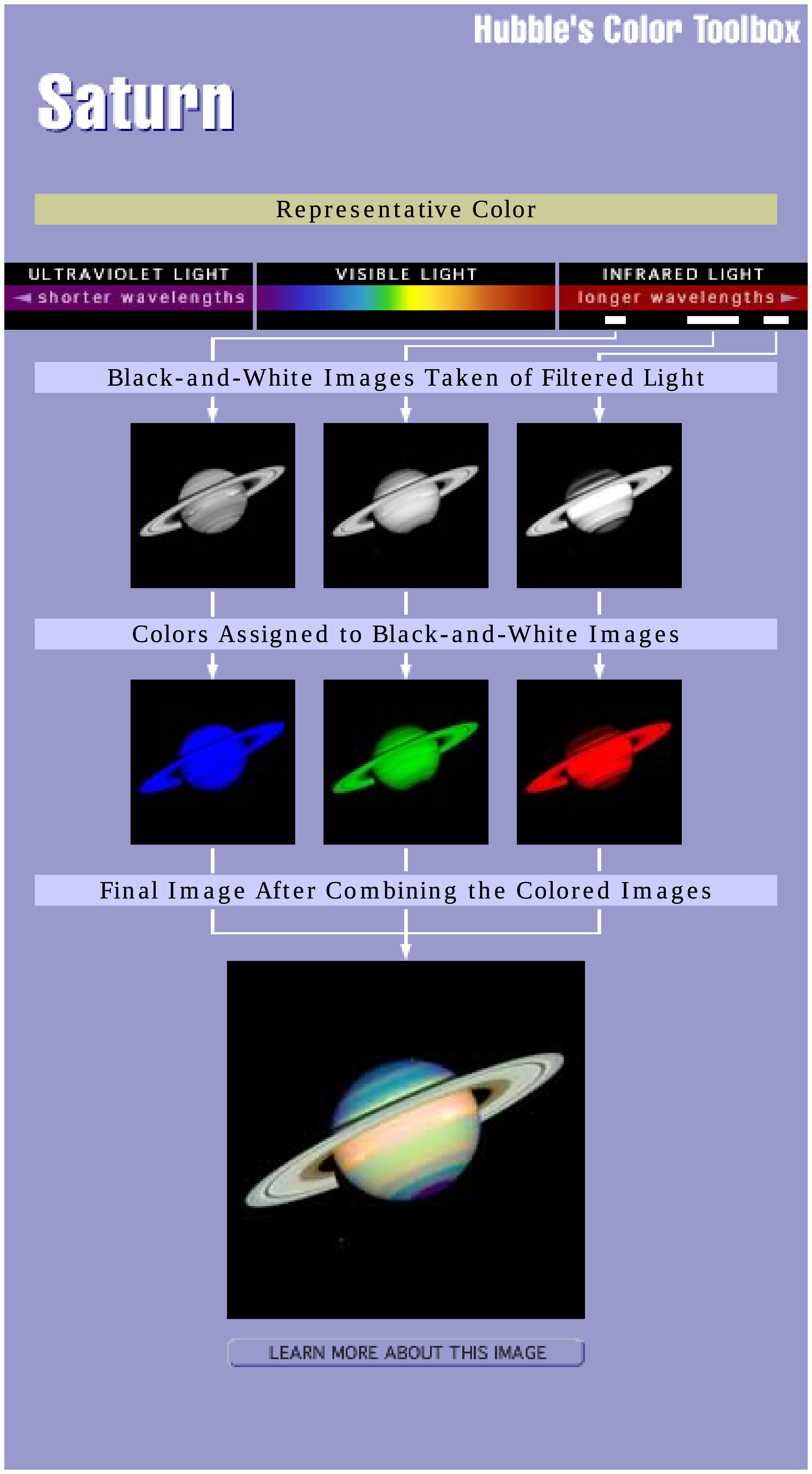
Galaxies



Representative Color: Saturn

The infrared light Hubble captured to make this image of Saturn is invisible to human eyes. We added colors to reveal details that our eyes might see if they were sensitive to infrared light.

We assigned the color blue to the shortest-wavelength infrared light, red to the longest-wavelength infrared light, and green to the intermediate-wavelength infrared light.

The colorful bands arise because chemical differences in Saturn's upper cloud layers cause those clouds to reflect sunlight in different ways.

Near the equator, Saturn's upper cloud layers strongly reflect the infrared light represented here by the colors red and green, which combine to make yellow in this kind of color reconstruction. Closer to the poles, the upper cloud layers are not so reflective and we can see down to the main cloud layer, which strongly reflects the kind of infrared light represented here by blue.

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- SATURN
- CAT'S EYE NEBULA
- MARS
- EGG NEBULA
- EAGLE NEBULA

1998

Hubble Space Telescope Completes Eighth Year Of Exploration

In honor of NASA Hubble Space Telescope's eighth anniversary, we have gift-wrapped Saturn in vivid colors. Actually, this image is courtesy of Hubble's infrared camera, which has taken its first peek at Saturn.

This view provides detailed information on the clouds and hazes in Saturn's atmosphere. The blue colors indicate a clear atmosphere down to the main cloud layer. Most of the Northern Hemisphere that is visible above the rings is relatively clear. The dark region around the South Pole indicates a big hole in the main cloud layer. The green and yellow colors indicate a haze above the main cloud layer. The red and orange colors indicate clouds reaching up high into the atmosphere. The rings, made up of chunks of ice, are as white as images taken in visible light.

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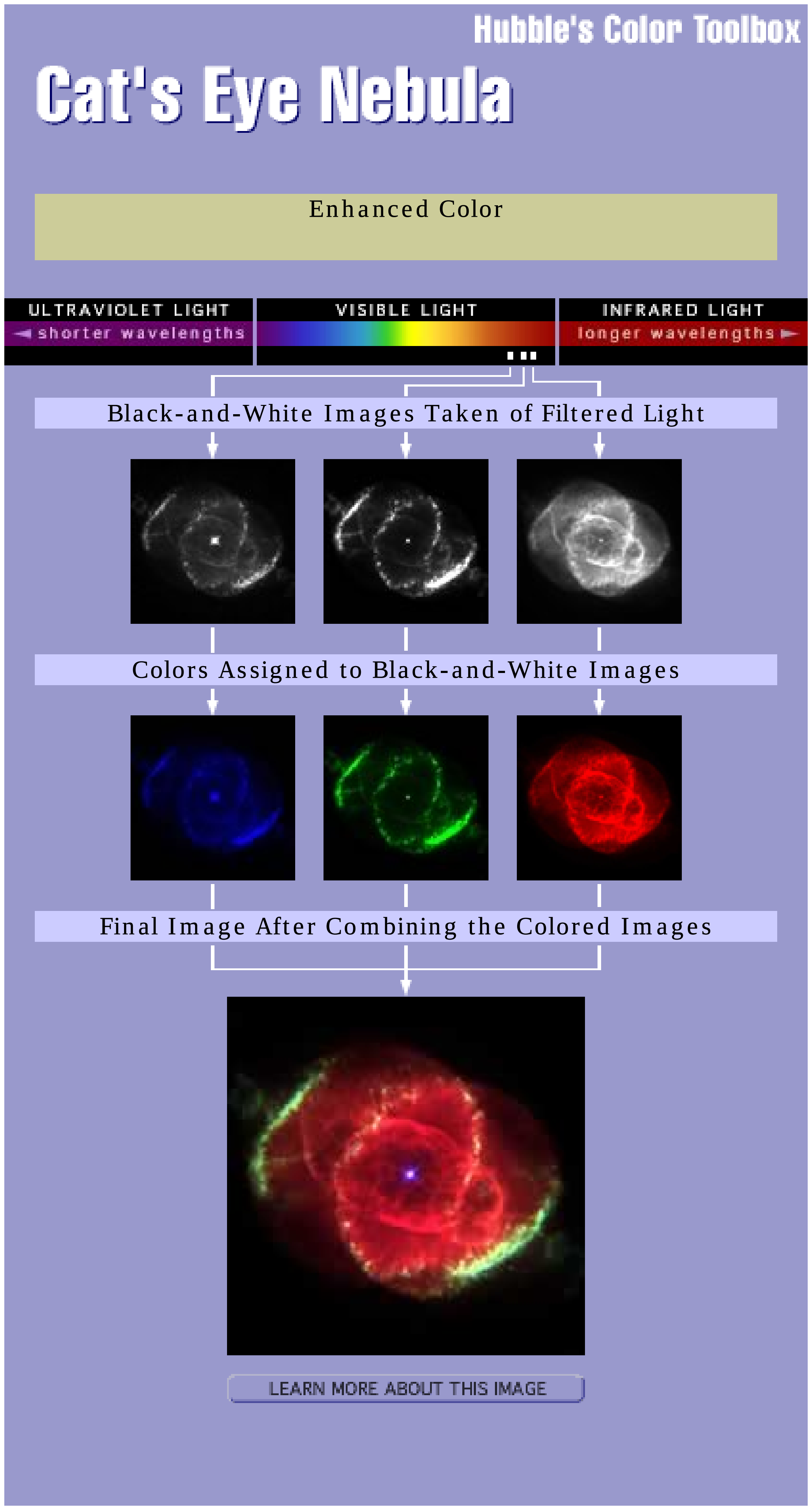

Enhanced Color:
Cat's Eye Nebula

The Cat's Eye Nebula consists of glowing gases ejected into outer space by a dying star. Individual chemical elements in the nebula emit light at very specific wavelengths.

The three black-and-white images used to construct this image represent light from hydrogen atoms, oxygen atoms, and nitrogen ions (nitrogen atoms with one electron removed).

All three images correspond to different shades of red light, so we enhanced the color differences to make the nebula's delicate structures more obvious.

In this case, light from hydrogen atoms is shown in red, light from oxygen is shown in blue, and light from nitrogen is shown in green.

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CAT'S EYE NEBULA
MARS
EGG NEBULA
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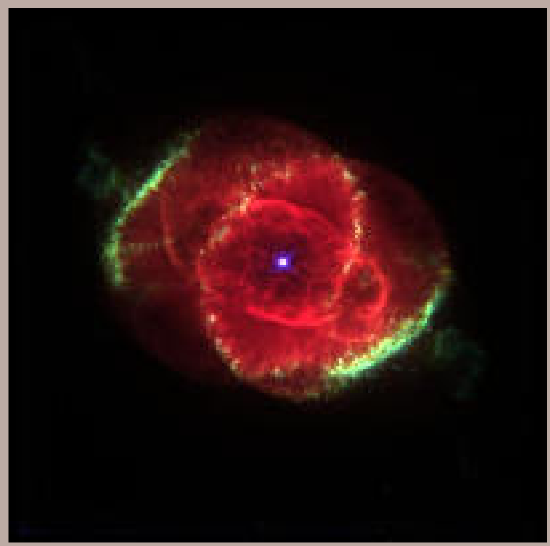
Hubble Probes the Complex History of a Dying Star



This Hubble telescope image shows one of the most complex planetary nebulae ever seen, NGC 6543, nicknamed the "Cat's Eye Nebula." Hubble reveals surprisingly intricate structures including concentric gas shells, jets of high-speed gas, and unusual shock-induced knots of gas. Estimated to be 1,000 years old, the nebula is a visual "fossil record" of the dynamics and late evolution of a dying star.

A preliminary interpretation suggests that the object might be a double-star system. The dynamical effects of two stars orbiting one another most easily explains the intricate structures, which are much more complicated than features seen in most planetary nebulae. The two stars are too close together to be individually resolved by Hubble and instead appear as a single point of light at the center of the nebula.

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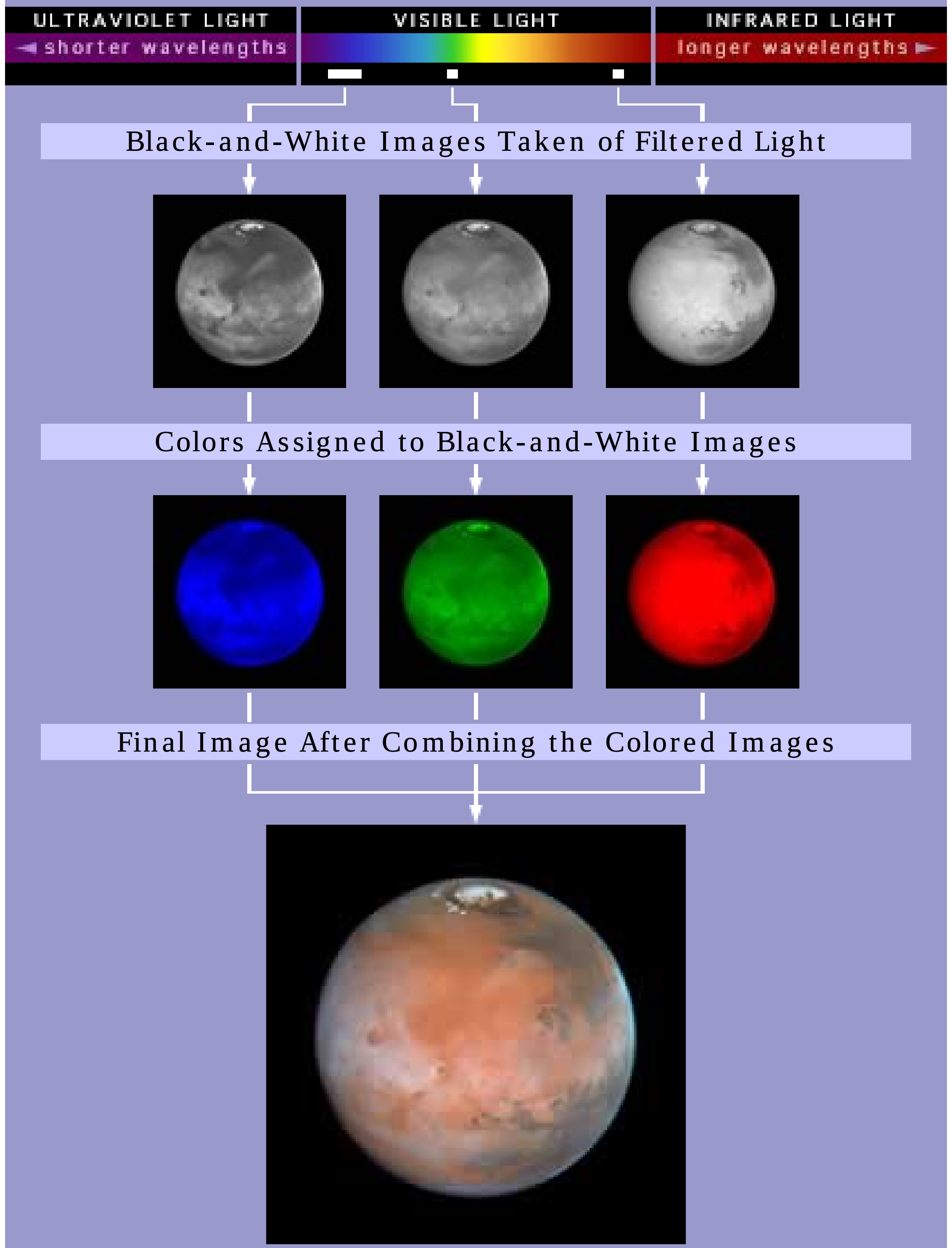
Hubble's Color Toolbox

Mars

Natural Color



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Natural Color: Mars

This image of Mars was constructed from three different black-and-white images recording red light, green light, and blue light reflected from the planet.

The colors assigned to each of these images were chosen to simulate Mars' actual colors.

Not surprisingly, the brightest black-and-white image of the red planet is the one taken through a red filter. However, note that the northern ice cap in these black-and-white images is equally bright in red, green, and blue light because its actual color is white.

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EAGLE NEBULA

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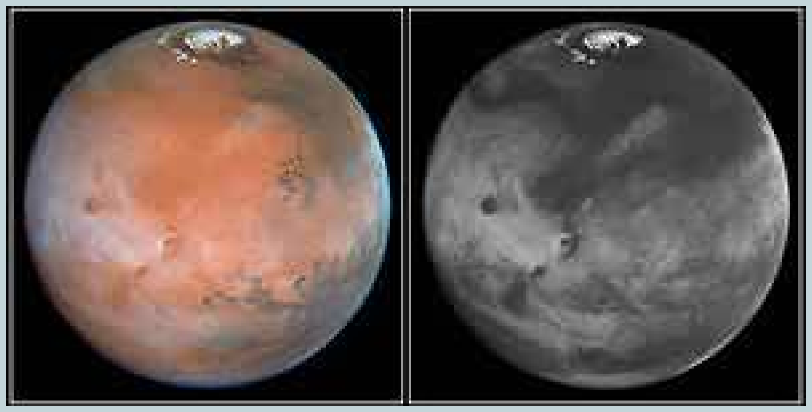
Hubble Finds Cloudy, Cold Weather Conditions for Mars-Bound Spacecraft



As two NASA spacecraft speed toward a mid-year rendezvous with Mars, astronomers using the Hubble telescope are providing updated planetary weather reports to help plan the missions.

Hubble's new images show that the "Martian invasion" of spacecraft will experience considerably different weather conditions than seen by the last U.S. spacecraft to land on Mars 21 years ago. Martian atmospheric conditions will affect the operation of both the Mars Pathfinder landing on July 4, 1997 and the September 11 arrival of the Mars Global Surveyor, which will map the planet from orbit. These two Hubble snapshots were taken barely three weeks after another Hubble observations of the Red Planet. The differences in the two sets of images are striking, revealing dramatic changes in some local conditions and show overall cloudier and colder conditions than the Viking orbiter encountered two decades ago.

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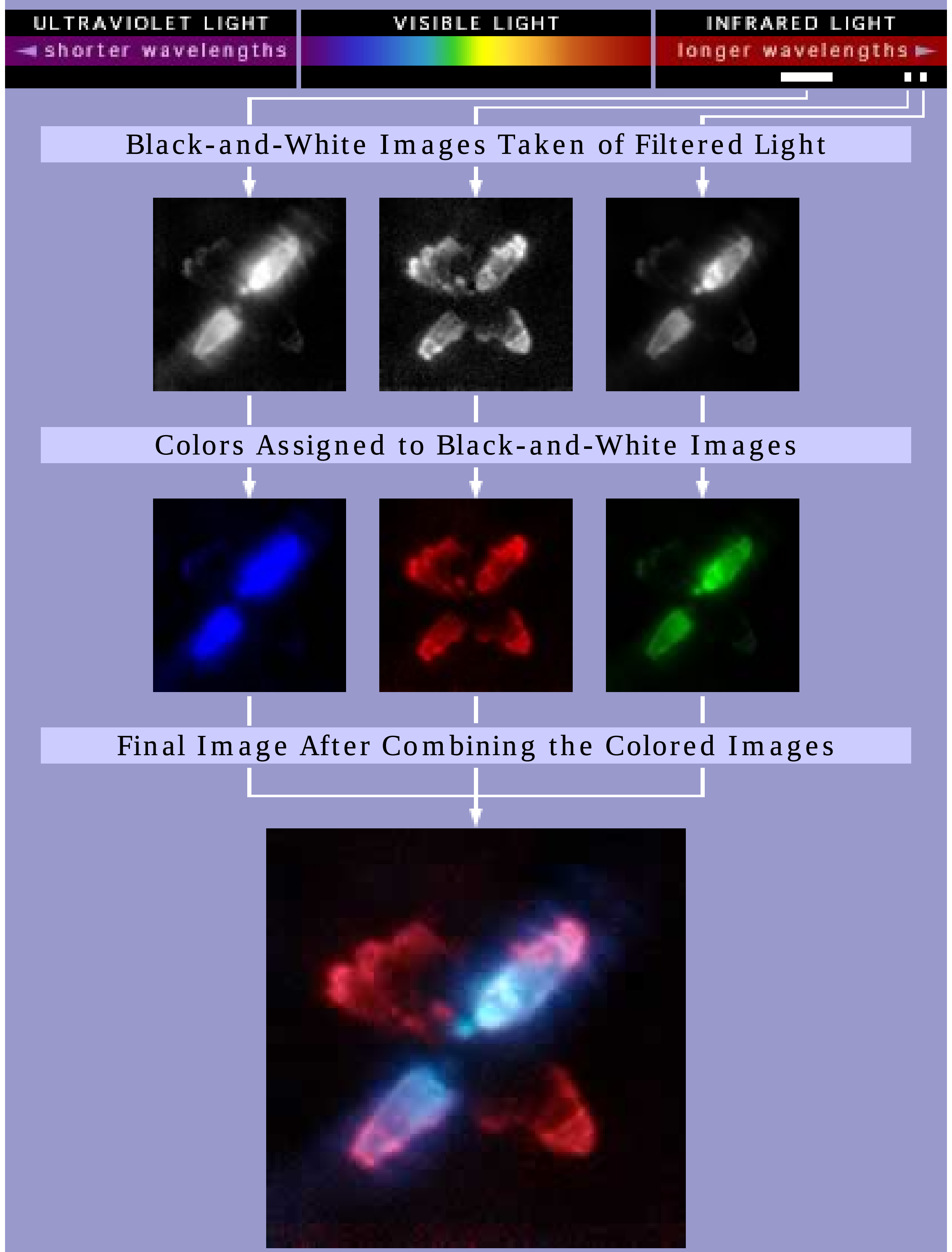
Hubble's Color Toolbox

Egg Nebula

Representative Color



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Representative Color: Egg Nebula

This picture of infrared light from the Egg Nebula shows the last gasps of a dying star. Because infrared light is invisible to humans, we have used three different colors to represent the three wavelengths of infrared light.

Blue represents intermediate-wavelength infrared starlight reflected by dust particles around the dying star. Green represents longer-wavelength reflected starlight. Red represents infrared light from hydrogen molecules surrounding the star.

The red color indicates where a belt of molecular gas surrounds the star. The blue color is strongest above and below the belt, because that's where the most starlight is escaping.

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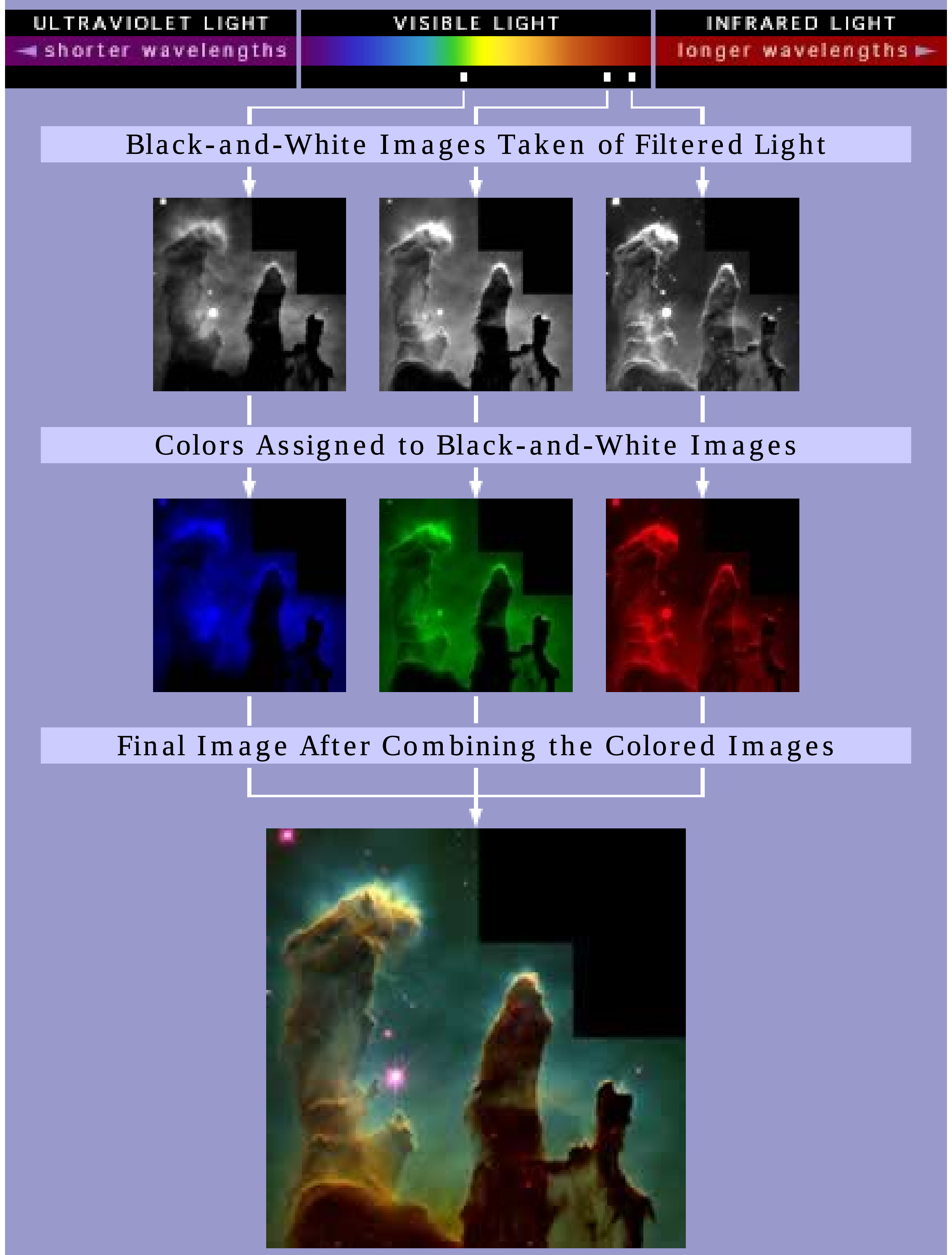
Eagle Nebula

Enhanced Color



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Enhanced Color: Eagle Nebula

The Eagle Nebula is a region of our galaxy where stars are currently forming out of dusty hydrogen gas. Ultraviolet light from newly-formed stars in the vicinity of the nebula is pumping energy into these gas clouds, causing them to glow in visible light.

The final image depicts red light from hydrogen atoms as green, red light from sulfur ions (sulfur atoms with one electron removed) as red, and green light from doubly-ionized oxygen (oxygen atoms with two electrons missing) as blue.

These color reassignments enhance the level of detail visible in the image, because otherwise the red light from hydrogen and that from sulfur would be hard to tell apart.

In the final image, the blue-green haze indicates light from hydrogen and oxygen surrounding the dark columns. The columns display reddish highlights identifying light from sulfur.

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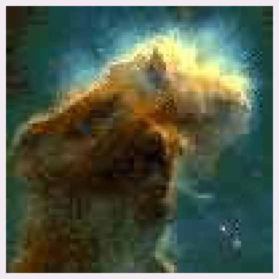
Embryonic Stars Emerge from Interstellar "Eggs"

Eerie, dramatic pictures from the Hubble telescope show newborn stars emerging from "eggs" — not the barnyard variety — but rather, dense, compact pockets of interstellar gas called evaporating gaseous globules (EGGs). Hubble found the "EGGs," appropriately enough, in the Eagle nebula, a nearby star-forming region 7,000 light-years from Earth in the constellation Serpens.



These striking pictures resolve the EGGs at the tip of finger-like features protruding from monstrous columns of cold gas and dust in the Eagle Nebula (also called M16). The columns — dubbed "elephant trunks" — protrude from the wall of a vast cloud of molecular hydrogen, like stalagmites rising above the floor of a cavern. Inside the gaseous towers, which are light-years long, the interstellar gas is dense enough to collapse under its own weight, forming young stars that continue to grow as they accumulate more and more mass from their surroundings.

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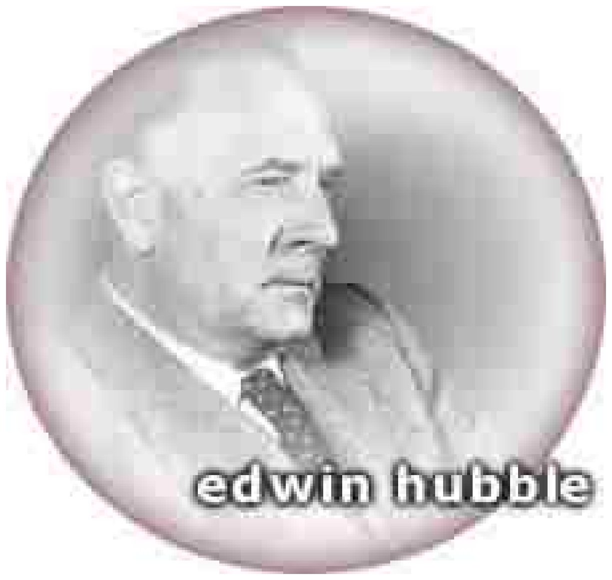
cost at launch		power storage

Hubble's Name



NASA named the world's first space-based optical telescope after American astronomer Edwin P. Hubble (1889–1953). Dr. Hubble confirmed an "expanding" universe, which provided the foundation for the Big Bang theory.

Scientists believe our universe began with a “big bang” some 12 to 15 billion years ago. If all the events in the history of the universe until now were squeezed into 24 hours, Earth wouldn’t form until late afternoon and humans would have existed for only **2 seconds**.

Mission

Launch: April 24, 1990 from space shuttle Discovery (STS-31)

Deployment: April 25, 1990

Mission Duration: Up to 20 years

Servicing Mission 1: December 1993

Servicing Mission 2: February 1997

Servicing Mission 3A: December 1999

Servicing Mission 3B: February 2002

Size

Length: 43.5 ft (13.2 m)
Weight: 24,500 lb (11,110 kg)
Maximum Diameter: 14 ft (4.2 m)

Hubble is nearly the size of a large school bus—but it can fit inside a space shuttle cargo bay.

Cost at Launch

$2.2 billion

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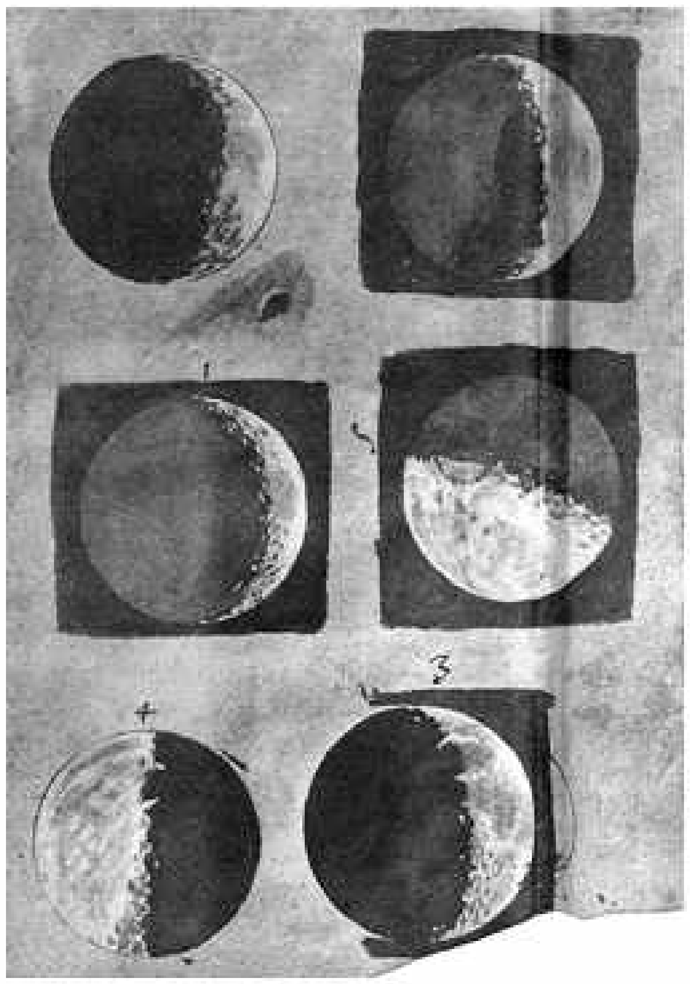
Looking Back at Looking Up

In 1609 an Italian physicist and astronomer named Galileo became the first person to point a telescope skyward. Although that telescope was small and the images fuzzy, Galileo was able to make out mountains and craters on the moon, as well as a ribbon of diffuse light arching across the sky—which would later be identified as our Milky Way galaxy.

Galileo's ink renderings of the moon: the first telescopic observations of a celestial object.



After Galileo's and, later, Sir Isaac Newton's time, astronomy flourished as a result of larger and more complex telescopes. With advancing technology, astronomers discovered many faint stars and the calculation of stellar distances. In the 19th century, using a new instrument called a spectroscope, astronomers gathered information about the chemical composition and motions of celestial objects.

Twentieth century astronomers developed bigger and bigger telescopes and, later, specialized instruments that could peer into the distant reaches of space and time. Eventually, enlarging telescopes no longer improved our view... all because of the Earth's atmosphere.

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Edwin Hubble

The Legacy of Edwin Hubble...

The Hubble Space Telescope was named after astronomer Edwin Powell Hubble (1889–1953), who made some of the most important discoveries in modern astronomy. As an astronomer, Dr. Hubble was a late bloomer. Before discovering his passion for the stars, Dr. Hubble earned a law degree and served in World War I. However, after practicing law for one year, he decided to “chuck law for astronomy,” knowing that “even if [he] were second rate or third rate, it was astronomy that mattered.”

In the 1920s, while working at the Mt. Wilson Observatory with the most advanced technology of the time, Dr. Hubble showed that some of the numerous distant, faint clouds of light in the universe were actually entire galaxies—much like our own Milky Way. The realization that the Milky Way is only one of many galaxies forever changed the way astronomers viewed our place in the universe.

But perhaps his greatest discovery came in 1929, when Dr. Hubble determined that the farther a galaxy is from Earth, the faster it appears to move away. This notion of an "expanding" universe formed the basis of the Big Bang theory, which states that the universe began with an intense burst of energy at a single moment in time—and has been expanding ever since.

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Lyman Spitzer

The Man Behind the Machine...

Lyman Spitzer, Jr. (1914–1997), a world-renowned theoretical astrophysicist, developed the concept of a telescope in space. In 1946—more than a decade before the launch of the first satellite—Spitzer proposed the development of a large, space-based observatory that would not be hindered by Earth's atmospheric distortion and span a broad range of wavelengths. This lofty vision ultimately became the Hubble Space Telescope.

Spitzer was instrumental in the design and development of the Hubble Space Telescope. Throughout the 1960s and 1970s, he was an enthusiastic lobbyist for the telescope, both with Congress and the scientific community. Even after Hubble's launch in 1990, Spitzer remained deeply involved in the program. Not only did he make some important astronomical observations with the telescope that was essentially his brainchild, but he also spent a great deal of time—right up until the end of his life—analyzing Hubble data.

In addition to space astronomy, Spitzer's work greatly advanced knowledge in other fields, including stellar dynamics, plasma physics, and thermonuclear fusion.

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A Telescope in the Sky? Why?

The next time you gaze up at the night sky, you're likely to spot a twinkling star. But is it really twinkling? What looks like a twinkling star to our eyes is actually steady starlight that has been distorted, or bent, by the Earth's atmosphere. The visual effect of this distortion is like looking at an object through a glass of water.

Telescopes here on the ground—which also must peer through Earth's atmosphere—are equally vulnerable to our atmosphere's visual tricks.

That's why astronomers around the world dreamed of having an observatory in space—a concept first proposed by astronomer Lyman Spitzer in the 1940s. From a position above Earth's atmosphere, a telescope would be able to detect light from stars, galaxies, and other objects in space before that light is absorbed or distorted. Therefore, the view would be a lot sharper than that from even the largest telescope on the ground.

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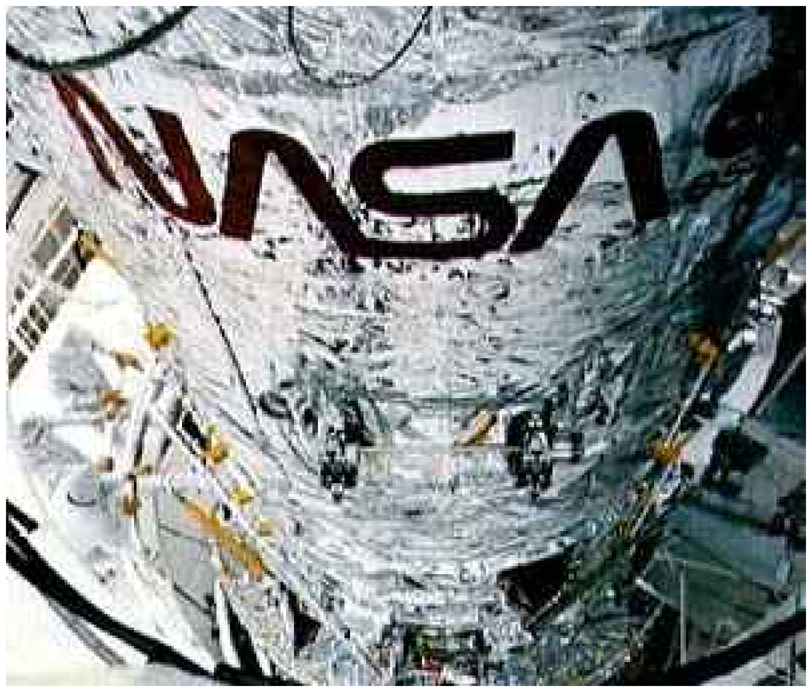
Vision Becomes Reality

In the 1970s the European Space Agency and the National Aeronautics and Space Administration began working together to design and build what would become the Hubble Space Telescope. On April 25, 1990, five astronauts aboard the space shuttle Discovery deployed the eagerly anticipated telescope in an orbit roughly 380 miles (600 km) above the Earth's surface.

That deployment and, later, the unprecedented images that Hubble delivered represented the fulfillment of a 50-year dream and more than two decades of dedicated collaboration between scientists, engineers, contractors, and institutions from all over the world.



The Hubble Space Telescope in Lockheed's cleanroom.

Hubble’s Job Description

- Explore the solar system.
- Measure the age and size of the universe.
- Search for our cosmic roots.
- Chart the evolution of the universe.
- Unlock the mysteries of galaxies, stars, planets, and life itself.

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Beyond Hubble: The Next Generation Space Telescope

Hubble's important mission will come to an end one day in the future. But the telescope's ultimate retirement will not signal the end of our unrivaled view of the universe. Rather, it will mark a new beginning—and even more amazing discoveries and images from space. For Hubble has a successor.

The Next Generation Space Telescope (NGST), which is being designed right now, may be launched as early as 2008.

When that day comes, scientists using NGST hope to discover and understand even more about our fascinating universe, such as

- The formation of the first stars and galaxies
- The evolution of galaxies and the production of elements by stars
- The process of star and planet formation.

Bigger! Better! Colder?

In order to peer back toward the beginning of the universe, NGST will make observations in the visible to the mid-infrared part of the electromagnetic spectrum. NGST is designed to operate in the infrared wavelengths, so it is important to keep the detectors and telescope optics as cold as possible (excess heat from the telescope itself would create unwanted “background noise”). In addition, NGST’s larger primary mirror will give it 10 times Hubble's light gathering capability.

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Spaceflight Statistics

The Hubble Space Telescope whirls around Earth at a speed of 5 miles per second. If cars moved that fast, a coast-to-coast trip across the continental United States would take only 10 minutes.

Orbit: At an altitude of 380 statute miles (612 km), inclined 28.5 degrees to the equator (low-Earth orbit)

Time to Complete One Orbit: 97 minutes

Speed: 17,500 mph (28,000 kph)

Optical Capabilities

Hubble Can’t Observe: The Sun or Mercury, which is too close to the Sun

Sensitivity to Light: Ultraviolet through infrared (110–2,500 nanometers)

First Image: May 20, 1990: Star Cluster NGC 3532

The most frequently observed celestial object is Earth. Earth is observed regularly for calibration—to make sure that all the charge-coupled detectors (CCDs) are working properly. The images from these "test" observations show no detail.

Data Stats

Each day, Hubble transmits enough data to fill 10,000 standard computer diskettes—the equivalent of 5 encyclopedias. This rapidly growing collection of pictures and data is stored on optical disks.

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Power Needs

Energy source: the Sun

Mechanism: two 22-foot solar panels

Power usage: 3,000 watts

In an average orbit, Hubble uses about the same amount of energy as 30 household light bulbs.

Pointing Accuracy

In order to take images of distant, faint objects, Hubble must be extremely steady and accurate. The telescope is able to lock onto a target without deviating more than 7/1000th of an arcsecond, or about the width of a human hair seen at a distance of 1 mile.

Pointing the Hubble Space Telescope and locking onto distant celestial targets is like holding a laser light steady on a dime that is 200 miles away.

Hubble's Mirrors

Primary Mirror

Diameter: 94.5 in (2.4 m)

Weight: 1,825 lb (828 kg)

Secondary Mirror

Diameter: 12 in (0.3 m)

Weight: 27.4 lb (12.3 kg)

Hubble's two mirrors were ground so that they do not deviate from a perfect curve by more than 1/800,000ths of an inch. If Hubble’s primary mirror were scaled up to the diameter of the Earth, the biggest bump would be only six inches tall.

Power Storage

Batteries: 6 nickel-hydrogen (NiH)
Storage capacity: equal to 20 car batteries

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the hubble deep field

a multimedia journey

LAUNCH

in a small window

- OR -

LAUNCH

in a window which will take up the entire screen

You can also go directly to the links page

in order to view the hubble deep field multimedia
you will need the flash plugin, speakers
and a PENTIUM II cpu or the equivalent

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the hubble deep field

a multimedia journey

Continue the Journey!

The following links offer more information on many facets of the Hubble Deep Field.

THANKS TO STEPHEN GWYN FOR HIS HDF SLICES

HDF Press Release Page
http://oposite.stsci.edu/pubinfo/pr/96/01.html

HDF South Press Release Page
http://oposite.stsci.edu/pubinfo/pr/1998/41/index.html

NICMOS Followup HDF Press Release http://oposite.stsci.edu/pubinfo/pr/1998/32/index.html

Distant Galaxy in HDF Press Release
http://oposite.stsci.edu/pubinfo/pr/96/24.html

Light in Visible Universe Press Release
http://oposite.stsci.edu/pubinfo/pr/1998/06/pr.html

HDF "Baby Boom" Press Release
http://oposite.stsci.edu/pubinfo/pr/96/37.html

HDF Project
http://www.stsci.edu/ftp/science/hdf/hdf.html

Amazing Space HDF Academy
http://amazing-space.stsci.edu/hdf-top-level.html

Hawaii Active HDF Catalog
http://www.ifa.hawaii.edu/%7Ecowie/tts/tts.html

Stephen Gwyn's Slice the HDF Page
http://astrowww.phys.uvic.ca/grads/gwyn/pz/dice.html

HDF region as seen by the Infrared Space Observatory
http://isowww.estec.esa.nl/science/galleries/cos/hdf_c.html

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Coming Attractions
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Spinning Stardust into Planets

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Behind the Pictures

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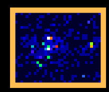
Out of the ordinary
...out of this world.

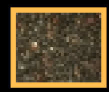
Chances are you haven't seen what NASA's orbiting Hubble Space Telescope sees. Hubble sees the raw beauty of the universe from above Earth's atmosphere and sends back a portrait of the universe in exquisite detail. Here's your chance to leave the ground for a while... and see what Hubble sees.

- News of Hubble's science and remarkable discoveries
- Gorgeous pictures of stars, planets, galaxies, nebulae, and more
- Richly illustrated facts about the telescope and its instruments
- Weather on Mars and comet collisions

NASA

Stars

 Globular Cluster  Stellar Jet  Nova Remnant

 Young Star Cluster  Star Cloud

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- Galaxies
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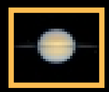
- Telescope

Solar System

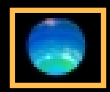
 Saturn

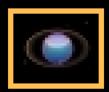
 Edge-on Saturn

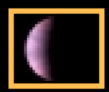
 Jupiter

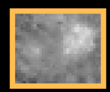
 Io Volcano

 Mars

 Neptune

 Uranus

 Venus

 Earth's Moon

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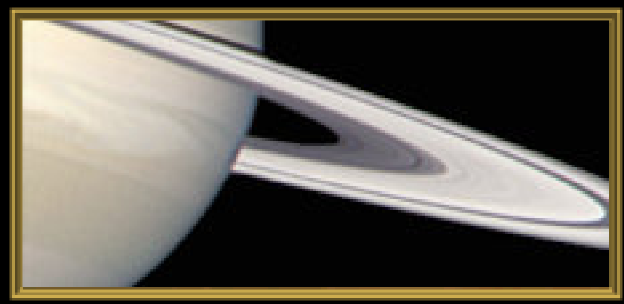
SATURN



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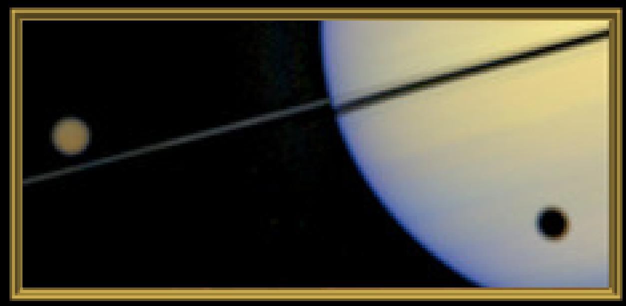

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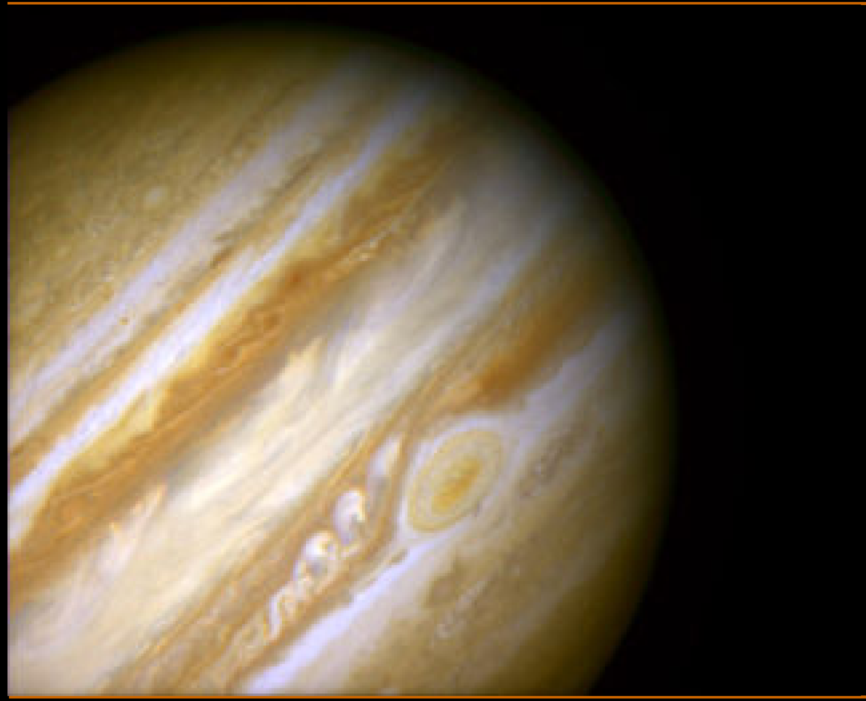

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JUPITER

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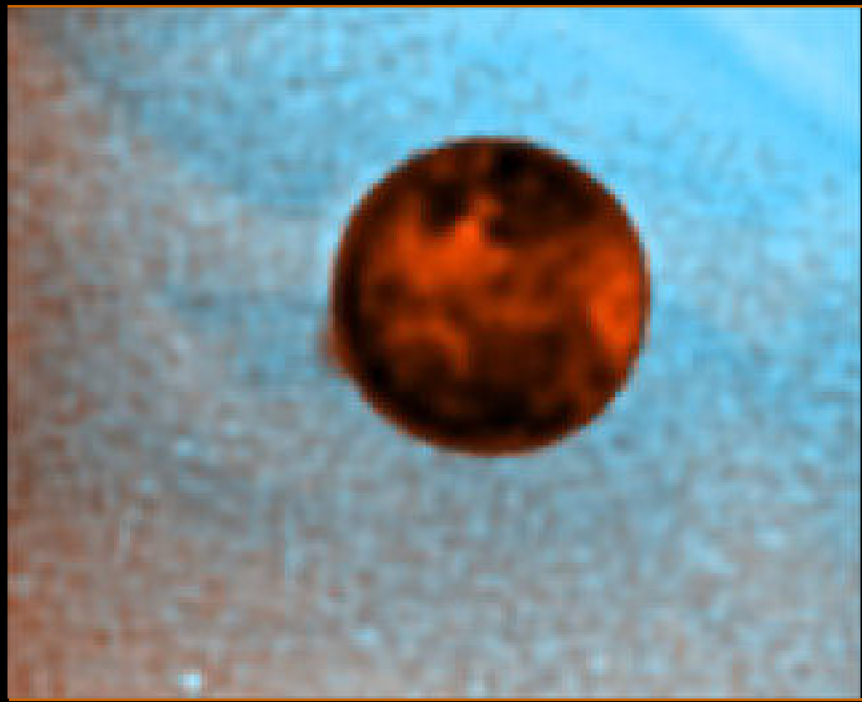

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IO VOLCANO

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MARS

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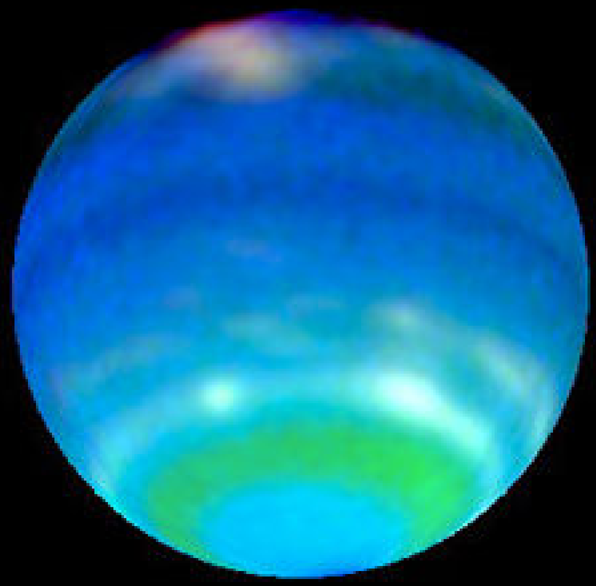

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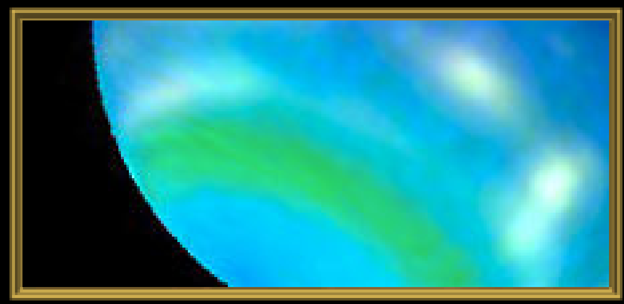
NEPTUNE



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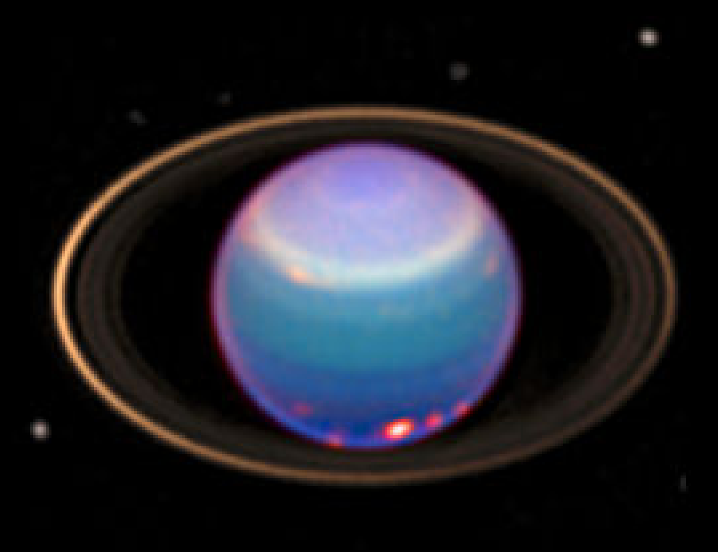
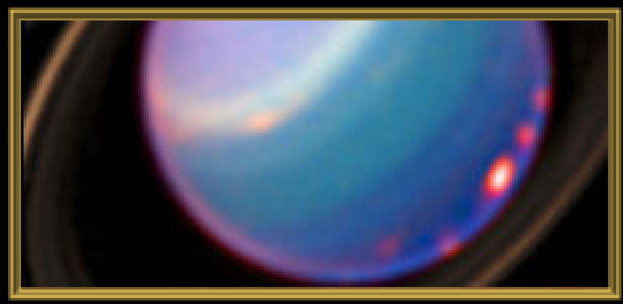


SOLAR SYSTEM

URANUS



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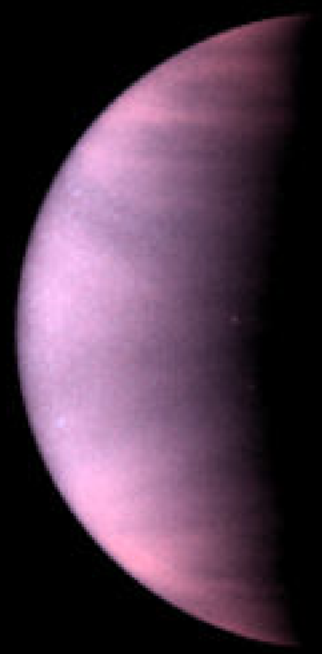

SOLAR SYSTEM

VENUS

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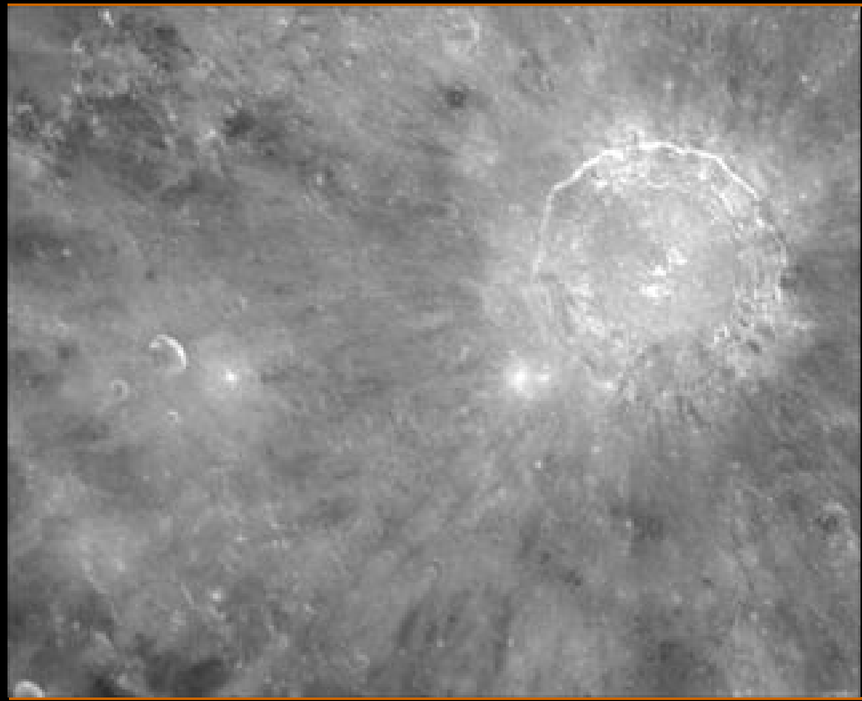
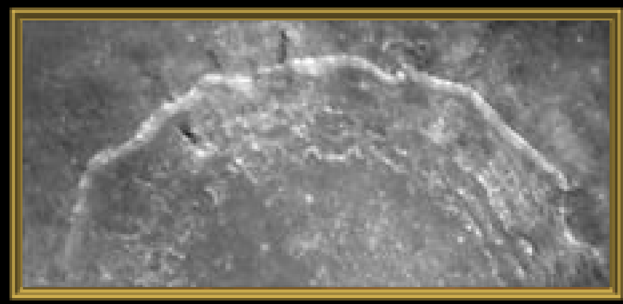


SOLAR SYSTEM

EARTH'S MOON



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STARS

GLOBULAR CLUSTER

M 80

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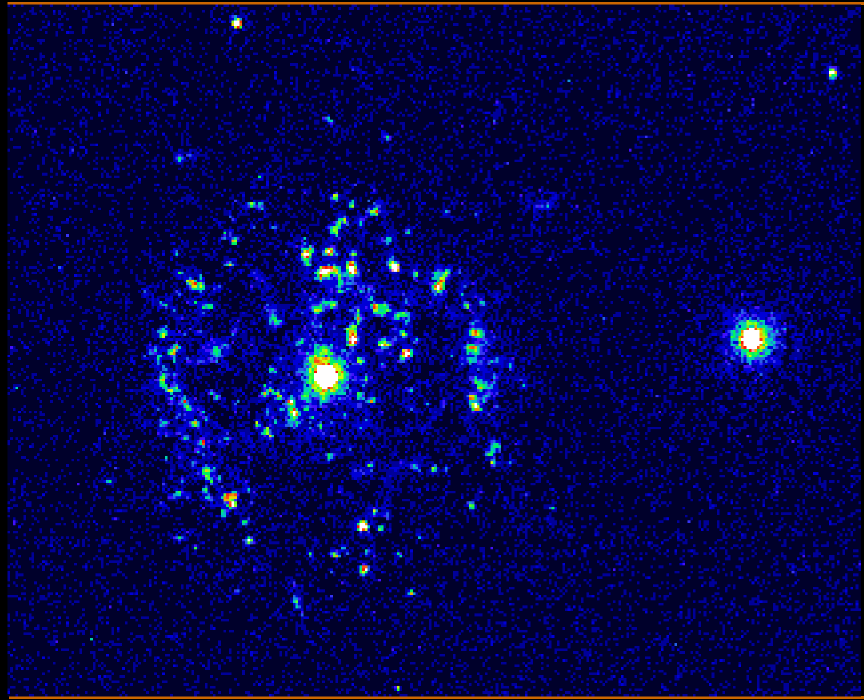
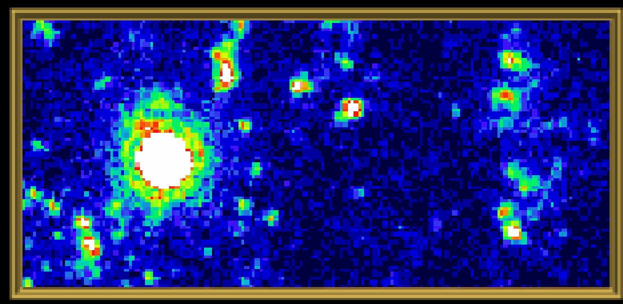


STARS

NOVA REMNANT



T PYXIDIS

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HUBBLESITE

STARS

YOUNG STAR CLUSTER

NGC 3603

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STARS

SAGITTARIUS STAR CLOUD

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Galaxies

 Starbust Ring

 Coma Cluster

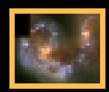
 Spiral Galaxy

 Active Galaxy

 Starburst Galaxy

 Cartwheel Galaxy

 Hubble Deep Field

 Antennae Galaxies

 Distant Galaxy

 Grazing Encounter

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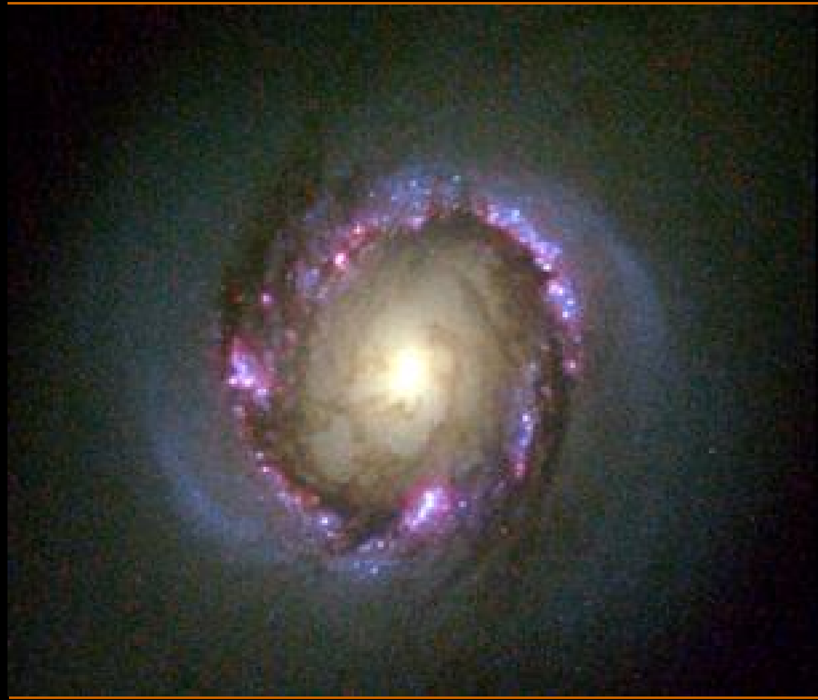
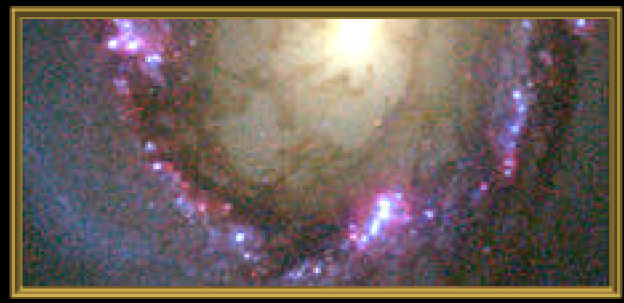


GALAXIES

STARBURST RING



NGC 4314

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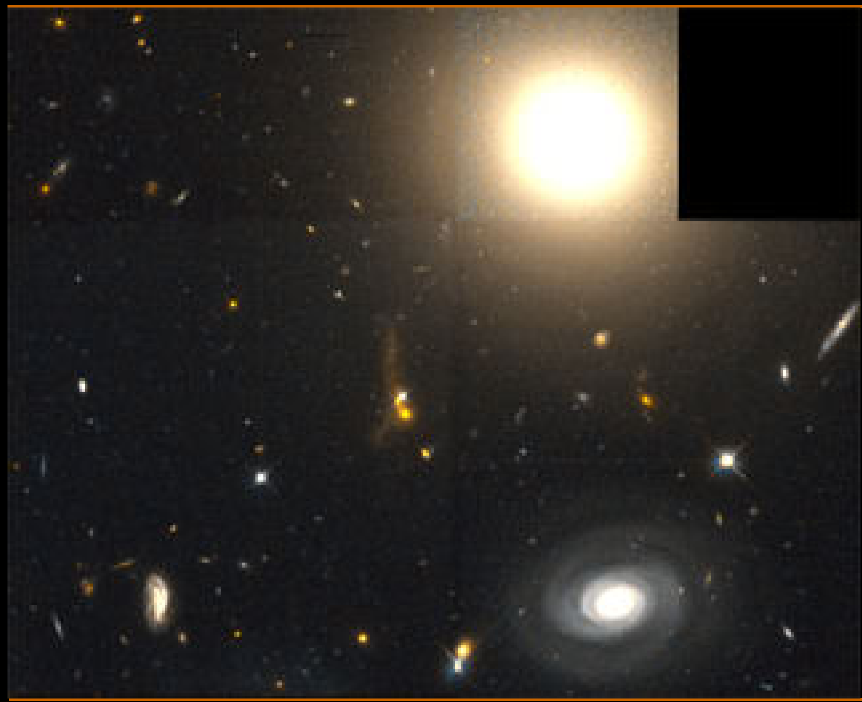

GALAXIES

COMA CLUSTER

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HUBBLESITE

GALAXIES

SPIRAL GALAXY

NGC 4414

NEXT GALAXY IMAGE LEARN MORE RETURN

HUBBLESITE

GALAXIES

ACTIVE GALAXY

NGC 7742

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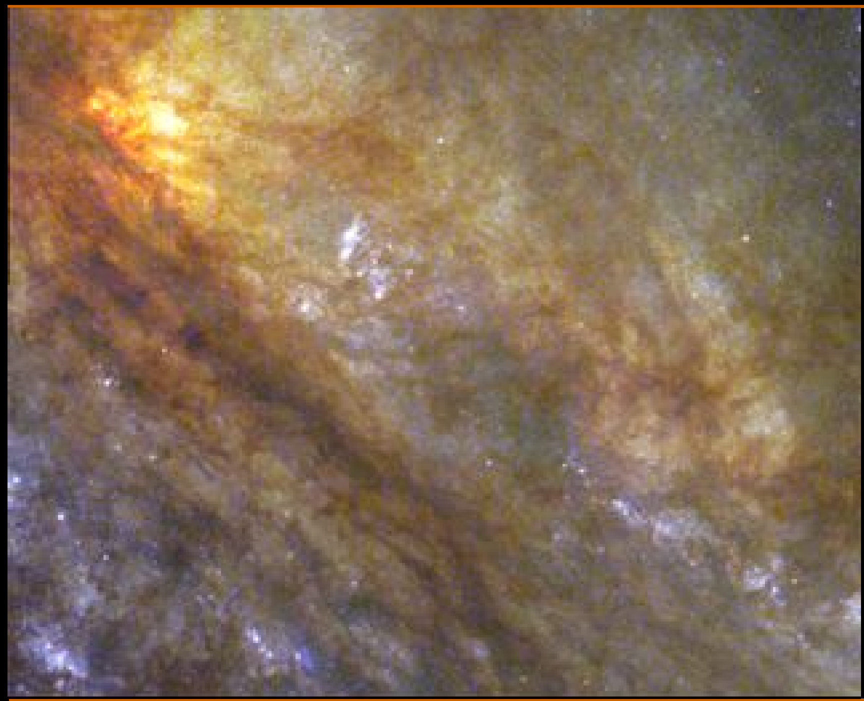

GALAXIES

STARBURST GALAXY

NGC 253

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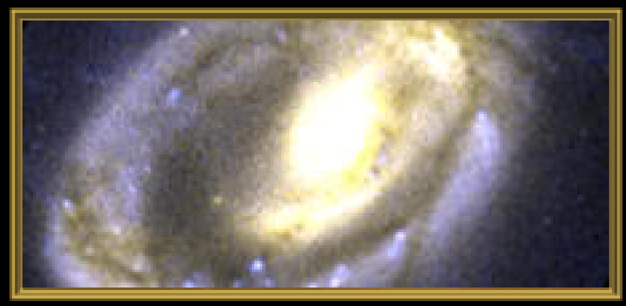
GALAXIES

CARTWHEEL GALAXY



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GALAXIES

HUBBLE DEEP FIELD

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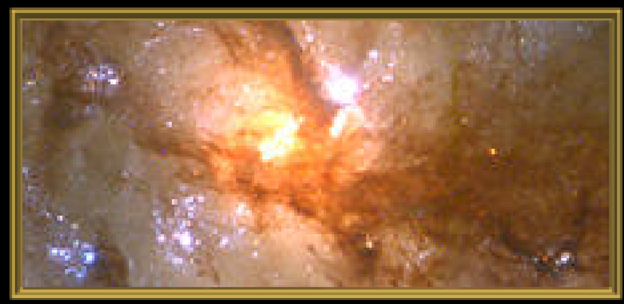
GALAXIES

ANTENNAE GALAXIES



NGC 4038/4039

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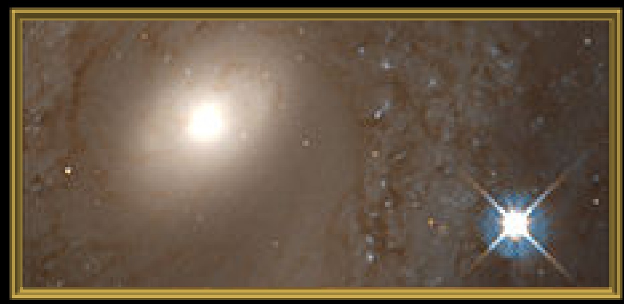
GALAXIES

DISTANT GALAXY



NGC 4603

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GALAXIES

GRAZING ENCOUNTER

NGC 2207 & IC 2163

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news & views

HUBBLESITE

1999

A Grazing Encounter between Two Spiral Galaxies

The Hubble telescope has caught a cosmic dance between two spiral galaxies. The larger galaxy, NGC 2207, is on the left; the smaller one, IC 2163, is on the right. Their dance has already caused quite a stir. Strong gravitational forces from NGC 2207 have distorted the shape of its smaller dance partner, flinging out stars and gas into long streamers that extend 100,000 light-years toward the right-hand edge of the picture. Eventually this dance will end. Billions of years from now the two galaxies will become one.

You may wish to find out the answers to questions such as these:

- How do galaxies meet?
- What happens after they merge?

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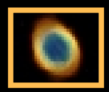
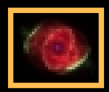
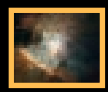
Nebulae

 Ring Nebula

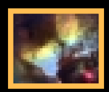
 Egg Nebula

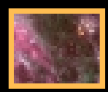
 Hourglass Nebula

 Cat's Eye Nebula

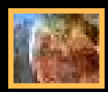
 Orion Nebula

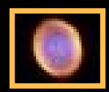
 Eagle Nebula

 Lagoon Nebula

 Tarantula Nebula

 Eskimo Nebula

 Keyhole Nebula

 Spirograph Nebula

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NEBULAE

RING NEBULA

M 57

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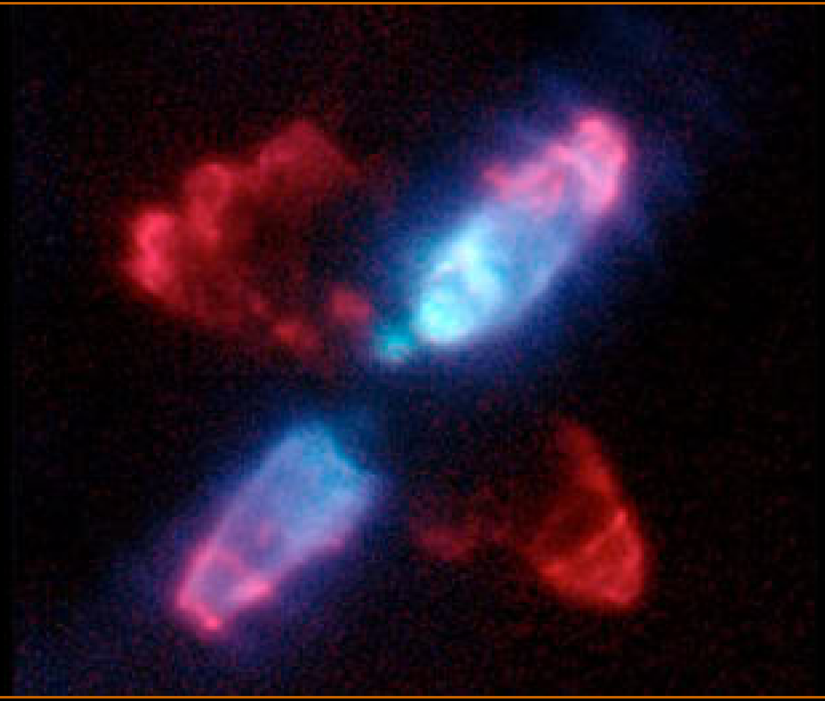

NEBULAE

EGG NEBULA

CRL 2688

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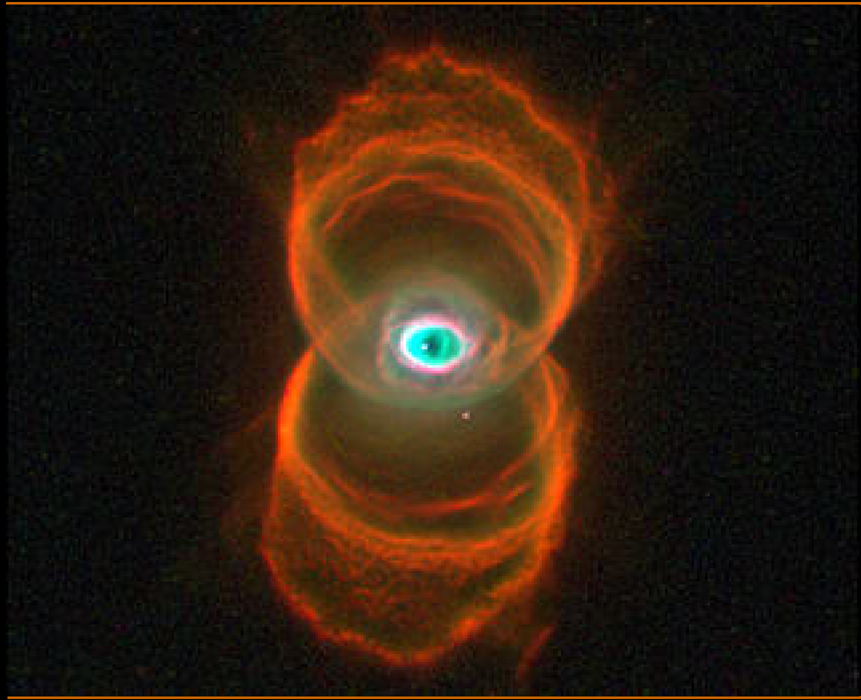

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HOURGLASS NEBULA

MYCN18

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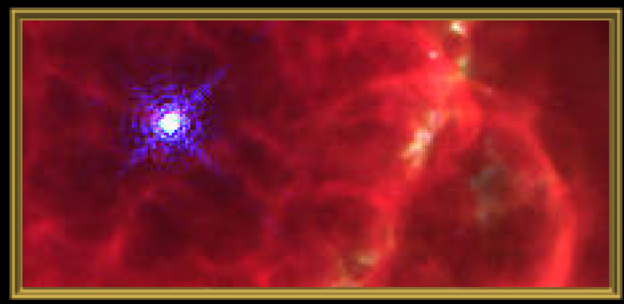
NEBULAE
CAT'S EYE NEBULA



NGC 6543

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NEBULAE

ORION NEBULA MOSAIC

M42

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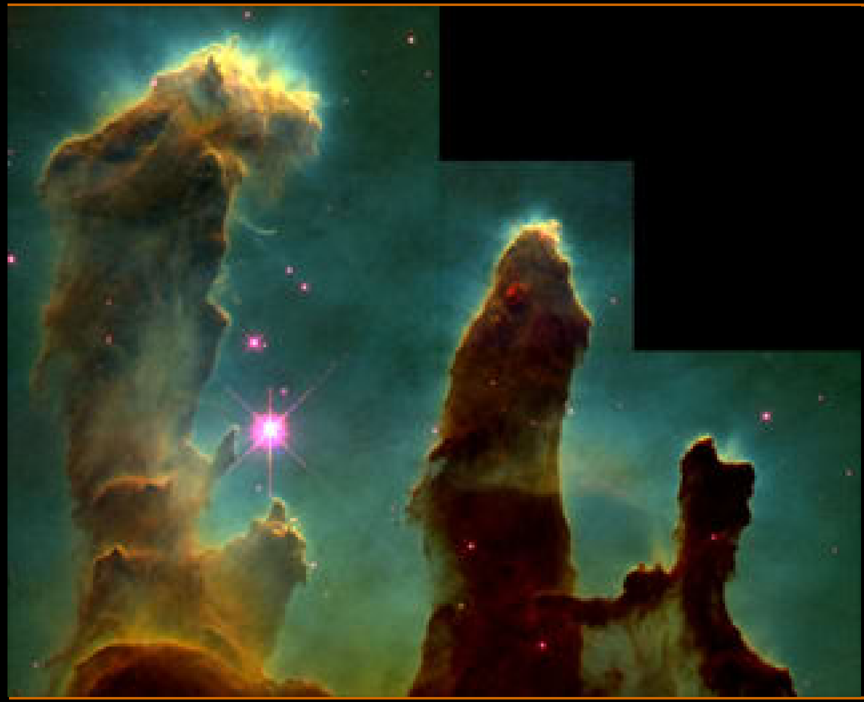

NEBULAE

EAGLE NEBULA

M 16

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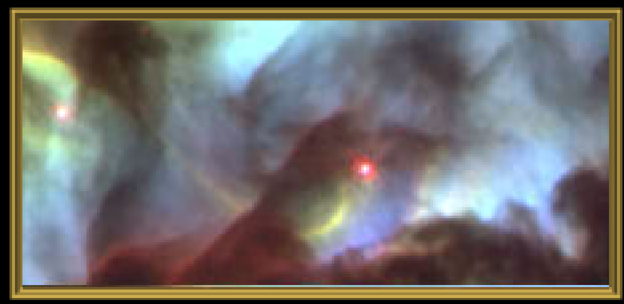
NEBULAE

LAGOON NEBULA



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NEBULAE

TARANTULA NEBULA

HODGE 301

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HUBBLESITE

NEBULAE

ESKIMO NEBULA

NGC 2392

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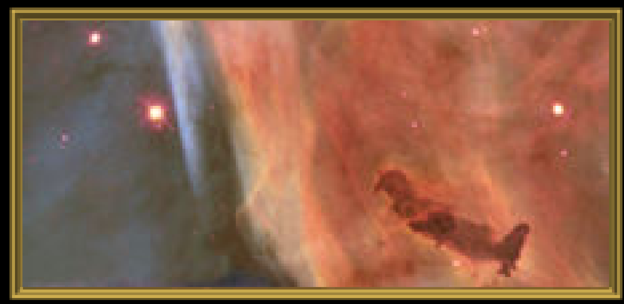
NEBULAE

KEYHOLE NEBULA



NGC 3372

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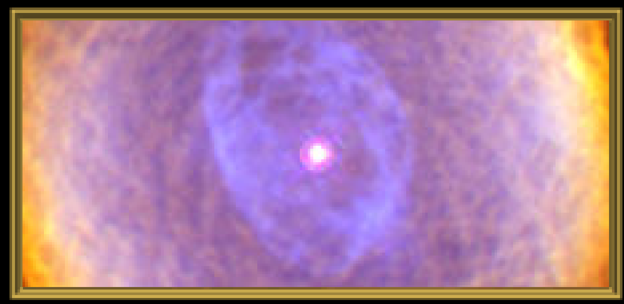
NEBULAE

SPIROGRAPH NEBULA



IC 418

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news & views

HUBBLESITE

IC 418: The "Spirograph" Nebula

Glowing like a multi-faceted jewel, the planetary nebula IC 418 lies about 2,000 light-years from Earth in the constellation Lepus. In this picture, the Hubble telescope reveals some remarkable textures weaving through the nebula. Their origin, however, is still uncertain.

You may wish to find out the answers to questions such as these:

- What is a planetary nebula?

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2000

Light and Shadow in the Carina Nebula

When 19th century astronomer Sir John Herschel spied a swirling cloud of gas with a hole punched through it, he dubbed it the Keyhole Nebula. Now the Hubble telescope has taken a peek at this region, and the resulting image reveals previously unseen details of the Keyhole's mysterious, complex structure. The Keyhole is part of a larger region called the Carina Nebula (NGC 3372), about 8,000 light-years from Earth.

You may wish to find out the answers to questions such as these:

- Where is the "keyhole" in the Hubble picture?

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2000

Hubble Reopens "Eye" on the Universe

The Hubble telescope reopened its "eye" on the universe following a successful December 1999 servicing mission by snapping a picture of the colorful death of a Sun-like star, dubbed the "Eskimo Nebula" (NGC 2392).

You may wish to find out the answers to questions such as these:

- How did the Eskimo Nebula get its name, and what are the most interesting details in the picture?

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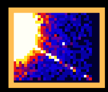
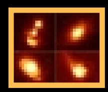
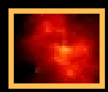
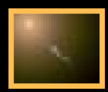
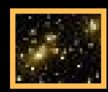
Exotica

 Brown Dwarf
 Quasar
 Black Hole
 Doomed Star
 Gravitational Lens
 Supernova
 Crab Nebula
 Cosmic Searchlight
 Lensing Cluster

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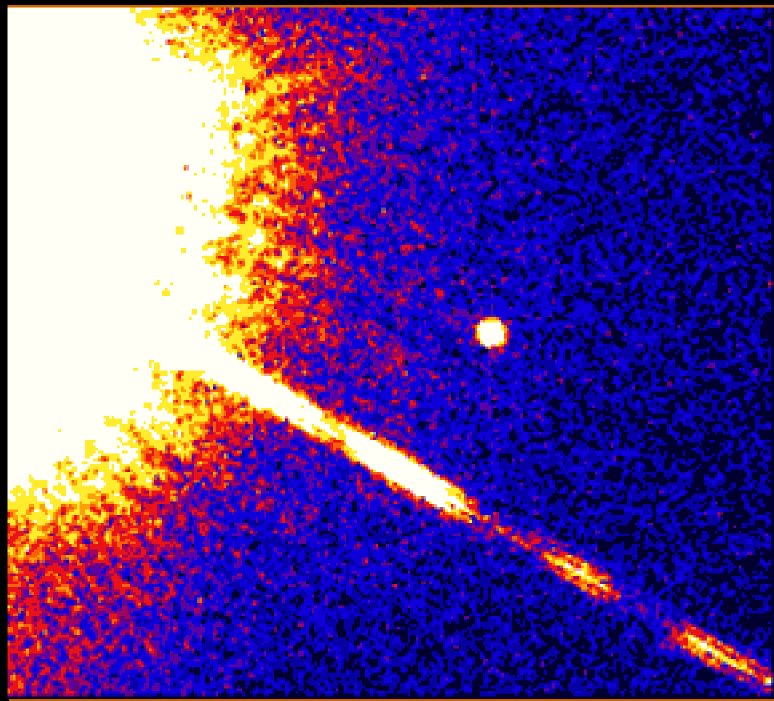
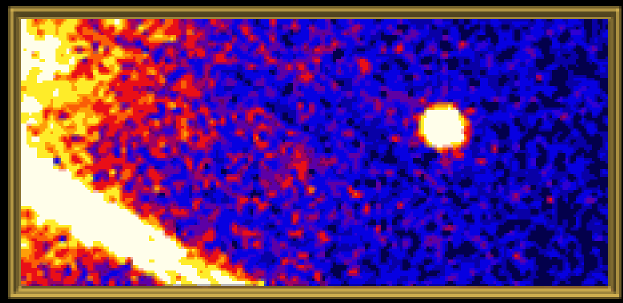


EXOTICA

BROWN DWARF



GLIESE 229B

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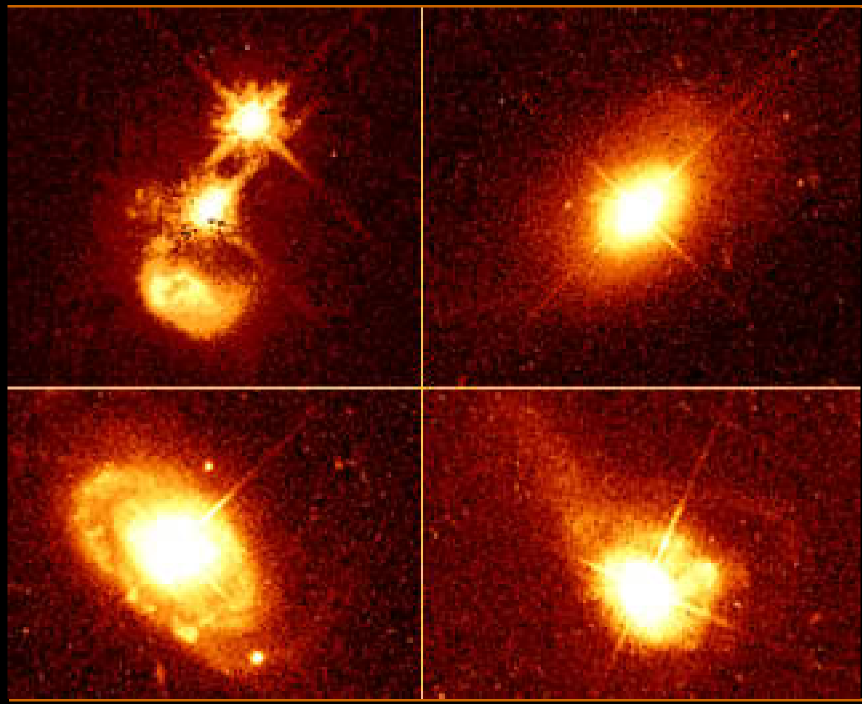

EXOTICA

QUASAR HOST GALAXIES

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EXOTICA

HIDDEN BLACK HOLE

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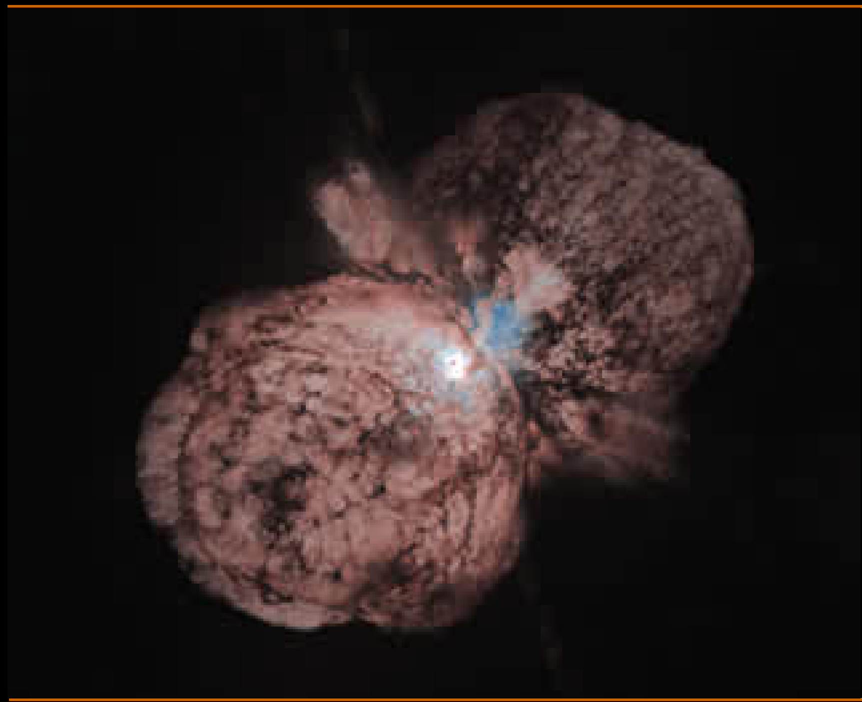

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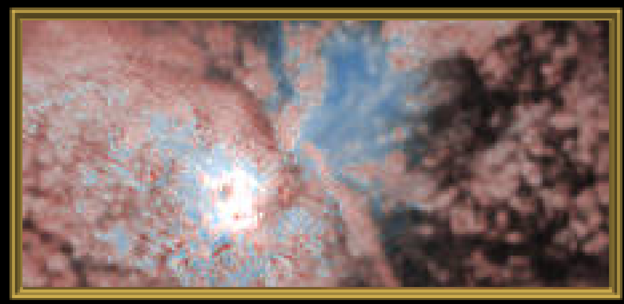
DOOMED STAR



ETA CARINAE

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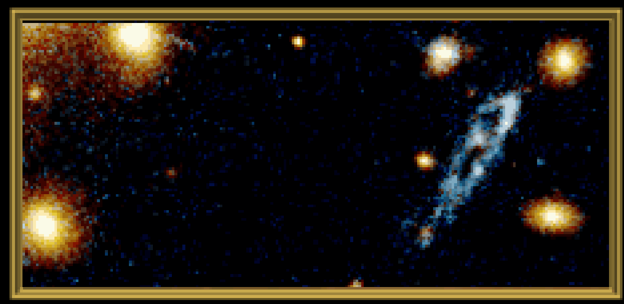
GRAVITATIONAL LENS



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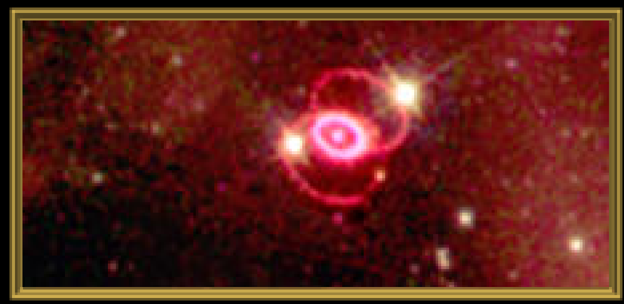
EXOTICA

SUPERNOVA 1987A



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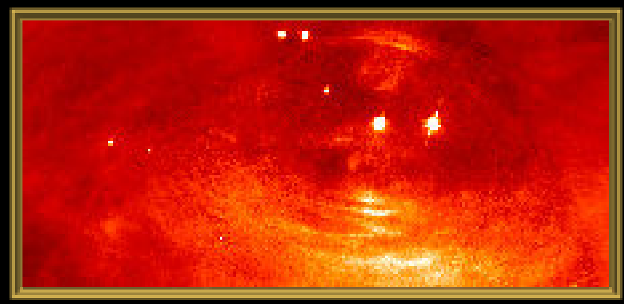
EXOTICA

CRAB NEBULA



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EXOTICA

COSMIC SEARCHLIGHT

M87 JET

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EXOTICA

LENSING CLUSTER

ABELL 2218

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2000

Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass

The Hubble telescope reopened its "eye" on the universe following a successful December 1999 servicing mission by imaging a hefty cluster of galaxies, Abell 2218, which acts like a giant zoom lens, magnifying the light of faraway galaxies.

You may wish to find out the answers to questions such as these:

- What does the picture of Abell 2218 reveal to astronomers?

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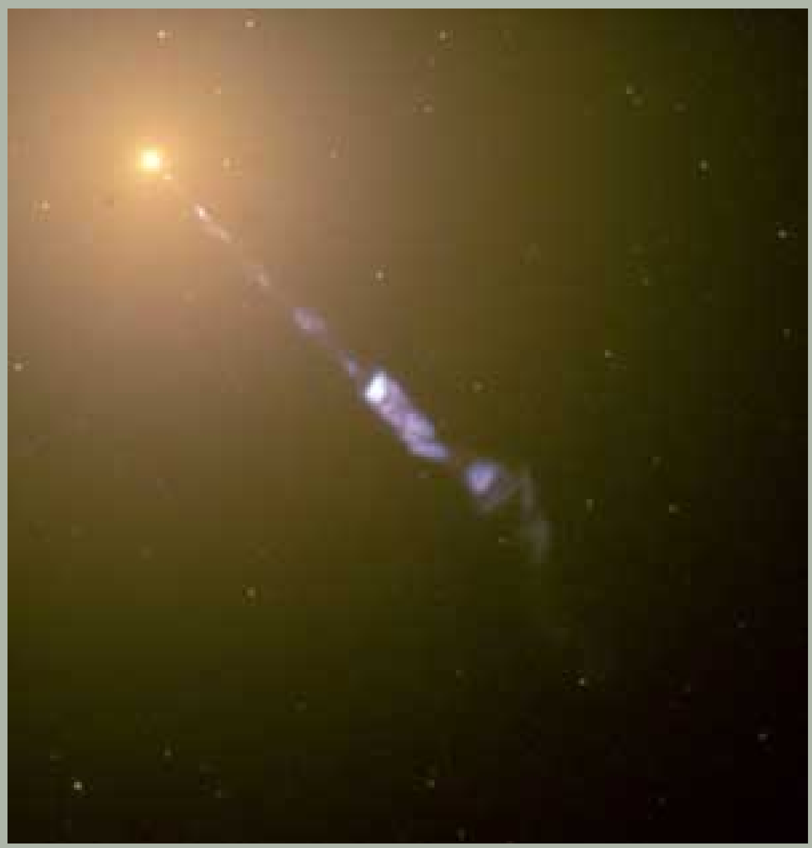
2000

A Cosmic Searchlight



Streaming out from the center of the galaxy M87 like a cosmic searchlight is one of nature's most amazing phenomena, a black-hole-powered jet of electrons and other sub-atomic particles traveling at nearly the speed of light. In this Hubble telescope image, the blue jet contrasts with the yellow glow from the combined light of billions of unseen stars and the yellow, point-like clusters of stars that make up this galaxy. Lying at the center of M87, the monstrous black hole has swallowed up matter equal to 2 billion times our Sun's mass. M87 is 50 million light-years from Earth.

You may wish to find out the answers to questions such as these:

- How does the black hole create the jet?

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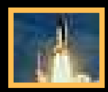
Telescope

 Shuttle Launch

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 Servicing

 Hubble Above Earth

 Earth's Limb

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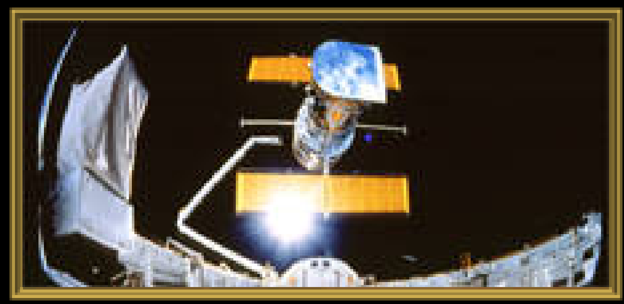
SENDING HUBBLE UP



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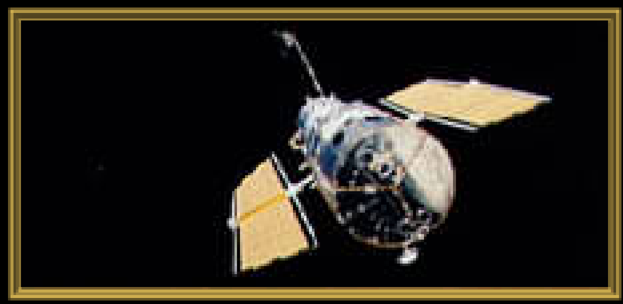
TELESCOPE

HUBBLE IN ORBIT



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TELESCOPE

HUBBLE SERVICING MISSION

NEXT TELESCOPE IMAGE

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TELESCOPE
HUBBLE ABOVE EARTH

NEXT TELESCOPE IMAGE

RETURN

TELESCOPE
EARTH'S LIMB

NEXT TELESCOPE IMAGE

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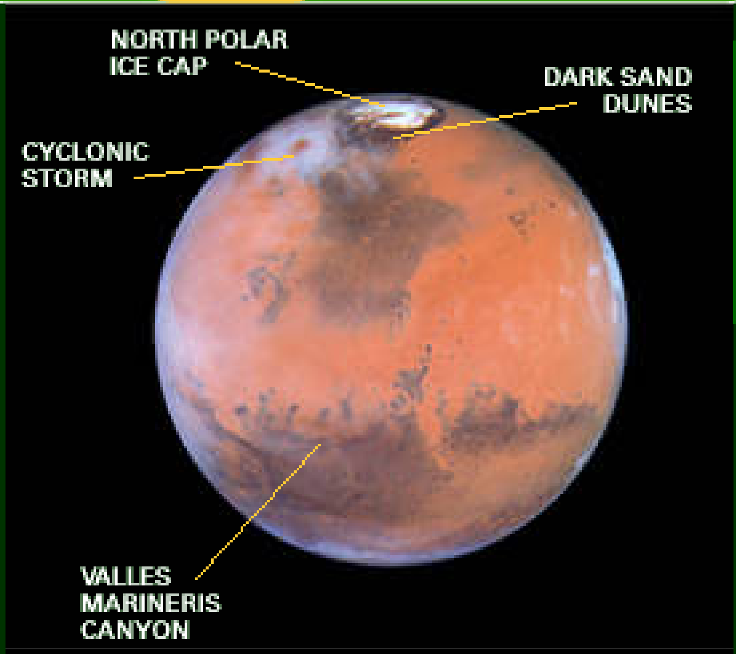
HUBBLE CHARTS CHANGES ON THE RED PLANET

ABOUT PLANETS | MARTIAN WEATHER | JUPITER GETS A BLACK EYE | SPACE/TIME: PLANETS

Hubble took this photograph of Mars in 1999 during the planet's closest approach to Earth in 8 years. Mars was 87 million km (54 million miles) away, or more than 200 times the distance from Earth to the Moon.

The photo was made at the height of Martian summer in the northern hemisphere. The carbon dioxide (dry ice) portion of the north polar ice cap has largely evaporated, revealing the permanent cap of water ice underneath. A cyclonic storm is churning nearby.



HIDE CAPTIONS

STORMS ON MARS

The Hubble Space Telescope captured this view of the planet Mars in the spring of 1999. Surface features as small as 12 miles (19 kilometers) across are visible, including numerous craters, cloud-shrouded volcanoes, and a massive cyclonic storm churning near the north polar ice cap.

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Hubble monitors the planets in our solar system. See how they change over time.

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Get a glimpse into the fantastic and tumultuous life cycle of stars.

Galaxies
Galaxies are in constant motion... and sometimes in conflict.

Universe
Hubble's "long views" offer the opportunity to look back in time.

Beyond Hubble
Hubble's successor will reach farther back in time to reveal the universe's earliest years.

HUBBLE SPACE TELESCOPE:

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Welcome to the online version of **Hubble Space Telescope: New Views of the Universe**, a traveling exhibition highlighting Hubble's contributions to astronomy. Take a journey into Hubble's amazing universe through cool pictures, interactives, and movies.

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Find out when **New Views of the Universe** will visit a museum near you.

About The Book
Check out the companion book, **Hubble Space Telescope: New Views of the Universe**, now available at online and brick-and-mortar bookstores.

Related Links
A reference for those who want to learn more about Hubble.

This icon, which appears at the bottom of every page in this site, provides a link to HubbleSite.

See the rest of HUBBLESITE

To learn more about Hubble's amazing findings, visit HubbleSite's "Discoveries" section.

HUBBLESITE

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THE TELESCOPE

Hubble In Space

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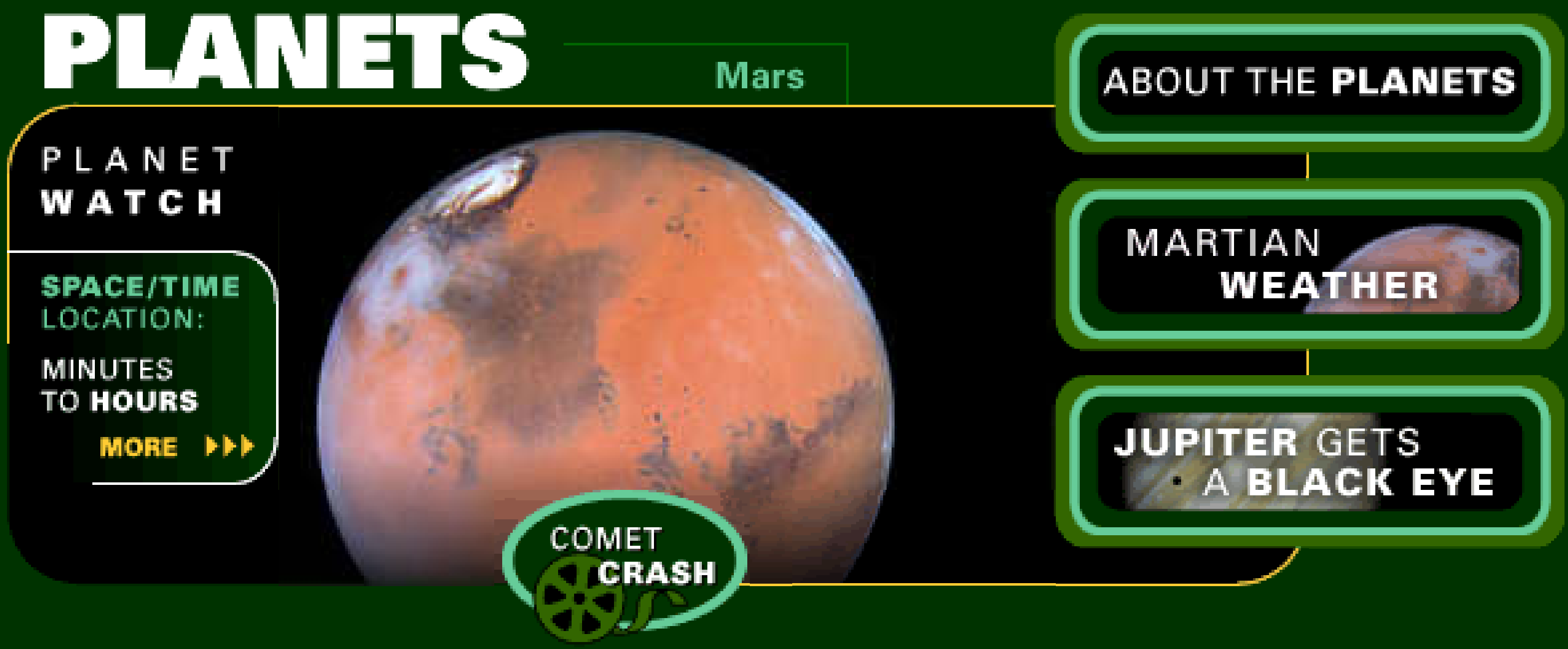
Mars



STARS

Eagle Nebula

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ABOUT GALAXIES
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MONSTER BLACK HOLES


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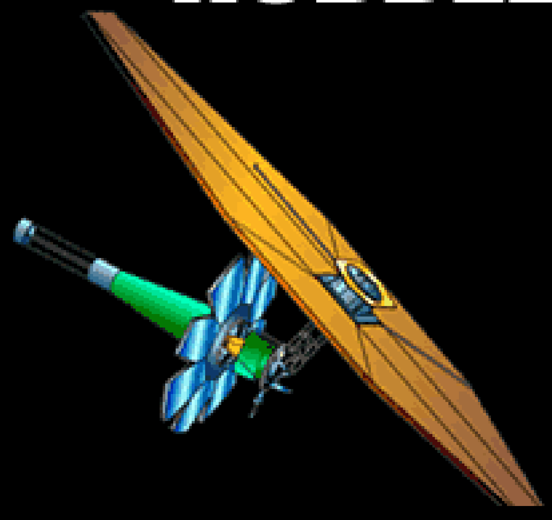
FROM THE BEGINNING OF TIME
SPACE/TIME LOCATION:
BILLIONS OF YEARS
MORE
LOOKING DEEP
ABOUT THE UNIVERSE
SPACE WARP

BEYOND HUBBLE



ONE OF THE PROPOSED DESIGNS FOR NGST

With ten times the light-gathering power of Hubble, NGST will peer deeper into the universe than ever before— back to the era when galaxies first formed.

Hubble's important mission will come to an end one day in the future. But the telescope's ultimate retirement will not signal the end of our unrivaled view of the universe. Rather, it will mark a new beginning— and even more amazing discoveries and images from space. For Hubble has a successor.

The Next Generation Space Telescope (NGST), which is being designed right now, may be launched as early as 2009. When that day comes, scientists using NGST hope to discover and understand even more about our fascinating universe.

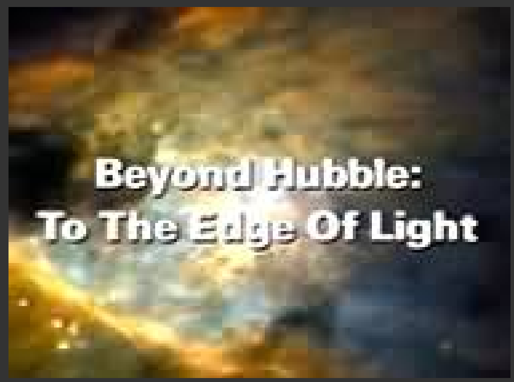
BEYOND HUBBLE

The journey is far from over... Find out what's next!

VIEW RELATED LINKS

BEYOND HUBBLE

The future of looking back in time.



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Choose a viewing format:

Streaming
(28.8k Modem)
(Requires RealPlayer)

High Quality
Play it! or Download it!
(44.0Mb)
(Requires Quicktime)

Download the text only

Beyond Hubble: To the Edge of Light

Whenever you build a new way of looking at the Universe - that's what a new telescope is - that goes beyond what you had last, it changes your view of the world.

Hubble gives a gain over the human eye of ten billion times - that is, we see ten billion times fainter with Hubble than we can with the unaided eye.

We really are after four basic scientific questions, which are, ultimately, basic human and philosophical questions. And they include:

How did the universe originate?

How did we get here?

Where are we going?

Are we alone?

Hubble has made a great contribution showing that the expanding cloud of hydrogen formed into these big things we call galaxies - the largest conglomerates of matter in the universe - much, much earlier than theory had predicted.

Hubble has proven that supermassive black holes - objects that are a billion, or two billion, times the mass of our Sun and are so crunched down that the speed of escape from these objects is greater than the speed of light, so nothing can get out - perhaps that says something about the ultimate fate of the universe. Will it all turn into a black hole some time? We don't know. But we do know that black holes are no longer science fiction. They're science fact.

Hubble has made great contributions in showing us the existence of many, many planetary disks - that is, disks of dust and gas around young stars that slowly form into planets. They're common. The process for producing planets is very, very common.

So... Hubble is just the first in an armada of space science satellites that will attack those four basic questions over the next hundred years.

The Next Generation Space Telescope is designed to go so far beyond Hubble that we see the edge of light in the universe.

The telescope will be more sensitive, first, just because it will be bigger. The Hubble telescope is about two point four meters in diameter. The Next Generation Space Telescope will be eight meters in diameter.

Because it is so much bigger, it will be that much more sensitive.

So the pictures that will be returned from the NGST will be every bit as beautiful as the pictures of the Hubble. Except, they'll be almost a thousand times more sensitive and they'll be looking at objects in the very distant reaches of the universe that we haven't yet seen because Hubble can't go that far.

And in a nutshell, that's what we hope to see - we hope to see the place where there's no more light!

That will allow us, then, to watch this whole epic of galaxies being born...

of the stars being created...

the light turning on...

assembling into galaxies...

the galaxies assembling through collisions.

But every time we put a telescope up, we discover new things.

ABOUT THE EXHIBITION

The exhibition immerses visitors in the magnificence and mystery of the Hubble mission. A scale model of the HST is the focal point of the installation. "Satellite" units incorporate hands-on activities about how the telescope works, and a "Space/Time" section features Hubble's contributions to the exploration of planets, stars, galaxies, and the universe.

Exhibition Schedule

Full Version

June 2 to August 26, 2001
NC State Museum of Natural Science
Raleigh, NC

February 2, 2002 to April 28, 2002
Tech Museum of Innovation
San Jose, CA

Small Version

June 2, 2001 to August 12, 2001
Chabot Space and Science Center
Oakland, CA

March 23, 2002 to June 9, 2002
Heritage-Hjemkomst Center
Moorhead, MN

ABOUT SITES

Since 1952, the Smithsonian Institution Traveling Exhibition Service (SITES) has been sharing the wealth of the Smithsonian's collections, research, and exhibitions with audiences around the world. Each year, millions of people beyond Washington, D.C. experience the treasures of the National Mall by visiting SITES exhibitions on display in local museums, planetariums, libraries, science centers, historical societies, aquariums, community centers, and schools.

Smithsonian Institution
Traveling Exhibition Service

ABOUT STScI

This companion Web site for the **Hubble Space Telescope: New Views of the Universe** exhibition was developed by the Office of Public Outreach at the Space Telescope Science Institute (STScI) in Baltimore, Maryland. We at STScI are working hard to study and explain the once-unimaginable celestial phenomena now made visible using Hubble's cutting-edge technology. In the course of this exploration we will continue to share with you the grace and beauty of the universe... because the discoveries belong to all of us.

SPACE TELESCOPE SCIENCE INSTITUTE
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Kathy Cordes

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Hubble Space Telescope:
NEW VIEWS OF THE UNIVERSE

The traveling exhibition was organized by the Smithsonian Institution Traveling Exhibition Service and the Space Telescope Science Institute, operated for the National Aeronautics and Space Administration (NASA) by the Association of Universities for Research in Astronomy, Inc. The exhibition and its educational programs have been made possible through the generous support of NASA's Offices of Space Science and Education and Lockheed Martin.

RELATED LINKS

BEYOND HUBBLE

The following are Web pages related to this section.

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denotes a link outside of HubbleSite

External Links Disclaimer:
Links outside of HubbleSite are provided solely as a service to our users. HubbleSite is not responsible for the content of those pages.

General Information:

What's next in orbiting observatories
http://hubble.stsci.edu/sci.d.tech/facts_.and._figures/telescope_history/telescope_history_4.shtml

NASA's Next Generation Space Telescope Web site
http://www.ngst.nasa.gov/

Press Releases:

NASA Selects Home for Next Generation Space Telescope (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+20

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HUBBLE DEEP FIELD

LOOKING DEEP

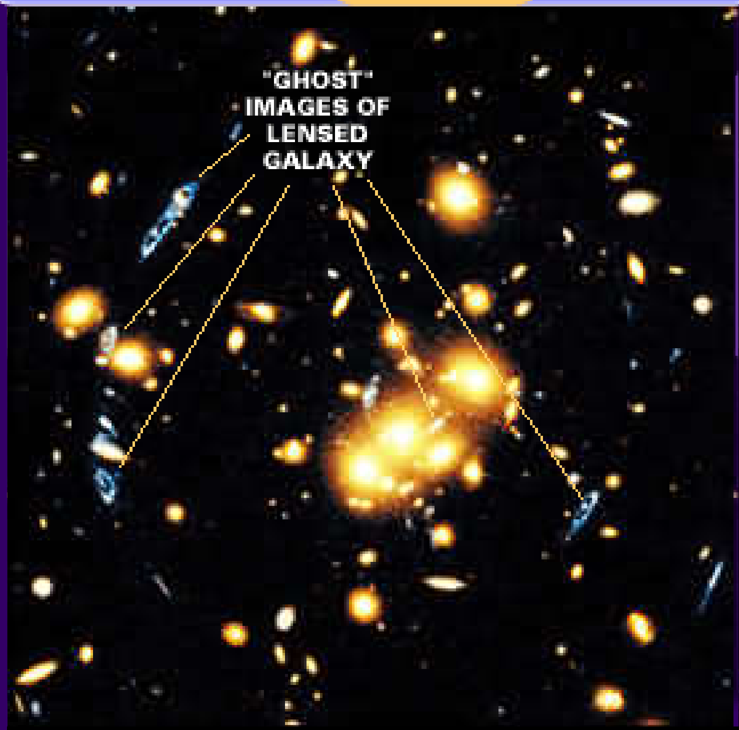
How Hubble takes the long view.

Hubble's longest exposures are like a core sample of the universe, recording galaxies at many different distances. This is one of the deepest core samples ever taken. It shows a few nearby stars in our Milky Way galaxy. The rest of the objects are distant galaxies, extending from 1 billion to over 10 billion light-years away.

GALAXY CLUSTERS WARP SPACE AND BEND LIGHT

Massive objects such as clusters of galaxies bend space in their vicinity, distorting and in some cases magnifying the objects behind them. This interesting effect is called gravitational lensing.

Gravitational lenses are being used to study young galaxies and to gain a better understanding of the total amount of matter in the universe. Hubble's observations of gravitational lenses show that the lensing clusters must have more matter than meets the eye.



HIDE CAPTIONS

This image shows "ghost" images of a single, distant galaxy. It lies far beyond the cluster that fills the frame. The multiple, distorted images are produced by the cluster's strong gravitational field, which bends passing light beams.

NEXT

VIEW RELATED LINKS

Shortcuts:

Hubble Deep Field

Graviational Lenses

UNIVERSE

The following are Web pages related to this section.

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Hubble Deep Field - General Information:

Hubble Deep Field - Web Pages Gallery image of the Hubble Deep Field.
http://hubble.stsci.edu/gallery/showcase/galaxies/g7.shtml

The Hubble Deep Field explained.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide40.shtml

Launch page for The Hubble Deep Field, a multimedia journey.
http://hubble.stsci.edu/sci.d.tech/discoveries/hubble_deep_field/index.shtml

Launch page for "Hubble Goes Deep," a Tour the Cosmos Web simulcast.
http://hubble.stsci.edu/sci.d.tech/discoveries/tour_the_cosmos/dec_98/index.shtml

A vast collection of Hubble Deep Field links.
http://hubble.stsci.edu/sci.d.tech/discoveries/hubble_deep_field/links_page.shtml

Students can train to be a scientist by enrolling in the interactive Hubble Deep Field Academy.
http://amazing-space.stsci.edu/hdf-top-level.html

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Hubble Deep Field - Press Releases

Hubble Finds Most of Visible Light in the Universe (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+06

Hubble's Deepest View of the Universe Unveils Bewildering Galaxies Across Billions of Years (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+01

Findings from Hubble Deep Field Hone In on Distant Galaxies (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+24

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Gravitational Lenses - Web Pages

Gallery image of a gravitational lens.
http://hubble.stsci.edu/gallery/showcase/exotica/e5.shtml

The phenomenon of gravitational lensing explained.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide36.shtml

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Gravitational Lenses - Press Releases

Hubble Reopens "Eye" on the Universe and Captures a Cosmic Magnifying Glass (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+08

Natural Lenses in Space Stretch Hubble's View of the Universe (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+18

World's Most Powerful Telescopes Team Up with a Lens in Nature to Discover Farthest Galaxy in the Universe (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+25

Hubble Space Telescope Completes Sixth Year of Exploration (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+10

Hubble Views Distant Galaxies Through a Cosmic Lens (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+14

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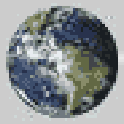
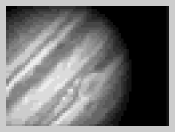
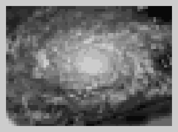
SPACE/TIME LOCATION



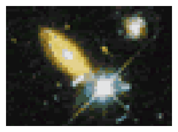


MINUTES TO **HOURS**

YEARS TO **THOUSANDS** OF YEARS



MILLIONS TO **BILLIONS** OF YEARS



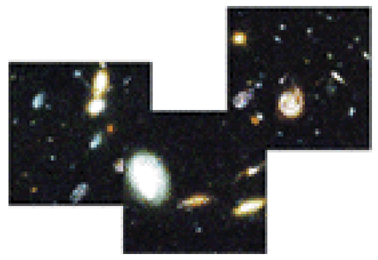
BILLIONS OF YEARS

TIME IT TAKES LIGHT TO REACH EARTH

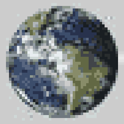
The light Hubble sees today may have taken thousands, millions, even billions of years to reach us, carrying the story of events that happened in the distant past. Click on the pictures at the top of this page to see how far we are looking back through time.

Light from the farthest regions of the universe takes billions of years to reach Hubble. Amazingly, when we look at these most distant of all views, we see events that occurred before Earth itself existed — when the universe was merely a fraction of its present age.

UNIVERSE



SPACE/TIME LOCATION



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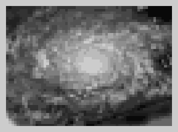

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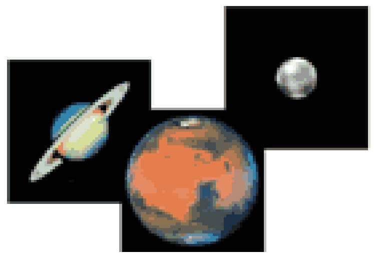
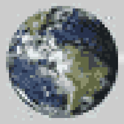
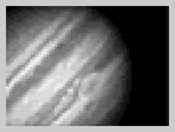
PLANETS



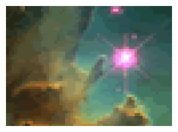
From Mars, light takes just a few minutes to reach Hubble. From Jupiter, a little over half an hour. From Saturn, a bit more than an hour. From Pluto, about 5 hours. Hubble can observe dramatic changes on the planets and their moons on the same day they occur.

SPACE/TIME LOCATION

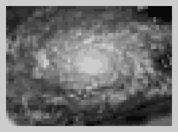




MINUTES TO **HOURS**



YEARS TO **THOUSANDS** OF YEARS



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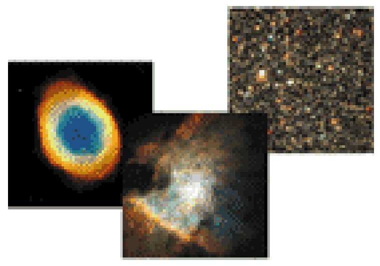
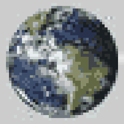
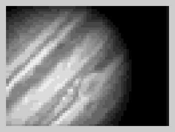
STARS



Our galaxy is 100,000 light-years across, which means that light takes that long to travel from one end to the other. The region that Hubble observes best (because the view is not blocked by dust) extends from a few light-years to a few thousand light-years away. This means that light now arriving from these objects left sometime during human history.

SPACE/TIME LOCATION





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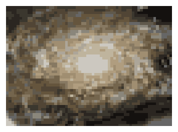

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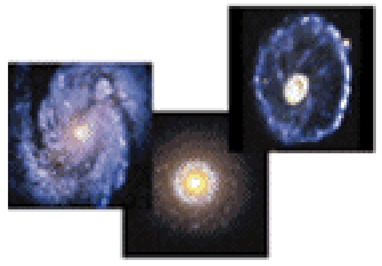
GALAXIES



Light from galaxies beyond our Milky Way galaxy takes millions to billions of years to reach the Hubble Space Telescope in its orbit above Earth. We see these islands of stars as they were in the far distant past.

Archives

TOUR THE COSMOS

Now Playing

Coming Attractions

Archives

Tune In:

- High Bandwidth (56K or faster)
- Low Bandwidth (28.8 Modem)
- Audio Only (14.4 Modem)

How to Tune In

Hubble Goes Deep

Aired December 15, 1998, Noon-1 p.m., EST

Hubble recently complemented an earlier "deep field" observation of the northern hemisphere by peering down a 12-billion-light-year-long corridor in the southern sky. It revealed a dazzling array of far-flung, previously unseen galaxies. Cosmological theory predicts that the sky should look the same in all directions. What do these observations reveal?

World-renowned astronomers discuss that question during this Web simulcast. Marc Steiner's guests include Dr. Carol Christian, STScI; Dr. Mark Dickinson, STScI; and Jim O'Leary, Baltimore Science Museum.

Guest Profiles

See the Pictures, Learn More

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HUBBLESITE

the hubble deep field

a multimedia journey

Continue the Journey!

The following links offer more information on
many facets of the Hubble Deep Field.

THANKS TO STEPHEN GWYN FOR HIS HDF SLICES

HDF Press Release Page
http://oposite.stsci.edu/pubinfo/pr/96/01.html

HDF South Press Release Page
http://oposite.stsci.edu/pubinfo/pr/1998/41/index.html

NICMOS Followup HDF Press Release http://oposite.stsci.edu/pubinfo/pr/1998/32/index.html

Distant Galaxy in HDF Press Release
http://oposite.stsci.edu/pubinfo/pr/96/24.html

Light in Visible Universe Press Release
http://oposite.stsci.edu/pubinfo/pr/1998/06/pr.html

HDF "Baby Boom" Press Release
http://oposite.stsci.edu/pubinfo/pr/96/37.html

HDF Project
http://www.stsci.edu/ftp/science/hdf/hdf.html

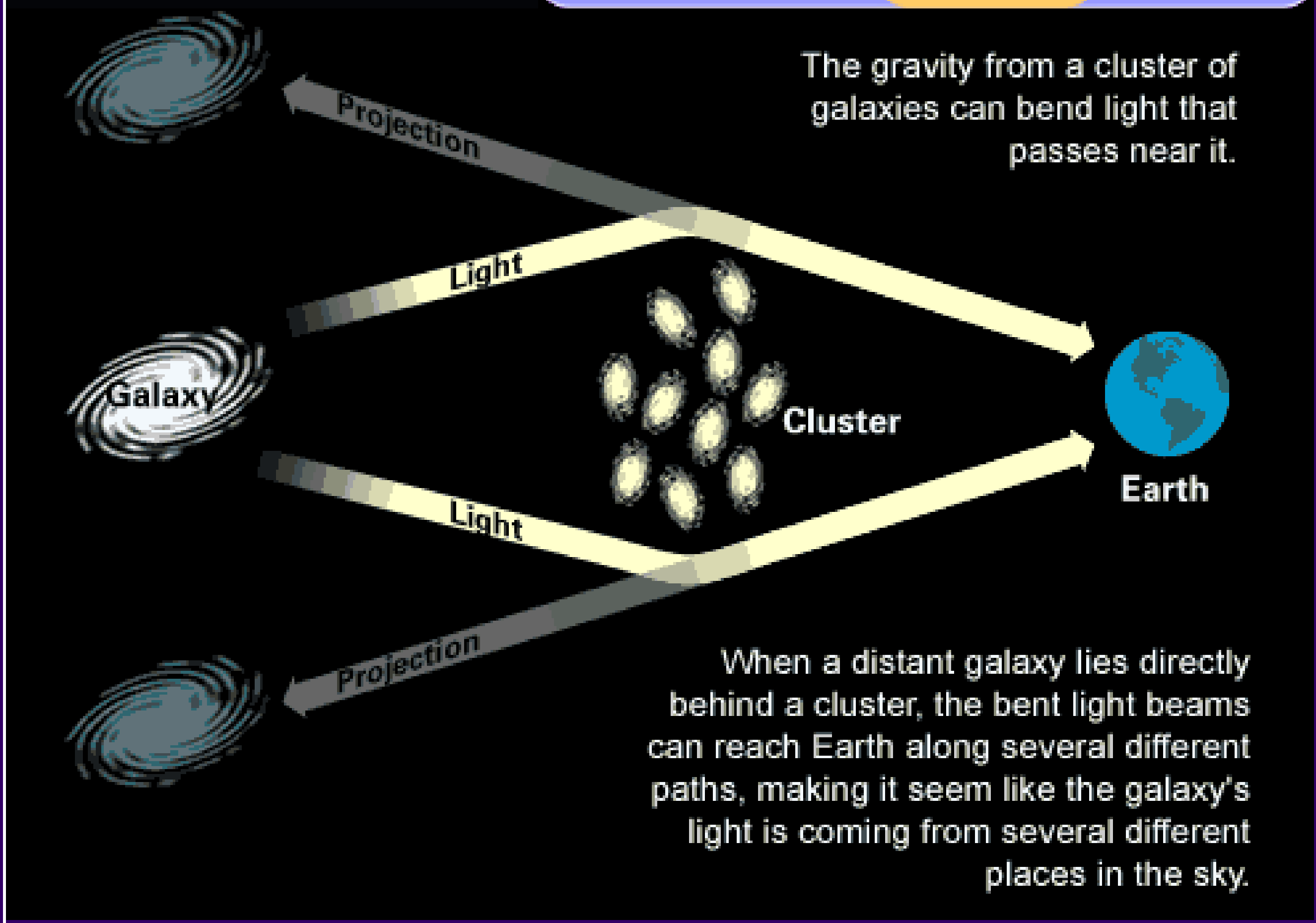
Amazing Space HDF Academy
http://amazing-space.stsci.edu/hdf-top-level.html

Hawaii Active HDF Catalog
http://www.ifa.hawaii.edu/%7Ecowie/tts/tts.html

Stephen Gwyn's Slice the HDF Page
http://astrowww.phys.uvic.ca/grads/gwyn/pz/dice.html

HDF region as seen by the Infrared Space Observatory
http://isowww.estec.esa.nl/science/galleries/cos/hdf_c.html

COSMIC ILLUSION



LOOKING DEEP

How to take a core sample of the cosmos ... and what it revealed.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

real player 7 FREE | QuickTime Get 4.

Choose a viewing format:

Streaming
(28.8k Modem)
(Requires RealPlayer)

High Quality
Play it! or Download it!
(21.1Mb)
(Requires Quicktime)

Download the text only

Looking Deep

Narrator: It took a dark, unassuming patch of sky to find young galaxies twinkling at the edge of the cosmos.

Ferguson: For the Hubble Deep Field it was important that we get an essentially unblocked view of the distant universe. We wanted to be unblocked by anything in our own galaxy, that is, bright stars or dust in our galaxy. We wanted to avoid any nearby galaxies that might have essentially dominated the picture. And so we had to do some studies to find a field of sky that was essentially boring in every way so that we could look at the distant galaxies.

Nar: The team targeted Hubble's Continuous Viewing Zone—narrow patches of sky near the North and South Poles where Hubble can stare for several days without being blocked by the Earth. The long exposure brings out wispy detail in galaxies as far as 12 billion light years away. But the telescope also captures light that astronomers need to filter out.

Ferguson: The problem is that the telescope itself is subject to radiation from charged particles, most of which come from the solar wind. And those also leave little spots of light on the detector. So when you see one of the Hubble images it's covered with these spots like measles. So you have to take a whole bunch of pictures. These spots will move around because they're not on the sky, but the galaxies and the stars will stay there. So you take a whole bunch and combine them together, keeping only the things that don't change from image to image.

Nar: In all, it took 350 images, with 3 color filters, for the team to piece together the final Hubble Deep Field image.

Ferguson: Well the thing that amazes me when I look at the Hubble Deep Field, first of all, is just how many galaxies there are. This tiny spot on the sky, and almost everything you see in the image is a galaxy. Each of those galaxies has anywhere from a billion to a hundred billion stars in it. And so we have before us in this image the history of the universe if we can figure out what it's trying to tell us. And, in many ways, it's like going out on a very dark night and staring up at the sky. And you realize how tiny a part of the sky it is, and yet you're seeing these vast systems of stars. What an amazing universe it is we're looking at.

A SPECTACULAR SPIRAL

HOW OLD IS THE UNIVERSE?

How old is the universe? Listen to astro-nomer's answers.

HIDE CAPTIONS

Galaxies come in diverse shapes and sizes. NGC 4414 — which is located about 62 million light-years away — is an example of a spiral galaxy. As with most spirals, the central region of NGC 4414 contains primarily older, yellow and red stars. The outer spiral arms are considerably bluer due to ongoing formation of young, blue stars.

The stars form a flat disk that circles the nucleus — a disk we see tilted, so it doesn't appear flat. Spiral galaxies like NGC 4414 display beautiful spiral arms made up of millions of young stars.

VIEW RELATED LINKS

TWO GALAXIES COLLIDE!

Every so often, one of the galaxies drifting through the universe will collide with another, creating the kind of spectacle seen here. This pair of crashing galaxies is called "The Antennae" because of the long streamers of stars thrown off early in the collision.

Collisions like these last hundreds of millions of years and were probably much more common in the early universe, when galaxies were much closer together.

VIEW RELATED LINKS

HIDE CAPTIONS

GALACTIC CRASH SCENE: RECONSTRUCTING COSMIC COLLISIONS

When confronted with the spectacular messes seen in this Hubble picture, astronomers usually resort to computer models of galaxy collisions. These models use known laws of physics to simulate what will happen when two galaxies collide. The trick is to specify the properties of the inital galaxies — size, shape, direction of motion, and speed — so that when they collide, they produce something similar to the observed mess.

RELATED LINKS

Shortcuts:

Spiral Galaxy NGC 4414

Age of the Universe

Colliding Galaxies

Black Holes

GALAXIES

The following are Web pages related to this section.

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Spiral Galaxy NGC 4414 - General Information

Gallery image of spiral galaxy NGC 4414.
http://hubble.stsci.edu/gallery/showcase/galaxies/g3.shtml

Background information on spiral galaxy NGC 4414.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide38long.shtml

Play with galaxies-the building blocks of the universe-in Galaxies Galore.
http://amazing-space.stsci.edu/galaxies-galore/index.html

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Spiral Galaxy NGC 4414 - Press Release

Magnificent Details in a Dusty Spiral Galaxy (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+25

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Age of the Universe - General Information

Determining the age of the universe.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/overview4.shtml

Using Cepheid variables to date the universe.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide37.shtml

The universal speed limit.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/speed.shtml

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Age of the Universe - Press Releases

Hubble Completes Eight-Year Effort to Measure Expanding Universe (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+19

Hubble Space Telescope On Track for Measuring the Expansion Rate of the Universe (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+21

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Colliding Galaxies - General Information

Gallery image of the Antennae galaxies.
http://hubble.stsci.edu/gallery/showcase/galaxies/g8.shtml

Colliding galaxies explained.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide31long.shtml

A spectacular image of a collision between galaxies NGC 2207 and IC2163.
http://heritage.stsci.edu/public/99nov4/displayngc2207.html

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Colliding Galaxies - Press Releases

A Bird's Eye View of a Galaxy Collision (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+34

Hubble Provides Multiple Views of How to Feed a Black Hole (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+14

Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+34

Hubble Views a Starry Ring World Born in a Head-On Collision (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+02

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Black Holes - General Information

Black holes explained in depth.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/blackholes.shtml

What is the signature of a black hole?
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide33.shtml

Astronomers find proof of a black hole's existence.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide32.shtml

Fall into one of the eeriest celestial phenomena in The Truth About Black Holes.
http://amazing-space.stsci.edu/blackholes/index-real_nf.html

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Black Holes - Press Releases

A Cosmic Searchlight (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+20

Hubble Records a Black Hole's Signature (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+12

Hubble Confirms Existence of a Massive Black Hole at Heart of Active Galaxy (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+23

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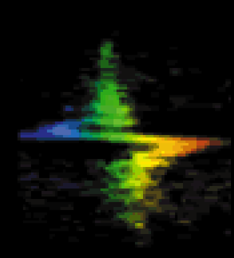
BIG BLACK HOLES LURK INSIDE MOST GALAXIES

Most galaxies (if not all) have unbelievably immense black holes at their centers. We can't see them, but instruments like the spectrograph on Hubble can measure how the black holes affect the matter surrounding them, which is how we determine their presence.

VIEW RELATED LINKS

HIDE CAPTIONS



The colorful "zigzag" at left is the signature of a supermassive black hole in the center of galaxy M84. The black hole was discovered using Hubble's imaging spectrograph.

NEXT

BLACK HOLE MYSTERIES

What is a black hole?
A black hole is an object so massive and dense that nothing—not even light—can escape from its powerful gravitational field.

How are black holes formed?
Smaller black holes (about 10 times as massive as the Sun) are created in supernova explosions, when the core of a dying star suddenly collapses. Supermassive black holes hundreds of millions of times as massive as the Sun are found at the centers of galaxies.

What happens inside a black hole?
The science of physics is not yet advanced enough to know for sure what happens inside a black hole. Anything that gets pulled in is probably compressed to a tiny point.

BACK

VIEW RELATED LINKS

HOW OLD IS THE UNVERSE?

Astronomers describe how to calculate the age of the universe.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

Choose a viewing format:

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Age of the Universe

The age that our group has measured of the universe is about 12 billion years, and that's give or take a couple of billion years.

It's about 13 billion years, give or take about 10 percent.

Somewhere between 12 and 17 billion years.

We get an age of about 14 billion years for the universe – plus or minus one or two billion years.

The first step was to use Hubble to measure distances to about two dozen nearby galaxies using a class of very bright, pulsating variable stars. And then, we used that set of galaxy distances to measure several other methods, which allowed us to extend our scale another factor of ten in distance farther out.

There's a particular type of supernova for which we have determined the actual brightness. And having established that, if you can find these supernovae in much more distant galaxies, by looking at how bright they appear, you can gauge how far away they are.

Well, we've been studying the supernovae themselves in a lot of detail. And by doing that, you get some clues to the ones that are a little bit brighter and the ones that are a little bit dimmer. That allows you to make more accurate estimates of the distance to each one.

The different approach that our group took was to measure distances – and therefore ages – using many different methods, so we wouldn't put all our eggs into one basket. And that differs from the approach of some other groups, which, for example, might use only Type 1A supernovae.

Well, we know how fast the various bits of the universe are expanding. So now if we can get distances to those bits, we can calculate how long it took to get there.

Once we've measured the distances to galaxies, then we can measure their speeds or their velocities. And that tells us how fast the universe is expanding. And then, just like a movie, we can run that in reverse, and we can see how long the universe has been expanding. And that gives us the age.

But it might not be the right age if the universe has been speeding up over time, or if it's been slowing down over time, because that age assumes that they've been going at constant speed. So we've been looking at very, very distant supernovae – very far away, very faint – and from those, we've been able to figure out that the universe has actually been speeding up, not slowing down as many people would expect. And that allows you to make a more accurate estimate for the age of the universe.

Each of these methods has its own weaknesses. The question is, which has the least? Now, do you gain by taking an average of several weak methods? Or do you pick the one that's the least weak and use that alone? And our judgment was that the particular supernova method was the best way to go.

What our group did, which is somewhat different from what other groups have done, is to measure distances – and therefore ages – using a number of different methods.

It's good to have a variety of them, but it's probably good to trust the best one.

Now, other groups have gotten slightly different answers than we have, but that's the way the scientific method works – to compare those results and over time, and to iron out the differences.

A STAR'S LIFE

Catch a glimpse of the fascinating life cycle of stars.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

Choose a viewing format:

Streaming
(28.8k Modem)
(Requires RealPlayer)

High Quality
Play it! or Download it!
(15.9Mb)
(Requires Quicktime)

Download the text only

STARS LIVE AND DIE

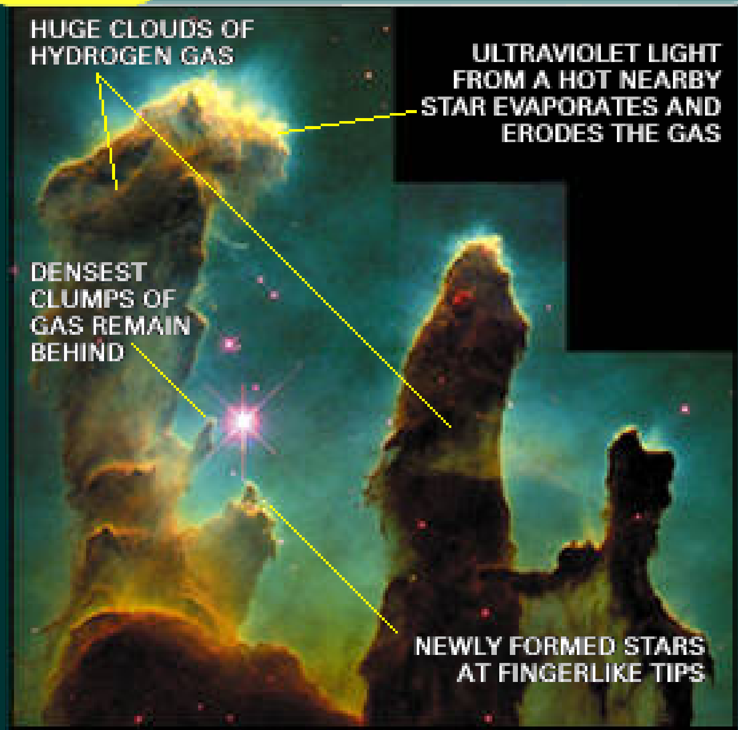
A STAR'S LIFE

Watch how a star evolves ... from birth to death.

Stars live and die over the course of millions to billions of years. It is unusual to see changes in individual stars. To learn more about them, we must piece together snapshots of stars at different life stages — from birth to death.

The birth, life, and rebirth of stars is an ongoing process in the universe. The byproducts of this process include planets and the elements that make life possible.

VIEW RELATED LINKS



HIDE CAPTIONS

THE EAGLE NEBULA

Stars form in huge clouds of hydrogen gas. This picture shows the Eagle nebula, in which stars are now being born. Millions of years from now the clouds seen here will be gone — eroded away by radiation and matter emanating from the newborn stars. Our own Sun probably formed from a similar cloud about 4.6 billion years ago.

NEXT

Shortcuts:

Eagle Nebula

Sagittarius Star Cloud

Supernova 1987a

Orion Nebula

Stellar Jets

Cat's Eye Nebula

Twin-Jet Nebula

Ring Nebula

Hourglass Nebula

STARS

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Eagle Nebula - General Information

Gallery image of the Eagle Nebula.
http://hubble.stsci.edu/gallery/showcase/nebulae/n6.shtml

A detailed description of the Eagle Nebula (with pictures).
http://hubble.stsci.edu/discoveries/10th/views/portfolio/slide24.shtml

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Eagle Nebula - Press Release

Embryonic Stars Emerge from Interstellar "Eggs" (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+44

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Sagittarius Star Cloud - General Information

Gallery image of the Sagittarius Star Cloud.
http://hubble.stsci.edu/gallery/showcase/stars/s5.shtml

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Supernova 1987a - General Information

Gallery image of Supernova 1987a.
http://hubble.stsci.edu/gallery/showcase/exotica/e6.shtml

A detailed description of Supernova 1987a (with pictures).
http://hubble.stsci.edu/discoveries/10th/views/portfolio/slide28.shtml

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Supernova 1987a - Press Releases

SN1987A in the Large Magellanic Cloud (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+04

Shock Wave Sheds New Light on Fading Supernova (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+08

Hubble Reveals Invisible High-Speed Collision Around Supernova 1987a (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+19

Supernova Blast Begins Taking Shape (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+03

Hubble Chemically Analyzes the Ring Around Supernova 1987a (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+14

Hubble Finds Mysterious Ring Structure Around Supernova 1987a (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+22

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Orion Nebula - General Information

Gallery image of the Orion Nebula.
http://hubble.stsci.edu/gallery/showcase/nebulae/n5.shtml

The Orion Nebula's role in the search for planetary systems.
http://hubble.stsci.edu/discoveries/10th/our_universe/in-depth/search.shtml

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Orion Nebula - Press Releases

Hubble Spies Brown Dwarfs in Nearby Stellar Nursery (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+19

Hubble Captures the Heart of the Orion Nebula (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+13

Panoramic Hubble Picture Surveys Star Birth, Protoplanetary Systems in the Great Orion Nebula (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+45

Hubble Confirms Abundance of Protoplanetary Disks Around Newborn Stars (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+24

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Stellar Jets - General Information

Gallery image of a stellar jet (HH-47).
http://hubble.stsci.edu/gallery/showcase/stars/s2.shtml

The colorful lives of stars.
http://hubble.stsci.edu/discoveries/10th/our_universe/in-depth/stars.shtml

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Stellar Jets - Press Releases

Movies from Hubble Show the Changing Faces of Infant Stars (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+32

Hubble Finds Young Stars in Cosmic Dance (2000)
http://hubble.stsci.edu/news_.and._views/pr.cgi.2000+05

Hubble Observes the Fire and Fury of a Stellar Birth (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+24

top

Cat's Eye Nebula - General Information

Gallery image of the Cat's Eye Nebula.
http://hubble.stsci.edu/gallery/showcase/nebulae/n4.shtml

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Cat's Eye Nebula - Press Release

Hubble Probes the Complex History of a Dying Star (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+01

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Twin-Jet Nebula - General Information

A portrait of star death.
http://hubble.stsci.edu/discoveries/10th/our_universe/overview2.shtml

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Twin-Jet Nebula - Press Release

Hubble Witnesses the Final Blaze of Glory of Sun-Like Stars (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+38

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Ring Nebula - General Information

Gallery image of the Ring Nebula.
http://hubble.stsci.edu/gallery/showcase/nebulae/n1.shtml

Planetary nebula gallery
http://hubble.stsci.edu/discoveries/10th/views/portfolio/slide27.shtml

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Ring Nebula - Press Releases

Looking Down a Barrel of Gas at a Doomed Star (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+01

A Glowing Pool of Light (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+39

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Hourglass Nebula - General Information

Gallery image of the Hourglass Nebula.
http://hubble.stsci.edu/gallery/showcase/nebulae/n3.shtml

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Hourglass Nebula - Press Release

Hubble Finds an Hourglass Nebula Around a Dying Star (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+07

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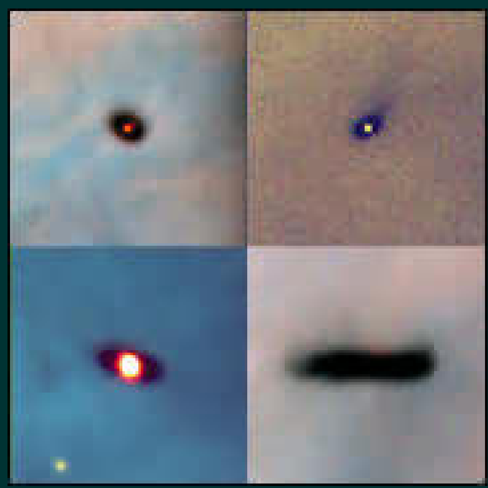
NEW STARS ARE BEING BORN IN THE ORION NEBULA

Hubble has captured vivid views of newly forming stars inside the Orion nebula. Stars form when a spinning cloud of interstellar gas collapses under the force of its own gravity. The collapsing cloud leaves behind a dark disk of orbiting debris that may well form a planetary system.

Planets are born in the spinning disks of debris left behind as stars form. The matter in these disks gradually collects into ever larger lumps that ultimately become planet-sized.

In the lower picture (four sections) the red dot at the center of each object is a young star. Surrounding each star is a dark disk of debris. About 4.6 billion years ago, before planets formed around our Sun, the solar system probably looked like this.



Details from the Orion Nebula

NEXT
VIEW RELATED LINKS

STARS LIKE THE SUN DIE IN A GLORIOUS DISPLAY

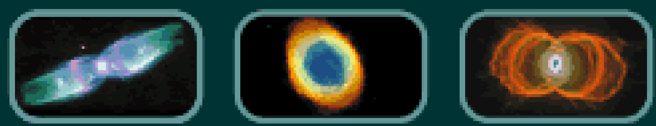
No star lives forever— our own Sun included. After a star has used up all its nuclear fuel, it throws off its outer layers and then fades away. Hubble's exquisite images of these glorious displays (called planetary nebulae) provide new insights into the complexities of a star's final days.

Despite the name, planetary nebulae have little to do with planets. They were named over a century ago because through the small telescopes of the day, they resembled planets.

CAT'S EYE NEBULA

Images of planetary nebulae — such as the Cat's Eye nebula — give us a preview of how the Sun's life will end. Stars like the Sun puff off their outer layers when they die, leaving behind a tiny white ember not much larger than the Earth.

See More Nebulae!



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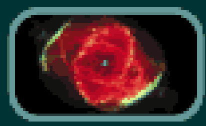
STARS LIKE THE SUN DIE IN A GLORIOUS DISPLAY

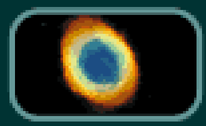
The Twin-Jet nebula shows how some dying stars eject their outer layers along their north and south poles. Astronomers still aren't sure why this happens, but dying stars that behave this way often have small orbiting companion stars that may prevent material from escaping at the equator.

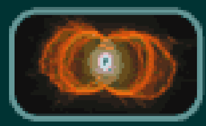
TWIN-JET NEBULA

VIEW RELATED LINKS

See More Nebulae!







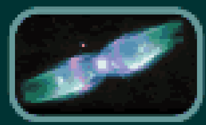
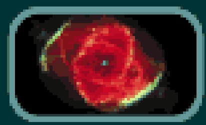
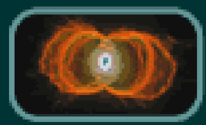
STARS LIKE THE SUN DIE IN A GLORIOUS DISPLAY

Hubble captured the sharpest view yet of the most famous planetary nebula — the Ring nebula. This view looks down a barrel of gas blown off thousands of years ago by the dying star at the center.

VIEW RELATED LINKS

RING NEBULA

See More Nebulae!

STARS LIKE THE SUN DIE IN A GLORIOUS DISPLAY

This image of the Hourglass nebula reveals very fine details in the nebula's structure that ground-based telescopes could not discern. Astronomers study these details for clues about the final days of such stars.

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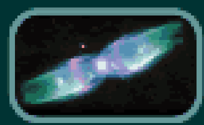
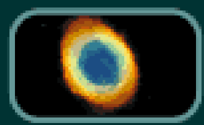
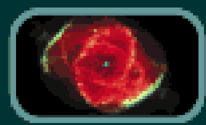
HOURGLASS NEBULA

See More Nebulae!

JETS FROM YOUNG STARS

As a spinning, collapsing cloud enters the final phase before becoming a full-fledged star, violent things happen. Here we see a spectacular jet of high-speed gas shooting out the pole of a forming star.

VIEW RELATED LINKS

The arrow shows the direction of a high-speed jet shooting from the forming star, which is located in the dark gas cloud in the upper left corner of the image.

HIDE CAPTIONS
BACK

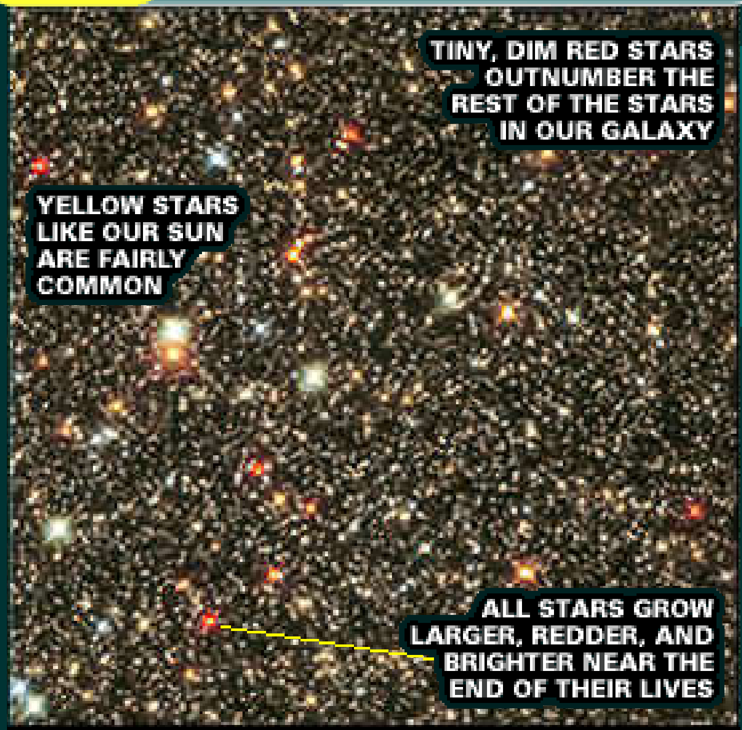
STARS LIVE AND DIE

ABOUT STARS | STAR BIRTH | STAR DEATH | SPACE/TIME: STARS

A STAR'S LIFE

Watch how a star evolves ... from birth to death.

Stars live by burning hydrogen and helium for millions to billions of years. This picture shows the many different-colored stars that inhabit the Sagittarius Star Cloud, which lies near the center of our Milky Way galaxy. A star's color reveals its temperature — and therefore clues to its age. Hot blue stars live only a few million years. Yellow stars like our Sun live for 10 billion years, and red stars live for tens of billions of years.



SAGITTARIUS STAR CLOUD

HIDE CAPTIONS

BACK NEXT

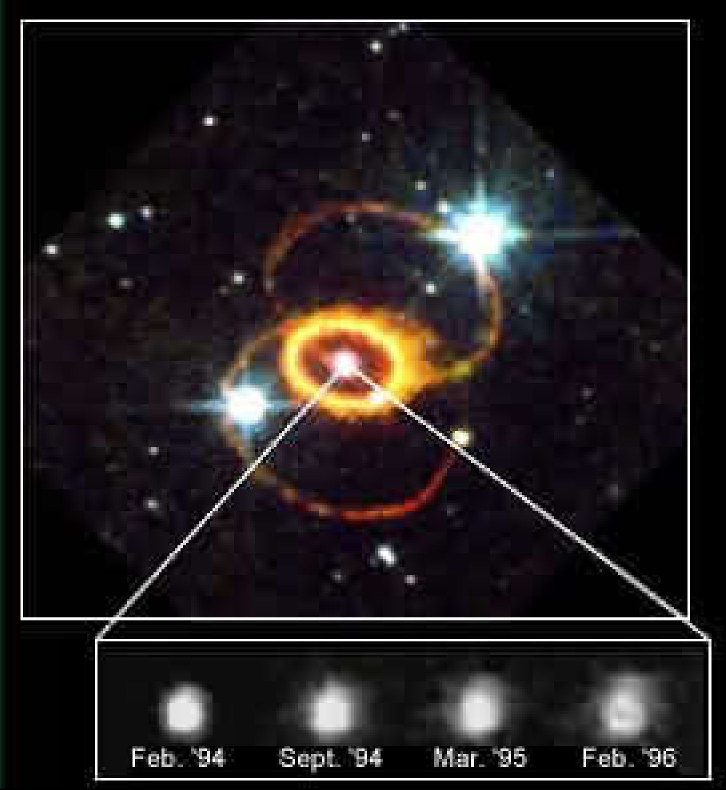
VIEW RELATED LINKS

STARS LIVE AND DIE

A STAR'S LIFE

Watch how a star evolves ... from birth to death.

Stars don't last forever. While some simply exhaust their fuel and die peacefully, others explode as supernovae. This picture shows the brightest supernova in four centuries, which lit up the southern sky in 1987. Astronomers using Hubble watched the remnant of the blast develop into a dumbell-shaped structure consisting of two blobs of debris expanding away from each other at nearly 6 million miles per hour.



SUPERNOVA 1987A

VIEW RELATED LINKS

BACK

A Star’s Life

Stars, born of gas and dust, shine billions of years, die and return dust to new stars. In the glowing dusty cloud of the Orion Nebula hundreds of stars are growing. Dusty disks as large as solar systems swirl around very young protostars.

As each star forms, some material pours from the disk onto the star and some fires out vast distances as huge jets. Within the disk, dust grains clump, become rocks, then planets. Mature stars, powered by nuclear fusion, shine on for millions, even billions of years.

Before stars like our Sun die they expand into red giant stars, growing large enough to engulf their companions. In a deadly dance, this red giant swallows its companion star.

Pinched at the equator, gas escapes along the poles -- creating sculptures of light in the sky—and returning dust to the next generation of stars.

COMET CRASH

Watch a large comet bruise the planet Jupiter.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

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HUBBLE MONITORS THE PLANETS

POINT AT EACH PLANET FOR MORE! >>>

Hubble has observed all the planets except for Earth and Mercury. Mercury is too close to the Sun for Hubble to risk an observation. The planets are shown here to scale.

VIEW RELATED LINKS

Shortcuts:

Jupiter

Mars

Neptune

Pluto

Saturn

Venus

Uranus

PLANETS

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Jupiter - General Information

Gallery image of Jupiter.
http://hubble.stsci.edu/gallery/showcase/solar_system/p3.shtml

An in-depth look at Jupiter's tussle with a comet.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide21.shtml

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

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Jupiter - Press Releases

Hubble Views Ancient Storm in the Atmosphere of Jupiter (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+29

Hubble Clicks Images of Io Sweeping Across Jupiter (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+13

Hubble Provides Complete View of Jupiter's Auroras (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+04

Hubble Provides Infrared View of Moon, Ring, and Clouds (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+37

Hubble Captures Volcanic Eruption Plume from Io (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+21

Rare Hubble Portrait of Io and Jupiter (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+30

Hubble Follows Rapid Changes in Jupiter's Aurora (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+32

Hubble Finds Oxygen Atmosphere on Jupiter's Moon, Europa (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+12

Hubble Discovers Bright New Spot on Io (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+37

Hubble Photo Gallery of Jupiter's Galilean Satellites (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+35

Hubble Views the Galileo Probe Entry Site on Jupiter (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+46

Hubble Tracks Jupiter Storms (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+18

Comet Fragment Slams into Jupiter (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+15

Color Hubble Image of Large Comet Impact on Jupiter (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+33

Hubble Space Telescope Resolves Volcanoes on Io (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+18

Hubble Observations Shed New Light on Jupiter Collision (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+48

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Mars - General Information

Gallery image of Mars.
http://hubble.stsci.edu/gallery/showcase/solar_system/p5.shtml

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

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Mars - Press Releases

Martian Colors Provide Clues about Martian Water (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+07

A Closer Encounter with Mars (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+27

Colossal Cyclone Swirls Near Martian North Pole (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+22

Hubble's Sharpest View of Mars (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+09

Hubble Finds Cloudy, Cold Weather Conditions for Mars-Bound Spacecraft (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+15

Hubble Watches the Red Planet as Mars Global Surveyor Begins Aerobraking (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+31

Springtime Dust Storm Swirls at Martian North Pole (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+34

Hubble Monitors Weather on Neighboring Planets (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+17

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Neptune - General Information

Gallery image of Neptune.
http://hubble.stsci.edu/gallery/showcase/solar_system/p6.shtml

Clouds and other odd weather on Neptune.

http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide23.shtml

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

The Hubble instrument used to observe Neptune.
http://hubble.stsci.edu/sci.d.tech/nuts_.and._bolts/instruments/wfpc2/wfpc2b.shtml

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Neptune - Press Releases

Hubble Provides a Moving Look at Neptune's Stormy Disposition (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+34

Hubble Space Telescope Helps Find Evidence that Neptune's Largest Moon Is Warming Up (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+23

Hubble Makes Movie of Neptune's Rotation and Weather (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+33

Hubble Space Telescope Observations of Neptune (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+09

Hubble Discovers New Dark Spot on Neptune (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+21

Hubble Identifies a Long-Sought Population of Comets Beyond Neptune (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+26

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Pluto - General Information

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

The Hubble instrument used to observe Pluto.
http://hubble.stsci.edu/sci.d.tech/nuts_.and._bolts/instruments/foc/

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Pluto - Press Releases

Hubble Reveals Surface of Pluto for First Time (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+09

Hubble Portrait of the "Double Planet" Pluto and Charon (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+17

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Saturn - General Information

Gallery image of Saturn.
http://hubble.stsci.edu/gallery/showcase/solar_system/p1.shtml

Gallery image of edge-on Saturn.
http://hubble.stsci.edu/gallery/showcase/solar_system/p2.shtml

What are Saturn's auroras?
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/views/portfolio/slide22.shtml

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

A Hubble instrument used to analyze Saturn's aurora.
http://hubble.stsci.edu/sci.d.tech/nuts_.and._bolts/instruments/stis/

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Saturn - Press Releases

Hubble Provides Clear Images of Saturn's Aurora (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+05

Hubble Space Telescope Completes Eighth Year of Exploration (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+18

Edge-On View of Saturn's Rings (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+16

Hubble Again Views Saturn's Rings Edge-On (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+31

Hubble Provides the First Images of Saturn's Aurorae (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+39

Hubble Discovers New Moons Orbiting Saturn (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+29

Hubble Views Saturn Ring-Plane Crossing (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+25

Saturn Ring-Plane Crossing, November 1995 (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+18

Hubble Observes a Saturn Storm (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+53

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Venus - General Information

Gallery image of Venus.
http://hubble.stsci.edu/gallery/showcase/solar_system/p8.shtml

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Venus - Press Releases

Venus in Ultraviolet Light (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+16

Hubble Monitors Weather on Neighboring Planets (1995)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1995+17

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Uranus - General Information

Gallery image of Uranus.
http://hubble.stsci.edu/gallery/showcase/solar_system/p7.shtml

Hubble's planet watch.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/our_universe/in-depth/planet.shtml

The Hubble instrument used to observe Uranus.
http://hubble.stsci.edu/sci.d.tech/nuts_.and._bolts/instruments/nicmos/

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Uranus - Press Releases

Huge Spring Storms Rouse Uranus from Winter Hibernation (1999)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1999+11

Hubble Finds Many Bright Clouds on Uranus (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+35

Hubble Watches Uranus (1997)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1997+36

Hubble Captures Detailed Image of Uranus's Atmosphere (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+15

Hubble Observes the Moons and Rings of the Planet Uranus (1994)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1994+50

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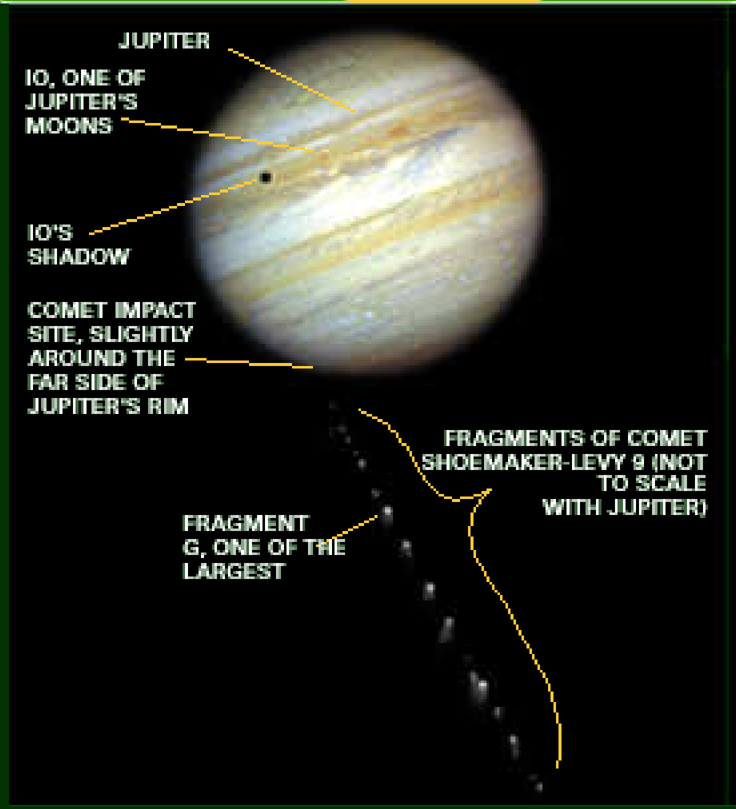
HUBBLE CAPTURES OUTCOME OF COSMIC COLLISION

COMET CRASH

See a defenseless gas giant get pelted while astronomers just sit by and WATCH.

Billions of years ago, the young planets withstood a steady rain of rock and ice as they slowly assembled from a disk of debris orbiting the Sun. The shower has since let up, but occasionally a big strike occurs.

A series of such events occurred July 16-22, 1994, when 21 fragments of Comet Shoemaker-Levy 9 plunged into Jupiter, exploding with the force of millions of nuclear bombs.



HIDE CAPTIONS

NEXT

VIEW RELATED LINKS

AFTER IMPACT

COMET CRASH

See a defenseless gas giant get pelted while astronomers just sit by and WATCH.

A plume of gas is rising from the impact site of the largest comet fragment.

Jupiter's rotation brings impact site into view, revealing dark dust rings spread across an Earth-sized area.

Dust rings are beginning to dissipate.

Dissipation continues. Dust blotch from impact of a later fragment can also be seen near Jupiter's edge.

VIEW RELATED LINKS

BACK

Comet Crash

It’s happening tonight! Virtually every telescope in the world is going to be pointed toward Jupiter. We’ve never seen this before. This is totally new ground.

John Holliman: “The comet is coming, and astronomers all over the world are seeing good pictures of Shoemaker-Levy 9 as it bashes into the atmosphere surrounding Jupiter.”

Miles O’Brien: “Astronomers all over the world are getting a real eyeful of information as Shoemaker-Levy 9 continues its fiery meeting with Jupiter. When the initial images came in it was time to break out the champagne and celebrate a little bit. There, the co-discovers of the comet, Eugene and Caroline Shoemaker and David Levy.”

Gene Shoemaker: “I think, we’re very, very privileged tonight to see an event that’s not once in a life time—but once in a millennium.!”

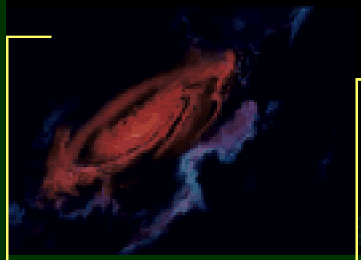
Michael Guillen: “First, let me remind everybody what all the commotion is about. There is a comet called Shoemaker-Levy ... it broke into all these pieces which have been labeled A through W just for identification purposes.”

Peter Jennings: “News about outer space today. The planet Jupiter continuous to take a pounding... Scientists have been watching as closely as they are able.”

That large ring, that big smudge—you could easily fit the Earth inside that diameter.   This is one, big, impact site.

Lucy McFadden: “I have one more thing I want to say. The HST results were spectacular. I loved sitting here listening to it. I was always amazed at the news reports. Once we can combine our efforts and combine our data, we will know a lot more than we know already, and it’s going to be a lot of fun.”

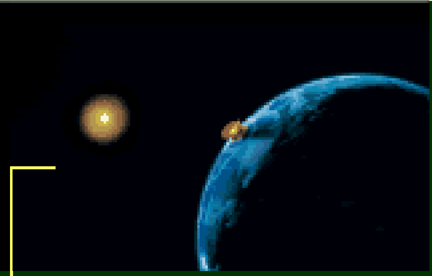
HOW THE SOLAR SYSTEM FORMED



About 4.6 billion years ago an interstellar cloud of gas and dust began to collapse under the force of its own gravity.

As the cloud collapsed, it began to rotate and flatten into a spinning disk. The large clump of gas at the center became the Sun.

Gas and dust around the newborn Sun began to clump into larger objects. The surfaces of early planets were bombarded by comets and asteroids left over from the original disk.



The bombardment gradually declined during the first half-billion years, but the comets and asteroids remaining still occasionally collide with planets — sometimes with dramatic consequences.

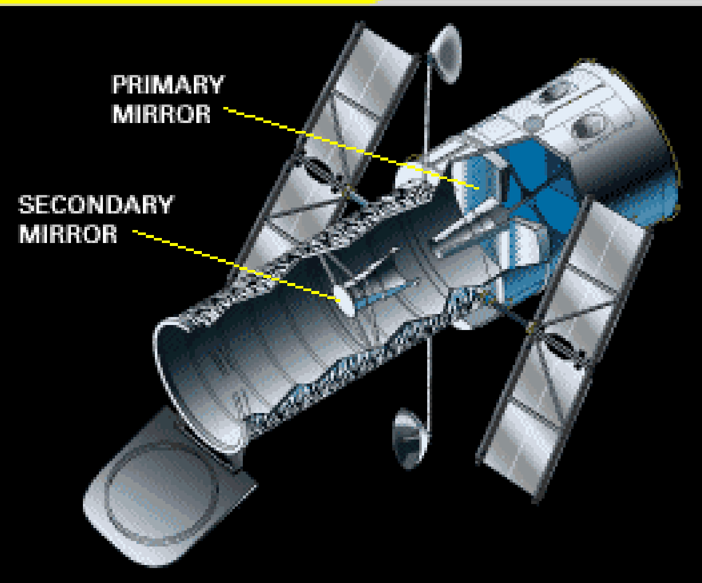
HUBBLE IS . . .
A REFLECTING TELESCOPE

Hubble works on the same principle as the first reflecting telescope built in the 1600s by Isaac Newton. Light enters the telescope and strikes a concave primary mirror, which acts like a lens to focus the light. The bigger the mirror, the better the image.

In Hubble, light from the primary mirror is reflected to a smaller secondary mirror in front of the primary mirror, then back through a hole in the primary to instruments clustered behind the focal plane (where the image is in focus).

VIEW RELATED LINKS

ABOUT THE TELESCOPE | VITAL STATISTICS



HIDE CAPTIONS

Mirror size
Primary mirror: 2.4 m (94.5 inches) in diameter
Secondary mirror: 0.3 m (12 inches) in diameter

Angular resolution
Hubble's angular resolution is 0.05 arcsecond. This is the "sharpness" of Hubble's vision. If you could see as well as Hubble, you could stand in New York City and distinguish two fireflies, 1 m (3.3 feet) apart, in San Francisco.

NEXT

RELATED LINKS

ABOUT THE TELESCOPE | VITAL STATISTICS

THE TELESCOPE

The following are Web pages related to this section.

denotes a link to another part of HubbleSite
denotes a link outside of HubbleSite

External Links Disclaimer:
Links outside of HubbleSite are provided solely as a service to our users. HubbleSite is not responsible for the content of those pages.

The Telescope- General Information

An in-depth look at Hubble's instruments, optics, and systems.
http://hubble.stsci.edu/sci.d.tech/nuts_.and._bolts/

Hubble's statistics, history, and founders.
http://hubble.stsci.edu/sci.d.tech/facts_.and._figures/

How to operate a telescope in space.
http://hubble.stsci.edu/sci.d.tech/team_hubble/

Gallery images of the telescope in space.
http://hubble.stsci.edu/gallery/showcase/telescope/index.shtml

A Hubble diary: The mission, the view, and the facts.
http://hubble.stsci.edu/sci.d.tech/discoveries/10th/telescope/index.shtml

From Galileo to Hubble: Why a Telescope in Space? A student-friendly interactive introduction to Hubble.
http://amazing-space.stsci.edu/galileo/galileo-to-hst1.html

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The Telescope - Press Releases

Hubble Space Telescope Completes Eighth Year of Exploration (1998)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1998+18

Hubble Achieves Milestone: 100,000th Exposure (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+25

Hubble Space Telescope Completes Sixth Year of Exploration (1996)
http://hubble.stsci.edu/news_.and._views/pr.cgi.1996+10

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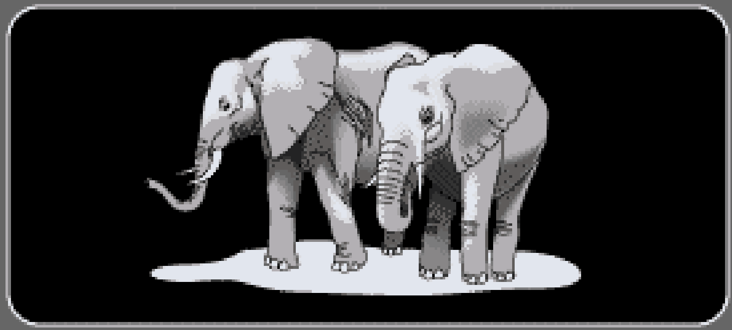
HUBBLE'S VITAL STATISTICS

Play with a scale model of Hubble [Quicktime VR activity]

Hubble is 13.3 m (43.5 feet) long — the length of a large school bus..

Hubble weighs 11,110 kg (24,500 pounds) — as much as two full-grown elephants.

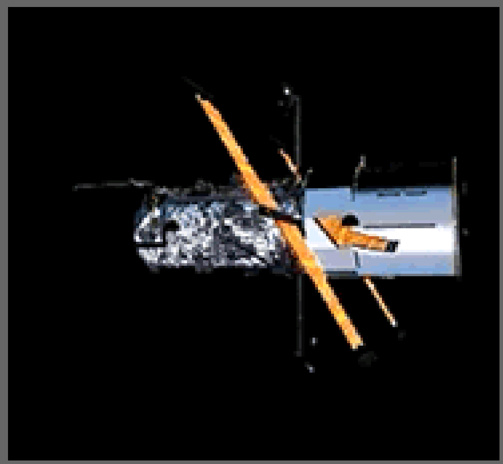


Hubble's latest solar arrays (to be installed during the Fourth Servicing Mission) cover 36 m^2 (384 square feet) — equal to the area of a highway billboard.

Hubble's primary mirror is 2.4 m (7 feet 10.5 inches) across — taller than basketball player Gheorghe Muresan, who is 2.3 m, or 7 feet 7 inches.

VIEW RELATED LINKS

VIRTUAL HUBBLE



Launch Virtual Hubble

(File size: 2.1Mb)

The Virtual Hubble is an interactive 3-D model of the Hubble Space Telescope. Once it is loaded, you can use your mouse to manipulate the telescope and see it from all sides.

Virtual Hubble uses QuicktimeVR, so you need to have the latest version of the Quicktime plug-in to see it.

If you don't have Quicktime, you will need to download it.

QuickTime Get 4.

VIRTUAL HUBBLE

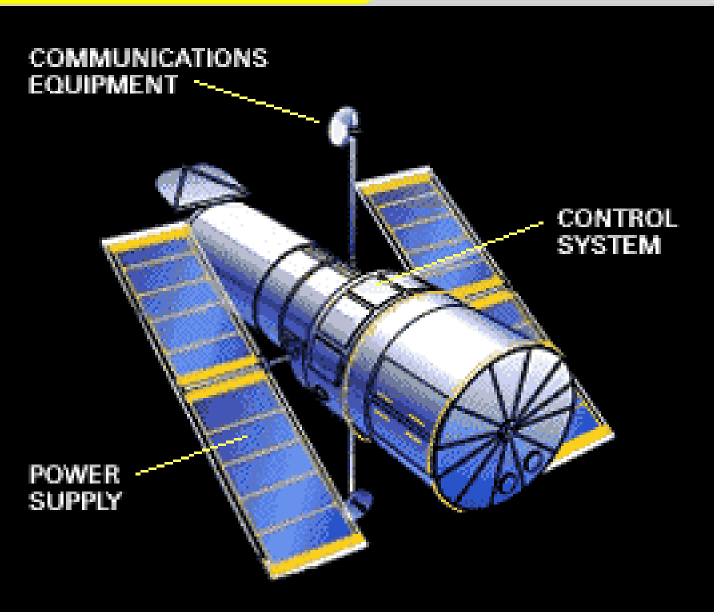
Click and drag the model with your mouse to see the Hubble from all sides.
(Requires the Quicktime plug-in -- get it here.)

HUBBLE IS . . . A SPACECRAFT

Power supply
Hubble's solar arrays collect sunlight, which is converted into electricity. Rechargeable batteries supply back-up power when Hubble is in Earth's shadow.

Communications equipment
Steerable antennas send scientific data to communications satellites for relay to ground systems. Data are stored on solid state recorders.

Control system
Reaction wheels point Hubble to any spot in the sky. When these wheels turn one way, Hubble turns the other. Fine guidance sensors keep Hubble locked onto its target.



HIDE CAPTIONS

Hubble is a telescope, but it is also a spacecraft — an object designed to operate in space. For this it needs a power supply, communications equipment, and a control system.

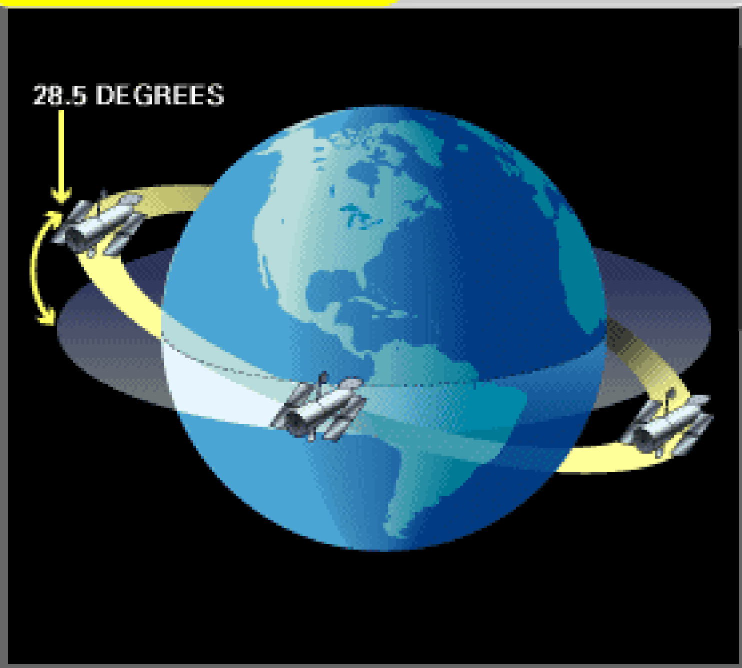
BACK | NEXT

VIEW RELATED LINKS

HUBBLE IS . . .
IN ORBIT AROUND THE EARTH

ABOUT THE TELESCOPE | VITAL STATISTICS

Hubble is not that far away — only about 600 km (370 miles) above Earth. Its nearly circular orbit takes it once around the planet every 97 minutes. The orbit is inclined (tilted) to the equator at an angle of 28.5 degrees, which means that it never travels farther north than 28.5 degrees N. latitude (the latitude of Cape Canaveral, Florida), or farther south than 28.5 degrees S. latitude (the approximate latitude of Brisbane, Australia).



HIDE CAPTIONS
BACK
VIEW RELATED LINKS

HUBBLE'S UNIVERSE

How the Hubble Space Telescope came to be.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

Choose a viewing format:

Streaming
(28.8k Modem)
(Requires RealPlayer)

High Quality
Play it! or Download it!
(63.6Mb)
(Requires Quicktime)

Download the text only

Hubble’s Universe

Narration
The year is 1929... An astronomer named Edwin Hubble changes our view of the Universe.

Using his era’s largest telescope, he discovers that beyond our Milky Way are billions of other galaxies, all flying away from us. The implication, that the cosmos is expanding – so one could trace it back to a moment of cosmic birth – shakes the astronomical world.

The rush is on for bigger and better telescopes to observe this new universe.

But astronomers face a daunting obstacle. Earth’s own atmosphere blurs light from space, dulling the sight of the sharpest telescopes.

Finally, in 1946, astronomer Lyman Spitzer proposes a solution that's brilliant, but impractical: put a telescope in space.

Lyman Spitzer
I think that all of my friends took a rather skeptical view of astronomical research out in space; they thought it was basically impractical, pie-in-the-sky...

Narration
Maybe so in 1946, but developments already under way will soon help to realize Spitzer's vision.

In the 1920s and 30s, Robert Goddard launches the field of rocketry.

Persevering through failures and successes, his work will soon open a pathway to space.

During World War II, Germany's V2 program refines Goddard's work.

After the war, German rocket engineers, led by Wernher von Braun, come to the United States.

Here, their goal is to transform the weapons of war into a vehicle that can go beyond the Earth's atmosphere.

Space travel takes another leap forward when the Soviet Union launches Sputnik in 1957.

And after early setbacks, the United States responds with a satellite of its own – called Explorer One – and the race for space is on.

With the founding of NASA in 1958, space quickly becomes a familiar place.

Alongside its manned missions, NASA begins exploring the solar system with robotic spacecraft.

Finally, Spitzer's dream begins to take form.

In 1968, the Orbiting Astronomical Observatory, precursor to Spitzer's space telescope, enters orbit. Its observations are a stunning success.

Then, for a while, NASA's focus is to put a man on the moon.

Neil Armstrong
That's one small step for man, and one giant leap for mankind.

Narration
In the afterglow of this triumph, NASA – and the astronomical community – begin to plan for the ultimate realization of Spitzer's dream: a large space telescope.

Through the early 1970s, they develop plans while building support for the telescope.

In 1977, Spitzer's tireless support wins the project Congressional approval.

With the European Space Agency signing on as a partner, the Large Space Telescope is at last a reality!

The same year, Lockheed Aerospace and Perkin-Elmer Corporation sign on to design and build the spacecraft.

Perkin-Elmer builds the telescope's mirrors and sighting equipment. It'll take them 2 years to polish off 200 pounds of glass from the 94-inch main mirror.

In 1984, the heart of the telescope – now renamed in Edwin Hubble's honor – moves to Lockheed for completion.

There, in the world's biggest clean room, Lockheed technicians connect the telescope to the rest of its spacecraft, in preparation for launch.

Announcer
And ... Liftoff of the Space Shuttle Discovery with the Hubble Space Telescope, our window on the Universe.

Narration

After forty years, Spitzer's dream has become reality. And through the Hubble Space Telescope, astronomers open up the depths of the expanding Universe, building on Edwin Hubble’s discoveries and exploring mysteries that could never be answered before.

IDEA TO IMAGE

How to make pictures out of digital data.

This movie requires a plug-in to be viewed. If you don't already have one of them installed, follow the links below:

real player 7 FREE | QuickTime Get 4.

Choose a viewing format:

Streaming
(28.8k Modem)
(Requires RealPlayer)

High Quality
Play it! or Download it!
(42.6Mb)
(Requires Quicktime)

Download the text only

Idea to Image

I'm writing a proposal to study the Hubble Deep Field with the new infrared camera on board the Hubble Space Telescope.

The Hubble Deep Field is a random place in the sky, up near the Big Dipper. But if you look at any random place in the sky, you see many faint galaxies. We've surveyed that before at optical wavelengths... now we want to go back and take a picture with the new infrared camera, NICMOS, on board Hubble.

For the last few months, I've been pulling together the ideas to make a convincing case for this and we're going to see if we can persuade people that this is the right thing to do.

So, this is it – the completed proposal – and now we send it by email to the Space Telescope Science Institute.

Mark's proposal is one of the thousand we've received this year, that's summarized in this stack. And most of these are well worth doing on the telescope, but somehow, we have to choose about two hundred of them to actually do.

Mark's proposal will be discussed by a small group of about eight scientists who are specialists in cosmology, his area of interest.

We got the time... but now's where the real work begins, because we have to take the general plan that we outlined in the proposal and actually send the details to Space Telescope Science Institute so that they can actually schedule the observations on the telescope.

We're starting to schedule Mark's observations. Mark does have several constraints for his observations. He wants a particular telescope orientation and while at that orientation we also have to be sure that Hubble has guide stars to track on and that the solar arrays are in full sunlight so that Hubble gets enough power.

We've met all of Mark's constraints and it looks like Mark is going to get some great data and all of the scheduling is going fine.

And now it has to go to the people at the control center to actually upload the instructions for the minute-by-minute operation of the telescope so that the operations can be carried out.

We have just received the set of instructions from the Space Telescope Science Institute that contains the set of instructions to run Mark's proposal. And now we're ready to load up the Hubble's computer with these instructions.

Because the Hubble is moving so fast – about 17 thousand miles per hour – we don't have enough time to really link up these instructions in one pass, so we have other satellites that we send these instructions to, which in turn relay those instructions to Hubble.

And then we ship that data to the Institute.

Well I just saw Mark this morning, he was very excited about his data, and I checked to see that it got here. It arrived last night.

We've taken the data, processed it so that a scientist can interpret it, and then we've stored it on optical platters downstairs.

Mark will take these exposures and stack them up into the pretty pictures that you'll see on the front page of The New York Times.

Well, this is it... this is the end product, the color composite picture that we've made from our infrared images of the Hubble Deep Field. And I think it's come out very nicely!

Detecting Flash, please wait ...

Detecting Flash, please wait ...

RELATED LINKS

Each section of this website has its own set of related links. For your convienience, all of these pages are listed below:

The Telescope

Planets

Stars

Galaxies

Universe

Beyond Hubble

Now Playing

Tour the Cosmos

Tune In:

- High Bandwidth (56K or faster) (800x600 disp)
- Low Bandwidth (28.8 Modem)
- Web Chat

How to Tune In

Spinning Stardust into Planets

Astronomers are getting a fresh look at what may be the early stages of planetary system formation. Recent pictures by NASA's Hubble Space Telescope don't show actual planets, but rather edge-on disks that provide some of the clearest views to date of potential planetary construction zones. The photos may hold clues to what happened some 4.5 billion years ago when the Earth and the other planets in the Solar System condensed out of a similar pancake-shaped disk around our young Sun.

Guest Profiles

See the Pictures, Learn More

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Tour The Cosmos

Now Playing
Teaser!
Coming Attractions
Archives
How to Tune In

Now Playing

Spinning Stardust into Planets

See it Now

This macromedia FLASH teaser requires a pentium 2 cpu in order to run smoothly.

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How to Tune In

"The Marc Steiner Show" is being broadcast in RealAudio and NetShow. To listen, one must obtain the appropriate player. Please follow the directions on the download site for your specific computer.

RealPlayer

Microsoft Media Player

The audio-only Webcast is being delivered at a modest 8Kbs (Kilobits per second). Anyone connected at 2400 baud or better should be able to receive a clear signal.

Coming Attractions

Next Show

Tour the Cosmos is on hiatus.

Archives

Missed a program?

Not a problem! Here's the link to the previous broadcasts:

Hubble Goes Deep, December 1998

Life's Cosmic Origins, October 1998

Planetary Nebulae, July 1998

Archives

TOUR THE COSMOS

Tune In:

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(56K or faster)

Low Bandwidth
(28.8 Modem)

Audio Only
(14.4 Modem)

How to Tune In

Life's Cosmic Origins

Aired October 14, 1998, Noon-2 p.m., EDT

Are we alone? Astronomical observations over the last few years indicate that environments suitable for life are probably plentiful in the universe. World-renowned astronomers tackle this compelling question during the "Tour the Cosmos" Web simulcast.

On this show, Marc Steiner's guests include Dr. Chris Burrows, Space Telescope Science Institute; Jim O'Leary, Maryland Science Center; Dr. Steven Squyres, Cornell University; and Dr. Mark Voit, Space Telescope Science Institute.

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Space Telescope Science Institute

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Operated for NASA by AURA

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About Us

National Public Radio news station WJHU-FM (88.1) and the Space Telescope Science Institute made "Tour the Cosmos" possible. The Association of Universities for Research in Astronomy (AURA), under contract to NASA, established the Institute in 1981.

The concept for Tour the Cosmos is the brainchild of Marc Steiner of WJHU and Carol Christian, Director of the Office of Public Outreach at the Space Telescope Science Institute.

For more information:

WJHU-FM (88.1)

Space Telescope Science Institute

NASA

AURA

HUBBLESITE

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TOUR THE COSMOS

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Tune in from:

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Using RealPlayer

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Space Telescope Science Institute

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Guest Profiles

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Chris Burrows

Dr. Chris Burrows graduated with a first-class honors degree in Mathematics and a Ph.D. in Theoretical High-Energy Physics from Cambridge University in England. Born and raised in London, Chris was the first to show that the Hubble Space Telescope was optically flawed. He developed the prescription for its fix, and was later rewarded with two NASA Public Service Medals. Recent accomplishments include the discovery of rings surrounding supernova 1987A, a warp in the Beta Pictoris disk that may indicate the presence of planets, measurements of the orbit of the only certain Brown Dwarf (GL229B), and the first clear image of a disk of material falling onto a star (HH30). Dr. Burrows also is a member of the European Next Generation Space Telescope team.

Jim O'Leary

Jim O'Leary is Senior Director for Technology at the IMAX/Planetarium at the Maryland Science Center at Baltimore's Inner Harbor. A gifted speaker who frequently appears on various television and radio programs to discuss astronomy-related topics, he also produces, researches and writes programs for the Center's Davis Planetarium. As part of his work with the Center, he currently oversees the refurbishment of the Center's Observatory. Jim serves as Consulting Editor and Contributing Writer for Odyssey magazine, writing science and technology articles geared to middle and high school students. He also serves as an advisor on science programming panels for the Smithsonian Institution, the National Wildlife Federation and several private corporations.

Steven W. Squyres

Steven W. Squyres, a Professor of Astronomy at Cornell University, has spent significant time working on many of NASA's planetary missions. Interested primarily in Mars and the moons of the outer planets, Steven recently was chosen Rover Principal Investigator for the Mars Surveyor Project scheduled for 2003. Other missions he has worked on include Cassini, the 1998 Mars Surveyor, the Near Earth Asteroid Rendezvous, Voyager, Magellan, Mars

Observer and the Russian Mars '96 program. He has served on various NASA Advisory Committees and currently chairs NASA's Solar System Exploration Subcommittee. He was awarded the American Astronomical Society's Harold Urey Prize for outstanding achievement by a young scientist.

Mark Voit

Dr. Mark Voit is an astronomer in the Office of Public Outreach at the Space Telescope Science Institute. His research interests range from star formation in our own Milky Way galaxy to the clustering of galaxies in the early universe and the impact of supermassive black holes on the evolution of galaxies. Before joining the Institute, Mark was a research fellow at Caltech and Johns Hopkins University. He has co-authored an introductory astronomy textbook, The Cosmic Perspective, which will be published this winter.

Marc Steiner

Marc Steiner, who has hosted the popular "Marc Steiner Show" for more than five years at NPR-affiliate WJHU-FM, covers everything from politics to cultural issues to science and the arts during his weekday program. Prior to his radio career, Marc was a civil-rights worker and a community organizer who founded several neighborhood enterprises, two newspapers and a national news service. He has worked as a therapist and school counselor, a political campaign consultant, an advertising producer and a documentary film producer. A former actor and theater director, he served as a faculty member at the Baltimore High School of the Arts for 10 years.

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TOUR THE COSMOS

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During the two-hour "Tour the Cosmos" Web simulcast, Steiner and his guests discuss NASA's search for signs of life elsewhere — particularly on Mars and Jupiter's moon, Europa — recent discoveries of other planets beyond our solar system and the evolution and fate of our universe.

Life elsewhere? Mars and Europa

Planets beyond the Solar System

The Evolution and Fate of the Universe

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Life elsewhere? Mars and Europa

Follow the links below for more information about the topics discussed in this episode of "The Marc Steiner Show."

Life on Mars

The Mars Environment

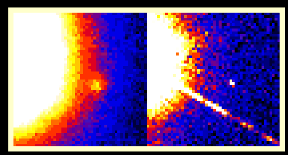
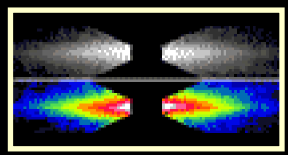
Mission to Mars for Signs of Ancient Life

Europa, Possibility of Life

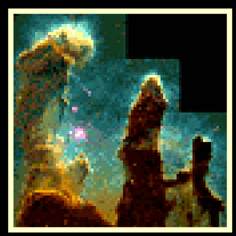
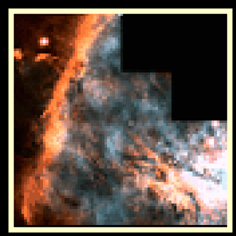
Planets beyond the Solar System

Follow the links below for more information about the topics discussed in this episode of "The Marc Steiner Show."

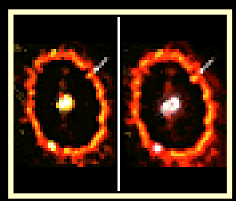
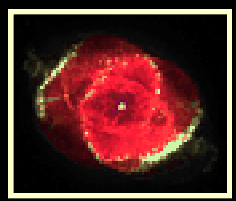
Discovering Other Planets

How do Planetary Systems Form?

Origins of Raw Materials for Stars, Planets, and Life

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TOUR THE COSMOS

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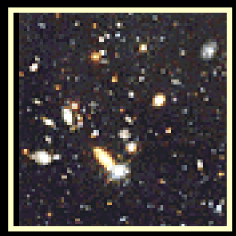
The Evolution and Fate of the Universe

Follow the links below for more information about the topics discussed in this episode of "The Marc Steiner Show."

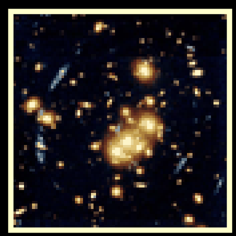
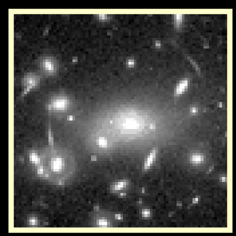
Remnants of the Early Universe Around Us

Looking Back in Time



Measuring Mass in the Universe

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The "Tour the Cosmos" series is continuing to break new ground in the use of multimedia to deliver compelling science information to the public. The Webcast successfully marries broadcast radio, video and the Web to give listeners an innovative learning experience that they can re-experience long after the show airs.

Please use our icons and descriptive text to create links to our shows:

Icons

Descriptive Text

Oct. 14 — "Tour the Cosmos" Web Simulcast — Noon-2 p.m. EDT

Link to: http://hubble.stsci.edu/go/tour

> Steiner and his guests discuss NASA's search for signs of life elsewhere — particularly on Mars and Jupiter's moon, Europa — recent discoveries of other planets beyond our solar system and the evolution and fate of our universe.

The Marc Steiner Show (WJHU-FM 88.1/National Public Radio) and Space Telescope Science Institute (STScI, Baltimore) take listeners on a tour of the cosmos via Internet simulcast from noon till 2 p.m. on October 14.

Astronomers say new information gathered over the last few years indicates that environments suitable for life are probably plentiful in the universe.

Noon-1 p.m. — Dr. Steve W. Squyres (Cornell University astronomy professor) talks on the exploration of Mars and detection of water on Jupiter's moon Europa.

1-2 p.m. — Dr. Mark Voit and Dr. Chris Burrows (Space Telescope Science Institute astronomers) and IMAX/Planetarium director Jim O'Leary (Maryland Science Center) talk about the evolution and structure of the universe, with special emphasis on the search for planetary systems beyond our solar system and what observations of young galaxies tell us about how the universe got to be the way it is today.

STScI will stream live audio and video of science images.

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Tour the Cosmos

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Planetary Nebulae, July 1998

Aired July 7, 1998, Noon-1 p.m., EST

Listen to the Radio Show!

Radio broadcaster Marc Steiner tackles all sorts of subjects on his popular talk show. Politics, world affairs and health are fair game. So, too, are topics that aren't quite so earthy. "Tour the Cosmos" is such a program. With help from some of the world's foremost astronomers, he takes his listeners on an otherworldly trip through the cosmos. Ports of call include:

Planetary Nebulae: A Cosmic Funeral
Nothing lasts forever, including stars, which burn for billions of years, fired by fusion in their cores. You'll never look at our Sun the same way again.

In the News
The scientific community is abuzz. Learn more about Hubble's headline-making discoveries.

The Hubble Advantage
Hubble is no ordinary telescope. Discover why scientists call it the incredible time machine.

Stargazer Profiles
Meet Steiner's guest astronomers.

Sit back and enjoy the scenery. This website, furnished by the Baltimore-based Space Telescope Science Institute, is your guide for learning more about the topics discussed on the program and seeing the Hubble images that are forcing scholars to rewrite the textbooks.

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Credits

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The show was broadcast live on **July 7, 1998**.

RealNetworks	
Audio Slideshow [Requires a frames capable browser and a speedy Internet connection]	
Audio Only Versions	
Streaming	**Downloadable** (3MB)

The Marc Steiner Show is being broadcast in **RealAudio**. To listen, one must obtain the RealPlayer. Please follow the directions on the download site for your specific computer.

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The audio-only Webcast is being delivered at a modest 8Kbs (Kilobits per second). Anyone connected at 2400 baud or better should be able to receive a clear signal.

FREE real 5.0 player

Related Links

- WJHU
- Space Telescope Science Institute

Planetary Nebulae:
A Cosmic Funeral

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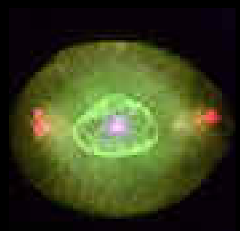
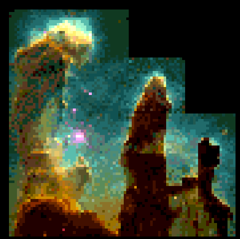
Planetary Nebulae? What are they?

Garden-variety stars like our Sun live undistinguished lives, churning out heat and light for billions of years. Like all good things, though, they eventually get old and die--but not before staging one last hurrah. That's when these ordinary stars swell into Red Giants and begin casting off their external gas layers in violent eruptions. These cast-off layers, among the most beautiful objects in the universe, are called planetary nebulae and they offer us a glimpse at our own Sun's fate millions of years from now.



One Size Doesn't Fit All

Eighteenth-century astronomers coined the name planetary nebulae. That's because these gas clouds reminded observers of the planet Saturn when seen through small telescopes. Modern-day telescopes like the Hubble Space Telescope have revealed, however, that these gas clouds are anything but planetary orbs. Their complex shapes, sizes and colors tell us that the events taking place at the end of a star's life are far more complicated than we had imagined.



Cosmological Recycling

When Sun-like stars shed their gaseous layers in death, they lay the foundation for new life through the creation and expulsion of life-giving chemical elements that are recycled to form successive generations of stars. Indeed, we're all made of star stuff!

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Planetary Nebulae: What are They?

TOUR THE COSMOS

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In another five billion years, our Sun will cease to exist. Like other main-sequence stars, its internal heat-producing engine will exhaust its supply of hydrogen, creating a fatal imbalance between the Sun's internal gas pressure and the intense weight of its external layers. As gravity takes over, the Sun's core will contract, which in turn will heat its outer layers, causing them to expand to 200 times the Sun's normal diameter.

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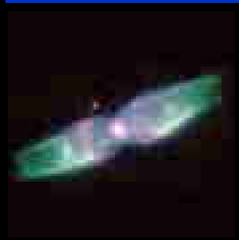
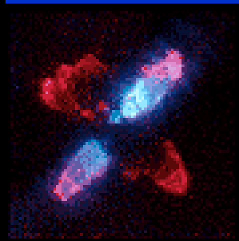
What happens next is nothing short of a death rattle. Now pulsating and shuddering, our oversized Sun--called a Red Giant--will begin flinging off its outer layers, which contain trace elements of newly-minted carbon and nitrogen cooked at the Sun's core. With each pulse, the element-laden gas layers are carried away by winds that will sculpt the gas layers into a planetary nebula.

Eventually, the Sun will stop ejecting gas into space and the gas expelled during the Sun's final days will merge with other gas in space. In the end, the only remnant of our once glorious Sun will be a burned-out cinder, an incredibly dense, Earth-sized White Dwarf.

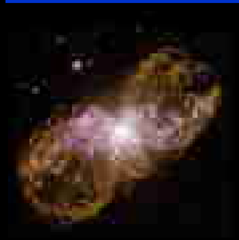
More Information



Final Blaze Of Glory



Heart of a Dying Star



More About Planetary Nebulae and Other Links

One Size Doesn't Fit All

Back

Sculpted by stellar winds and heated by radiation streaming off the dying star, planetary nebulae take on a variety of shapes and colors. New infrared instruments on Hubble can detect these complex symmetries, proving that for planetary nebulae one size doesn't fit all. Here is sampling of the most common shapes:

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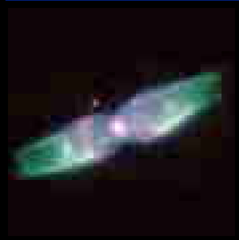
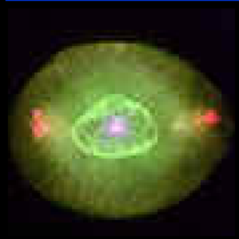


Bipolar

- M2-9 Siamese Squid Nebula
- Hubble 5

Spherical

- IC 3568 "Simple" Planetary Nebula

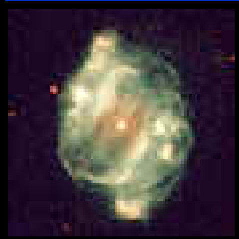


Oval

- NGC 6826 The Blinking Planetary Nebula
- NGC 7009

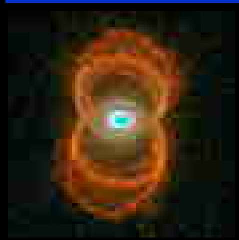
Complex (Spherical and Jets)

- NGC 3918 The Blue Planetary Nebula



Pinwheel

- NGC 5037



Hourglass

- MyCn 18

Cosmological Recycling

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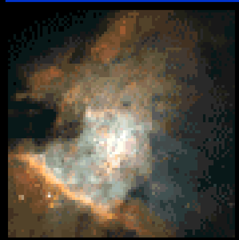
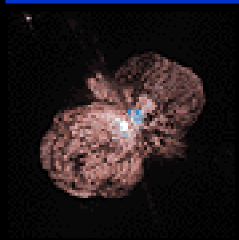
The star's life has ended and the chemical elements it created during a lifetime of thermonuclear combustion--carbon, nitrogen and oxygen--swirl away in clouds of gas to merge with the interstellar medium, the hydrogen gas that exists in the vast expanses of space. More than a "light show," these planetary nebulae perform a much-needed job. They disperse life-giving elements cooked at the star's core, which are then used in the creation of successive generations of stars, planets and even life itself. The elements that make up our bodies are in reality the remains of a once-flourishing star. In essence, stellar death is just an example of interstellar recycling. Nothing goes to waste. Each generation of stars recycles a significant amount of material back into the reservoir of gas from which new life can form. That's why astronomers study planetary nebulae. They tell us the story of our own Sun's eventual fate and shed light into how the cosmos came to be.

More Information


Crucible Of Creation


Star Birth in M16


Doomed Star: Eta Carinae

In the News

Circling Earth every 90 minutes, the Hubble Space Telescope has traveled more than 1.2 billion miles, taken 120,000 exposures and observed more than 10,000 astronomical objects. Its 8-year sojourn has been a productive one. It has observed a myriad of objects, some so distant that scientists believe they may have formed just shortly after the creation of the universe 12 to 15 billion years ago. It has looked at everything from possible planets in other solar systems to black holes and colliding galaxies. Here are some of Hubble's more notable discoveries:

- Hubble Snaps a Photo of a Possible Planet
- Astronomers Track Down Asteroids in Hubble Archive
- Hubble Uncovers Dust Disk Around a Massive Black Hole
- Hubble Provides Multiple Views of How to Feed a Black Hole
- Gamma-Ray Burst Found to be Most Energetic Event in the Universe
- Hubble Celebrates its 8th Birthday: Greatest Hits on Parade
- Hubble Reveals Stellar Fireworks Accompanying Galaxy Collisions
- Hubble Witnesses The Final Blaze Of Glory Of Sun-Like Stars (Planetary Nebulae)

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The Hubble Advantage

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First proposed by astronomer Lyman Spitzer in the 1940s, the Hubble Space Telescope is ideally suited for capturing unprecedented details of celestial objects like planetary nebulae, black holes and other space exotica. It sees clearly because it orbits 380 miles above Earth's surface--far above our turbulent atmosphere that blurs starlight, making it difficult to see detail. Its suite of sophisticated, state-of-the-art science instruments that are updated or replaced during regularly scheduled astronaut servicing missions further enhances its observing power.

More Information:

- Hubble Space Telescope Primer
- General Overview of the Hubble Space Telescope

Stargazer Profiles

Dr. Carol Christian

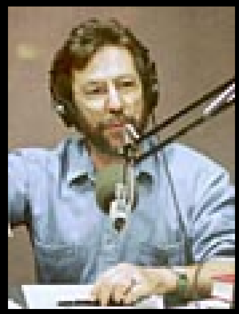
Dr. Carol Christian directs the Office of Public Outreach at the Space Telescope Science Institute. Carol's background lies in astrophysics, with a specialty in stellar populations. Her current research involves experimental methods using emerging technologies as applied to instructional multimedia resources.

Dr. Mario Livio

Dr. Mario Livio is an astronomer at the Space Telescope Science Institute and an adjunct professor at Johns Hopkins University. The author of more than 250 scientific papers, Mario's principal research areas include neutron stars and white dwarfs, novae and supernovae, active galactic nuclei, black holes, binary systems and planetary nebulae. He won the Kline Prize for Outstanding Research in 1985 and the Jacknow Prize for Excellence in Teaching in 1989. Prior to joining the Space Telescope Science Institute in 1991, Mario was a physics professor at the Technion-Israel Institute of Technology in Haifa, Israel.

Jim O'Leary

Jim O'Leary is Senior Director for Technology at the IMAX/Planetarium at the Maryland Science Center located at Baltimore's Inner Harbor. A gifted speaker who frequently appears on various television and radio programs to discuss astronomy-related topics, he also produces, researches and writes programs for the Center's Davis Planetarium. As part of his work with the Center, he is currently overseeing the refurbishment of the Center's Observatory. Jim serves as Consulting Editor and Contributing Writer for Odyssey magazine, writing science and technology articles geared to middle and high school students. He also serves as an advisor on science programming panels for the Smithsonian Institution, the National Wildlife Federation and several private corporations.



Marc Steiner

Marc Steiner has been host of The Marc Steiner Show for over five years at WJHU-FM, an NPR affiliate. His program airs ten episodes a week, Monday through Friday at noon. Topics range widely from politics to cultural issues to science and the arts. He interviews authors, leading figures in our society and everyday citizens doing extraordinary things. The show is noted for building bridges between disparate communities and making the difficult accessible.

What brings his radio to life is not his radio career but the things that he experienced before radio. Marc Steiner was a civil-rights worker and a community organizer who founded several neighborhood enterprises, two newspapers and national news service. For twelve years he worked as a therapist and counselor in schools and with troubled youth. He worked as a political campaign consultant (never winning an election) and designed marketing campaigns for non-profit organizations (most of which were successful). He has been a documentary and industrial film maker, advertising producer and an actor, director and teacher of theater, serving as a faculty member at the Baltimore High School of the Arts for ten years.

Credits go to...

"Tour the Cosmos" was made possible by National Public Radio news station WJHU (88.1 FM) and the Space Telescope Science Institute. The Institute was established in 1981 by the Association of Universities for Research in Astronomy (AURA) under contract to the National Aeronautics and Space Administration (NASA contract NAS5-26555).

Special thanks go to:

- Marc Steiner, WJHU-FM, Program Host
- Carol Christian, AURA, Program Guest, Principal Investigator
- Mario Livio, AURA, Program Guest
- Jim O'Leary, Maryland Science Center, Program Guest
- Carole Rest, AURA, Program Manager
- Ray Villard, AURA, News Chief
- Stratis Kakadelis, AURA, Web
- Jonathan Eisenhamer, AURA, Web
- James Gitlin, AURA, Graphics
- Stephanie Brown, AURA, Graphics
- Bonnie Eisenhamer , AURA, Evaluator
- Zolt Levay, AURA, Photographer
- Ed Weibe, Allied Signal, Sound Engineer
- Cathy Cordes, AURA, Copy Editor
- Lori Keesey, Keesey & Associates, Writer

More Information

- WJHU 88.1 FM
- Space Telescope Science Institute
- NASA
- AURA

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Low Bandwidth — Full Audio and Video

28.8 modem

Using RealPlayer

In Brief

- Stellar disks point to a turbulent beginning for our Solar System (0:40)
- Hubble image paints an eerie portrait of a stellar disk (0:44)
- Dramatic process of starbirth hints at Earth's beginnings (0:36)

The Whole Story

- Surplus matter from ancient dying stars may beget new planets, solar systems (4:11)
- Complete NASA press conference (34:18)
- Complete Marc Steiner radio show - audio only (51:27)

How to Tune In

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NASA

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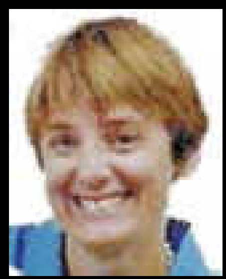
Steven Beckwith

Steven Beckwith is currently the Director of the Space Telescope Science Institute and a professor of physics and astronomy at the Johns Hopkins University in Baltimore, MD. His principal research interests are the formation and early evolution of planets, including those outside the Solar System and the birth of galaxies in the early universe.

Carol Christian

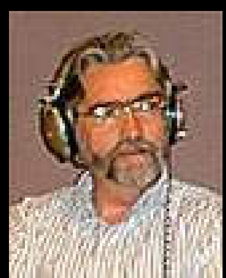


Carol Christian directs the Office of Public Outreach at the Space Telescope Science Institute. Carol's background lies in astrophysics, with a specialty in stellar populations. Her current research involves experimental methods using emerging technologies as applied to instructional multimedia resources.

David Leckrone

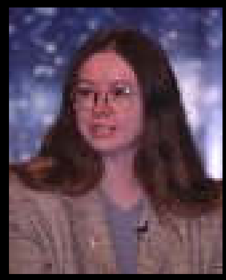
David Leckrone is Senior Project Scientist on the Hubble Space Telescope Science Institute Project at the NASA Goddard Space Flight Center. As a career NASA scientist, he has worked on the Hubble project since 1976. In his current position, he is responsible for providing scientific leadership in all phases of the Hubble program.

Jim O'Leary



Jim O'Leary is Senior Director for Technology at the IMAX/Planetarium at the Maryland Science Center at Baltimore's Inner Harbor. He frequently appears on various television and radio programs to discuss astronomy-related topics. Jim also is a Consulting Editor and Contributing Writer of Odyssey magazine.

Deborah Padgett



Deborah Padgett is a staff scientist at the Infrared Processing and Analysis Center run jointly by the California Institute of Technology and NASA's Jet Propulsion Laboratory. She principally studies the formation of stars and planetary systems.

Glenn Schneider

Glenn Schneider is the project instrument scientist for the Hubble Space Telescope's Near Infrared Camera and Multi-Object Spectrometer and a faculty member at the University of Arizona's Steward Observatory. His current research interests center on studying the environments of nearby stars.

Karl Stapelfeldt

Karl Stapelfeldt is an astronomer and research scientist at the NASA Jet Propulsion Laboratory and an associate member of the Science Team for the Hubble Space Telescope's Wide Field and Planetary Camera. He specializes in the study of young stars and their surrounding material as indicators of planetary formation.

Marc Steiner

Marc Steiner, who has hosted the popular "Marc Steiner Show" for more than five years at NPR-affiliate WJHU-FM, covers everything from politics to cultural issues to science and the arts during his weekday program.

See the Pictures, Learn More

Although astronomers have discovered more than a dozen possible extrasolar planets (though not imaged) over the past few years, they've never seen detailed pictures of the spinning disks of gas and dust that may be the birthplace of planets. The latest Hubble discovery involves six very young stars 450 light-years away in the constellation Taurus.

Press Release
Vast Stellar Disks Set Stage for Planet Birth in New Hubble Images

Want to Link to this Webcast?

Tour The Cosmos

The "Tour the Cosmos" series, sponsored by the Space Telescope Science Institute, the NASA Public Affairs Office and WJHU-FM's "Marc Steiner Show," continues to break new ground in the use of multimedia to deliver compelling science information to the public. Available only on the web, the series combines radio broadcasts, television video and the latest Hubble Space Telescope images to give viewers an innovative learning experience that they can visit time and time again.

Please use our icons and descriptive text to create links to our shows:

Icons

Descriptive Text

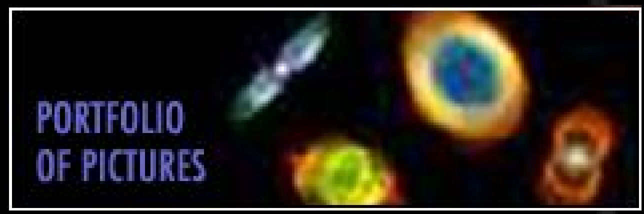
Tour the Cosmos — Spinning Stardust into Planets

Link to: http://hubble.stsci.edu/go/tour

You may have heard about it on the news. Now, you can get behind the scenes of a NASA news conference and a recently aired National Public Radio talk show to learn how planets form from gigantic disks of gas and dust surrounding very young stars. To find out more about the Hubble Space Telescope's latest discovery, check out the "Tour the Cosmos" series available only on the web. How do planets form? Recent Hubble Space Telescope images provide the clearest views to date of potential planetary construction zones around six very young stars 450 light-years away in the constellation Taurus. STScI will stream audio and video of science images used during a recent NASA news conference and WJHU-FM's "Marc Steiner Show."

HUBBLESITE

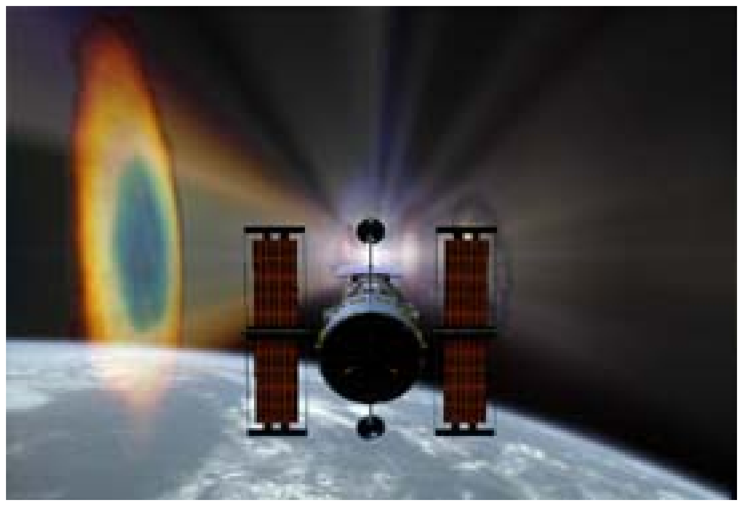
A DECADE OF DISCOVERY
THE HUBBLE SPACE TELESCOPE



A DECADE OF DISCOVERY

VIDEO!

Hubble: The First Decade



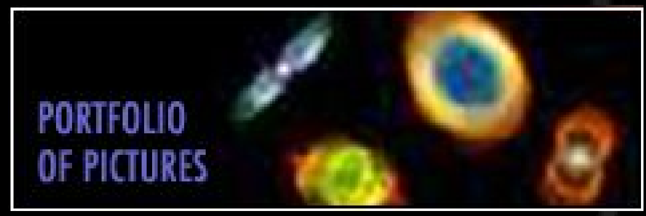
A video overview of Hubble's most significant contributions to astronomy and the world.

Running Time: 8.5 minutes

Media	Bandwidth
real player 7 FREE	Low Bandwidth - 28.8Kb modem High Bandwidth - 56Kb modem
QuickTime Get 4.	Download Movie - 11 Mb

HUBBLESITE

A DECADE
THE HUBBLE SPACE TELESCOPE
OF DISCOVERY



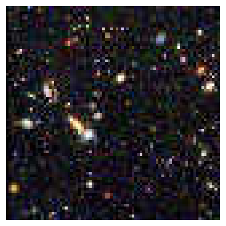
HUBBLESITE

A DECADE OF DISCOVERY
TELESCOPE & SCIENCE

A DECADE OF DISCOVERY

WHAT A VIEW: HUBBLE'S "EYE" ON THE COSMOS

In the 1920s, as famed astronomer Edwin Hubble was discovering the vastness of the cosmos through the lens of his Earth-bound telescope, others were trying to break free of the planet and its turbulent atmosphere by launching unmanned rockets into space. No one dreamed then the two pursuits would become intertwined decades later when scientists used rocket technology to launch orbiting observatories, including NASA's Hubble Space Telescope.



Hubble, the astronomer, looked beyond the boundaries of our home galaxy, the Milky Way, and discovered that the universe is much larger than we thought. Hubble, the telescope, has peered even farther into the outer reaches of our universe, further enhancing our understanding of the cosmos.

Named for Edwin Hubble, the telescope has brought the universe into view with far greater clarity than ever before. Since its launch in 1990 aboard the space shuttle Discovery, Hubble has confirmed the existence of black holes, refined our knowledge of the age and size of the universe, and stared back to nearly the dawn of time, revealing a jumble of primordial galaxies.

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A DECADE OF DISCOVERY

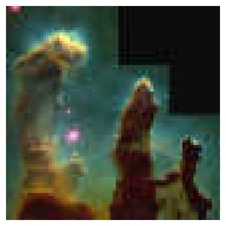
WHAT A VIEW: HUBBLE'S "EYE" ON THE COSMOS

HUBBLE'S SUPER VIEW

Larger earthbound telescopes can see as far as Hubble can. All telescopes are essentially "time machines." Probing the secrets of "deep" space means looking farther back in time. That's because light from faraway galaxies takes millions to billions of years to reach Earth, providing astronomers with a record of how those objects appeared long ago. But the "eye" in space has sharper vision because of its super location. At 368 miles above our planet, the orbiting observatory is outside Earth's turbulent blanket of air that makes star images wiggle.

Hubble can snap those sharper images while moving. Unlike terrestrial observatories, which are perched on mountain tops, Hubble doesn't stay put. It whirls around Earth every 90 minutes at 17,000 mph (27,200 kph). The telescope has no rocket motor: it is in orbit around Earth and runs on sunlight. Hubble also does what it's told. Earthbound computers send detailed instructions, telling it where to point and which cameras to use.

A VERSATILE TELESCOPE



Other orbiting observatories have probed the secrets of space, but Hubble is the largest and most versatile. Its visible-light camera — called the Wide Field and Planetary Camera 2 — has consistently delivered stunning images of celestial objects, including the pillars of dust and gas that harbor nascent stars and the colorful death shrouds of aging, Sun-like stars.

Although the visible-light camera may be Hubble's "bread and butter" instrument, it's by no means the telescope's only source of celestial revenue. Hubble has a fleet of other science instruments that covers a broad range of light, from ultraviolet to near infrared. These instruments allow Hubble to probe a galaxy's hottest stars and to peer far across space to study the evolution of galaxies. With Hubble's help, astronomers have monitored weather patterns on our solar system planets and harvested important information about stars and galaxies.

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A DECADE OF DISCOVERY

SCHOOL BUS IN THE SKY

LOW RESOLUTION (42Kb) JPEG

HIGH RESOLUTION (509Kb) JPEG

The Hubble Space Telescope is very big — about the size of a large school bus or tanker truck. The tubular part of Hubble's body is 14 feet across, and the telescope stands 43 feet tall — about as high as a five-story building. On the ground, it would weigh over 25,000 pounds, but in space it weighs nothing. When the space shuttle Discovery carried Hubble into orbit, the telescope completely filled Discovery's cargo bay. Hubble is pictured in Discovery's cargo bay during the December 1999 servicing mission.
(Longer Caption)

A DECADE OF DISCOVERY

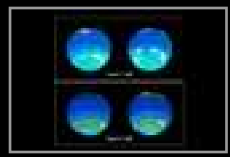
Investigating Space
The Hubble Story

INVESTIGATING SPACE

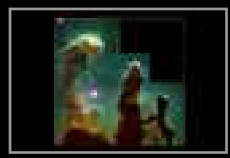
Jupiter with Comet Impacts

Saturn's Auroras

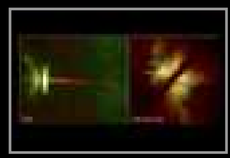
Neptune Clouds



Eagle Nebula



Young Stellar Disks

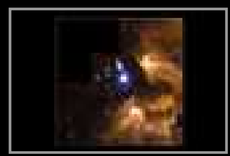


Stellar Dust Ring Around Star HR 4796A

Planetary Nebula Gallery

Supernova 1987A

Cluster and Nebula NGC 3603



Globular Star Cluster M80

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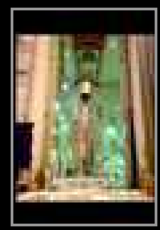
HUBBLESITE
TELESCOPE & SCIENCE
PHOTOS
VIDEO
THE VAULT

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

THE HUBBLE STORY

School Bus in the Sky


Design and Build of Hubble


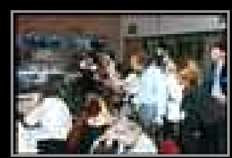
Servicing Improves Hubble

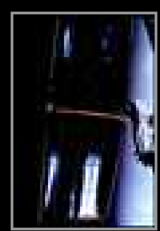

Hubble's Optics

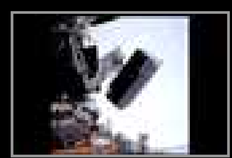

Hubble's Orbit


Fine Guidance Sensors


Hubble's Control Center


STScI


Solar Arrays


Science Instruments


A DECADE OF DISCOVERY

SCHOOL BUS IN THE SKY

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LOW RESOLUTION (42Kb) JPEG

HIGH RESOLUTION (509Kb) JPEG

The Hubble Space Telescope is very big — about the size of a large school bus or tanker truck. The tubular part of Hubble's body is 14 feet across, and the telescope stands 43 feet tall — about as high as a five-story building. On the ground, it would weigh over 25,000 pounds, but in space it weighs nothing. When the space shuttle Discovery carried Hubble into orbit, the telescope completely filled Discovery's cargo bay. Hubble is pictured in Discovery's cargo bay during the December 1999 servicing mission.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY
THE VAULT

A DECADE OF DISCOVERY

ALL ABOUT HUBBLE

NASA's Hubble Space Telescope is the first major infrared-optical-ultraviolet telescope to be placed into orbit around the Earth. Located high above Earth's obscuring atmosphere, the telescope has provided the clearest views of the universe yet obtained in optical astronomy.

The telescope is named after the American astronomer Edwin P. Hubble, who in the 1920's found galaxies beyond our Milky Way and discovered that the universe is uniformly expanding. The heart of the telescope is the 94.5 inch-diameter (2.4-meter) primary mirror. It is the smoothest optical mirror ever polished, with a surface tolerance of one-millionth of an inch. It is made of fused silica glass and weighs about 1,800 pounds.

Outside the blurring effects of Earth's turbulent atmosphere, the telescope can resolve astronomical objects with an angular size of 0.05 arc seconds, which is like seeing a pair of fireflies in Tokyo from your home in Maryland. This razor-sharp vision is 10 to 20 times better than typical resolution with large ground-based telescopes (depending on atmospheric observing conditions).

The space telescope can detect objects as faint as 31st magnitude, which is slightly better than the sensitivity of much larger earth-based telescopes. (The human eye can see celestial objects as dim as sixth magnitude.) Because generally the fainter an object is the farther away it is, Hubble has been used to probe the limits of the visible universe and uncover never-before-seen objects near the horizon of the cosmos. Because it is outside our atmosphere, the telescope can view astronomical objects across a broad swath of the electromagnetic spectrum, from ultraviolet light, to visible, to near-infrared wavelengths. The telescope can also see faint objects near bright objects. This is an important requirement for studying the environments around stars and the glowing nuclei of active galaxies.

Hubble's crystal-clear vision has triggered a revolution in optical astronomy. It has revealed a whole new level of detail and complexity in a variety of celestial phenomena, from nearby stars to galaxies near the limits of the observable universe. This has provided key new insights into the structure and evolution of our universe across a broad scale.

HISTORY

The Hubble Space Telescope was launched April 24, 1990 by the space shuttle Discovery. Hubble was originally equipped with five science instruments: the Wide-Field Planetary Camera, the Faint Object Camera, the Faint Object Spectrograph, the Goddard High-Resolution Spectrograph, and the High Speed Photometer. In addition, three fine guidance sensors were used for pointing and for precision astrometry, the measure of angles on the sky.

After Hubble was launched, scientists discovered that its primary mirror was misshapen due to a fabrication error. This resulted in spherical aberration: the blurring of starlight because the telescope could not bring all the light to a single focal point. Using image-processing techniques scientists were able to do significant research with Hubble until an optical repair could be developed.

In December 1993 the first Hubble servicing mission carried replacement instruments and supplemental optics aboard the space shuttle Endeavor to restore the telescope to full optical performance. A corrective optical device, called the Corrective Optics Space Telescope Axial Replacement, was installed (requiring removal of the High Speed Photometer) so that it could improve the sharpness of the first generation instruments. The Wide-Field and Planetary Camera was replaced with a second camera, which has a built-in correction for the aberration in the primary mirror.

In February 1997 the space shuttle Discovery returned to Hubble for a second servicing mission. Two advanced instruments: the Near Infrared Camera and Multi-Object Spectrometer and the Space Telescope Imaging Spectrograph were swapped out with the two first-generation spectrographs. The astronauts also replaced or enhanced several electronic subsystems and patched unexpected tears in the telescope's shiny, aluminized thermal insulation blankets, which give the telescope its distinctive foil-wrapped appearance.

In December 1999 the space shuttle Discovery rendezvoused with Hubble for a third servicing mission. Astronauts replaced faulty gyroscopes, which had suspended science observations for nearly a month. The telescope also got a new high-tech computer and a data recorder. The astronauts left the telescope in "better than new" condition.

Two more Hubble servicing missions are planned for 2001 and 2003. The Advanced Camera for Surveys will be installed in 2001. It will yield even sharper pictures and a wider field of view. The Wide Field Camera 3 and the Cosmic Origins Spectrograph will be installed in 2003. The telescope's science operations are expected to end in 2010.

HUBBLE OPERATIONS

Hubble is controlled at the Goddard Space Flight Center in Greenbelt, Md. The science mission is directed by the Space Telescope Science Institute at the Johns Hopkins University in Baltimore, Md. Hubble research and funding engages a significant fraction of the worldwide professional astronomical community.

Astronomers compete annually for observing time on Hubble. The over-subscription is typically four to one. Observing proposals are submitted to peer review committees of astronomer experts. The institute director makes the final acceptance and can use his own discretionary time for special programs.

Accepted proposals must be meticulously planned and scheduled by institute experts to maximize the telescope's efficiency. The telescope is not pointed by direct remote control, but instead automatically carries out a series of preprogrammed commands over the course of a day. A data "pipeline" assembled and maintained by the institute ensures that all observations are stored on optical disk for archival research. The data are sent to research astronomers for analysis and then made available to astronomers worldwide one year after the observation.

HUBBLESITE

A DECADE OF DISCOVERY

HUBBLE TRIVIA

- In its 10 years of surveying the heavens, NASA's Hubble Space Telescope has made 330,000 exposures and probed 14,000 celestial targets.
- Hubble has whirled around Earth 58,400 times, racking up 1.5 billion miles. That's like making 8 round trips to the Sun.
- The orbiting observatory's observations have amounted to 3.5 terabytes of data.
- Each day the telescope generates enough data - 3 to 5 gigabytes — to fill a typical home computer.
- Hubble's archive delivers between 10 and 15 gigabytes of data a day to astronomers all over the world.
- Astronomers have published 2,651 scientific papers on Hubble results.

A DECADE OF DISCOVERY

THE TELESCOPE'S JOURNEY: FROM FICTION TO FACT

1923:	Famed rocket scientist Hermann Oberth publishes an article speculating on telescopes in orbit.
1946:	Astronomer Lyman Spitzer writes a report entitled the "Astronomical Advantages of an Extra-terrestrial Observatory," in which he discusses the feasibility of building, launching, and operating a satellite observatory.
1957:	Russians launch first satellite, Sputnik.
1958:	Congress creates the National Aeronautics and Space Administration (NASA), a civilian space agency.
1962:	A National Academy of Sciences study group recommends a large space telescope as a long-range goal of NASA.
1968:	NASA successfully launches OAO-II, a small space observatory that orbited Earth for 41/2 years, measuring ultraviolet emissions of galaxies, stars, planets, and comets.
1969:	The National Academy of Sciences publishes the "Scientific Uses of the Large Space Telescope" and approves the telescope project.
1971:	The Large Space Telescope Science Steering Group is established and begins feasibility studies for a 3-meter space telescope.
1975:	The European Space Agency agrees to participate in the project. The telescope's size is reduced to 2.4 meters.

1977: Congress approves the budget for a space telescope. Lockheed Missiles and Space Company wins the contract to design and build the telescope. Perkins-Elmer is awarded the contract to construct the optical telescope assembly, which includes the 2.4-meter primary mirror, the secondary mirror, and the three fine guidance sensors.

1979: Astronauts begin underwater training with telescope mockup.

1981: The Space Telescope Science Institute is established as the telescope's science operations center on the campus of the Johns Hopkins University in Baltimore, Md.

1983: The telescope is named the Hubble Space Telescope after renowned astronomer Edwin P. Hubble.

1986: The telescope's launch is delayed after the Challenger accident. The telescope is kept in storage at Lockheed.

1989: The telescope is shipped from Lockheed Missiles and Space Company in California to the Kennedy Space Center in Florida.

1990: Hubble is launched aboard space shuttle Discovery.

1990: After analyzing Hubble's first pictures in June, astronomers discover that the telescope has "blurred vision," caused by a slight distortion in the 2.4-meter primary mirror.

1990: The telescope resolves a ring of material around Supernova 1987A.

1992: Hubble identifies nearby intergalactic clouds.

1993: The orbiting observatory discovers protoplanetary disks in the Orion Nebula.

1993: The first servicing mission takes place. Astronauts add a corrective optics system to fix the telescope's myopic vision.

1994: Hubble provides a detailed view of the Comet Shoemaker-Levy collision with Jupiter; offers definitive confirmation of the existence of supermassive black holes; reveals details of Pluto's surface; and captures a close-up look at jets and disks in young stellar objects.

1995: Through the "eyes" of Hubble, a brown dwarf star is seen clearly. Another observation, called the Hubble Deep Field, allows astronomers to see to the edge of the universe.

1996: Hubble resolves the host galaxies of quasars.

1997: The second servicing mission takes place. Astronauts install two new science instruments.

1997: Hubble identifies exotic populations of stars in globular clusters; sees the visible afterglow of a gamma-ray burst in a distant galaxy; and provides preliminary evidence for an accelerating universe from supernova observations.

1998: The orbiting observatory detects a shock wave of debris striking a ring of material around Supernova 1987A.

In the Hubble Deep Field South observation, the telescope peers across space in the southern sky.

Another observation using Hubble's infrared camera provides the "deepest" views of the universe.

1999: Hubble observations allow astronomers to refine the universe's expansion rate to within 10 percent accuracy.

1999: The third servicing mission takes place. Astronauts replace the telescope's six gyroscopes, which help the orbiting observatory point at celestial objects.

A DECADE OF DISCOVERY

HUBBLE SCIENCE: AN IN-DEPTH LOOK

A DECADE OF DISCOVERY

THE HUBBLE SPACE TELESCOPE: SCIENCE IN THE FIRST DECADE

There is no doubt that the Hubble Space Telescope in its first decade of operation has had a profound impact on astronomical research. But Hubble did much more than that. It literally brought a glimpse of the wonders of the universe into millions of homes worldwide, thereby inspiring an unprecedented public curiosity and interest in science.

Hubble has seen farther and sharper than any optical/ultraviolet/infrared telescope before it. Unlike astronomical experiments that were dedicated to a single, very specific goal (like the Cosmic Background Explorer), Hubble's achievements are generally not of the type of singular discoveries. More often, Hubble has taken what had been existing hints and suspicions from ground-based observations and has turned them into certainty.

In other cases, Hubble's level of detail forced theorists to re-think previous broad-brush models and construct new ones that would be consistent with the superior emerging data. In a few instances, the availability of Hubble's razor-sharp vision at critical events provided unique insights into individual phenomena.

In total, by observing more than 14,000 astronomical targets, Hubble has contributed significantly to essentially all the topics of current astronomical research, covering objects from our own solar system to the most distant galaxies.

INVASION OF JUPITER

In the solar system, Hubble allowed for a front seat view of the impact of comet Shoemaker-Levy 9 on Jupiter. The high-resolution images provided exquisite details on the plumes' geometry, on the growth and dispersion of the impact features, and on atmospheric waves expanding around the impact sites. The precise nature of these waves is still the subject of some debate, thus this is a case where by unveiling more details the "simple" can become complex. The comet impact is a relatively rare phenomenon, where a thousand years may pass before a similar event is observed again.

LIFE CYCLE OF STARS

Moving from planets to stars, Hubble has documented in unprecedented detail the births and deaths of stars. It has visually demonstrated that protoplanetary dust disks around young stars are common, suggesting that at least the raw materials for planet formation are in place.

Hubble has shown for the first time that jets in young stellar objects emanate from the centers of accretion disks (in objects such as Herbig Haro 30), thus turning what were previously merely theoretical expectations into an observed reality. Hubble has provided many spectacularly detailed images of stellar deaths, in the form of morphologies of planetary nebulae, a mysterious three-ring structure around Supernova 1987A, and corrugated bipolar lobes in the Luminous Blue Variable Eta Carinae. While some of the basic physics developed for these objects from earlier ground-based observations has not changed significantly, the dramatic realization that almost none of these objects is spherically symmetrical, but rather that bi-polarity and point-symmetry are extremely common, has stimulated a flurry of theoretical work on nebular shaping. Thus, again, broad-brush models proved insufficient given the level of detail of the Hubble data.

A COSMIC COLLISION

Furthermore, the observations of Supernova 1987A, the closest supernova in four centuries, have already provided (for the first time) and will continue to provide for the next decade, details on the interaction of a blast wave from a supernova with its surrounding environment. Not only has the three-ring structure been an unexpected feature, but the fireworks expected when the supernova ejecta will hit the central ring (an event which has already started) during the next decade will illuminate the surrounding material and thereby literally throw light on the exploding star's history.

PROBING STARS IN DENSE REGIONS

Hubble's superb resolution is one of its major assets when observing dense stellar environments. Hence, it is no wonder that Hubble has produced a plethora of results on resolved stellar populations in globular clusters (galactic and in the Local Group), in field populations of nearby galaxies, and in stellar aggregates in the Magellanic clouds. Exciting results in this area include:

(i) The spread of ages among galactic globulars is relatively narrow, implying a short time scale for the formation of spheroidal components of galaxies.

(ii) The horizontal branch morphology has been determined in globulars as far as in M31 and M33, providing clues concerning the formation age of globulars in the Local Group.

(iii) Hubble has revealed for the first time the sequence of cooling white dwarfs in several nearby globulars and explored the bottom of the main sequence.

(iv) Hubble has shown that the star formation histories of resolved dwarf galaxies exhibit a wide variety of behaviors.

(v) Hubble has provided valuable information on star formation and the Initial Mass Function (IMF) in the Magellanic clouds. These data may have important implications for star formation in the (a universe deficient in the heavier elements) early universe.

VORACIOUS EATING MACHINES

In the dense environments of galactic centers Hubble has confirmed previous suspicions and provided decisive evidence showing that supermassive black holes reside in the centers of many (not necessarily active) galaxies. High-resolution images revealed the presence of dusty gas tori around the central object. The ability to spectroscopically determine velocities at multiple locations led to reliable determinations of the black hole masses.

GALACTIC WRECKS

In the violent environment of colliding galaxies, Hubble showed that young, massive, compact star clusters are formed when two galaxies collide or interact strongly. The formation time is of the order of 10 million years or less, and these clusters may be the progenitors of globular clusters.

THE HOMES OF QUASARS

Findings from ground-based observations suggested that quasars reside in host galaxies, but Hubble unambiguously confirmed it. Furthermore, using its superb resolution, Hubble has demonstrated that a very high fraction of the hosts are interacting galaxies. This information could be an important clue for how the central black hole is fed.

Using its unique capability to collect ultraviolet light, Hubble discovered low-redshift counterparts to the quasar absorption systems discovered initially at high redshifts in ground-based data. The Hubble discovery further allowed the low-redshift absorbers to be directly identified as galaxies and confirmed the theoretical expectation that the density of Lyman Alpha forest lines is higher at low-redshift than might have been suggested by a simple extrapolation from the high-redshift observations.

As expected, Hubble really shined in observations of the high-redshift universe. Using deep imaging, as in the Medium Deep Survey, and in the two Hubble Deep Fields, Hubble showed that the angular sizes of faint galaxies are small. Since beyond a redshift of 1 a small angular size corresponds to a physically small source, this observation, when coupled to the one below, can have important implications for galaxy formation.

The high resolution obtained in the Hubble Deep Fields allowed for a determination of galaxy morphologies at high redshift and demonstrated that high-redshift galaxies have less well-defined, more disturbed appearances. Generally, there is an increasing fraction of irregular and multiple-component systems into the past.

The Near Infrared and Multi-Object Spectrometer observations showed that this conclusion remains true, even when one takes into account that optical images really give the ultraviolet rest frame appearance of galaxies (and thus show mostly star formation knots).

Both of the above findings generally support the hierarchical model for structure formation, in that high redshift galaxies are often only the building blocks from which present day galaxies formed, via interactions and mergers.

Determinations of the ultraviolet luminosity density (using the Hubble Deep Fields) have helped to sketch out the cosmic star formation history back into the distant past. Much of the lower-redshift data came from ground-based observations, but the Hubble

Deep Fields provided and inspired much of the follow-up, high-redshift work in this area. It now appears that the cosmic star formation rate was higher in the past, with a peak value around redshift 1.25. In the still more distant past, the star formation rate was about constant up to about redshift 5.

AN EXPANDING UNIVERSE

Ever since Edwin Hubble's discovery of the expansion of the universe in the late 1920s, measuring the value of the Hubble constant (the reciprocal of which indicates the age of the universe) has been a prime target for observational cosmology. In May 1999 a Hubble key project team announced the completion of a program aimed at measuring the distances to 18 galaxies, some as far as 20 megaparsecs away (e.g. the Virgo cluster galaxies).By calibrating a variety of methods with Cepheid Variable distances, the team arrived at a value of 70 km/s/Mpc for the Hubble constant, with an uncertainty of about 10 percent. This project would have been absolutely impossible without Hubble's resolution and depth.

By calibrating the absolute magnitudes at maximum of a sample of Type Ia supernovae, another team determined the distances to galaxies in the Hubble flow, finding a value of 60 km/s/Mpc (with a 10 percent uncertainty) for the Hubble constant. Thus, the decades-long discrepancy among the values determined by different groups (and different methods) is finally reaching its resolution.

COSMIC EXPLOSIONS

Hubble teamed up with X-ray and gamma-ray satellites, as well as with ground-based optical telescopes in a quest for understanding gamma-ray burst sources. Gamma-ray bursts may represent the most powerful explosions in the universe since the Big Bang. Before 1997 astronomers were frustrated: although more than 2,000 "bursts" had been observed, it was impossible even to determine whether these fireballs occurred in our own galaxy's halo or at cosmological distances. The discovery of X-ray afterglows by the BeppoSax satellite, followed by the discovery of optical transients (from the ground), led eventually to a clear confirmation of the cosmological nature of at least a subclass of bursts. Hubble provided images that showed unambiguously that the gamma-ray bursts actually reside in galaxies that are forming stars at high rates. Furthermore, by pinpointing a burst's precise location, Hubble showed that at least in one case the gamma-ray burst is probably not associated with an active galactic nucleus.

A SPEEDY UNIVERSE

One of the most dramatic astronomical discoveries of this century came in 1998, when two teams found (independently) strong evidence that the cosmic expansion is accelerating. This conclusion, based on distance measurements to Type Ia supernovae (if confirmed), also implies the existence of a cosmological constant, which contributes about 70 percent of the cosmic energy density. While many of the observations were made with the Keck telescope, Hubble provided the resolution needed for the high-redshift ($z>\sim0.5$) supernovae, for their light to be correctly distinguished from that of the host galaxies. Hubble's contribution was crucial in establishing that the more distant Type Ia supernovae are dimmer (by about 0.25 magnitude) than expected from the Hubble Law.

An examination of the above list of accomplishments reveals that Hubble has enormously improved our understanding of the cosmos, from the universe's size, age, and fate, to the meteorology of planets, from stellar births to their deaths. But perhaps even more importantly, Hubble has not only established itself as a premier observatory that makes discoveries that are at the forefront of astronomy, it has become the public's premier gateway to science.

A DECADE OF DISCOVERY

HUBBLE SPACE TELESCOPE: PAST, PRESENT, AND FUTURE

During the past 10 years NASA's Hubble Space Telescope has pushed back the frontier of virtually every area of astronomy. Hubble has made dramatic contributions in understanding:

- the atmospheres of planets
- the birth, life, and death of stars
- the properties of galaxies out to the farthest reaches of the universe
- supermassive black holes and their galactic hosts
- the abundance of light and heavy elements in the universe
- the age of the universe
- the fate of the cosmic expansion

Some Hubble "firsts" include:

- discovering that the sizes of galaxies are smaller in the distant universe
- sketching the cosmic star formation rate into the early history of the universe
- discovering young, massive star clusters formed in the collisions of galaxies
- identifying absorbers of quasar light as galaxies
- determining accurate distances to variable stars in the Virgo cluster of galaxies
- imaging the plume resulting from the impact of comet fragments on Jupiter and of the "scars" at the impact sites
- imaging jets emanating from the center of an accretion disk around a young star

At the conclusion of Servicing Mission 4, scheduled for 2003, astronomers will leave Hubble with the most powerful suite of scientific instruments ever flown on the observatory.

During Hubble's second decade, the science program will differ from the present one in two important respects. In the second decade the remaining two Great Observatories - the Chandra X-ray Observatory and the Space Infrared Telescope Facility - will be in full operation.

The Next Generation Space Telescope will be launced two years before Hubble's retirement. Coordinated research campaigns involving all four of these extremely powerful telescopes will be common.

It is difficult to imagine a larger "quantum leap" in astronomy than that provided by a view of the universe in which astronomers will have simultaneous coverage from X-rays through optical and near-infrared wavelengths to the deep infrared using this fleet of major space telescopes.

Secondly, special emphasis will be placed on large programs intended to push Hubble to its limits and to address the most important scientific questions that can be answered by the telescope before its mission comes to an end. These are called "Treasury Programs." Past examples of this approach include the Hubble Deep Field, the Hubble Constant Key Project, and the comet Shoemaker-Levy 9 impact on Jupiter. All of these programs had a huge impact on science.

A DECADE OF DISCOVERY

EXPECTED HUBBLE DISCOVERIES IN THE COMING DECADE

NASA's Hubble Space Telescope was responsible for many great discoveries during the past decade. Nevertheless, there is much revolutionary research left for the observatory to do. Predicting what Hubble will discover in the next millennium is truly a challenge; new results are generally unexpected and cannot be listed in advance. Still, here are some science expectations for the future:

EXPECTED NEW DISCOVERIES FROM SPECIFIC OBSERVATIONS

1) A front-seat view of the effects of a supernova explosion In 1987 astronomers discovered the closest supernova seen in four centuries. Follow-up observations by Hubble revealed several mysterious rings of illuminated matter around the supernova, still aglow after being flashed by the supernova's brilliant light. During the next decade matter flying outward from the supernova will ram into the central ring, a process that has already started. Astronomers anticipate that a fantastic celestial fireworks display will ensue, and Hubble, with its unparalleled eye for detail, will give astronomers the best view of this drama. For the first time astronomers will see in detail how the blast wave from a supernova interacts with the environment around it, and they expect to learn a great deal about the structure of the exploding star, its evolutionary history, and the nature of the enigmatic rings around it. Since supernovae of this type are also the main source of oxygen for the interstellar medium, from which later generations of stars and planets form, it is important to understand this interaction.

2) Are there planets around stars in the oldest clusters? Globular clusters are collections of hundreds of thousands of relatively old stars that are deficient in heavier elements. No planets have ever been detected around any star in a globular cluster. Hubble will potentially detect as many as 50 planets (if they exist) around globular cluster stars. Due to its uniquely sharp view, Hubble can resolve as many as

40,000 stars in one field in a globular cluster and follow the tiny variations (of about a percent) in their brightness as giant planets pass in front of stars. The detection of such planets will be of enormous significance, since it will not only demonstrate that planets can form even when there are fewer heavier elements than in the solar system, but also that planets can survive in crowded stellar environments. If planets are not detected, this will also place meaningful constraints on planet formation.

3) Filling in the missing links of life's origin Exploding stars create the elements necessary for life, but before these elements can be incorporated into newly formed planets and stars, they must cycle through a galaxy's "ecosystem." Astronomers suspect that many of the elements created in stellar explosions within the disk of a galaxy first get blown into the galaxy's halo. To date this halo gas has remained largely unobservable. The Cosmic Origins Spectrograph, the most sensitive ultraviolet-light spectrograph ever to be flown into space, will enable us for the first time to systematically study this crucial stage in the ecosystems of other galaxies. By observing quasar light shining through the halos of galaxies, astronomers will obtain "core samples" of the halo material and its composition, filling in this important missing link in our understanding of life's origin.

4) A giant step towards understanding how comets form Comets are small, icy objects that spend most of their lives well beyond the orbit of Pluto. They are generally recognized only on the rare occasions when one dives into the inner solar system, thereby developing a spectacular tail. One of the main regions where billions of comets reside is the Kuiper belt — a region extending from about the orbit of Neptune out to about 50 times the Earth's distance from the Sun. One of the main challenges of any theory for the formation of the solar system is to explain the formation and properties of this large number of comets.

Hubble observations of Kuiper belt objects in the infrared (using the refurbished Near Infrared Camera and Multi-Object Spectrometer and the Wide Field Camera 3) will determine the composition of these objects. This will be a huge step forward in the direction of determining their origin and formation process. Given the fact that the evolution of life on Earth has been dramatically influenced by comet impacts, an understanding of the origin of comets is vital.

MORE SPECULATIVE POTENTIAL NEW DISCOVERIES

1) Cosmic enigmas An examination of the Hubble Deep Field North — one of the two deepest images of the universe ever taken in optical/ultraviolet/infrared light, revealed the presence of a mysterious object with very unusual properties. While the object is readily visible in near infrared light (1.6 and 2.2 microns), it is totally undetected in visible light (wavelengths shorter than 1.1 microns). One intriguing possibility is that this galaxy (with a redshift of 12.5) is far across the cosmos, existing when the universe was only a few hundred million years old. Intervening galaxies may have absorbed most of its light.

The recharged Near Infrared Camera and Multi-Object Spectrometer will reveal if the object is indeed point-like, as in the case of a star, or has a "fuzzy" appearance, as one would expect for a galaxy. But more importantly, the Wide Field Camera 3 with its wide (and deep) field of view will be superb in searching for other objects of this type, determining how common they are, and whether they constitute a new class of objects.

2) "Far-out" giant planets? The dusty circumstellar disks observed with the Near Infrared Camera and Multi-Object Spectrometer and the Space Telescope Imaging Spectrograph reveal various gaps and ring structures, which are potentially attributed to the gravitational influence of large planets or protoplanets. A "problem" with this interpretation is that the structures are seen at large distances from the parent star, much farther away than the known giant planets in our own solar system. Interestingly, the analysis of some cometary orbits in the solar system also suggests the potential existence of a perturbing planet at a great distance from the Sun.

Are there unexpected families of giant planets in the far outskirts of planetary systems? Hubble surveys of faint moving objects could reveal such new planets around the Sun, and Hubble's highly sensitive infrared vision may even image such an object directly.

EXPECTED DISCOVERIES OF A MORE INCREMENTAL NATURE, BUT IN THE CONTEXT OF A "BIG PICTURE"

1) What makes the largest explosions in the universe? For decades astronomers have

detected bursts of gamma-rays coming from the heavens, but until recently they had no idea where they were coming from. During the past two years Hubble has played a crucial role in pinpointing their origin in very distant galaxies.

Gamma-ray bursts are now recognized to be the largest explosions in the universe since the Big Bang, but astronomers still do not know what causes them. Hubble's superb vision will allow astronomers to determine the precise location of the "bursts" inside their host galaxies, and will thereby help to identify the nature of the exploding objects. Furthermore, observations in ultraviolet light shortly after the burst, and in the optical many months after the burst (both are possible only with the unique capabilities of Hubble), will complement observations with the High Energy Transient Explorer II and the Chandra X-ray Observatory. These observations will allow direct tests of the physical processes occurring during these cosmic fireballs, and will potentially help determine the rate at which stars form during the cosmic history.

2) What is the universe's ultimate fate?
Edwin Hubble's discovery of the universe's expansion in the 1920s redefined astronomers' view of the cosmos. Until just a few years ago common wisdom held that the gravitational pull of each galaxy on every other galaxy must have been slowing down the expansion. However, some recent observations of distant supernovae have led many astronomers to wonder whether the universe's expansion is in fact accelerating under the influence of a somewhat mysterious repulsive force.

In order to settle this question, astronomers are busy working to discover and monitor ever more distant supernovae. Hubble is absolutely critical to this effort because its superior vision is crucial for distinguishing the supernova's light from that of its surrounding galaxy. Only by measuring with high precision the power of supernovae at distances spanning half the universe's age will astronomers be able to tell if the acceleration is real and thereby determine if the universe's ultimate fate is infinite expansion towards a cold death.

3) Mapping normal matter in the universe
Large, ground-based surveys are currently mapping the distribution of galaxies in the local universe. But these galaxies represent only a fraction of the "normal" matter — the kind that makes up the Sun, the Earth, and

human beings. A considerably larger proportion lies in the vast spaces between galaxies. Much of this matter is likely to be in the form of clouds that never formed galaxies. With the Cosmic Origins Spectrograph aboard Hubble, astronomers will be able to begin mapping out these large gaseous clouds, which will hopefully lead to an understanding of why some clouds form galaxies while others do not.

4) Where does the dark matter in the universe reside? By studying how galaxies move in response to gravity, astronomers have found that most of the matter in the universe is dark — does not shine like stars. Yet, it is this dark matter that holds galaxies and clusters of galaxies together. Astronomers have been refining techniques to study dark matter by measuring how severely its gravitational pull distorts light from distant galaxies, acting like a lens.

With the installation of the Advanced Camera for Surveys in 2001, Hubble will gain an invaluable new tool for unmasking the dark matter in the universe. This camera will surpass previous Hubble instruments in the size of its field of view and sensitivity and will take full advantage of Hubble's razor-sharp vision to detect the minute, but telltale, distortions that signal the presence of dark matter. In particular, the Advanced Camera for Surveys will excel in mapping out the dark matter that binds galaxies and clusters of galaxies. The luminous parts of galaxies are just like the mini-lights on a huge holiday tree, and the Advanced Camera for Surveys will enable astronomers to see the tree itself.

5) A broader view of the distant universe
The most distant galaxies in the universe are detectable only in infrared light. Near Infrared Camera and Multi-Object Spectrometer observations detected some of the most distant galaxies ever seen. In the next few years astronomers hope to extend the frontiers of the known universe both farther and wider, once the near-infrared camera's cryocooler has been replaced and the infrared-sensitive Wide Field Camera 3 has been installed. With its much wider field of view, the Wide Field Camera 3 will allow for the simultaneous study of unprecedented numbers of distant galaxies, allowing astronomers to contrast and compare galaxies dating from within a billion years of the Big Bang. All of this will naturally pave the way for the Next Generation Space Telescope.

A DECADE OF DISCOVERY

HUBBLE'S PLANET WATCH

A comet slamming into Jupiter, blooming clouds on Uranus, monster storms on Neptune, auroras on Jupiter and Saturn, wacky weather on Mars - NASA's Hubble Space Telescope has kept its "eye" on our solar system planets.

For nearly a decade Hubble has monitored the weather on the red planet, Mars. Hubble observations in the spring and summer of 1997 provided detailed reports to help plan the landing of NASA's Mars Pathfinder and the arrival of Mars Global Surveyor. Pictures taken about a week before the landing of the Pathfinder spacecraft show a dust storm churning through the deep canyons of Valles Marineris, just 600 miles (1,000 kilometers) south of the landing site.

Hubble snapped an image on April 27, 1999 of an enormous cyclonic storm system raking the northern polar regions of the Mars. Nearly four times the size of the state of Texas, the storm is composed of water ice clouds like storm systems on Earth, rather than the dust typically found in Martian storms.

Hubble observations of the turbulent clouds of Jupiter were used to help target close-up picture-taking by the Jupiter-orbiting Galileo probe.

In 1994 Hubble caught an invasion of Jupiter when 21 fragments of comet Shoemaker-Levy 9 slammed into the planet. As each comet fragment crashed into the giant planet, Hubble imaged mushroom-shaped plumes along the edge of the planet. The largest fragment impact created an Earth-sized "bull's-eye" pattern on Jupiter.

Hubble's sharp images show that the fragments, the largest of which were probably a few miles across, did not break up catastrophically before plunging into Jupiter's atmosphere. This reinforces the notion that solid, massive bodies produced the comet's atmospheric explosions.

Hubble telescope observations were used

to make global maps of Jupiter for tracking changes in the dark debris caught up in the high-speed winds at Jupiter's cloud tops. This debris is a natural tracer of wind patterns and allows astronomers a better understanding of the physics of the Jovian atmosphere.

Auroras, curtains of light that seem to dance above the north and south poles of Saturn and Jupiter, have also been studied by the telescope. Astronomers used the Hubble's ultraviolet-light camera, the imaging spectrograph, to probe these auroras. Saturn's auroras rise more than 1,000 miles above the clouds. These auroral displays are caused by an energetic "wind" of charged particles from the Sun that sweeps over the planet, much like Earth's aurora.

The Hubble telescope has monitored weather and cloud patterns on Uranus. An infrared view of the planet shows 20 clouds, some circling the planet at more than 300 mph.

Astronomers used Hubble telescope images, taken from 1994 to 1998, to create a time-lapse movie that shows for the first time seasonal changes on the planet. Once considered one of the blander-looking planets, Uranus is now revealed as a dynamic world with the brightest clouds in the outer solar system and possessing a fragile ring system that wobbles like an unbalanced wagon wheel. The clouds are probably composed of methane crystals, which condense as warm bubbles of gas well up from deep in the atmosphere of Uranus. The movie clearly shows for the first time the wobble in the ring system, which is made up of billions of tiny pebbles. This wobble may be caused by Uranus's shape, which is like a slightly flattened globe, along with the gravitational tug from its many moons.

Uranus is tilted completely over on its side, giving rise to extreme 20-year-long seasons and unusual weather. For nearly a quarter of the Uranian year, the Sun shines directly over each pole, leaving the other half of the planet plunged into a long, dark, frigid winter. The Northern Hemisphere of Uranus is just now coming out of the grip of its decades-long winter. As the sunlight reaches some latitudes, it warms the atmosphere.

Neptune's unusual weather patterns also were the subject of a time-lapse rotation movie. Using Hubble telescope pictures, the movie shows that the planet has some of the wildest, weirdest weather in the solar system. The telescope captured the most insightful images to date of a planet whose blustery weather — monster storms and equatorial winds of 900 mph — bewilder scientists.

Even the outermost planet in our solar system hasn't escaped the telescope's scrutiny. The Hubble telescope unveiled the never-before-seen surface of Pluto, which orbits at the dim outer reaches of the solar system nearly 3 billion miles (5 billion kilometers) from the Sun. Pluto is two-thirds the size of the Earth's moon but is 12,000 times farther away. Viewing surface detail is as difficult as trying to read the printing on a golf ball located 30 miles away! The Hubble's Faint Object Camera (FOC) imaged nearly the entire surface of Pluto as it rotated through its 6.4-day period in late June and early July 1994. The images, made in blue light, show that Pluto is an unusually complex object, with more large-scale contrast than any planet except Earth.

A DECADE OF DISCOVERY

THE SEARCH FOR PLANETARY SYSTEMS

Our Earth and solar system were born 4.5 billion years ago. Clues to our genesis are fragmentary, so astronomers must look at the birth of stars in neighboring stellar "maternity wards" to see a replay of the events that created our Sun and planets.

By studying debris disks, composed of dust and gas, whirling around developing stars, the NASA Hubble Space Telescope's high resolution has opened up a new level of detail that reinforces earlier theories and offers some new surprises about planet birth. The ultimate goal, which only may be realized by a next-generation space telescope, will be to inventory planets and solar systems around other stars and ultimately identify Earth-like planets.

In 1994 Hubble discovered dozens of dust disks around young stars in the great Orion Nebula. Dubbed "proplyds" these disks are widely considered to be precursors to full-fledged planetary systems. Such disks were proposed in the eighteenth century by Immanuel Kant to explain the simple fact that all the planets of the solar system lie in nearly the same plane, and so were born from a primordial disk that provided the raw material for planet growth.

The Hubble images may long be remembered as the first tantalizing visual evidence that planets might be ubiquitous in the galaxy. Dozens of stars in the Orion region — which itself is just one of thousands of star birth regions in the Milky Way Galaxy — have these disks. Though it is not clear if they will go on to condense into planetary systems, their abundance alone is firm visual evidence that the first baby steps toward planet formation are very common.

The Hubble telescope has also spied these disks around isolated young stars ranging in age from 1 million to 10 million years. Astronomers have used the Hubble's arsenal of cameras to capture these disks in ultraviolet to near-infrared light. By chronicling these disks at different stages of a star's early life, astronomers are adding information to the planet-making recipe.

The telescope's sharp vision analyzed disks around eight young stars in the nearby constellation Taurus. Images taken in near-infrared and visible light show that material falling onto the disks are driving outflowing jets of gas from the developing stars. Many of these disks are 8 to 16 times the diameter of Neptune's orbit.

Hubble's Wide Field and Planetary Camera 2 spotted the first example of an edge-on disk in a young double-star system. These images offer further evidence that planet formation should be possible in binary star systems. Theory holds that gravitational forces between the two stars tend to tear apart fragile planet-forming disks. Astronomers also found evidence of dust in the disks clumping together and beginning to make larger bodies.

Looking at a disk around a slightly older star, astronomers using Hubble's Space Telescope Imaging Spectrograph found evidence of more clumping of material. The 2- to 4-million-year-old star, called AB Aurigae, is in constellation Auriga. These clumps are much farther away from the star than Pluto, our outermost solar system planet, is from our Sun.

Turning its gaze to a fully developed star about 10 million years old, Hubble's Near Infrared Camera and Multi-Object Spectrometer captured images of a 6.5-billion-mile-wide dust ring. This ring around the star, called HR4796A, resembles Saturn's rings, but on a larger scale. The gaps between the rings could be the result of unseen bodies sweeping out lanes. The star is 220 light-years from in the constellation Centaurus.

A DECADE OF DISCOVERY

THE COLORFUL LIVES OF STARS

NASA's Hubble Space Telescope has unveiled a of variety shapes, structures, and fireworks that accompany the birth and death of stars. Hubble images of newly forming stars reveal blowtorch-like jets of hot gas streaming from deep within the disks around the stars. Possibly shaped into long slender streamers by magnetic fields, these jets are an "exhaust product" of star formation. They travel across space for billions of miles before slamming into material in the star's vicinity. In dramatic images, Hubble has shown the effects of very massive young stars on their surrounding nebulae. The astronomical equivalent of a hurricane, the intense flow of visible and ultraviolet radiation from an exceptionally massive young star eats into surrounding clouds of cold hydrogen gas, laced with dust. This helps trigger a firestorm of star birth in the neighborhood around the star.

Hubble has produced a dazzling array of images of colorful shells of gas blasted into space by dying stars. These intricate structures are "fossil evidence," showing that the final stages of stars' lives are more complex than once thought. An aging star sheds its outer layers of gas through stellar winds. Late in a star's life, these winds become more like a gale and consequently sculpt strikingly complex shapes. When massive stars die, they don't die as quietly as lighter-weight stars. They end their lives with mammoth explosions. The Hubble has been keeping an "eye" on one such nearby explosion, Supernova 1987A. The star's self-destruction was first seen nearly 12 years ago on February 23, 1987 by a ground-based telescope. In July 1997 the Hubble telescope's imaging spectrograph captured the first images of material ejected by the exploding star ramming into an inner ring around the dying object. Shocked by the 40-million-mile-per-hour sledgehammer blow, a 100-billion-mile-wide knot of gas in a piece of the ring has already begun to "light up," as its temperature surges from a few thousand degrees to a million degrees Fahrenheit. By analyzing this glowing ring, astronomers may find clues to the final years of the doomed star's existence.

A DECADE OF DISCOVERY

BLACK HOLES: FROM FANTASY TO FACT

Black holes were theorized more than 200 years ago, and later were predicted by Einstein's theory of general relativity. The discovery of active galaxies forced astronomers to think that monstrous black holes really do exist and are the "engines" at the heart of these fireworks. The gushers of light and other radiation from such objects could not be explained by starlight alone.

By definition, a black hole is very hard to find. It is a celestial object that squeezes a lot of material into a very small space. The resulting gravitational pull is so intense that anything passing nearby, even light, is trapped forever.

Like a ghost in a mystery story, a black hole's presence must be inferred by the effects on its surroundings. Its powerful gravity will influence the motion of neighboring stars. The closer the stars are to the black hole, the faster they should be moving, just as orbiting planets move faster the closer they are to the Sun. If no black hole is present, the speed of the stars should slow toward the hub of a galaxy, because most of the gravity influencing their motion would come from the other stars in the galaxy.

Once the speed of the entrapped material is measured, astronomers can calculate the mass of the black hole using the simple laws of gravity, just as the orbital speed of the Moon can be used to calculate Earth's mass. If it turns out that there is far more mass present than there are stars, the matter must be tucked away in something that is invisible and compact.

Similar observations have been made with ground-based telescopes since the mid-1980s; but having to look through the Earth's turbulent atmosphere severely limits the accuracy of such telescopes for detecting and measuring a large, central mass. While the ground-based data give ambiguous lower limits to the central mass, NASA Hubble Space Telescope observations are decisive for accurately measuring the mass and ruling out all other possible explanations.

The first black hole confirmation was nailed down when the space telescope uncovered a spiral disk of gas swirling around the hub of the giant elliptical galaxy M87. The shape alone suggested that the material was caught in a gravitational whirlpool. Using Hubble's spectrographs, astronomers were able to measure the velocity of the gas by a method known as Doppler shift. As the disk spins like a carousel, one side of it approaches us and is blueshifted, while the other side rotates away and is redshifted.

Astronomers concluded that the gas is whirling at more than a million miles an hour. This information can be used to calculate how much mass is packed into the core of M87. It turns out that the mass of two billion Suns is compressed into a region of space no bigger than our solar system. Hubble has made similar observations in two other elliptical galaxies, NGC 4261 and NGC 3115. These monstrous black holes weigh in, respectively, at 200 million solar masses and two billion solar masses.

Surveys of galaxy nuclei in both active and quiescent galaxies suggest black holes are common to virtually all galaxies. The mystery is how the black holes formed in the first place. The abundance of quasars in the early universe, objects at the hearts of galaxies that pour out a torrent of radiation, suggest that monstrous black holes must have formed very early, though it is still not known how this happened.

Hubble images of quasars show that they reside in a variety of galaxies, both spiral and elliptical. Many but not all of the quasar host galaxies, are engaged in a collision or interaction with other bypassing galaxies. The infall of gas resulting from such collisions fuels the monster black holes.

A DECADE OF DISCOVERY

LOOKING TOWARD THE EDGE OF THE UNIVERSE

Astronomers used NASA's Hubble Space Telescope to look out into the universe over distances exceeding 12 billion light-years. These "deepest" views of the heavens, made with Hubble's visible and infrared cameras, are collectively called the Hubble Deep Field.

Because the starlight harvested from remote objects began its journey toward Earth billions of years ago, Hubble, as well as all large telescopes, look farther back into time the farther they look into space. Hubble has seen back to a time when the universe was only about five percent of its present age. These "long exposures" of the universe have revealed galaxies that existed when the universe was less than one billion years old. Some of the objects viewed were so dim that seeing them would be as difficult as discerning a flashlight on the Moon as seen from Earth.

The Deep Field uncovered more than 1,000 galaxies in a patch of sky no larger than a grain of sand held at arm's length. Extrapolated across the entire sky, this means the universe contains at least 120 billion galaxies. These thousands of galaxies are at various stages of evolution and are strung along a corridor of billions of light-years.

Hubble's high resolution enables astronomers to actually see the shapes of galaxies in the distant past and study how they have evolved over time. They found that galaxies looked more fragmentary in the distant past and took time to evolve to the majestic spirals and giant elliptical galaxies of today. They also found that the universe formed most of its stars when it was less than half its present age. Astronomers will spend years sorting the myriad shapes of the galaxies in this image to understand how they formed and how have evolved since the Big Bang.

A variety of other telescopes, with sensitivities ranging from X-rays to radio waves, have also been aimed at the Deep Field to see if astronomers can match various astronomical phenomena to the visible-light galaxies.

THE UNIVERSAL SPEED LIMIT

In the 1920s astronomer Edwin Hubble discovered that galaxies are all moving away from us at a rate proportional to their distance. The farther a galaxy is, the faster it appears to be moving away. This relationship, called the Hubble constant, establishes an expansion rate that is critical for estimating the age and size of the universe. The universe is expanding because it was born in a fiery explosion, called the Big Bang, many billions of years ago.

The quest to precisely determine the Hubble constant was headed by the Key Project team, a group of astronomers who used NASA's Hubble Space Telescope to look far away for accurate "milepost markers," a special class of stars called Cepheid variables. The rhythmic pulsation of these aged, bright stars yields their intrinsic brightness, which in turn is needed to measure precise distances. Hubble's clear vision has allowed astronomers to accomplish in a few years Cepheid observations that previously required decades of painstaking work with ground-based telescopes.

Astronomers used Hubble to systematically search for Cepheids in our galactic neighborhood out to the distance of the Virgo cluster of galaxies. Cepheids were used to calibrate even more remote markers such as supernovae, which are so bright they can be seen at far greater distances, billions of light-years.

The team found that the universe is between 12 and 14 billion years old, depending on the density of matter in space.

Hubble played an important role in the discovery that the expanding universe may actually be accelerating. In other words, the galaxies are rushing away from each other ever faster as time goes on.

Hubble observations of distant supernovae were used to measure how quickly the universe was expanding long ago.

Astronomers were surprised to discover that the universe was actually expanding at a slower rate billions of years ago. This implies that there may be a mysterious force, an "anti-gravity" that pushes galaxies apart at an increasingly faster rate the farther away they are from each other. This means the universe may continue expanding forever and never collapse in a fiery "Big Crunch."

A DECADE OF DISCOVERY

GAMMA-RAY BURSTS: THE LIGHT FANTASTIC

The most titanic explosions in the universe take the form of gamma-ray bursts. These bright bursts of energy appear from random regions in space and typically last a few seconds. United States Air Force Vela satellites first discovered them in the 1960s. Since then, numerous theories of their origins have been proposed, but the causes of gamma-ray bursts remain unknown.

NASA's Hubble Space Telescope has helped astronomers trace these bursts back to distant galaxies. The principal limitation in understanding the bursts was the difficulty in pinpointing their direction in the sky. Unlike visible light, gamma rays are exceedingly difficult to observe with a telescope, and the burst's short duration exacerbates the problem.

Hubble has teamed up with several observatories, including X-ray satellites, to collect information on bursts. Among the most energetic was the gamma-ray burst labeled GRB971214, detected Dec. 14, 1997. Astronomers measured the distance to a faint galaxy from which the burst originated. Using the Italian/Dutch satellite BeppoSAX, astronomers pinpointed the direction of the burst, which permitted follow-up observations with the world's most powerful telescopes. These follow-up observations tracked the burst's "afterglow" in radio waves and X-ray, visible, and infrared light. While gamma-ray bursts last only a few seconds, their afterglows can be studied for several months. By analyzing these afterglows, astronomers have discovered that the bursts do not originate within our own galaxy, the Milky Way, but rather are associated with extremely distant galaxies.

The Hubble telescope images of GRB971214 confirmed the association of the burst's afterglow with a faint galaxy.

Astronomers still don't understand the origins of bursts. Theories suggest they happen where vigorous star formation takes place. Gamma-ray bursts may be created by the mergers of a pair of neutron stars or black holes or a hypernova, a theorized type of exceptionally violent exploding star.

A DECADE OF DISCOVERY

A DECADE OF HST CONTRIBUTIONS TO SCIENCE

RESEARCH AREA	**PRE-HST KNOWLEDGE** (circa 1990)	**HST CONTRIBUTION** (circa 2000)
Distant galaxies & galaxy evolution	Very little known about galaxies beyond a few billion light-years.	Deep imaging traces the evolution of galaxies and rate of star formation. Galaxies seen within a billion years of the Big Bang.
Remote supernovae as distance indicators	Not possible to discriminate supernova light from light of host galaxy.	In collaboration with ground-based telescope surveys HST detects supernovae all the way back to half of universe's age. The results show universe is accelerating.
Universe's rate of expansion	Two research groups disagree by a factor of two, this yields estimates for age of universe as between 10 to 20 billion years.	Value converges toward 10 percent accuracy, suggesting an age of 12-14 billion years.
Environments around protostars	Little known about circumstellar environment. Jet-like features noted, stellar disks seen in infrared wavelengths.	Protoplanetary disks are common. Circumstellar disks confine and direct the flow of jets.
Super-massive black holes	Ground-based data are suggestive, but telescopes cannot see close enough to suspected black holes to provide absolute proof.	HST precisely measures gas velocity around black hole, providing definitive proof. HST surveys reveal that black holes are common to the cores of galaxies.

Quasars	Quasars originated early in the universe. Some are surrounded by a "fuzz" which is interpreted as the host galaxy. Quasars are likely powered by black holes.	HST clearly resolves a variety of galaxies hosting QSOs. Some are involved in mergers with other galaxies. These collsions fuel the central black hole.
Gravitational lenses	A few examples are known.	Many small lenses uncovered in medium deep survey. Lenses have potential to contribute to cosmological tests of the curvature of space and age of universe.
Pluto	Transits and eclipses of Pluto's moon Charon yield a brightness map of surface.	HST confirms earlier map by showing a variegated surface. Images clearly separate planet from its moon, Charon.
Supernova 1987A	The nearest supernova in 400 years, and armada of telescopes watch its changes following the February. 1987 explosion.	Only HST has the resolution to trace yearly change happening at the sub-light-year scale, including changes in the fireball debris and circumstellar ring of enriched gas.
Galactic bulge structure	Only the Milky Way's central bulge and those of nearby galaxies can be viewed in detail.	Large bulges formed early in the universe along with elliptical galaxies. Smaller bulges can be "inflated" by ongoing starbirth fueled by disk instabilities or galaxy mergers.

HUBBLESITE

A DECADE OF DISCOVERY

SPACE STAMPS

A colorful ring of material encircling a dying star. Sky-high pillars of dust and gas that serve as incubators for embryonic stars. NASA's Hubble Space Telescope has brought the beauty of space to the living rooms of the world. Named in honor of famous American astronomer Edwin Powell Hubble, the Earth-orbiting observatory's name has become synonymous with space discovery. Now the U.S. Postal Service is paying tribute to Hubble, the astronomer, and Hubble, the telescope, by offering five stamps bearing spectacular Hubble images — Eagle Nebula, Ring Nebula, Lagoon Nebula, Egg Nebula, and Galaxy NGC 1316. The stamp pane's selvage image is a 1949 black-and-white photograph of Edwin Hubble posing with the 48-inch Schmidt Telescope at Palomar Observatory.

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

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NEXT

HUBBLE DEEP FIELD NORTH

LOW RESOLUTION (23Kb) JPEG

HIGH RESOLUTION (680Kb) JPEG

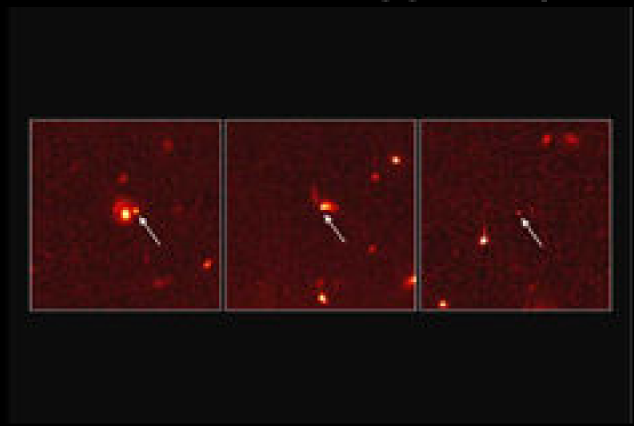
To fully appreciate this Hubble image, imagine peeking through a keyhole and seeing this wild menagerie of galaxies in the sky, some so old that they probably formed shortly after the beginning of the universe. Called the Hubble "Deep Field," the observation covers a speck-sized spot in the sky, yet contains at least 1,500 galaxies at various stages of evolution.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

DISTANT SUPERNOVAE

BACK
NEXT



LOW RESOLUTION (18Kb) JPEG

HIGH RESOLUTION (189Kb) JPEG

These Hubble images pinpoint three distant supernovae, which exploded and died billions of years ago. Researchers are using these objects to determine whether the expansion of the universe decelerated (slowed down) long ago but is now accelerating (speeding up).
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SPIRAL GALAXY NGC 4414

BACK
NEXT

LOW RESOLUTION (19Kb) JPEG

HIGH RESOLUTION (388Kb) JPEG

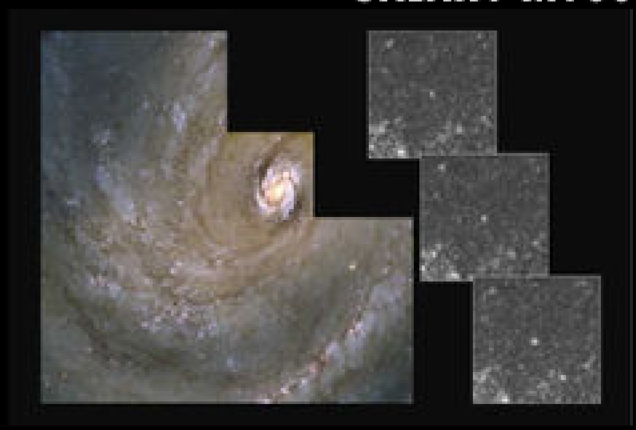
This Hubble image of a spiral-shaped galaxy is more than just a pretty picture. A series of images like this allowed astronomers to measure its distance 10 times more accurately than ever before. Knowing the distance, which happens to be 60 million light-years from Earth, contributes to astronomers' overall knowledge of the universe's rate of expansion and its age.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

BACK
NEXT

CEPHEID VARIABLE STARS IN GALAXY M100



LOW RESOLUTION (25Kb) JPEG

HIGH RESOLUTION (373Kb) JPEG

Contained within the arms of this majestic spiral galaxy is a rare class of pulsating stars called Cepheid variables. Astronomers use Cepheids to reliably determine the distances of galaxies from Earth – a measure that ultimately helps them determine the age and size of the universe.
(Longer Caption)

A DECADE OF DISCOVERY

GRAVITATIONAL LENSING IN GALAXY CLUSTER ABELL 2218

BACK
NEXT

LOW RESOLUTION (19Kb) JPEG

HIGH RESOLUTION (377Kb) JPEG

Your eyes aren't playing tricks on you. This image of a massive cluster of galaxies, called Abell 2218, does show several arc-shaped patterns, which are duplicate images of galaxies that lie five to 10 times farther than Abell 2218. How can that happen? The cluster is so massive that its enormous gravitational field bends, distorts, and duplicates light rays passing through it. This phenomenon is called a gravitational lens.
(Longer Caption)

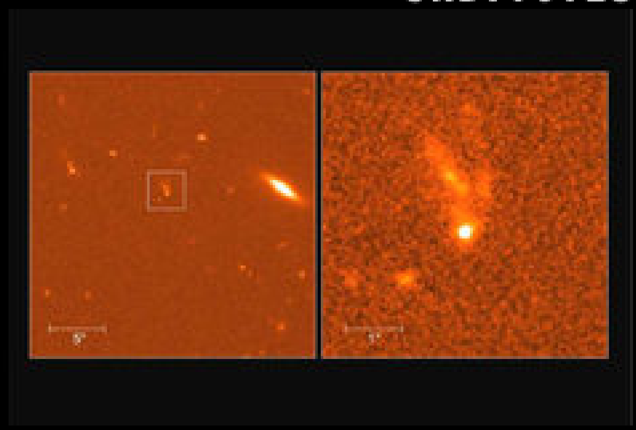
HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

GAMMA RAY BURST GRB990123

BACK
NEXT



LOW RESOLUTION (29Kb) JPEG

HIGH RESOLUTION (446Kb) JPEG

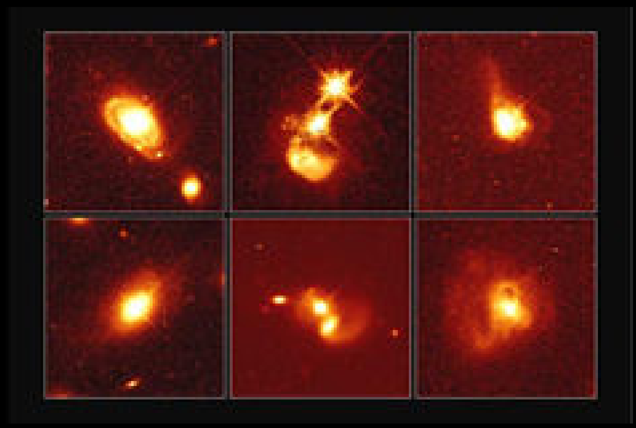
Chasing down high-energy gamma rays isn't easy, but astronomers had their big break in early 1999 when the Hubble Space Telescope, joined by ground telescopes from around the globe, tracked the visible glow of the most energetic gamma-ray burst ever recorded. For a brief moment, the light from the blast was equal to the radiance of 100 million billion stars.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

QUASAR HOST GALAXIES

BACK
NEXT



LOW RESOLUTION (33Kb) JPEG

HIGH RESOLUTION (615Kb) JPEG

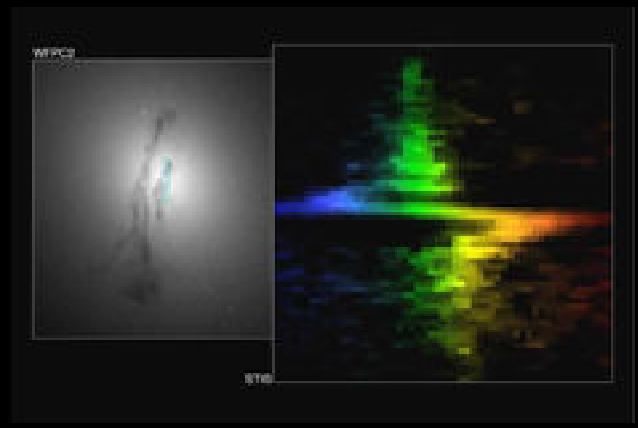
Quasars are distant, brilliant sources of light, believed to occur when a massive black hole in the center of a galaxy feeds on gas and stars. As the black hole consumes the material, it emits intense radiation, which is then detected as a quasar. These Hubble images show where quasars can be found.
(Longer Caption)

A DECADE OF DISCOVERY

HUBBLESITE

BLACK HOLE IN GALAXY M84

BACK
NEXT



LOW RESOLUTION (18Kb) JPEG

HIGH RESOLUTION (163Kb) JPEG

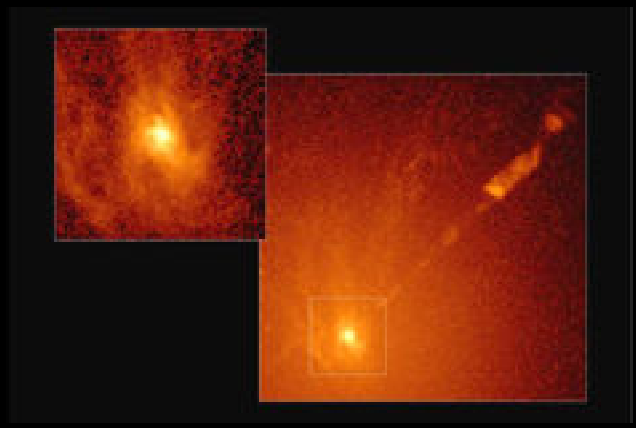
The colorful zigzag on the right is the signature of a supermassive black hole in the center of galaxy M84. The image on the left shows the galaxy's core in visible light.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

ACTIVE GALAXY M87 JET

BACK
NEXT



LOW RESOLUTION (27Kb) JPEG

HIGH RESOLUTION (513Kb) JPEG

This Hubble observation gave astronomers the evidence they needed to prove that a massive black hole lives in the center of M87, a giant galaxy located 50 million light-years away in the constellation Virgo. If it's not a black hole – an object so massive that nothing escapes its intense gravitational pull, including light – then it's something even harder to understand, astronomers say. (Longer Caption)

BACK

NEXT

COLLIDING GALAXIES NGC 4038 AND 4039

LOW RESOLUTION (25Kb) JPEG

HIGH RESOLUTION (327Kb) JPEG

Head-on collisions don't happen just on Earth. They happen in space, too. In this Hubble image, we see the cores of two galaxies (orange blobs) that have collided and triggered a firestorm of star-birth activity as evidenced by the bright blue star clusters in the center.

(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

GLOBULAR STAR CLUSTER M80

BACK
NEXT

LOW RESOLUTION (32Kb) JPEG

HIGH RESOLUTION (641Kb) JPEG

This knot of stars is one of the densest of the 147 known globular star clusters in the Milky Way. Known as NGC 6093 or M80, the cluster contains hundreds of thousands of stars, held together by their mutual gravitational attraction.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

CLUSTER AND NEBULA NGC 3603

BACK
NEXT

LOW RESOLUTION (19Kb) JPEG

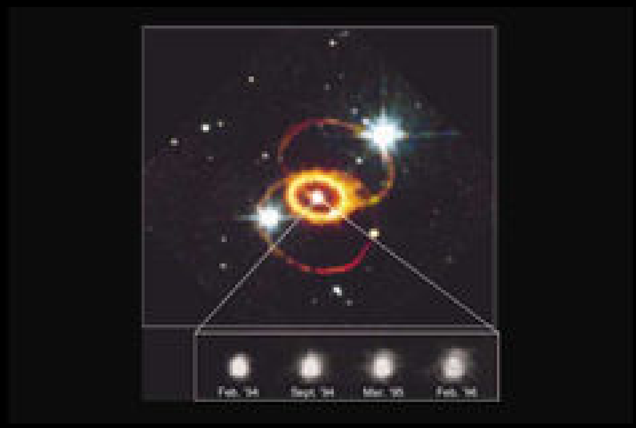
HIGH RESOLUTION (236Kb) JPEG

The life cycle of stars – from cradle to grave – is captured in this single Hubble Space Telescope image of a giant galactic nebula known as NGC 3603. The blue supergiant (upper left) is nearing the end of its life, while close to the center of the image new stars form in a starburst cluster.
(Longer Caption)

A DECADE OF DISCOVERY

SUPERNOVA 1987A

BACK
NEXT



LOW RESOLUTION (16Kb) JPEG

HIGH RESOLUTION (223Kb) JPEG

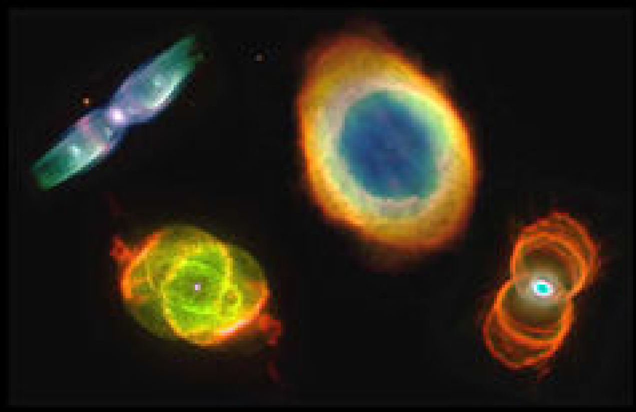
In 1987, astronomers received a once-in-a-lifetime opportunity to study a star explosion. This Hubble image shows the evolution of Supernova 1987A. At the center the debris from the explosion is expanding at 6 million mph. The rings are material ejected by the star before it exploded, which are now illuminated by radiation from the blast.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

PLANETARY NEBULA GALLERY

BACK
NEXT



LOW RESOLUTION (17Kb) JPEG

HIGH RESOLUTION (196Kb) JPEG

At one time, the end of a Sun-like star's life was thought to be simple. The star cast off a shell of gas and then settled into a long retirement as a burned-out white dwarf. This collection of images reveals a far more complicated situation as evidenced by the elegant and intricate shapes and patterns of these dying stars. (Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

STELLAR DUST RING AROUND STAR HR 4796A

BACK
NEXT

LOW RESOLUTION (13Kb) JPEG

HIGH RESOLUTION (146Kb) JPEG

This hoola-hoop in space is actually a dust ring around a young star, known as HR 4796A, which is about 70 percent larger than the Sun and probably less than 10 million years old. Dust rings like this one can only remain intact by some mechanism confining the dust. Astronomers believe that mechanism might be the formation of new planets.
(Longer Caption)

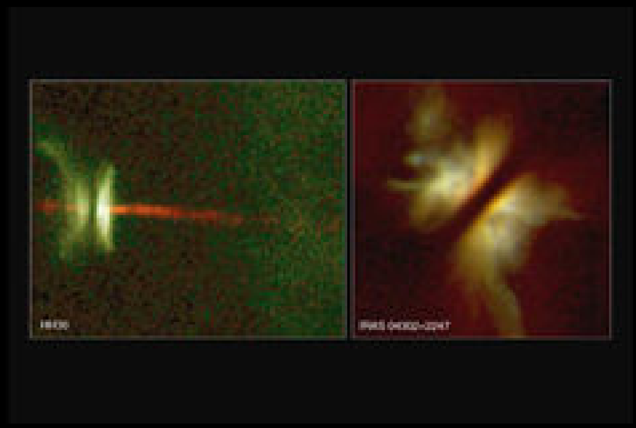
HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

YOUNG STELLAR DISKS

BACK
NEXT



LOW RESOLUTION (19Kb) JPEG

HIGH RESOLUTION (184Kb) JPEG

These odd-looking shapes are believed to be planetary construction zones around newly forming stars. They give us a good idea of what our solar system might have looked like when it formed out of a pancake-shaped disk of dust and gas 4.5 billion years ago.
(Longer Caption)

A DECADE OF DISCOVERY

EAGLE NEBULA

BACK
NEXT

LOW RESOLUTION (17Kb) JPEG

HIGH RESOLUTION (270Kb) JPEG

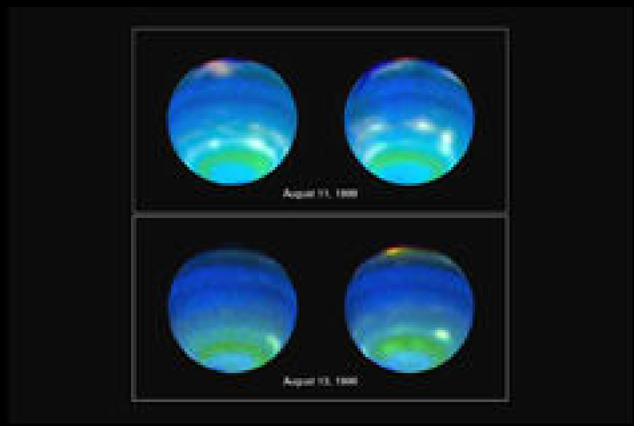
These monstrous pillar-like structures are actually columns of cool hydrogen gas and dust that protrude like stalagmites on a cavern floor. Although wondrous in appearance, the structures actually are incubators for new stars and are located in the Eagle Nebula 7,000 light-years from Earth.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

BACK
NEXT

NEPTUNE CLOUDS



LOW RESOLUTION (18Kb) JPEG

HIGH RESOLUTION (175Kb) JPEG

Earth has wild and wacky weather, but apparently it's mild compared with Neptune's. This Hubble image shows that the eighth planet from the Sun endures monster storms and 900 mph equatorial winds.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SATURN'S AURORAS

BACK
NEXT

LOW RESOLUTION (25Kb) JPEG

HIGH RESOLUTION (955Kb) JPEG

Saturn's north and south poles are ablaze in this Hubble image of the planet's auroras. The auroral display is caused by an energetic solar wind that sweeps over the planet, much like it does on Earth. But unlike Earth's auroras, Saturn's are seen only in ultraviolet light.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

JUPITER WITH COMET IMPACTS

BACK
NEXT

LOW RESOLUTION (13Kb) JPEG

HIGH RESOLUTION (134Kb) JPEG

Jupiter looks badly bruised after fragments of Comet Shoemaker-Levy 9 collided into the giant planet in July 1994. The collision gave scientists worldwide a once-in-a-lifetime opportunity to watch comet pieces – traveling at 130,000 mph – slam into the planet and explode with 100 times the power of the world's arsenal of nuclear warheads at the peak of the Cold War.
(Longer Caption)

A DECADE OF DISCOVERY

HUBBLE RETURNS TO DUTY

LOW RESOLUTION (21Kb) JPEG

HIGH RESOLUTION (384Kb) JPEG

Following the successful Servicing Mission 3A, Hubble is refreshed and back to work producing amazing science images. Hubble is scheduled for two more servicings, Servicing Mission 3B in 2001 and Servicing Mission 4 in 2003. In the upcoming missions, new science instruments and new solar arrays will be installed. All other systems on Hubble will be brought up to their best working condition for the remaining 10 years of life.

Hubble is scheduled to be decommissioned in 2010.
(Longer Caption)

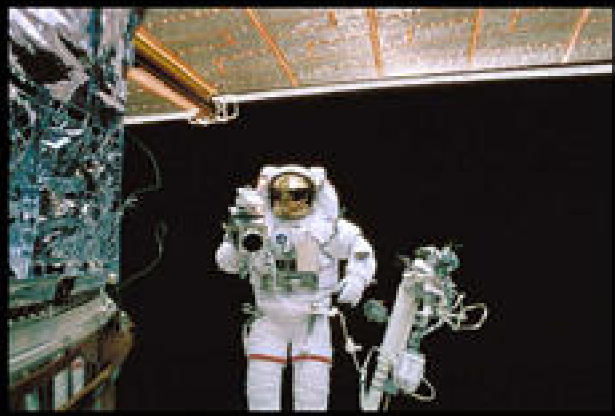
A DECADE OF DISCOVERY

Investigating Space

The Hubble Story

PHOTOS OF HUBBLE

BACK
NEXT



LOW RESOLUTION (43Kb) JPEG

HIGH RESOLUTION (476Kb) JPEG

This photo of astronaut Mark Lee was taken by fellow crew member Steven Smith during Hubble’s Second Servicing Mission. Mark Lee is preparing to document the day's activities using one of the extravehicular activity cameras. It is critical that astronauts take pictures of Hubble when they first see it and they photographically document their completed work. Since engineers cannot walk into a building and view Hubble, they rely on this photo documentation to accurately design and build new hardware. This photo activity is important as we continue servicing the Hubble Space Telescope.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

INSULATION REPAIR

BACK
NEXT

LOW RESOLUTION (47Kb) JPEG

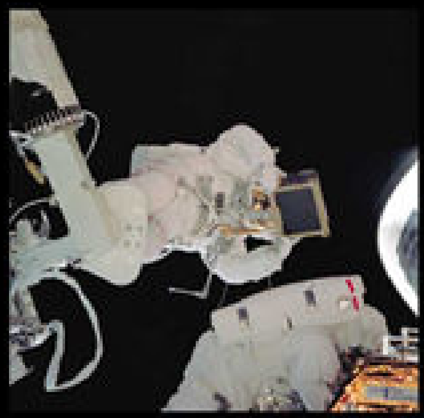
HIGH RESOLUTION (507Kb) JPEG

This photo shows STS-82 astronaut Scott Horowitz with a multi-layer insulation (MLI) repair patch. During the Second Servicing Mission, astronauts detected damage to insulation on the outside of Hubble. Astronauts working inside the shuttle created repair patches with the materials they had on hand. MLI covers 80 percent of Hubble's exterior. This insulation, coupled with supplemental electric heaters, maintains the temperature of the equipment and optics within safe limits.
(Longer Caption)

A DECADE OF DISCOVERY

REPLACING A DATA RECORDER

BACK
NEXT



LOW RESOLUTION (22Kb) JPEG
HIGH RESOLUTION (261Kb) JPEG

This photo shows an astronaut holding a reel-to-reel tape recorder prior to stowing it for return to the ground. It was replaced by a new solid-state data recorder. Hubble uses data recorders to store engineering and science data that cannot be sent to the ground in real time. When communications permit, ground controllers command a recorder playback to send the data to the ground for processing.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

ASTRONAUT TOOLS

BACK
NEXT

LOW RESOLUTION (36Kb) JPEG

HIGH RESOLUTION (314Kb) JPEG

Astronaut Steve Smith is holding a power ratchet tool on orbit in front of Hubble's aft shroud compartment. The Hubble Space Telescope is the first spacecraft designed with replaceable parts and instruments for planned servicing. To enable astronauts to change out parts, special tools and aids had to be designed, tested, and built.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

TRAINING IN THE CLEAN ROOM

BACK
NEXT

LOW RESOLUTION (40Kb) JPEG

HIGH RESOLUTION (540Kb) JPEG

The astronauts shown here are training on the electrical section of Hubble. This is a full-size mockup of the section of Hubble that houses the electrical components, such as transmitters, batteries, tape recorders, and electronics to operate other parts of Hubble. Astronauts come to Goddard several times prior to each mission to familiarize themselves with Hubble's components and the tools required to service them.
(Longer Caption)

GODDARD'S CLEAN ROOM

LOW RESOLUTION (49Kb) JPEG

HIGH RESOLUTION (856Kb) JPEG

The Spacecraft Systems Development and Integration Facility is an 86,000-square-foot building used to integrate and test space hardware. Located at NASA's Goddard Space Flight Center in Greenbelt, Md., this facility houses the 1.3-million-cubic-foot High Bay Clean Room. The largest of its kind anywhere, this clean room plays an important role in preparing for Hubble servicing. (Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SIMULATING WEIGHTLESSNESS

BACK
NEXT

LOW RESOLUTION (45Kb) JPEG

HIGH RESOLUTION (650Kb) JPEG

In preparation for servicing missions to Hubble, astronauts undergo extensive training. A huge underwater tank provides the closest training environment for weightlessness. During this training, the astronauts wear special underwater-pressurized suits similar to the suits worn on orbit. This 40-foot-deep tank contains full-scale underwater mockups of Hubble, the instruments being changed out and the carriers that hold the instruments. Astronauts spend many weeks in this underwater training, accompanied by weeks of classroom instruction.
(Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

STIS

BACK
NEXT

LOW RESOLUTION (38Kb) JPEG

HIGH RESOLUTION (525Kb) JPEG

The Space Telescope Imaging Spectrograph (STIS) resides in an axial bay behind the Hubble main mirror. STIS is nearly seven feet by three feet by three feet and weighs over 800 pounds. The spectrograph breaks incoming light into its various component colors to enable scientists to study the composition and physical properties of the universe.

This picture shows STIS in a caddy in a clean room at Ball Aerospace in Boulder, Colo., where it was manufactured.
(Longer Caption)

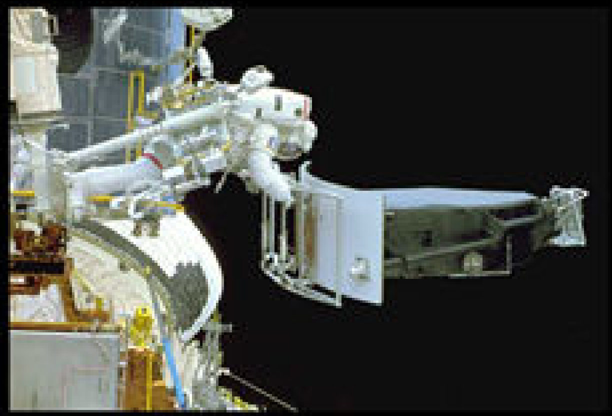
HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

WFPC

BACK
NEXT



LOW RESOLUTION (33Kb) JPEG

HIGH RESOLUTION (328Kb) JPEG

The Wide Field and Planetary Camera 2 (WFPC2) is the "workhorse" camera for Hubble. It provides us with pictures of the universe on a grander scale than any camera to date. The camera can detect stars over one billion times fainter than we can see with our eyes. This picture shows astronauts removing the Wide Field and Planetary Camera 1 (WFPC1), to be replaced by WFPC2 during the First Servicing Mission in 1993. WFPC1 and WFPC2 were built at the Jet Propulsion Laboratory in Pasadena, Calif. (Longer Caption)

HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SCIENCE INSTRUMENTS

BACK
NEXT

LOW RESOLUTION (26Kb) JPEG

HIGH RESOLUTION (297Kb) JPEG

The science instruments aboard Hubble are large, complex devices. Some are similar in size and shape to a telephone booth and others are similar to a grand piano. The telescope was designed to hold four telephone booth-sized instruments and four piano-shaped instruments. The latter includes three Fine Guidance Sensors, which can also collect science data. The instruments take electronic pictures of stars and send the picture data to the ground where scientists analyze the information to make discoveries about our universe.

This picture shows an astronaut removing the Goddard High Resolution Spectrograph in preparation for a new instrument during the Second Servicing Mission.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SOLAR ARRAYS

BACK
NEXT

LOW RESOLUTION (27Kb) JPEG

HIGH RESOLUTION (294Kb) JPEG

Hubble uses electricity generated by solar energy to run its equipment and instruments. Hubble's large solar arrays convert sunlight into electricity. The arrays are nearly eight feet by 40 feet. The solar arrays supply power to the spacecraft and charge the batteries while in the sunlit part of the orbit. The batteries supply power during the night portion of the orbit. This photo shows astronaut Kathy Thornton jettisoning a damaged solar panel into space during the First Servicing Mission.
(Longer Caption)

A DECADE OF DISCOVERY

STScI

BACK
NEXT

LOW RESOLUTION (38Kb) JPEG

HIGH RESOLUTION (404Kb) JPEG

In this photo, astronomers at the Space Telescope Science Institute anxiously await results from the impact of Comet Shoemaker-Levy 9 with the planet Jupiter in July 1994. The institute is responsible for carrying out daily observations and ensuring that professional astronomers worldwide have access to the world's foremost observatory. Typically, the institute receives more than 1,000 proposals a year and selects about 300. (Longer Caption)

A DECADE OF DISCOVERY

HUBBLE'S CONTROL CENTER

LOW RESOLUTION (38Kb) JPEG

HIGH RESOLUTION (461Kb) JPEG

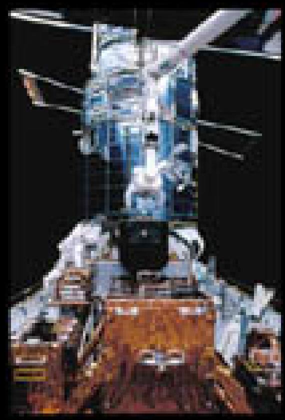
Command and control for Hubble is done at the Space Telescope Operations Control Center at NASA's Goddard Space Flight Center in Greenbelt, Md. Here, ground controllers send commands and computer instructions to Hubble and monitor data from the observatory to check that it is functioning properly. This picture was taken in the Space Telescope Operations Control Center during Servicing Mission 3A.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

FINE GUIDANCE SENSORS

BACK
NEXT



LOW RESOLUTION (45Kb) JPEG

HIGH RESOLUTION (433Kb) JPEG

This photo shows a team of astronauts removing a Fine Guidance Sensor from its protective enclosure in the shuttle during a servicing mission. The Fine Guidance Sensors were built by Hughes Danbury Optical Systems in Danbury, Conn.

Hubble has three Fine Guidance Sensors. Two are normally used in observations to locate and lock onto a target star while observations are made with a science instrument. One of the three Fine Guidance Sensors is also used to precisely measure the positions and ratios of stars, and detect whether a star is single or has companions. This is the science of astrometry.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

BACK
NEXT

HUBBLE'S ORBIT

LOW RESOLUTION (20Kb) JPEG

HIGH RESOLUTION (229Kb) JPEG

Hubble orbits the Earth about every 90 minutes at an altitude of about 368 miles. Hubble passes into the shadow of the Earth each orbit for about 28-36 minutes.
(Longer Caption)

HUBBLE'S OPTICS

LOW RESOLUTION (38Kb) JPEG

HIGH RESOLUTION (379Kb) JPEG

The Hubble Space Telescope uses mirrors to collect science data. Hubble's main mirror is about eight feet in diameter. Light enters the telescope and strikes the main mirror, which reflects the light forward to a smaller (12-inch) secondary mirror. This small mirror reflects the light again, sending it through a two-foot hole in the center of the large mirror to the science instruments. These powerful instruments analyze the incoming light stream and translate it into information and images for scientists back on Earth.

After Hubble's launch in 1990, NASA discovered a flaw in the large, main mirror. The flaw was tiny — about 1/50th the thickness of a piece of paper — but significant enough to distort Hubble's vision. During the First Servicing Mission, astronauts added corrective optics to compensate for the flaw. The optics acted like eyeglasses to correct Hubble's vision.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space

The Hubble Story

SERVICING IMPROVES HUBBLE

BACK

NEXT

LOW RESOLUTION (18Kb) JPEG

HIGH RESOLUTION (292Kb) JPEG

Hubble is scheduled for routine servicing much like your family car. When you take care of your car with regular maintenance — such as new tires and batteries — it will last much longer and perform better. The same is true of Hubble. But instead of bringing Hubble to the ground for servicing, astronauts are trained to make "house calls" hundreds of miles above the Earth. Astronauts pilot the shuttle to rendezvous with Hubble, use a robotic arm to place it in the shuttle's cargo bay, and then install the new equipment. After the work is complete, the crew sets Hubble free and returns it to service. This picture shows the start of a servicing mission with the launch of the space shuttle.
(Longer Caption)

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

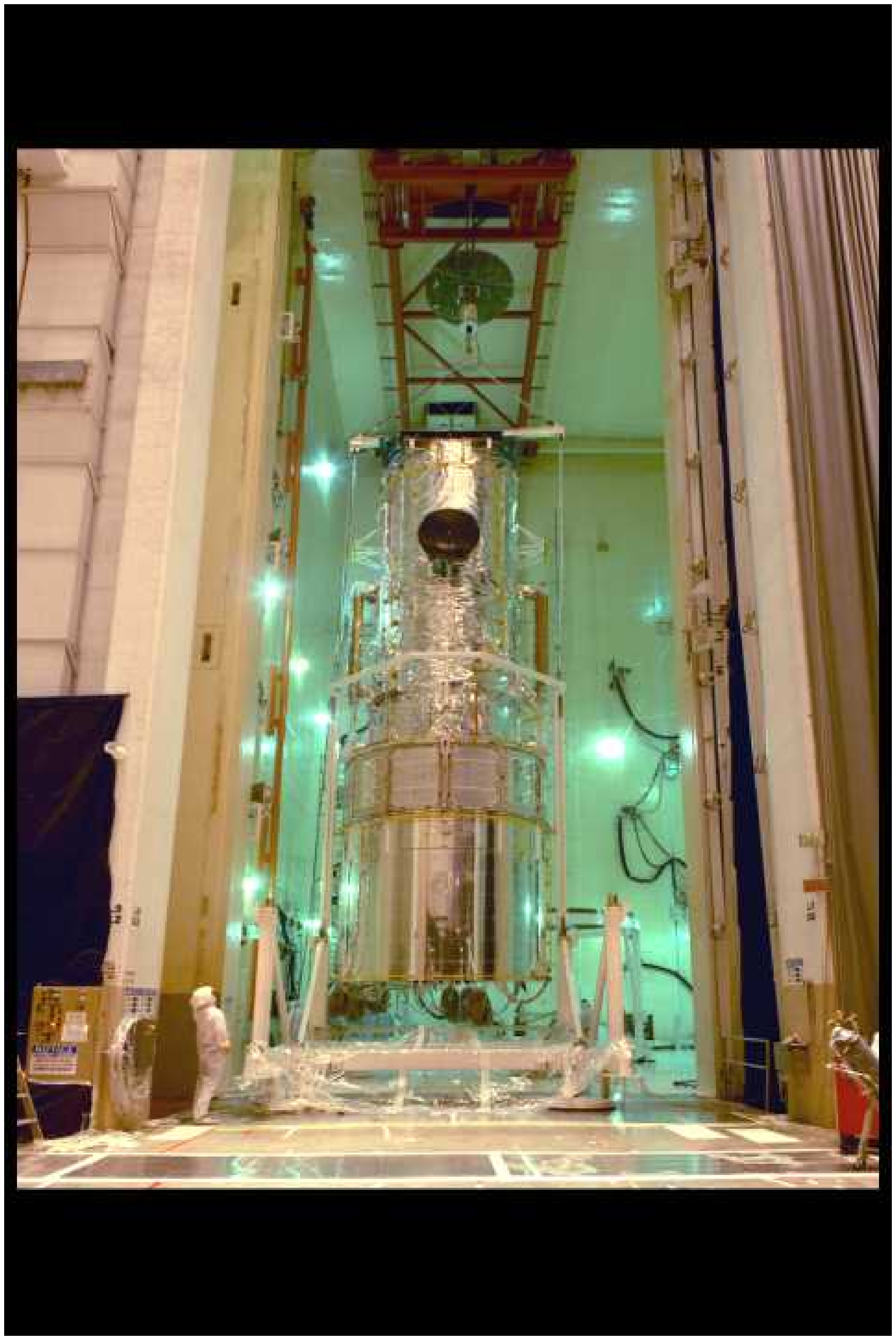
DESIGN & BUILD OF HUBBLE

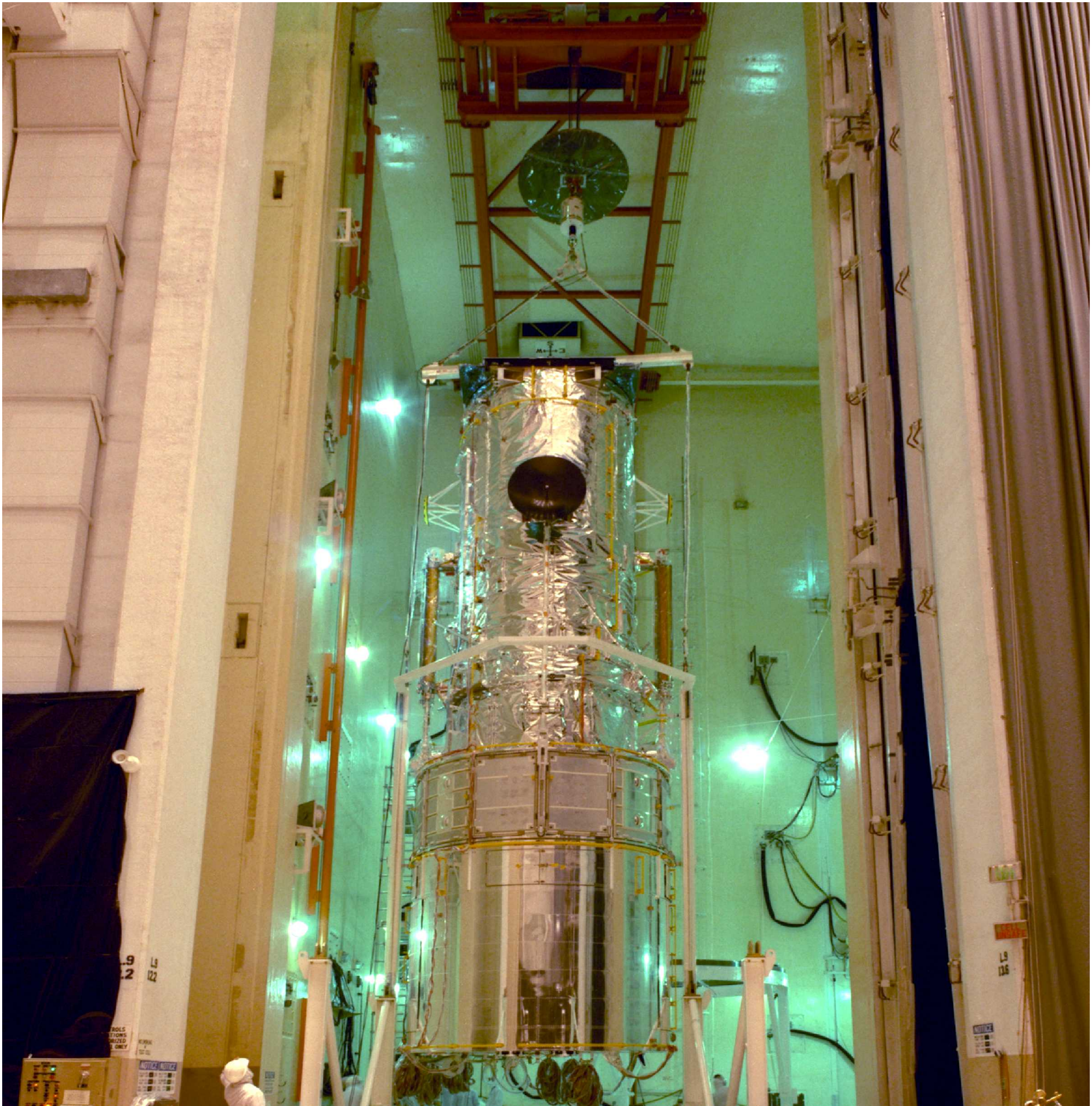
BACK
NEXT

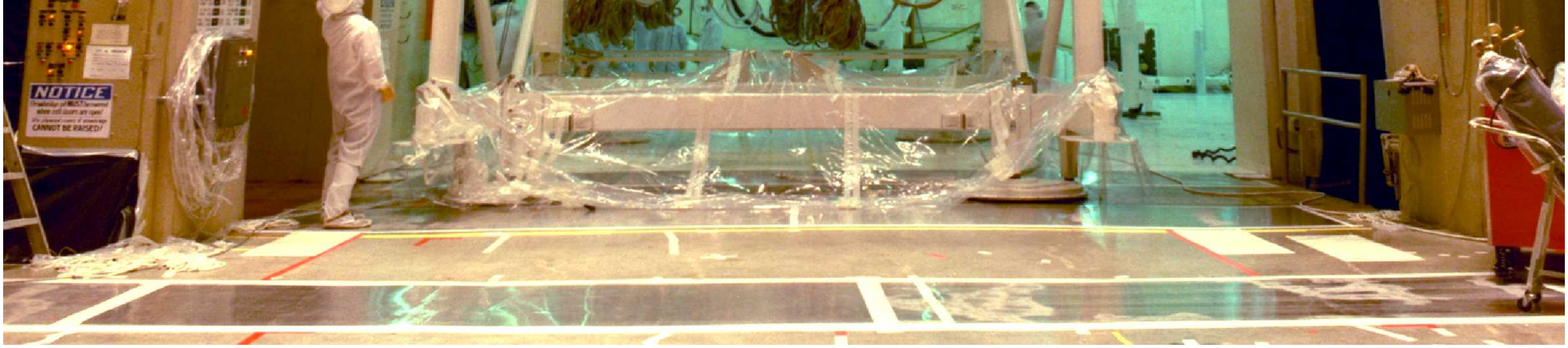
LOW RESOLUTION (36Kb) JPEG

HIGH RESOLUTION (508Kb) JPEG

Hubble — built, integrated, and tested in the 1970s and 1980s at Lockheed Martin's Sunnyvale, Calif., plant — was designed to be updated throughout its long life. The photograph shows Hubble being lifted into the upright position at Kennedy Space Center before its launch aboard the space shuttle Discovery April 24, 1990. Look how small the people seem standing next to Hubble. (Longer Caption)






NOTICE
CANNOT BE RAISED!

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

DESIGN & BUILD OF HUBBLE

BACK

The idea of putting a telescope in space has been around for a long time. Earth's atmosphere distorts light and causes a great deal of viewing problems for ground telescopes. A telescope above the atmosphere has a much clearer view of the universe.

Finally, after many years of dreaming, the orbiting telescope took shape during the 1970s and 1980s. Its designers were wise to realize that technology would advance dramatically during Hubble's long life, so they built Hubble to be upgraded by astronauts. Hubble was built, integrated, and tested at Lockheed Martin's Sunnyvale, Calif., plant.

Many of Hubble's major structures are visible in this picture. The telescope is divided into sections that are stacked together like canisters. In the front is the aperture door and light shield that protect the sensitive mirror and instruments from bright light, such as the sunlight or earthshine. Next is the forward shell that encloses the optical telescope assembly mirrors. Then comes the equipment section that houses most of the Hubble subsystems. At the rear end of Hubble is the aft shroud that covers the science instruments and Fine Guidance Sensors. The solar arrays and communications antennas are attached to the side of the telescope. You can also see external handrails that aid the astronauts in performing maintenance and repair tasks.

The photograph shows Hubble being lifted into the upright position in the Vertical Processing Facility at Kennedy Space Center in preparation for launch. Finally, after many delays, including the Challenger disaster, Hubble was launched on April 24, 1990 aboard the space shuttle Discovery.

BACK

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SERVICING IMPROVES HUBBLE

BACK

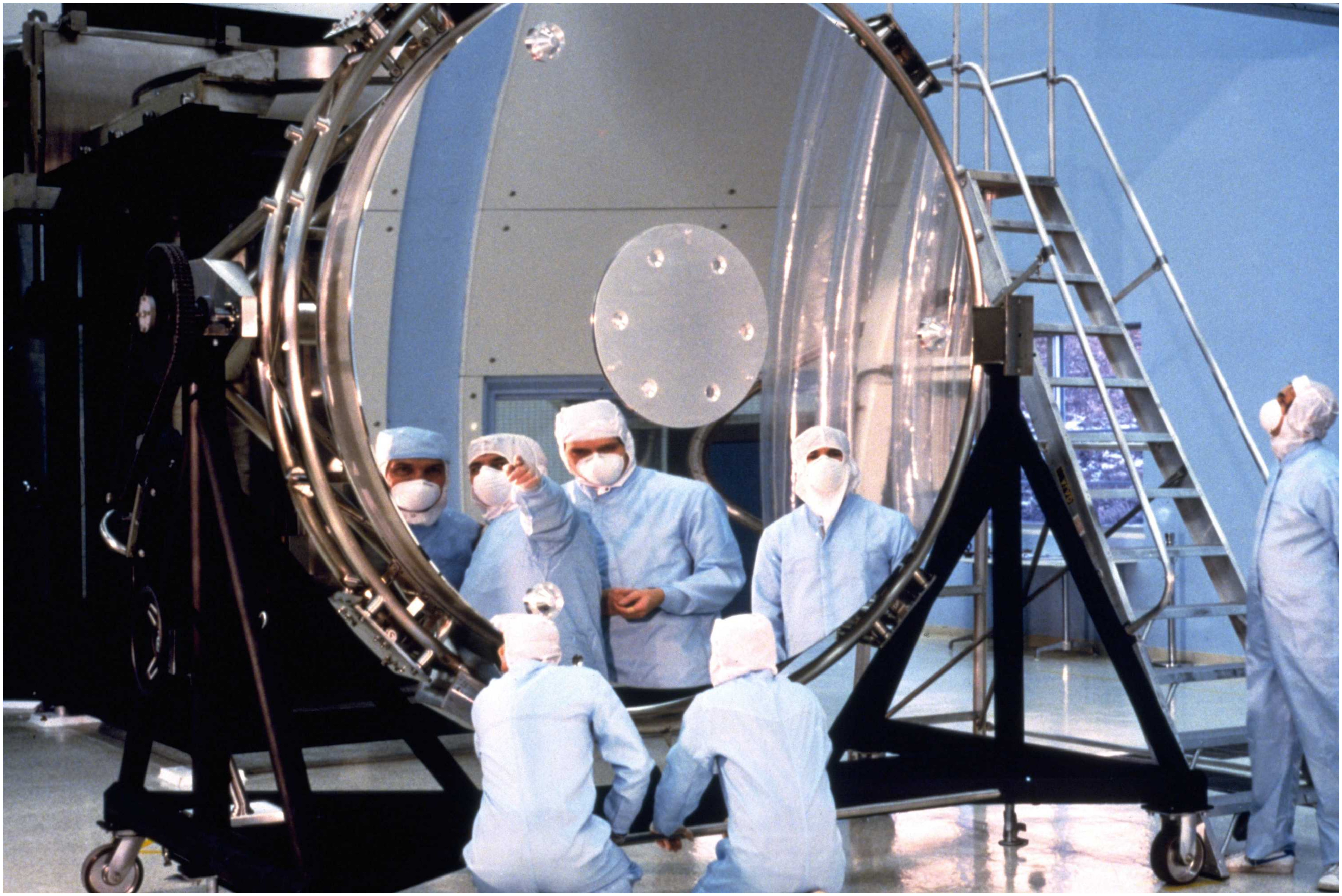
This picture shows the start of a servicing mission with the launch of a space shuttle.

Hubble is designed for on-orbit servicing by a team of astronauts. Servicing missions allow for planned, periodic replacement and improvement of Hubble's science instruments and other equipment. During a servicing mission the crew maneuvers the shuttle to rendezvous with Hubble, uses a robot arm to place the telescope in the shuttle's cargo bay, and then installs the new equipment. After the work is complete, the crew sets Hubble free and returns it to duty.

The Hubble Space Telescope's purpose is to spend 20 years probing the cosmos from the nearby planets of our own solar system to the farthest and faintest galaxies. Crucial to fulfilling this objective is a series of on-orbit servicing missions. Hubble was placed in orbit on April 25, 1990, and subsequent servicing followed in December 1993 and February 1997. The third servicing mission has been separated into two flights. The first of these flights, Servicing Mission 3A, was in December 1999, and the second, Servicing Mission 3B, is scheduled for 2001.

During the December 1999 mission, astronauts installed six fresh gyros, a powerful new computer, an enhanced Fine Guidance Sensor, a new solid-state data recorder, a new radio transmitter, and improvement kits for batteries and electronics. On the next service call, astronauts will install a powerful new instrument called the Advanced Camera for Surveys. This third generation science instrument will greatly enhance Hubble's imaging capabilities.

BACK



HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

HUBBLE'S OPTICS

Hubble operates on the same principle as reflecting telescopes invented in the 17th century by Newton, Cassegrain, and Gregory. A Cassegrain telescope is a reflecting telescope in which light is reflected from a large primary mirror onto a secondary mirror, which then focuses the light back through a hole in the primary to a point behind the mirror. The science instruments are located directly behind the primary mirror, which, for Hubble, makes instruments easier to replace on-orbit. In Hubble the primary mirrors are exactly configured to eliminate the optical aberrations of ordinary telescopes.

The main mirror in Hubble is about eight feet in diameter. Light enters the telescope and strikes the main mirror. The light is reflected forward to a smaller (12-inch) secondary mirror where the light is reflected again, returning down the telescope through a two-foot hole in the center of the large mirror where the image forms. The science instruments record the images and analyze the incoming light stream.

After launch in 1990, NASA discovered that the large mirror was flawed. The flaw was tiny — about 1/50th the thickness of a piece of paper — but significant enough to distort Hubble's vision. During the First Servicing Mission, astronauts added corrective optics to compensate for the flaw. The optics acted like eyeglasses to correct Hubble's vision.

BACK

A DECADE OF DISCOVERY

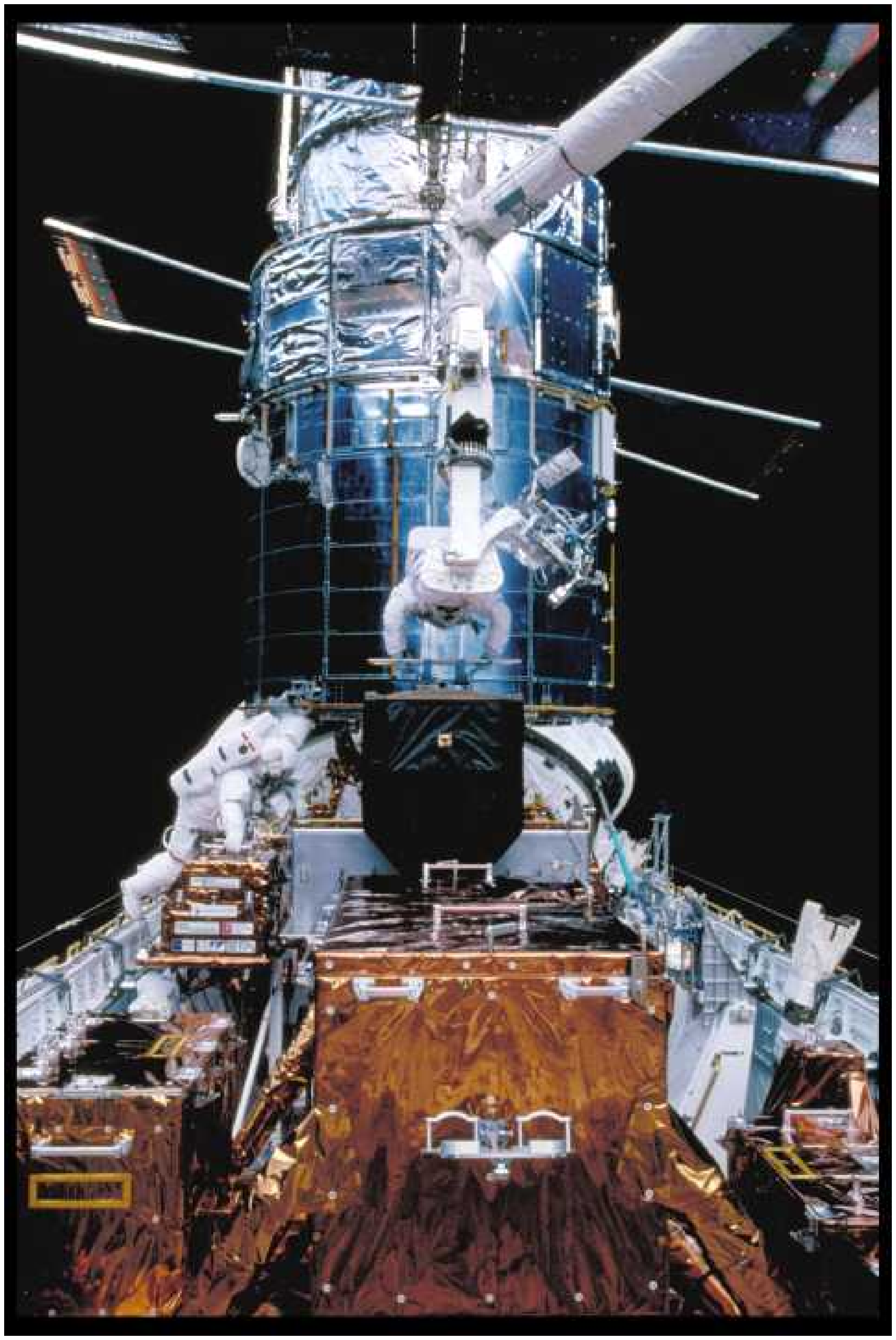
HUBBLE'S ORBIT

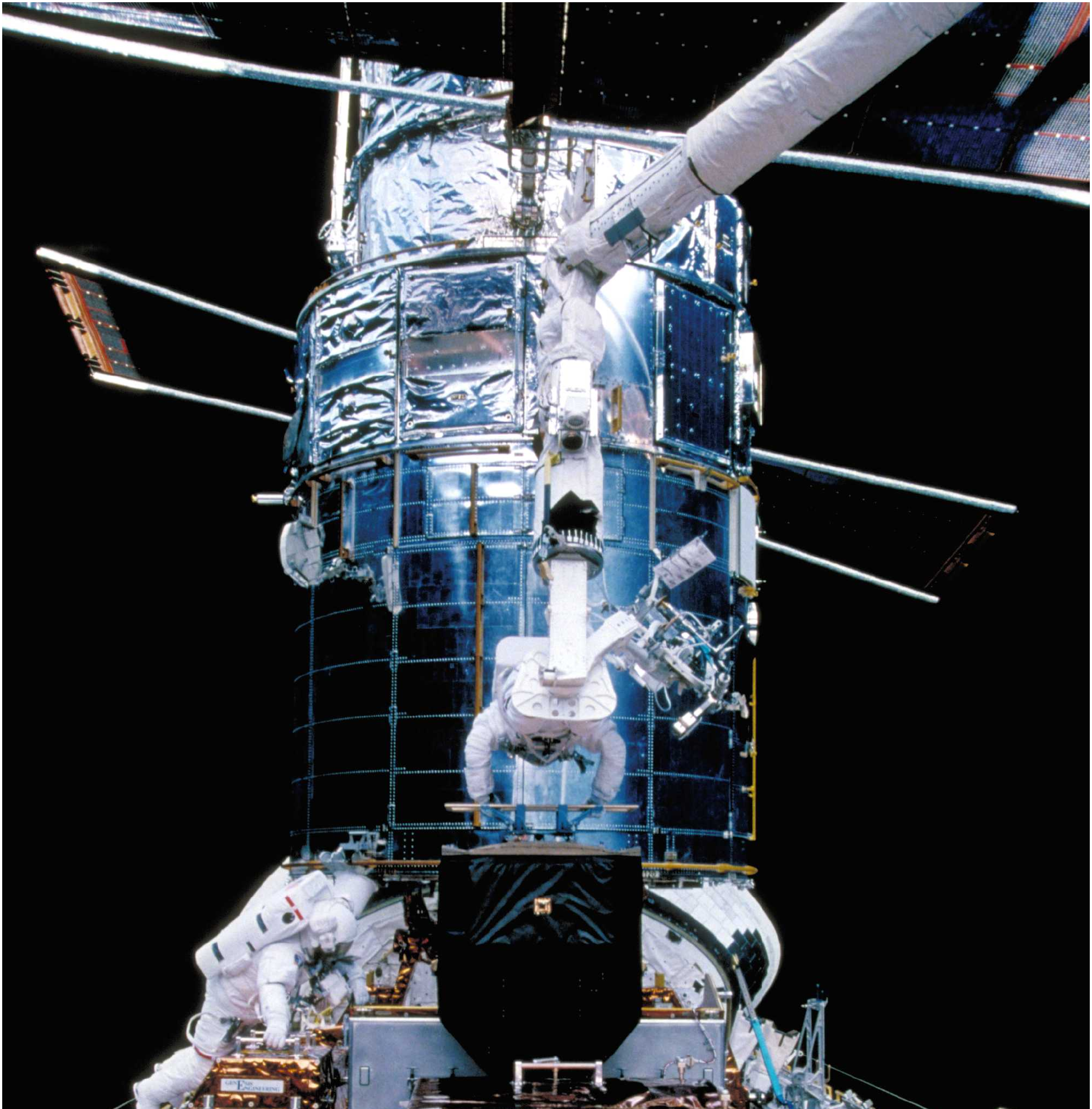
Hubble orbits the Earth at an altitude of about 368 miles. It takes about 90 minutes to complete one orbit around the Earth. Hubble passes into the shadow of the Earth for 28 to 36 minutes in each orbit. The orbit inclines at a 28.5-degree angle.

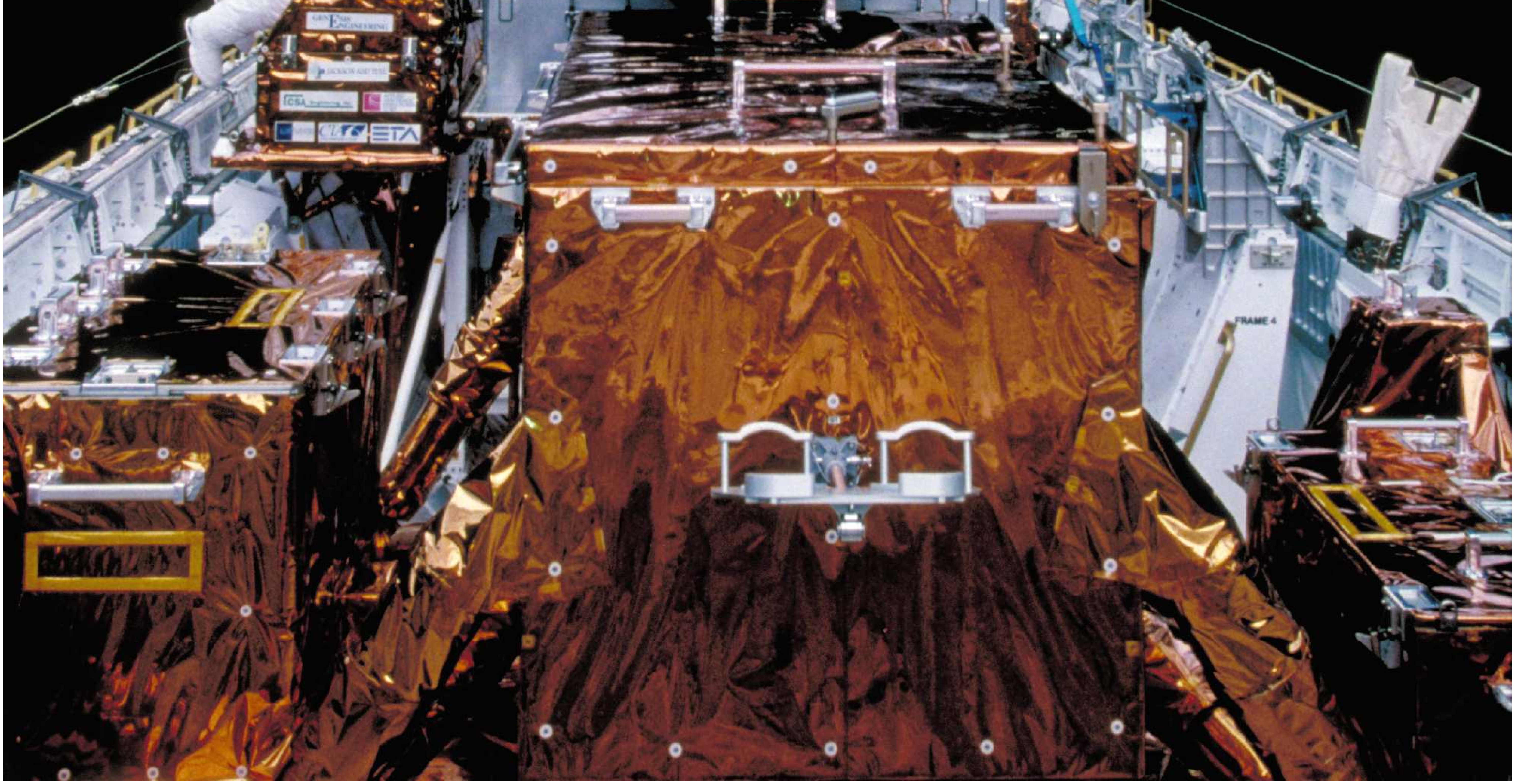
This orbit is high enough that Hubble is above the Earth's atmosphere and can conduct its science operations without the negative effects of the atmosphere.

Seeing through Earth's atmosphere is similar to looking at objects through a pool of water. Remember how little you can see when you open your eyes under water and how much better you can see when you are out of the water. It is very similar as far as science is concerned with the telescope. The Earth's atmosphere acts similarly to water and greatly reduces what we can see in space from the ground. Hubble is in orbit above the atmosphere because it has unrestricted visibility into space and can "see" much better than anyone or anything on the ground.

BACK



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HUBBLESITE

A DECADE OF DISCOVERY

FINE GUIDANCE SENSORS

BACK

This photo shows a team of astronauts replacing one of three Fine Guidance Sensors on Hubble during a servicing mission.

These sensors are located at 90-degree intervals around the circumference of the focal plane structure. Each Fine Guidance Sensor is just over five feet wide and three feet long and weighs 485 pounds. Each Fine Guidance Sensor enclosure houses a very precise optical system called an interferometer. The telescope's high pointing accuracy and stability is due largely to the Fine Guidance Sensors. Two Fine Guidance Sensors are normally used in observations to locate and lock onto a target star while observations are made with a science instrument. From time to time one of the Fine Guidance Sensors is also used to perform scientific measurements, determining highly precise positions and motions of stars, and detecting the positions of companion stars. The process of determining the positions of stars is called astrometry.

One re-certified Fine Guidance Sensor was installed as a replacement during the Second Servicing Mission and another re-certified Fine Guidance Sensor was installed as a replacement during Servicing Mission 3A. The Fine Guidance Sensors were built by Hughes Danbury Optical Systems in Danbury, Conn.

BACK


NASA
NASA

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

HUBBLE'S CONTROL CENTER

BACK

Command and control for Hubble is done at the Space Telescope Operations Control Center at NASA's Goddard Space Flight Center in Greenbelt, Md. Here, ground controllers send commands and computer instructions to Hubble and monitor data from the observatory to check that it is functioning properly. This picture was taken in the Space Telescope Operations Control Center during Servicing Mission 3A.

Hubble Space Telescope operations are of two types: science operations and mission operations. The science operations, carried out at the Space Telescope Science Institute, plan and conduct the Hubble science program of observing celestial objects and gathering scientific data. Mission operations, conducted from the Space Telescope Operations Control Center, command and control Hubble to implement the observation schedule, and maintain the telescope's overall performance.

Science programs are integrated into day-to-day operations programs for Hubble. The Space Telescope Operations Control Center controls and monitors the execution of the programs on the spacecraft.

BACK

A DECADE OF DISCOVERY

STScI

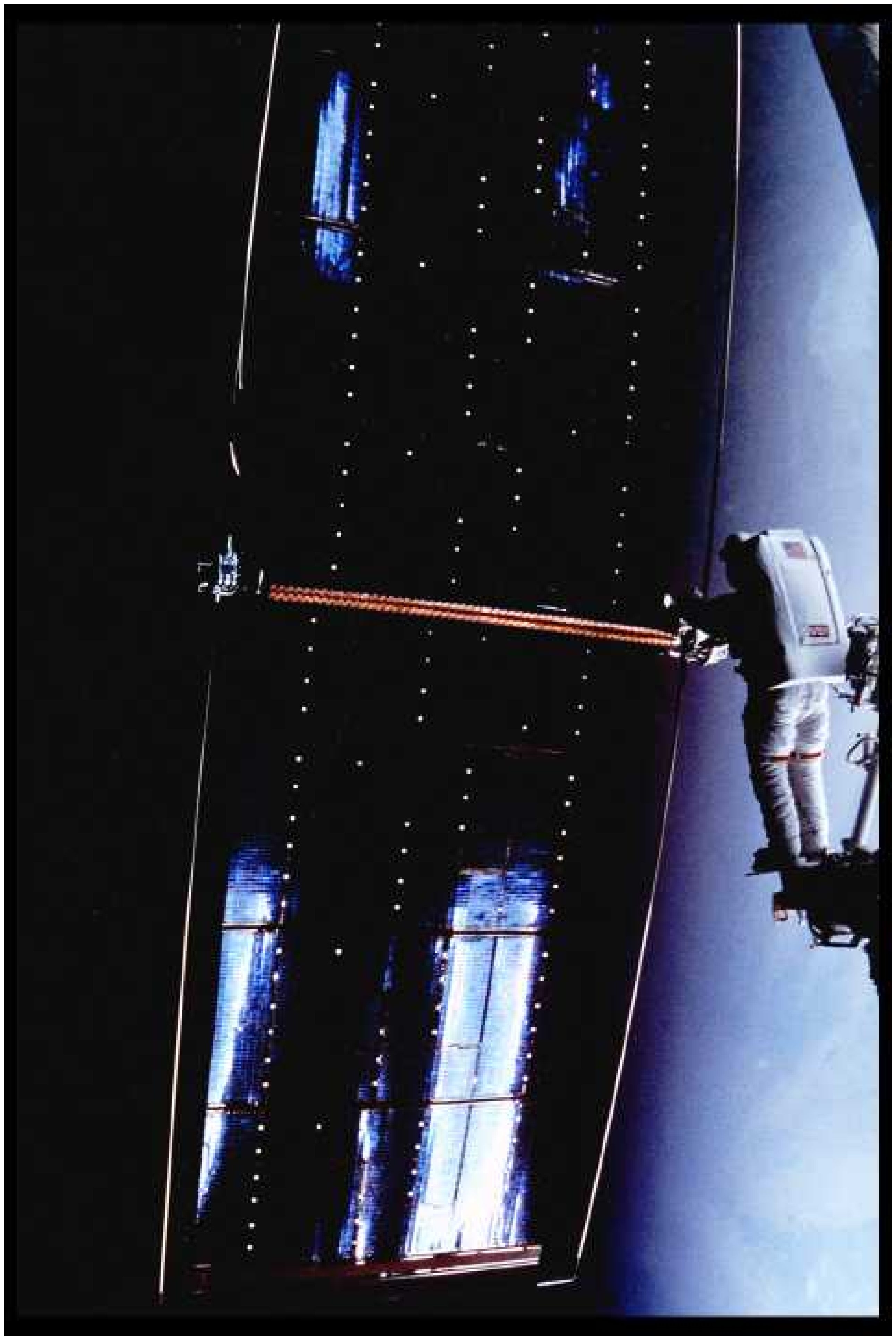
BACK

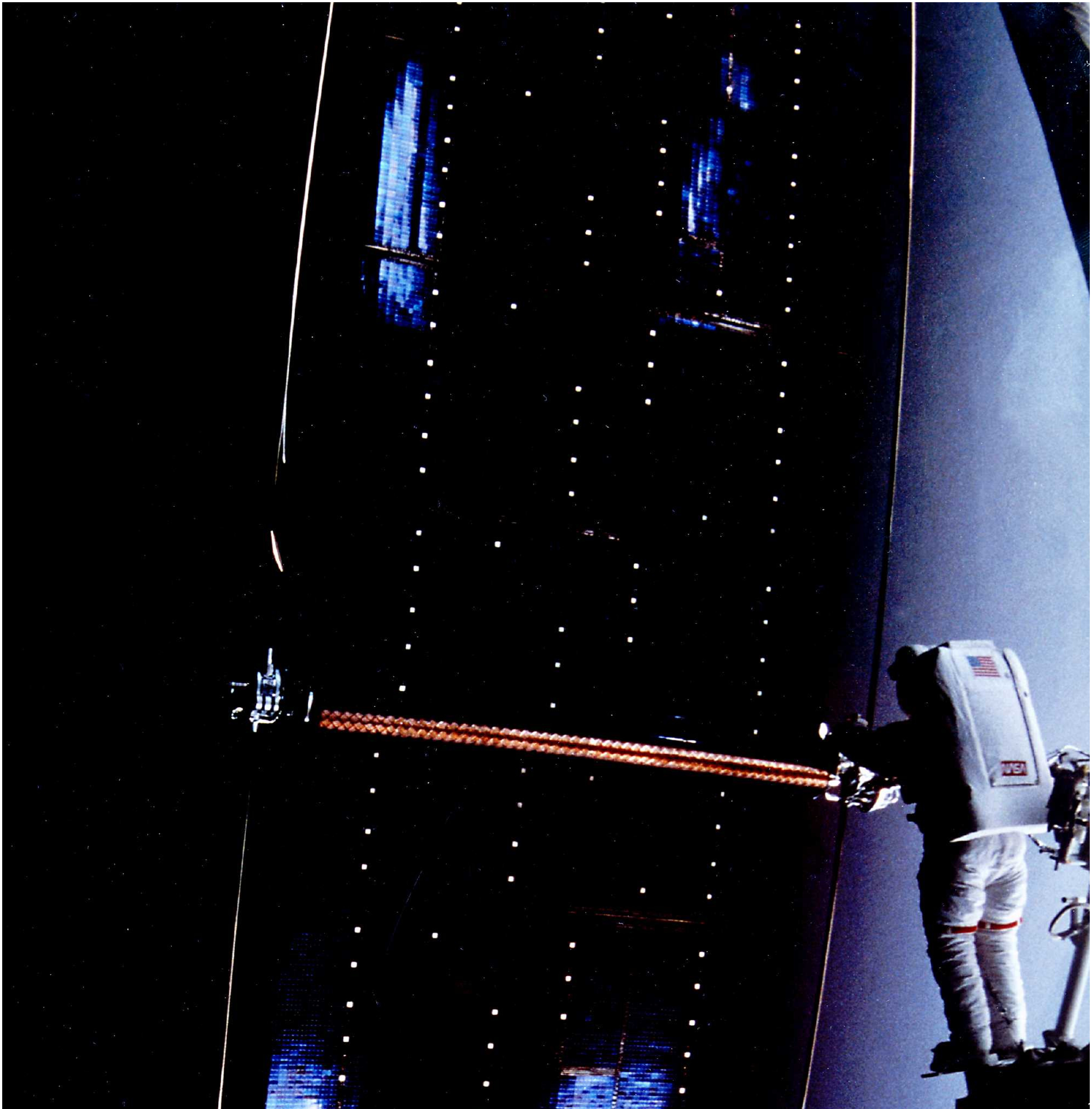
The Space Telescope Science Institute, in Baltimore, Md., selects observing proposals, plans observations, retrieves and archives Hubble data, and makes the information available to the public. In this photo you see astronomers at the Space Telescope Science Institute anxiously awaiting results from the impact of Comet Shoemaker-Levy 9 with the planet Jupiter in July 1994.

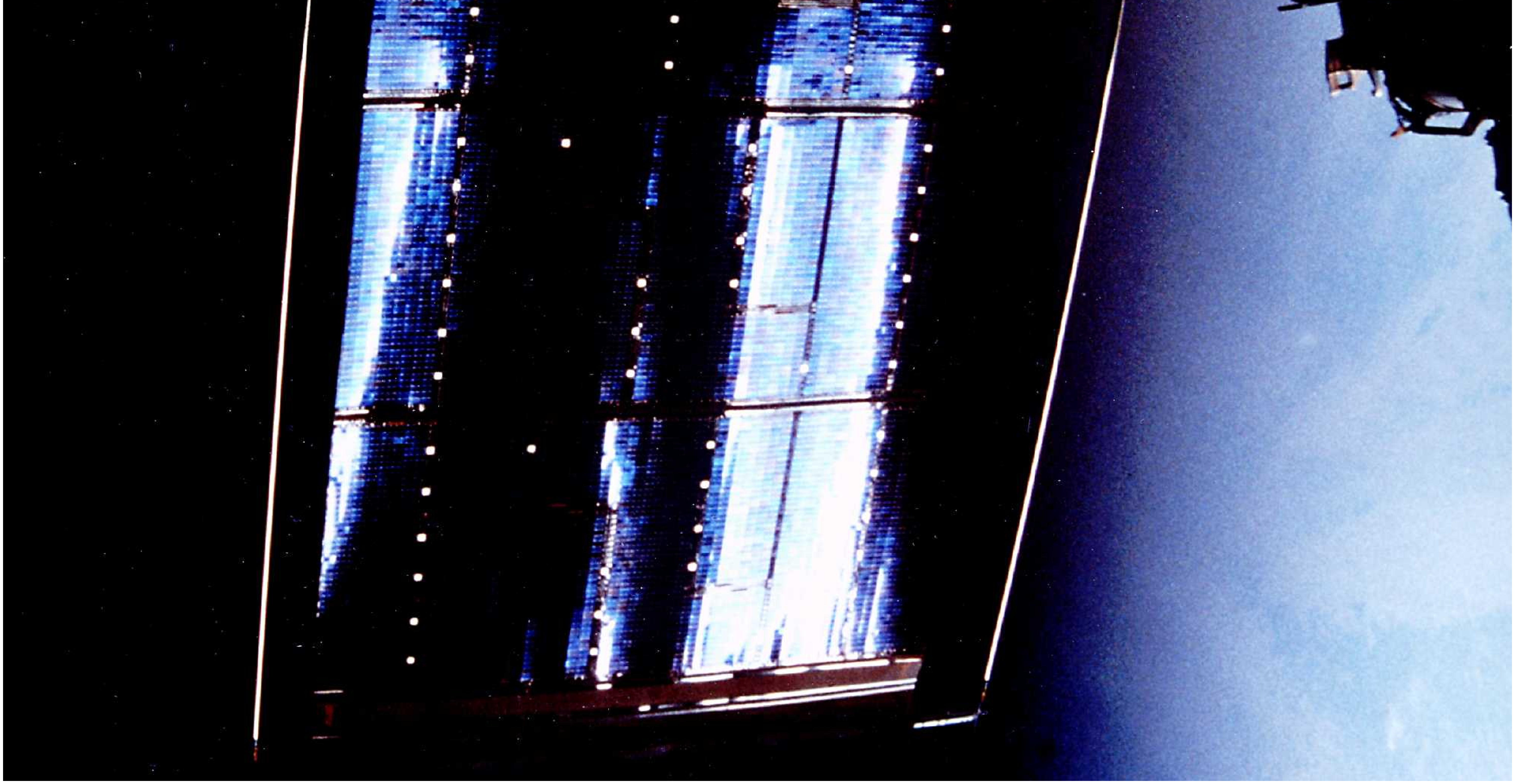
Each year astronomers from dozens of countries submit proposals to the institute. An international panel of scientists judges them on a list of criteria, selecting the best. Typically, the institute receives more than 1,000 proposals a year and selects about 300.

The data from Hubble's observations are sent to Earth by way of a NASA relay satellite. The data are then forwarded to the institute, where they are analyzed and stored. Observers may then study the data at the institute or from a remote location.

BACK





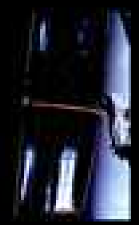


A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SOLAR ARRAYS

BACK



Power for Hubble omes from the electrical power system. The major components are two solar array wings, six nickel-hydrogen batteries, six charge-current controllers, one power control unit, and four power distribution units. The solar arrays are the primary source of electrical power. The arrays are nearly eight feet by forty feet. Each array has a solar cell blanket that converts sunlight into electrical energy. Electricity produced by the solar arrays charges Hubbles' batteries. The solar arrays supply power to the spacecraft and charge the batteries while in the sunlit part of the orbit. The batteries take over supplying power during the night portion of the orbit (when Hubble is in the Earth's shadow).

This photo shows astronaut Kathy Thornton jettisoning the damaged solar panel into space. During the First Servicing Mission, when the solar panels were changed out, astronauts detected a bend in the panel casing. The panel couldn't safely be returned to Earth and was jettisoned into space. According to NORAD, the Hubble solar array reentered Earth's atmosphere on October 28, 1998 at 12:08 a.m. EST.

BACK


GODDARD
SPACE
LOCKHEED MARTIN
Orbital

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

SCIENCE INSTRUMENTS

The science instruments aboard Hubble are large, complex devices. Some are similar in size and shape to a telephone booth and others are similar to a grand piano. The telescope was designed to hold four telephone booth-sized instruments and four piano-shaped instruments. The instruments take digital electronic pictures of stars and send the picture data to the ground where scientists analyze the information to make discoveries about our universe. This picture shows an astronaut removing the Goddard High Resolution Spectrograph in preparation for a new instrument during the Second Servicing Mission in 1997.

Three instruments are in active scientific use on Hubble: the Wide Field and Planetary Camera 2, the Space Telescope Imaging Spectrograph, and a Fine Guidance Sensor. Other instrument bays are occupied by the Near Infrared Camera and Multi-Object Spectrometer, which is now dormant due to the depletion of its coolant; the Faint Object Camera; and the corrective optical device called COSTAR, which is no longer needed.

During the next servicing mission, the Faint Object Camera will be replaced by a new instrument, the Advanced Camera for Surveys. The final servicing mission will feature the removal of COSTAR and the installation of another new instrument, the Cosmic Origins Spectrograph.

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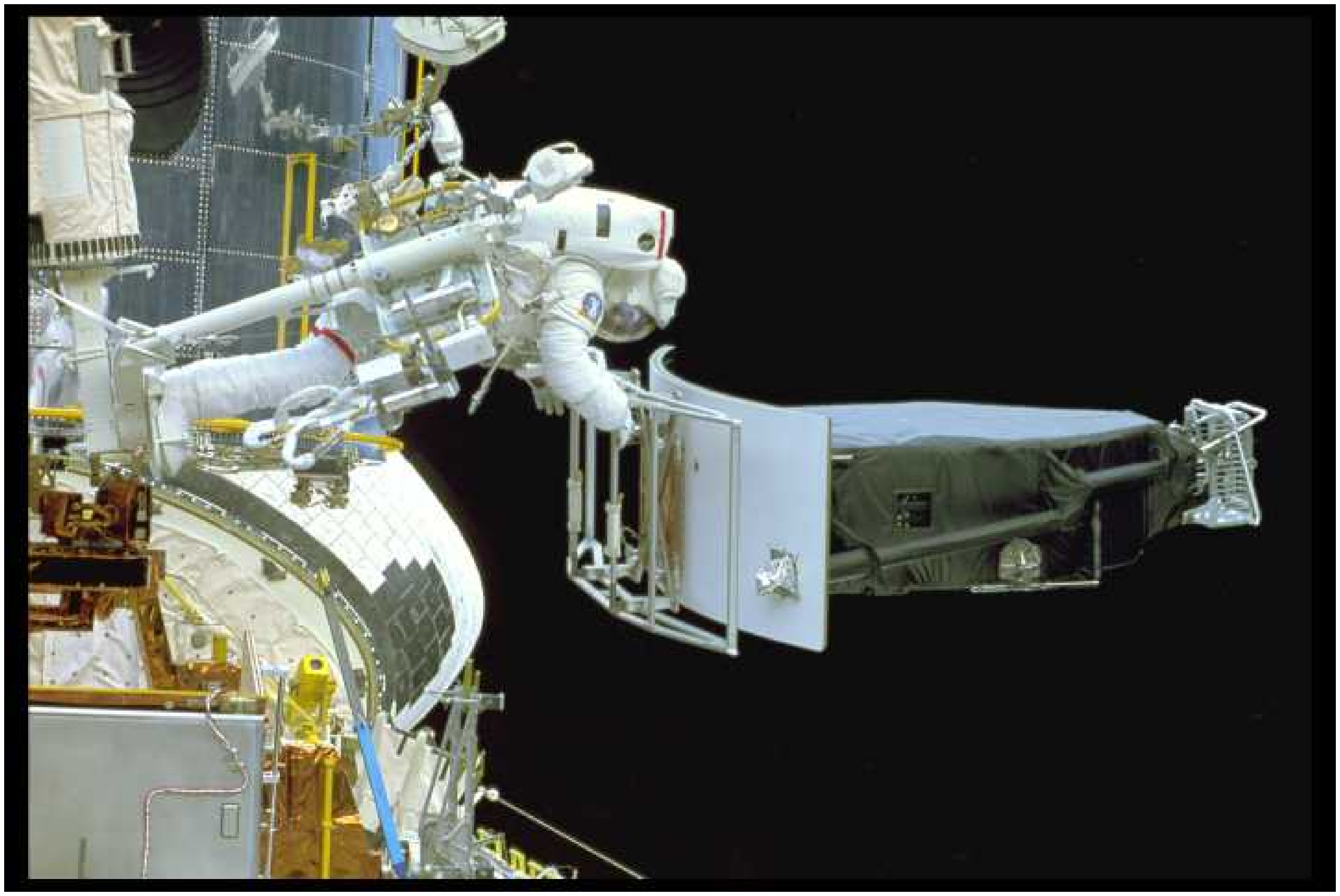
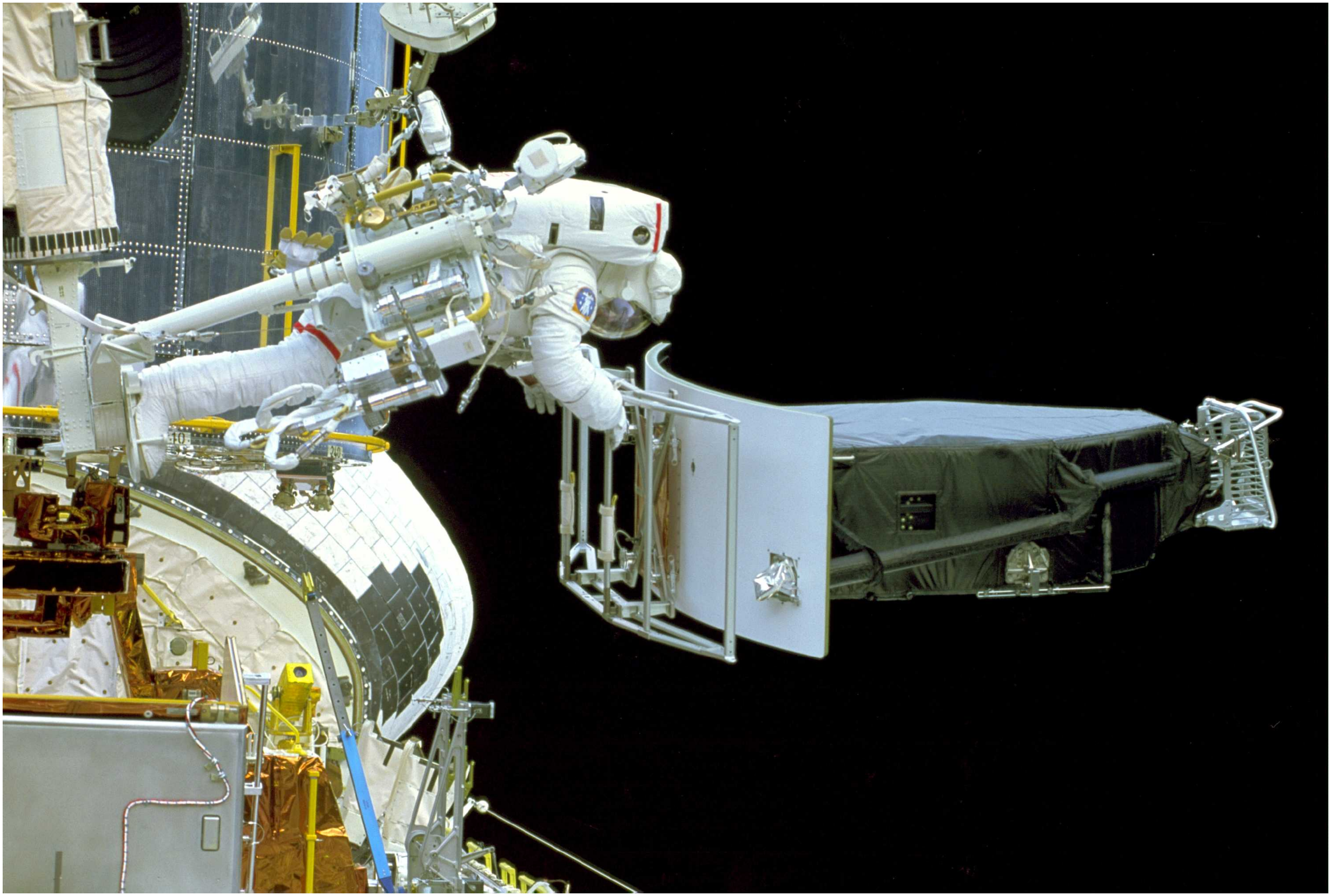




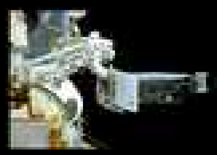
A DECADE OF DISCOVERY

Investigating Space

The Hubble Story

WFPC

BACK



The Wide Field and Planetary Camera 2 (WFPC2) is the "workhorse" camera for Hubble. It provides us with pictures of the universe on a grander scale than any camera to date. The camera can detect stars over one billion times fainter than we can see with our eyes. This picture shows astronauts removing the Wide Field and Planetary Camera 1 (WFPC1), to be replaced by WFPC2. WFPC2 is shaped somewhat like a grand piano and weighs 619 pounds. The camera records two-dimensional images through a selection of 48 color filters covering a spectral range from far ultraviolet to red wavelengths. WFPC2 has four charge-coupled detector cameras arranged to record simultaneous images in four separate fields of view at two magnifications. The planetary camera provides a magnification about 2.2 times larger than the wide field camera. The planetary camera provides the best sampling of the telescope's images at visible wavelengths and is used whenever the finest spatial resolution is needed.

WFPC2 uses charge-coupled detectors (CCDs) to take data. CCDs have finer resolution, better linearity, and the ability to convert image data directly into digital form. A CCD consists of an array of light-sensitive picture elements (pixels) built upon a thin wafer of silicon. Complex electronic circuits also built on the wafer control the light-sensitive elements. As light falls upon the array, photons of light interact with the sensor material to create small electrical charges (electrons) in the material. The charge is very nearly proportional to the number of photons of light absorbed. The electronic circuits read out the array and send signals that allow the reconstruction of the pattern of incoming light, and hence, a picture.

The CCDs in WFPC2 consist of 800 rows and 800 columns of pixels, equaling 640,000 pixels in each array. Each pixel can be thought of as a tiny square, about 15 micrometers on a side.

BACK


STIS


Ball
HUBBLE SPACE TELESCOPE
STIS
SPACE TELESCO
SPECTRO

A DECADE OF DISCOVERY

STIS

BACK

This picture shows the Space Telescope Imaging Spectrograph (STIS) in a caddy in a clean room at Ball Aerospace in Boulder, Colo., where it was manufactured.

STIS resides in an axial bay behind the Hubble main mirror. STIS is nearly seve feet by three feet by three feet and weighs over 800 pounds. The instrument is designed to work in three different wavelength regions, each with its own detector. Scientists using STIS focus their science on many areas, including the search for massive black holes; the measurement of distribution of matter in the universe; the study of stars forming in distant galaxies; and the imaging of large (Jupiter-sized) planets around nearby stars.

The STIS instrument provides enhanced capabilities over the two original spectrograph instruments. STIS covers a broader wavelength range with two-dimensional capability, adds a coronograph capability, and has a high time-resolution capability in the ultraviolet. This instrument also images and provides objective prism spectra in the intermediate ultraviolet.

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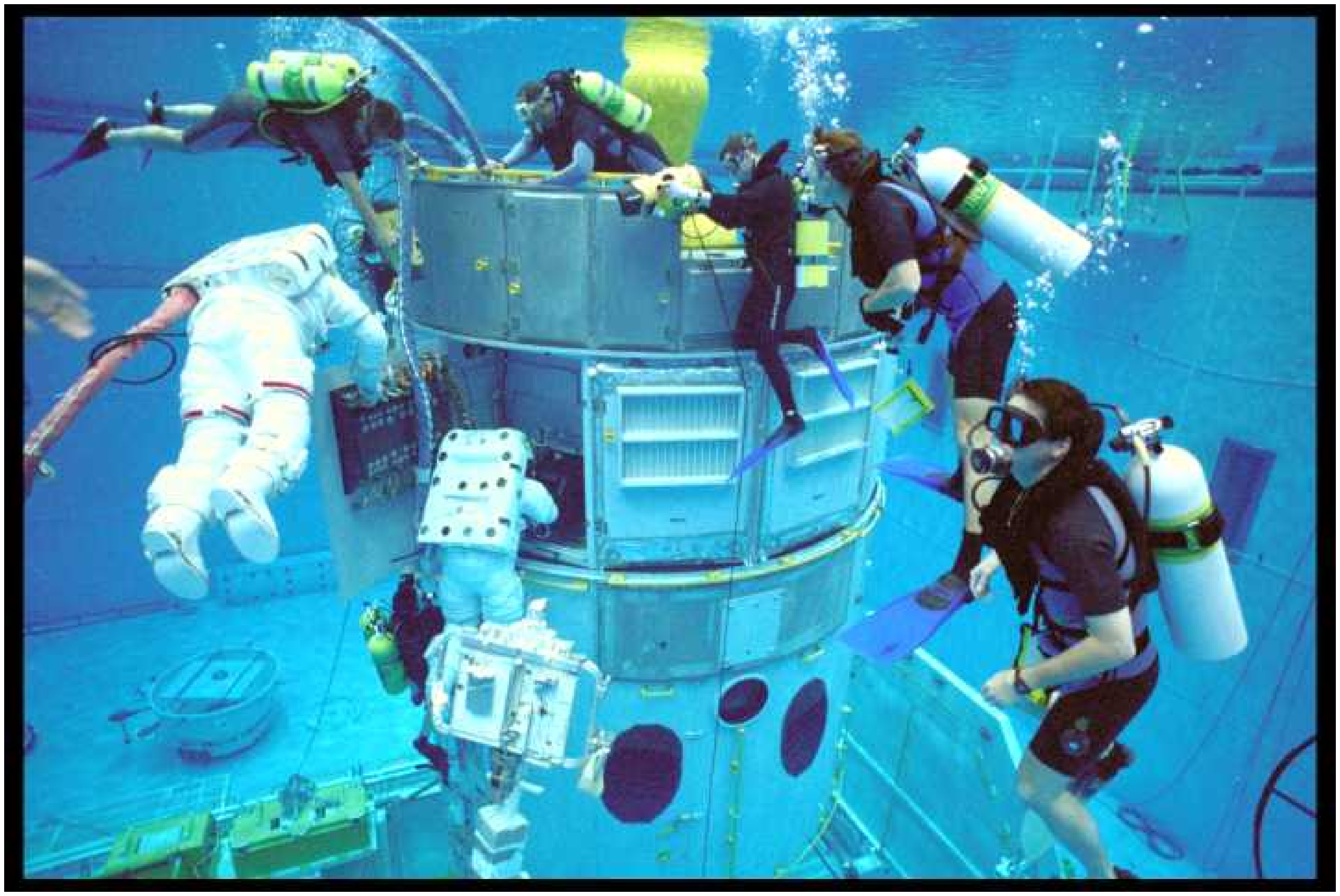

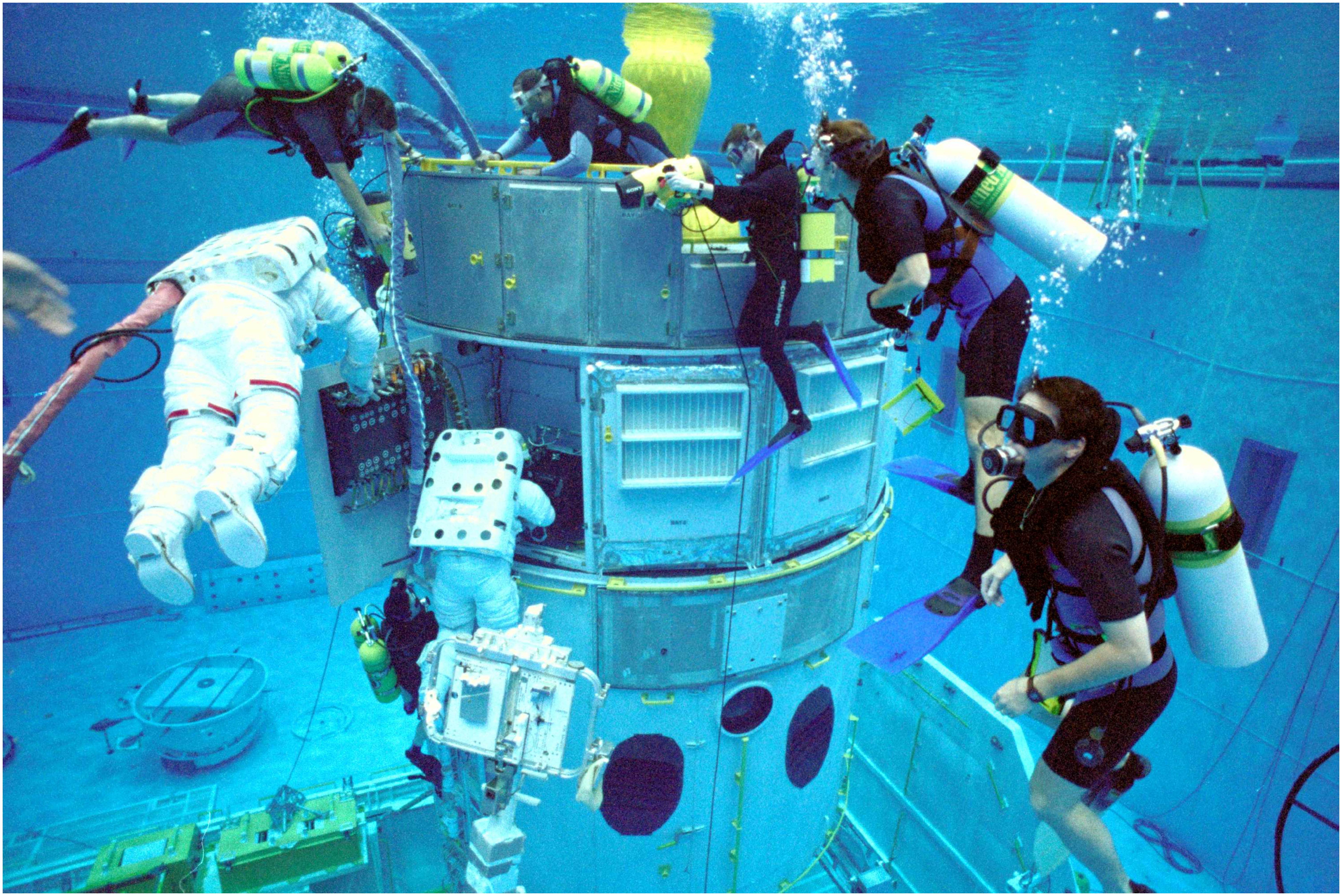

A DECADE OF DISCOVERY

SIMULATING WEIGHTLESSNESS

BACK

In preparation for servicing missions to Hubble, astronauts undergo extensive training. A huge underwater tank provides the closest training environment for weightlessness. During this training, the astronauts wear special underwater-pressurized suits similar to the suits worn on orbit. This 40-foot-deep tank contains full-scale underwater mockups of Hubble, the instruments being changed out and the carriers that hold the instruments. Astronauts spend many weeks in this underwater training, accompanied by weeks of classroom instruction.

This underwater training is performed at NASA's Johnson Space Center Neutral Buoyancy Laboratory. While at the Johnson Space Center, astronauts also train using virtual reality and practice in a thermal vacuum chamber, which simulates the space environment with temperature variations of minus 200 to 200 degrees Fahrenheit. Additional training is available at NASA's Goddard Space Flight Center, where the astronauts train with high fidelity mockups of Hubble, the flight instruments, and the flight tools required to service Hubble.

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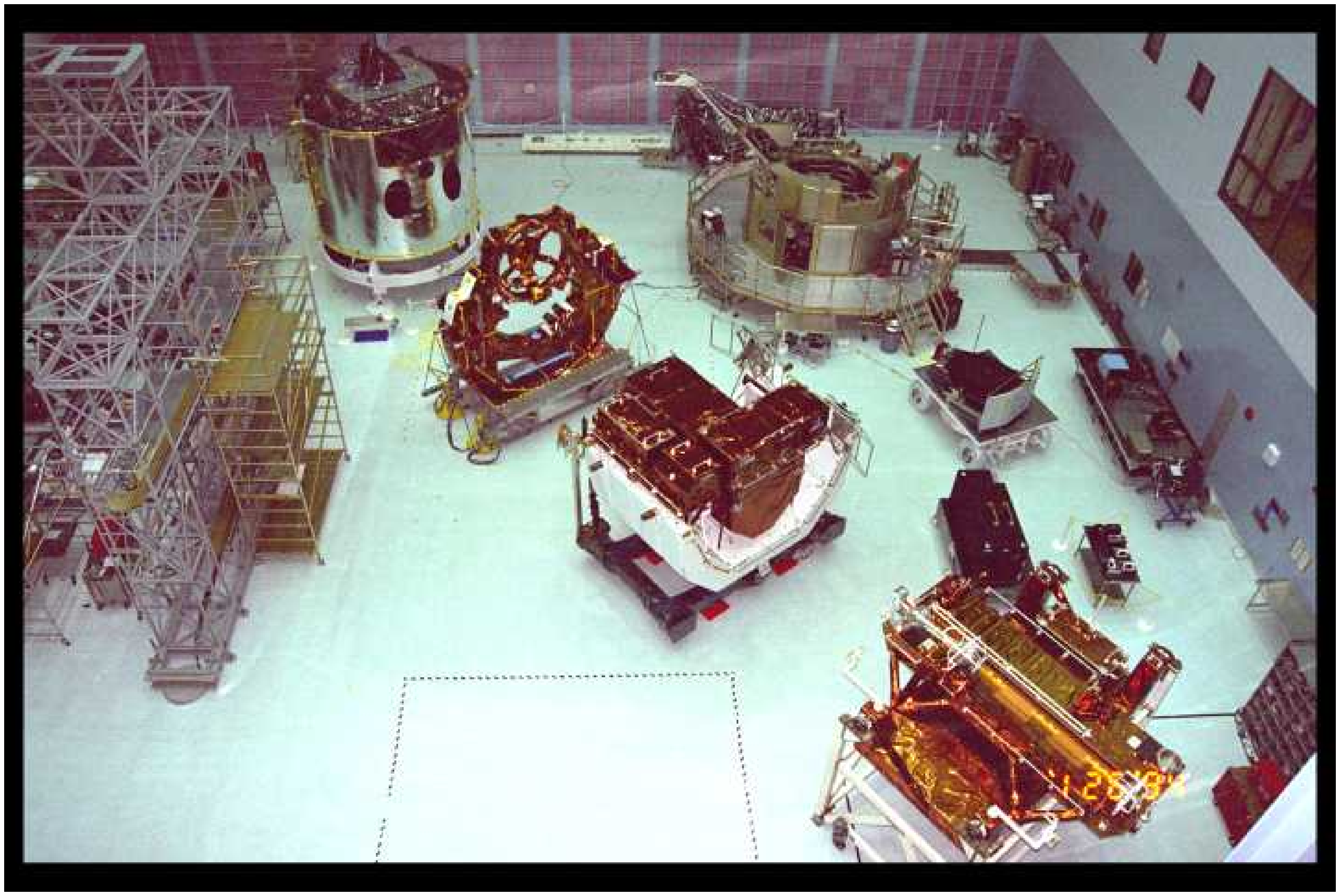

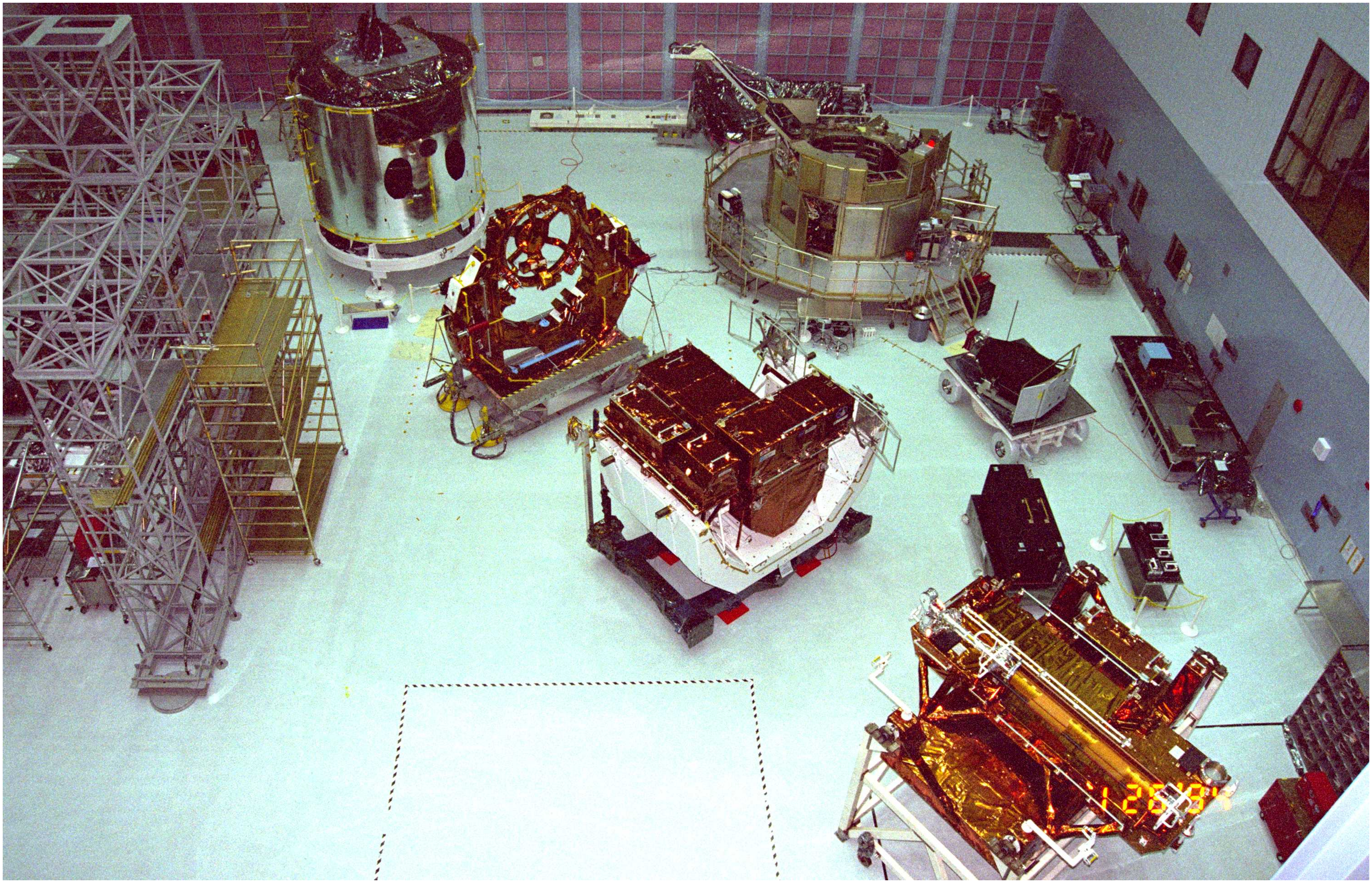

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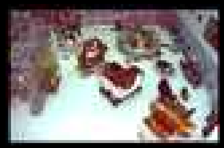


GODDARD'S CLEAN ROOM

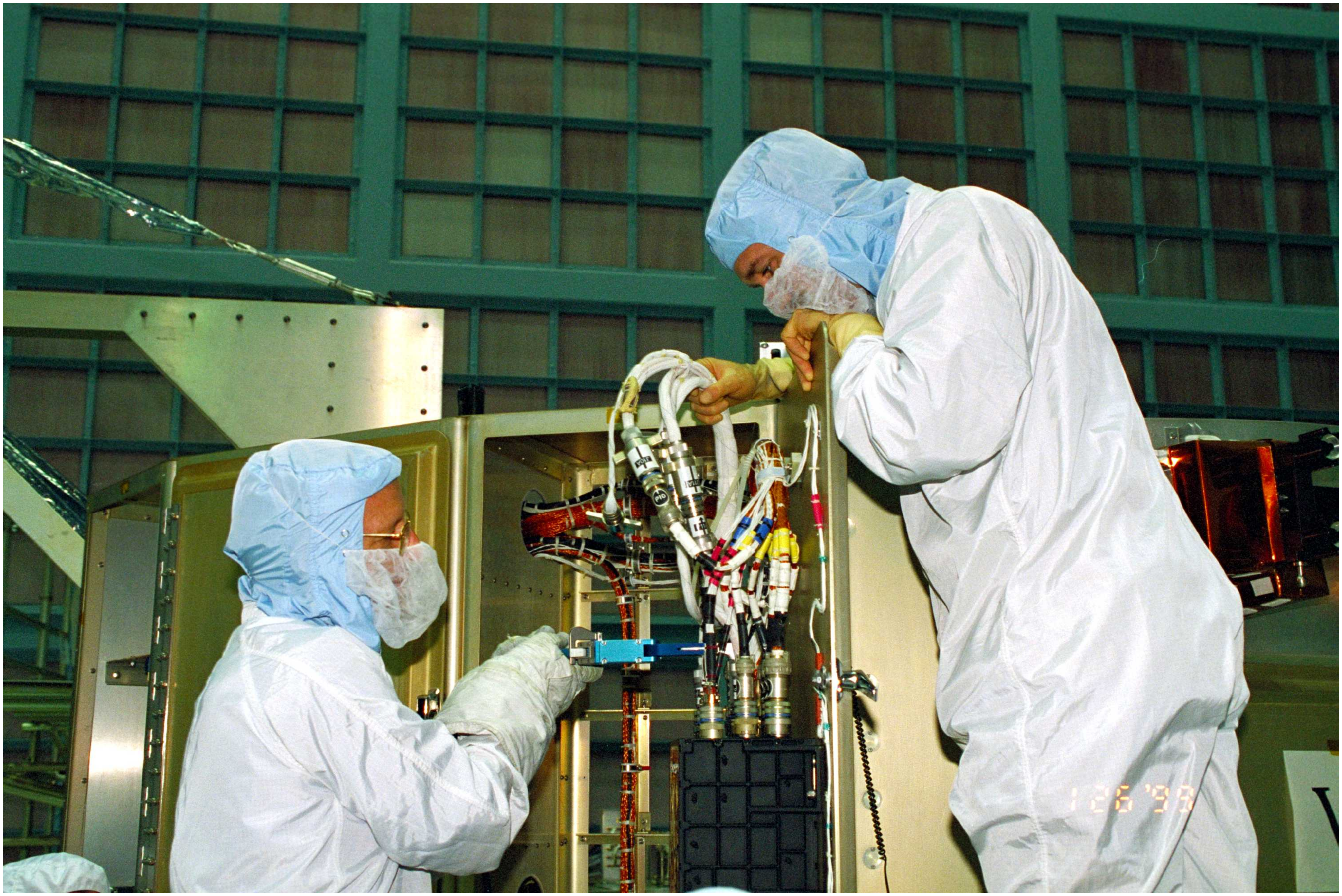
BACK

The Spacecraft Systems Development and Integration Facility is an 86,000-square-foot building used to integrate and test space hardware. Located at Goddard Space Flight Center in Greenbelt, Md., this facility houses the 1.3-million-cubic-foot High Bay Clean Room. The largest of its kind anywhere, this clean room plays an important role in preparing for Hubble servicing.

The STS-103 astronauts from Servicing Mission 3A trained in this room, as did the crews from the two previous Hubble servicing missions. Using the clean room's very precise mechanical and electrical simulators, they practiced installing the actual Hubble hardware. This is where the platform, used to anchor Hubble to the shuttle during a servicing mission, resides. It is also home to the shuttle carriers that take new Hubble instruments, tools, and other hardware to orbit.

This picture shows the carriers used to hold the flight hardware for the STS-61 mission in 1993. These carriers are transported to Kennedy Space Center where they are integrated into the shuttle bay. The Wide Field and Planetary Camera 2 is visible on the cart on the right side of this photo.

BACK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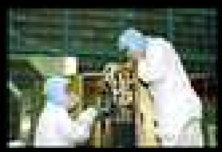
TRAINING IN THE CLEAN ROOM



The astronauts shown here are training on the electrical section of Hubble. This is a full-size mockup of the section of Hubble that houses the electrical components, such as transmitters, batteries, tape recorders, and electronics to operate other parts of Hubble. Astronauts come to Goddard several times prior to each mission to familiarize themselves with Hubble's components and the tools required to service them.

Everyone entering this room must wear a "bunny suit" — these are special coveralls, hoods, boots, gloves, and masks. This gear helps protect the sensitive flight hardware from particles that could interfere with performance.

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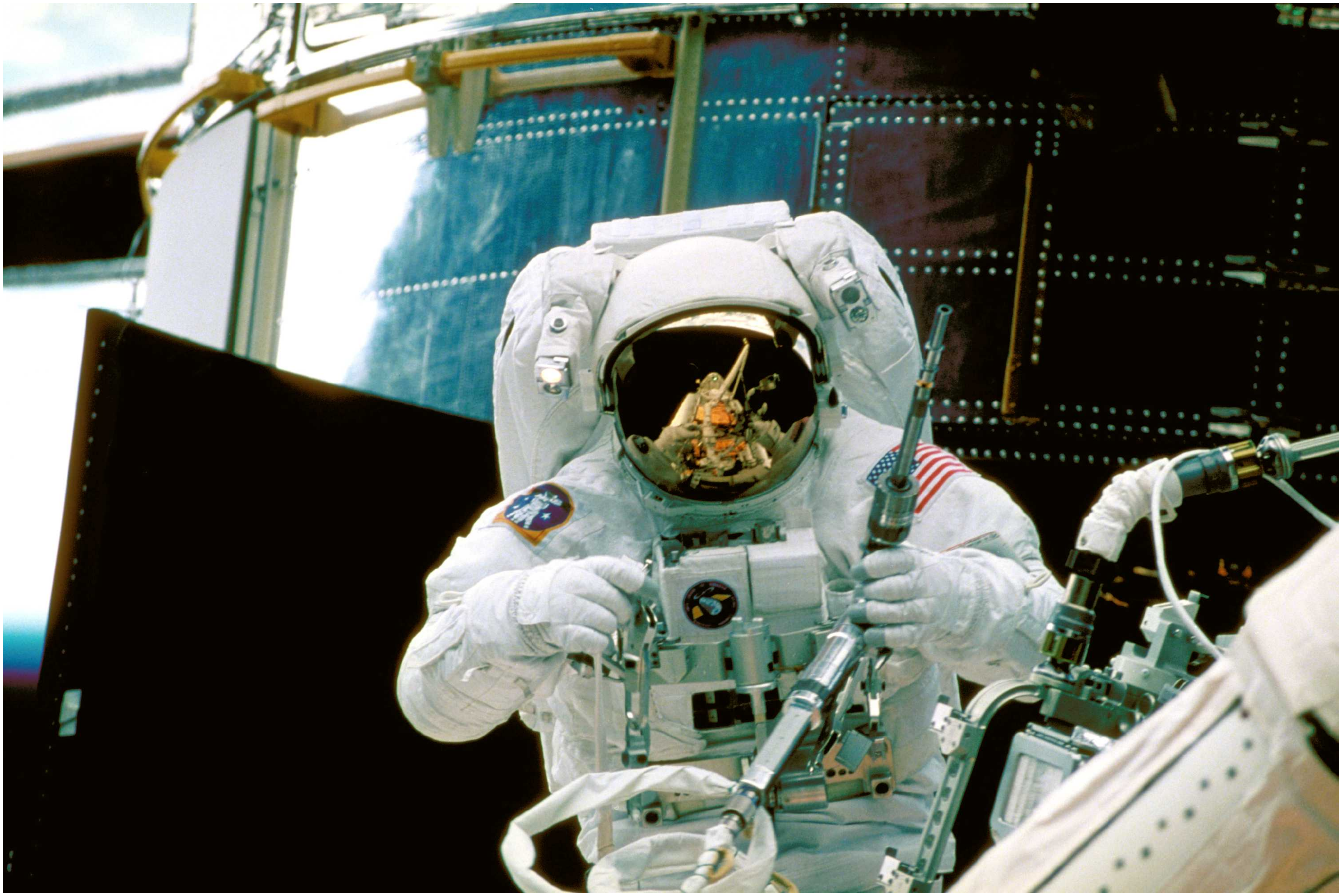

A DECADE OF DISCOVERY

ASTRONAUT TOOLS

BACK

Astronaut Steve Smith is holding a power ratchet tool on orbit in front of Hubble’s aft shroud compartment. The Hubble Space Telescope is the first spacecraft designed with replaceable parts and instruments for planned servicing. To enable astronauts to change out parts, special tools and aids had to be designed, tested, and built.

Hubble was built with 225 feet of handrails and 31 astronaut restraint platforms to give astronauts safe, convenient worksites as they orbit Earth at 17,000 mph to service the telescope. In addition, many special-purpose tools have been developed to meet the unique change-out requirements for the telescope. The power ratchet tool is a 3/8-inch-drive, right-angle power tool used for tasks, requiring controlled torque, speed, and/or turns. This tool is one of two power tools designed, built, and tested at NASA's Goddard Space Flight Center and Johnson Space Center to be strong and reliable enough to withstand the harsh environment of space. They have been used successfully on the three Hubble servicing missions.

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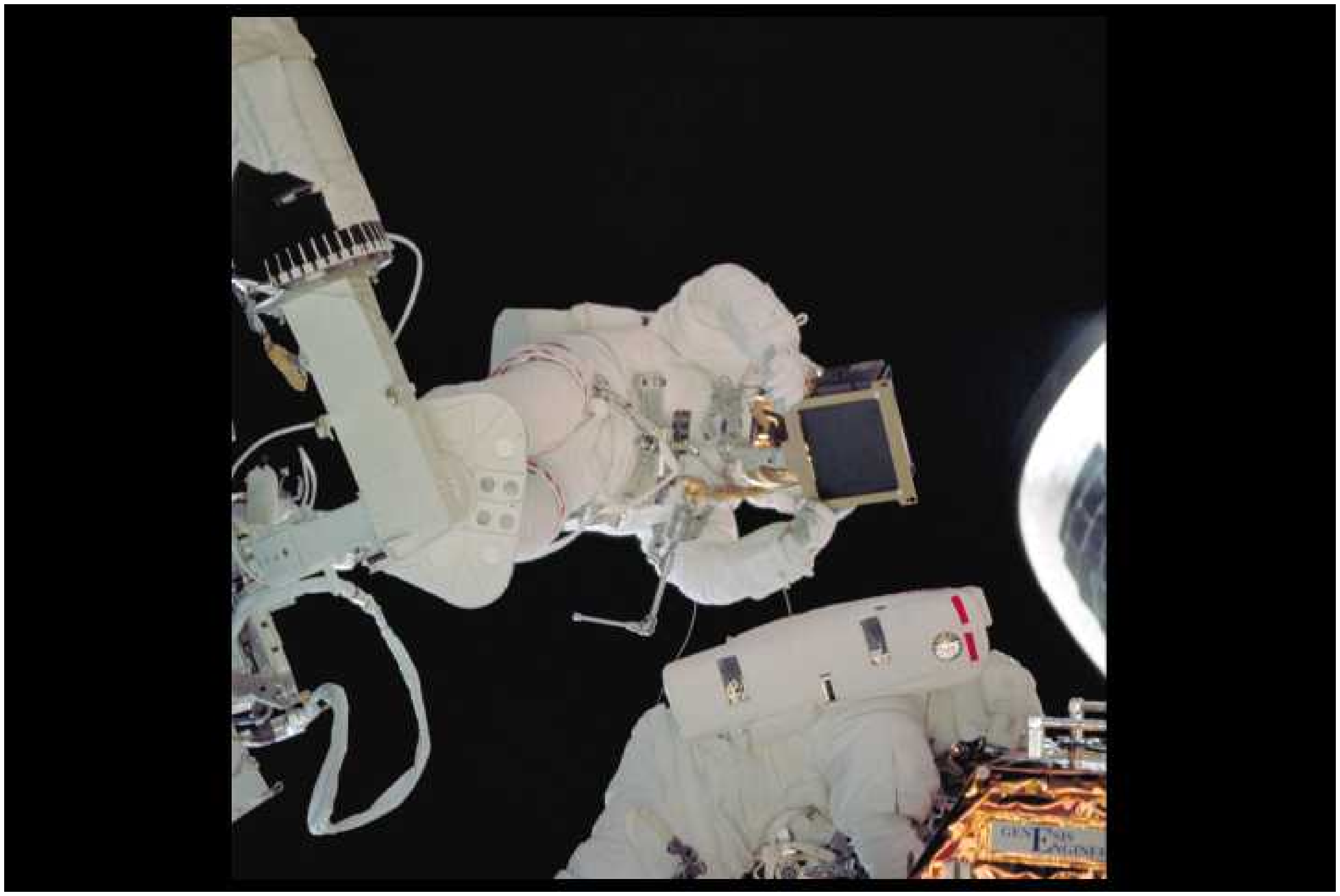

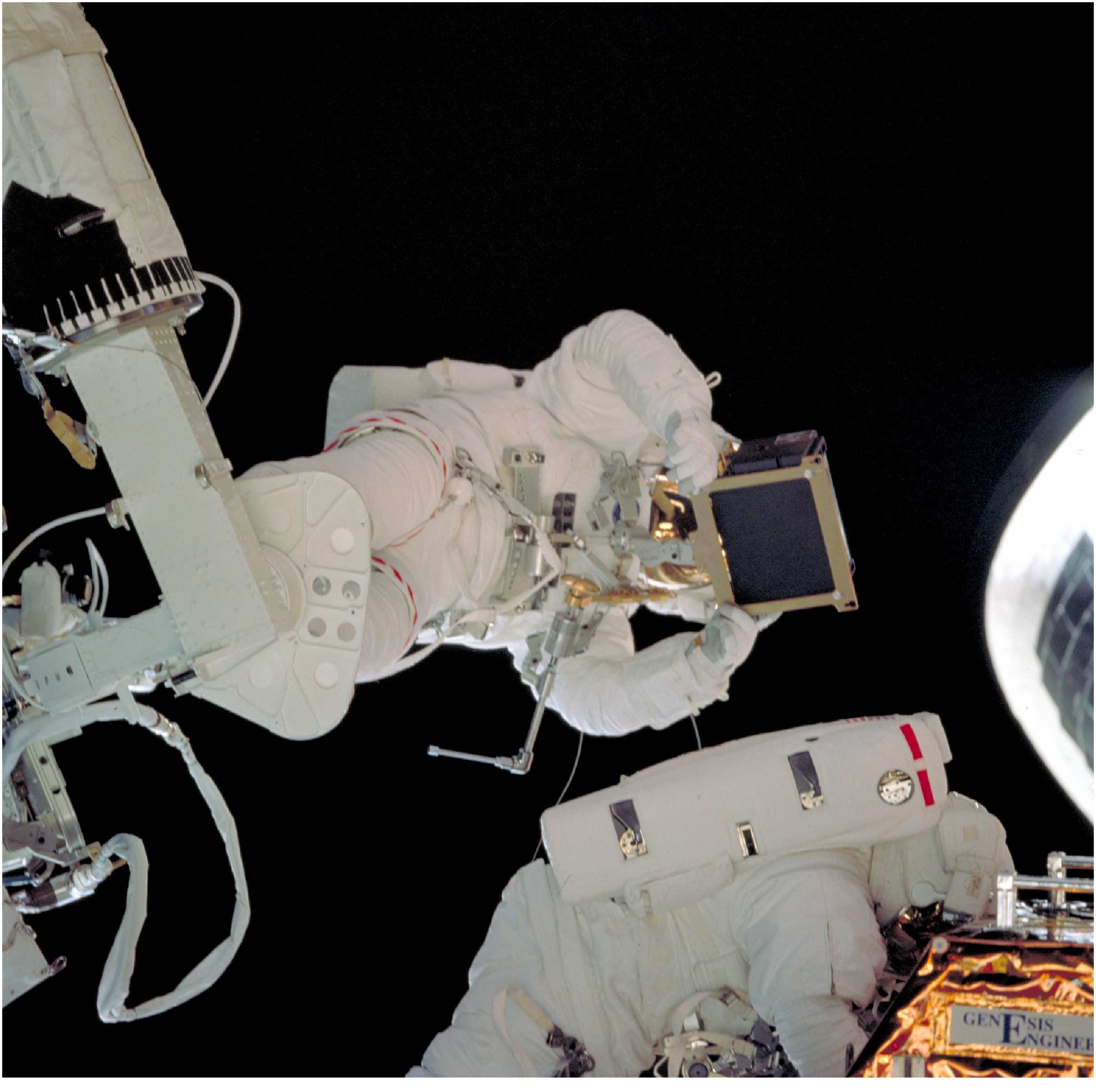
GENESIS ENGINEER

HUBBLESITE

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Investigating Space
The Hubble Story

REPLACING A DATA RECORDER

BACK

This photo shows an astronaut holding a reel-to-reel tape recorder prior to stowing it for return to the ground. Hubble originally used reel-to-reel tape recorders to store data that could not be sent to the ground in real time. The on-board recorders would record the engineering or science data, and then the ground controllers would command a playback or tape recorder dump at a later time when communications permitted it.

During the Second Servicing Mission, the first solid-state recorder was installed, replacing one of the original reel-to-reel recorders. A second recorder was installed during Servicing Mission 3A. The new recorders have no reels or tape and no moving parts to wear out and limit lifetime. Data is stored digitally in computer-like memory chips until the ground controllers command the recorders to play the data back to the ground.

The new recorders are the same size as the reel-to-reel tape recorders, but they store over 10 times more data than the old recorders. The new recorders can record two data streams at one time, so both engineering and science data can be recorded. In addition, data can be recorded and played back at the same time.

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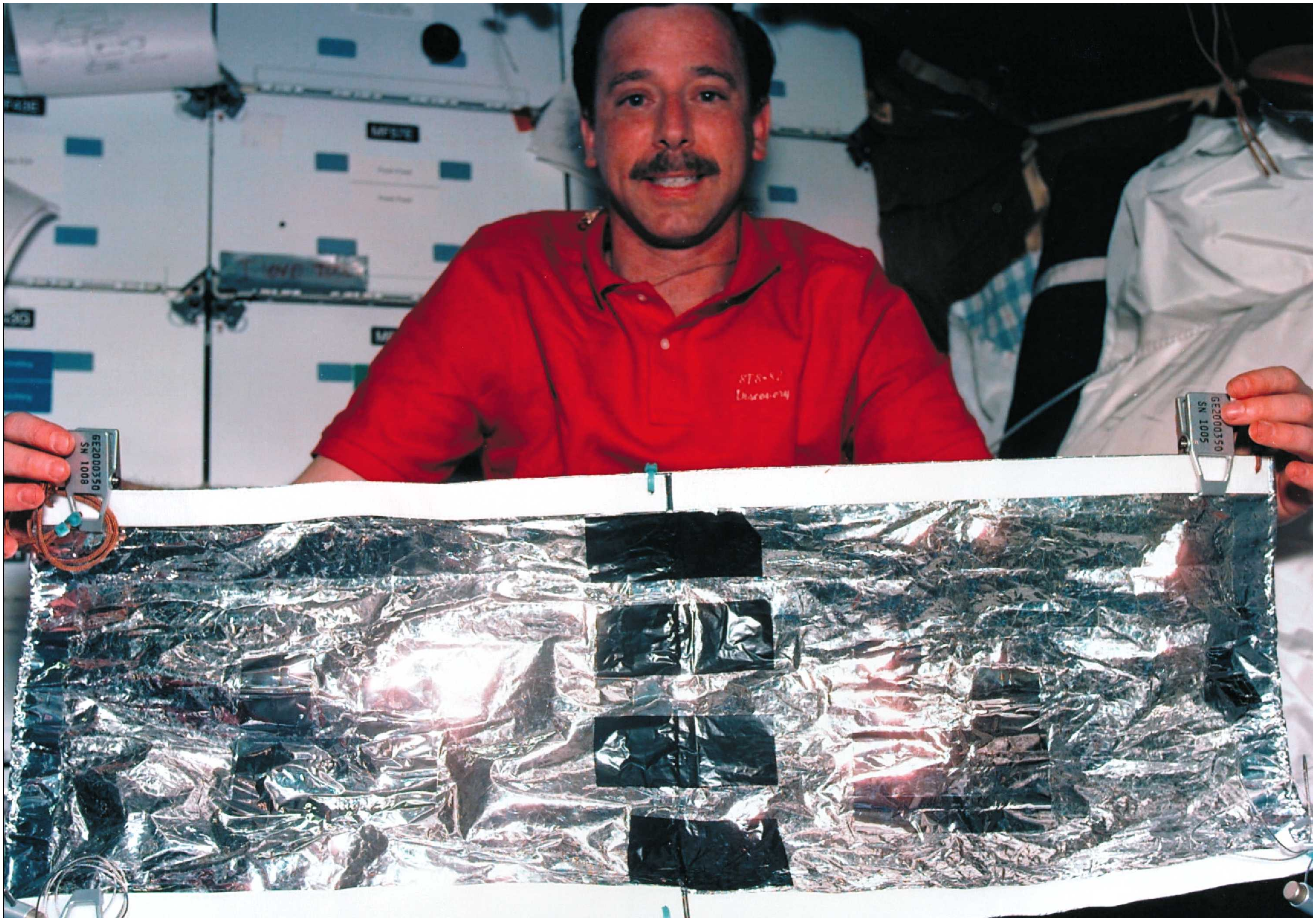
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HUBBLESITE

A DECADE OF DISCOVERY

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The Hubble Story

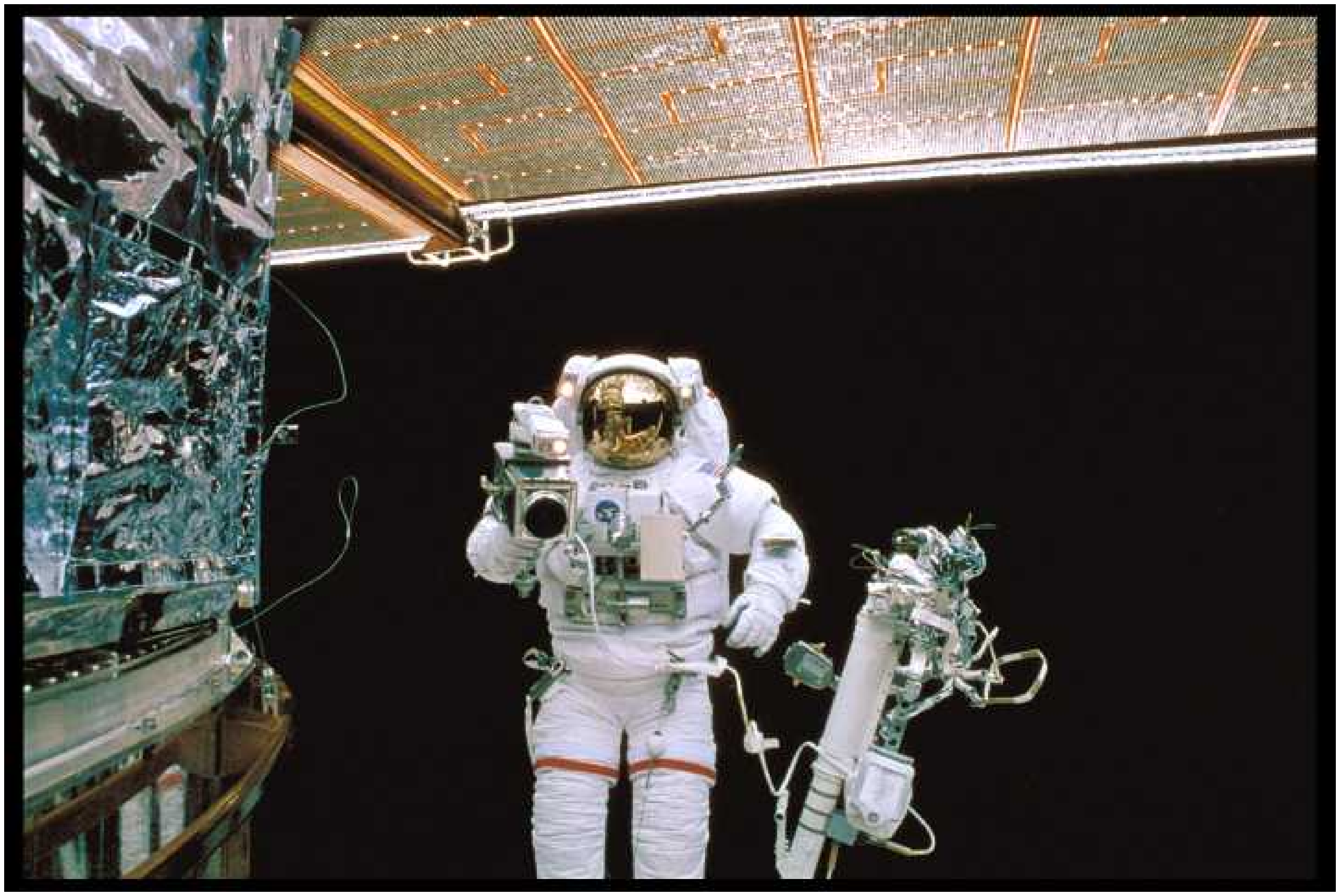
INSULATION REPAIR

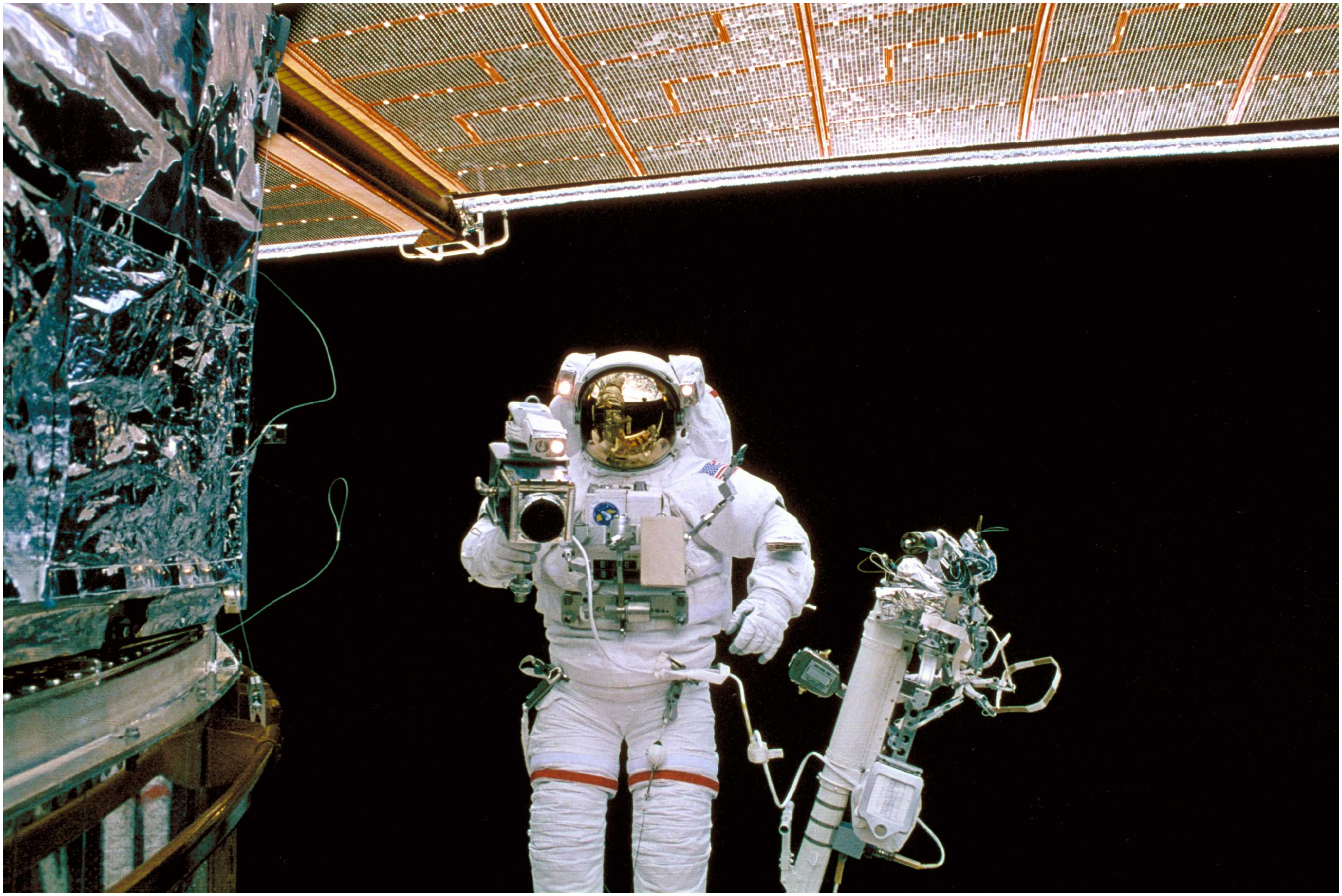
BACK

This photo shows STS-82 astronaut Scott Horowitz with a multi-layer insulation (MLI) repair patch. During the Second Servicing Mission, astronauts detected damage to insulation on the outside of Hubble. Astronauts working inside the shuttle created repair patches with the materials they had on hand. MLI covers 80 percent of Hubble's exterior. This insulation, coupled with supplemental electric heaters, maintains the temperature of the equipment and optics within safe limits. If insulation deteriorates or becomes damaged over time, the insulation must be repaired or replaced to maintain the correct temperature environment for the satellite.

In space care must be taken to ensure that equipment and systems do not become too cold or too hot. Hubble's insulation blankets are 15 layers of aluminized Kapton, with an outer layer of aluminized Teflon. Aluminized or silvered, flexible reflector tape covers most of the remaining exterior. These coverings protect against the cold of space and reflect excessive heat from the sun. Hubble is thermally designed to maintain safe component temperatures, even for worst-case conditions in space.

BACK





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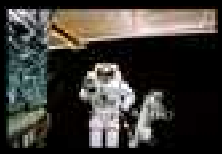
PHOTOS OF HUBBLE

BACK



This photo of astronaut Mark Lee was taken by fellow crew member Steven Smith during Hubble's Second Servicing Mission. Mark Lee is preparing to document the day's activities using one of the extravehicular activity (EVA) cameras. It is critical that astronauts take pictures of Hubble when they first see it and they photographically document their completed work. Since engineers cannot walk into a building and view Hubble, they rely on this photo documentation to accurately design and build new hardware. This photo activity is important as we continue servicing the Hubble Space Telescope.

In addition to hand-held EVA cameras, there are video cameras mounted on each of the four corners of the orbiter bay and in two places on the Remote Manipulator System or "robotic arm." The crew members inside the shuttle have a Hasselblad and various 35mm and video cameras to document all on-board activities.

BACK

A DECADE OF DISCOVERY

HUBBLE RETURNS TO DUTY

BACK

Following the successful Servicing Mission 3A, Hubble is refreshed and back to work producing amazing science images. There are two more scheduled servicings in Hubble's future, Servicing Mission 3B in 2001; and Servicing Mission 4 in 2003.

Servicing Mission 3B will focus on the installation of the Advanced Camera for Surveys and more efficient, rigid solar arrays. Astronauts also will install the aft shroud cooling system, which will allow the science instruments to operate simultaneously at lower temperatures. In addition, an advanced cooling system will be installed on the Near Infrared Camera and Multi-Object Spectrometer, which became dormant after its solid nitrogen coolant was exhausted in January 1999. The application of new external thermal coverings will be completed.

Servicing Mission 4 will see the addition of two new science instruments, the Cosmic Origins Spectrograph and the Wide Field Camera 3. A refurbished Fine Guidance Sensor also will be installed, completing the refurbishment of all Fine Guidance Sensors on Hubble.

Hubble is scheduled to be decommissioned in 2010.

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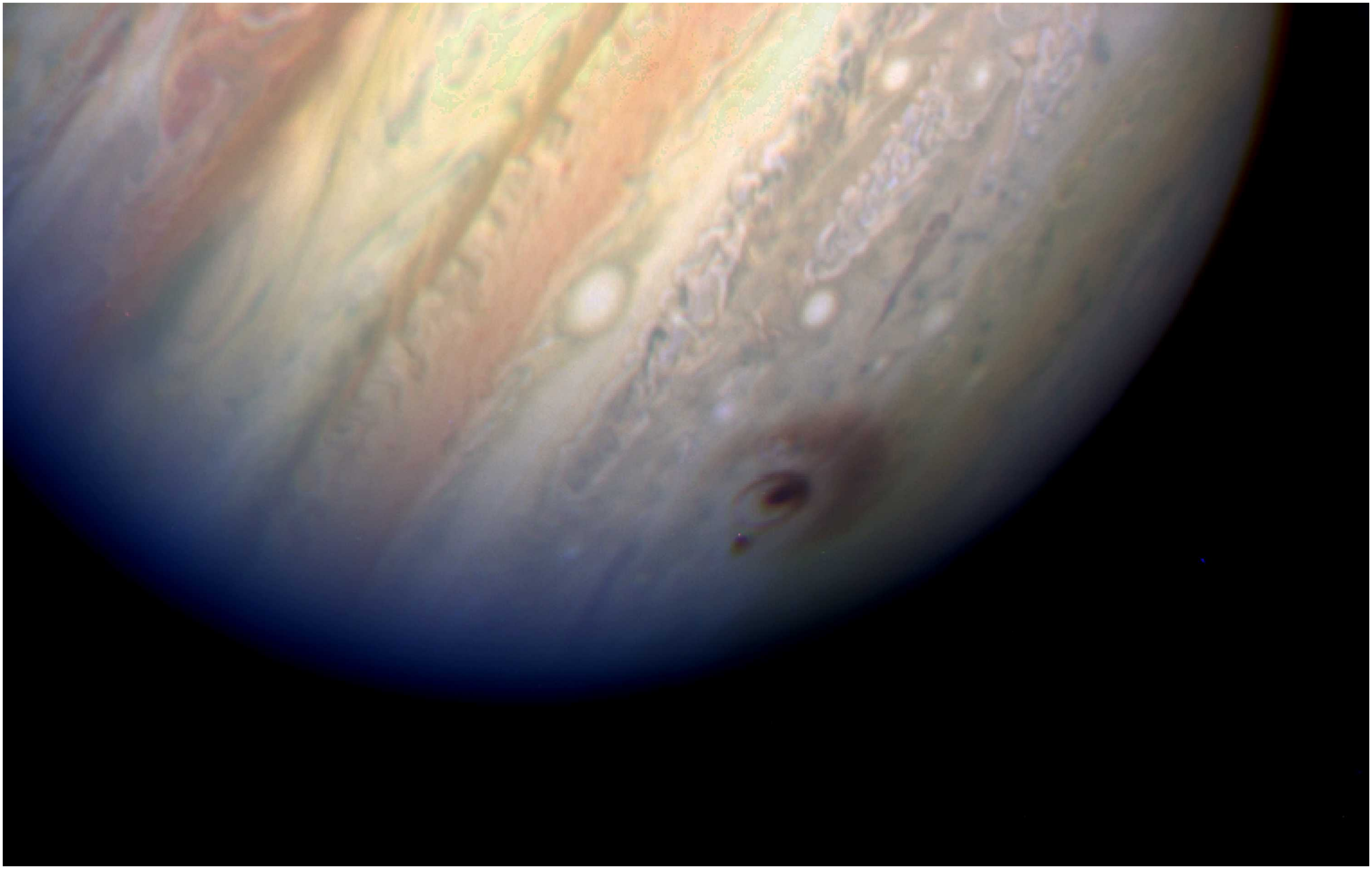

HUBBLESITE

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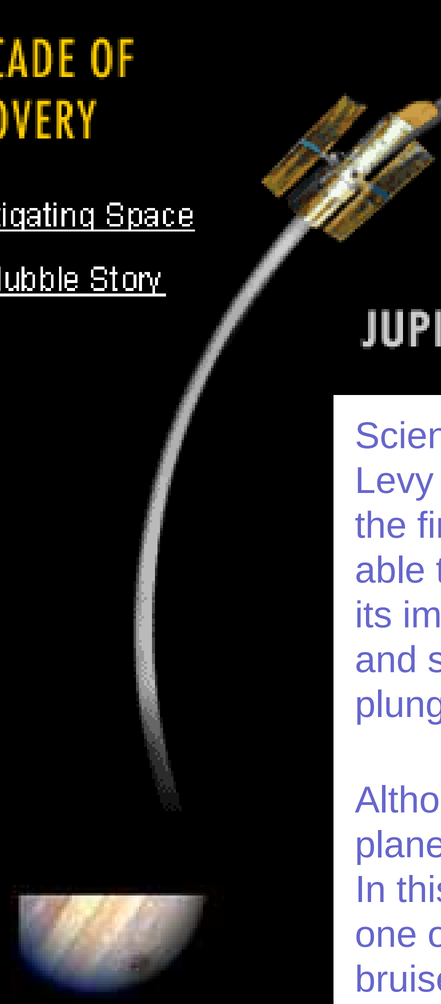

JUPITER WITH COMET IMPACTS

BACK

Scientists worldwide watched Comet Shoemaker-Levy 9 slam into Jupiter in July 1994, representing the first time in human history that scientists were able to discover a celestial body in the sky, predict its impact and then record with an armada of ground- and space-based telescopes the comet's fiery plunge.

Although Jupiter clearly won the match, the largest planet in our solar system didn't emerge unscathed. In this Hubble image, taken nearly two hours after one of the fragments struck, the planet looks bruised. The impact area features a central dark spot 1,550 miles (2,500 km) in diameter, surrounded by rings that also are thousands of miles in diameter. Evidence suggests that the darkened spots on Jupiter and all the mighty plumes that soared into the planet's upper atmosphere occurred because of an object no more than one mile (1-1/2 km) in diameter.

Originally, scientists believed the comet measured at least six miles (9 km) in diameter before it broke up into fragments after an earlier pass by the planet in 1992. Despite its small size, scientists agree that Comet Shoemaker-Levy 9 packed a mighty powerful punch. One year after the comet crash, astronomers could still see vestiges of the bruises. Interestingly, theorists had not predicted the bruising. In fact, scientists weren't certain of what they would see during the collision.

BACK

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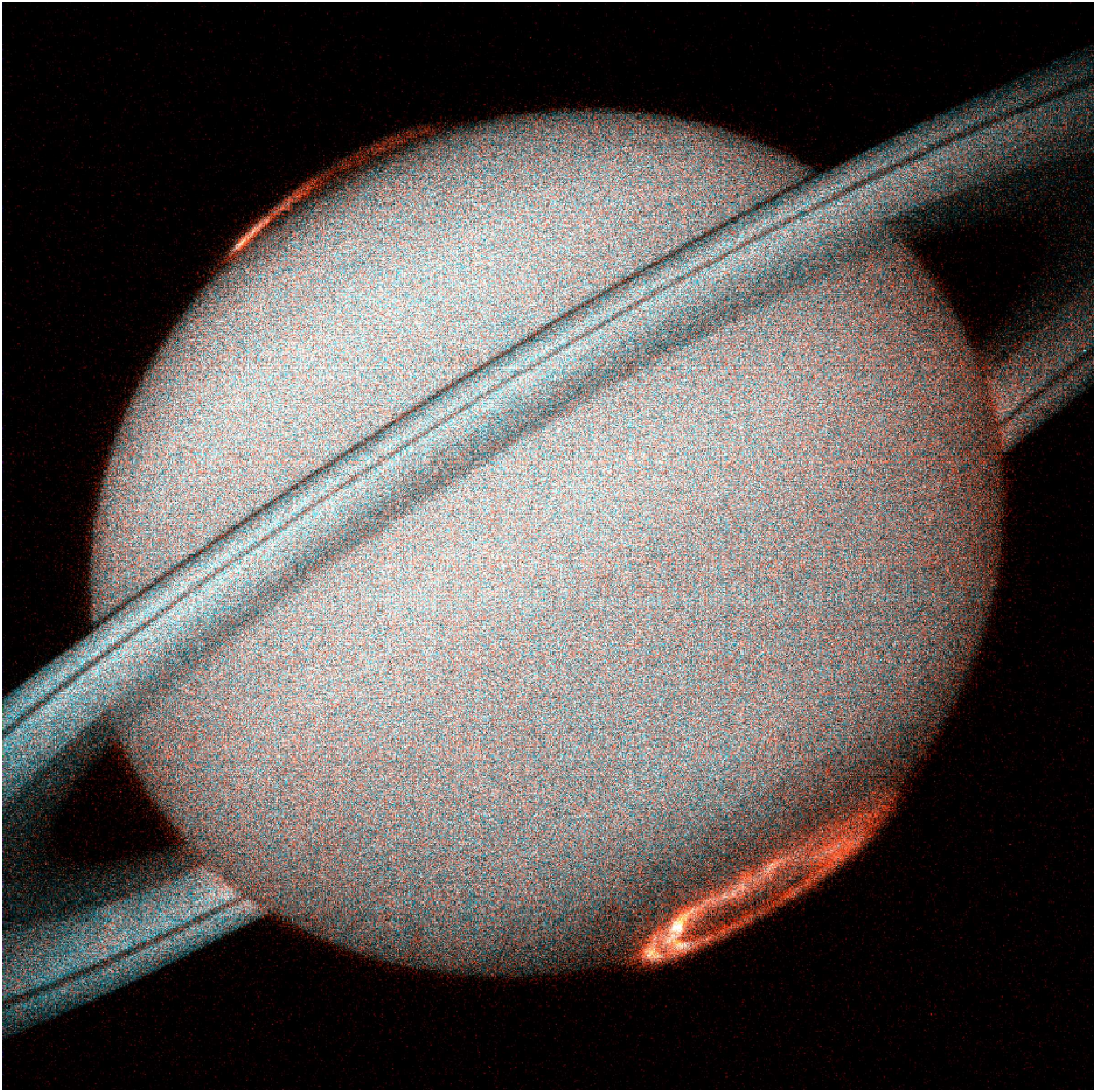

HUBBLESITE

A DECADE OF DISCOVERY

SATURN'S AURORAS

Saturn was 810 million miles (1.3 billion km) away when the Hubble Space Telescope took this ultraviolet image of the planet, revealing a vivid auroral display rising thousands of miles above the cloud tops over both of the planet's poles. These spectacular light shows are caused by an energetic solar wind that sweeps over the planet, much like it does on Earth. However, unlike on Earth, Saturn's auroras can be seen only in ultraviolet light, and therefore is visible only from space using instruments sensitive to ultraviolet radiation. The new Hubble images reveal ripples and overall patterns that evolve slowly, appearing generally fixed in our view and independent of planet rotation. These variations indicate that the auroras are primarily shaped and powered by a tug-of-war between Saturn's magnetic field and the flow of charged particles from the Sun. Study of Saturn's auroras began in 1979 when the Pioneer 11 spacecraft observed a far-ultraviolet brightening on Saturn's poles. The Saturn flybys of Voyager 1 and 2 in the early 1980s then provided a basic description of the planet's enormous magnetic field.

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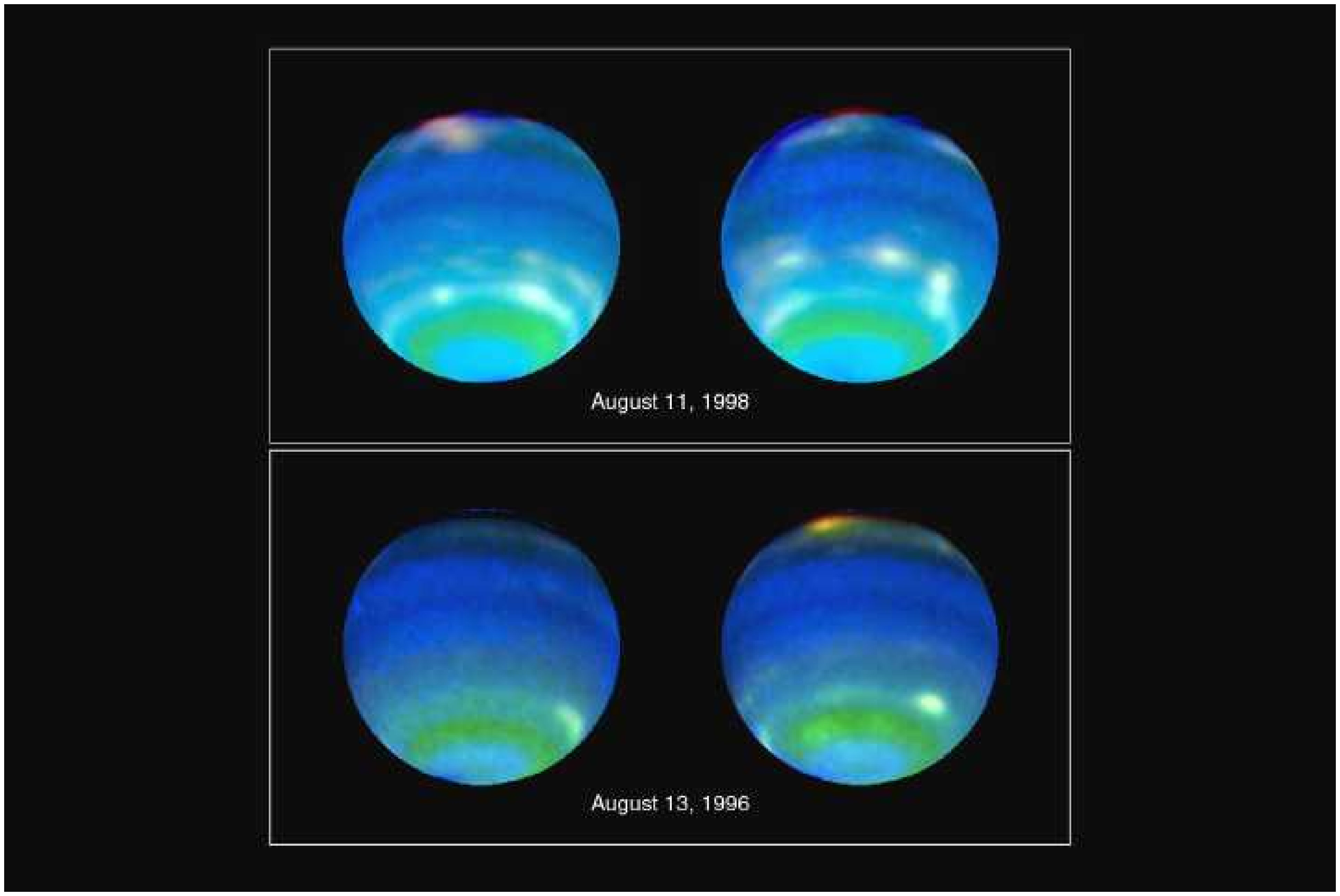
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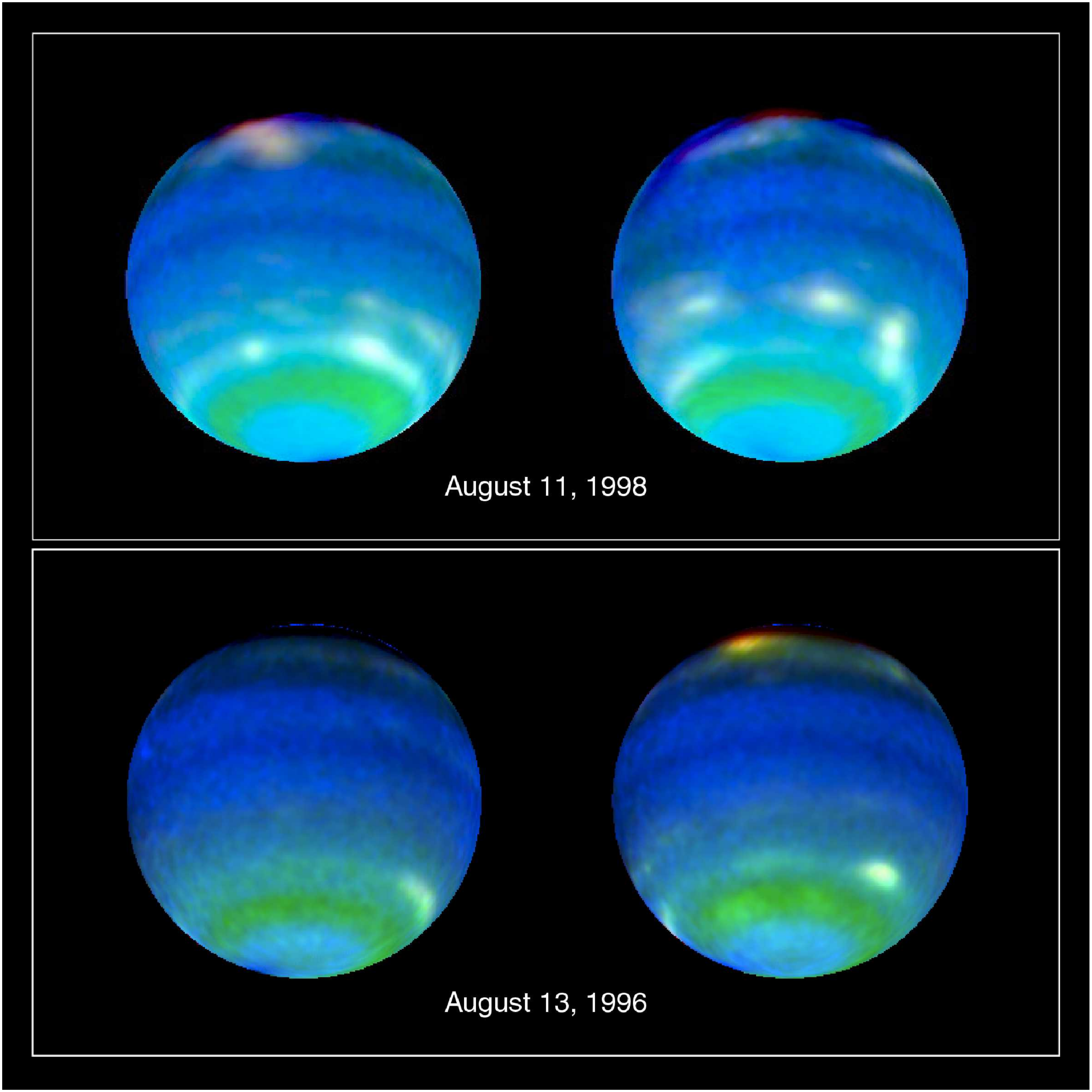
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HUBBLESITE

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

NEPTUNE CLOUDS

The Sun's energy heats the atmosphere and the oceans, which then drive the weather on Earth. On Neptune, though, the Sun is 900 times dimmer. What then causes the monster storms and the 900-mph equatorial winds captured here in this Hubble image? Astronomers are trying to find out. Using Hubble and NASA's Infrared Telescope Facility in Hawaii, a team of scientists created a time-lapse rotation movie of Neptune that allowed them to watch the ebb and flow of the distant planet's weather. They measured Neptune's circulation, mapped its cloud tops and discovered distinct bands of weather that run parallel to the planet's equator. These bands encircle the planet and, in some respects, may be similar to the equatorial region of the Earth where tropical heat provides the energy to make clouds.

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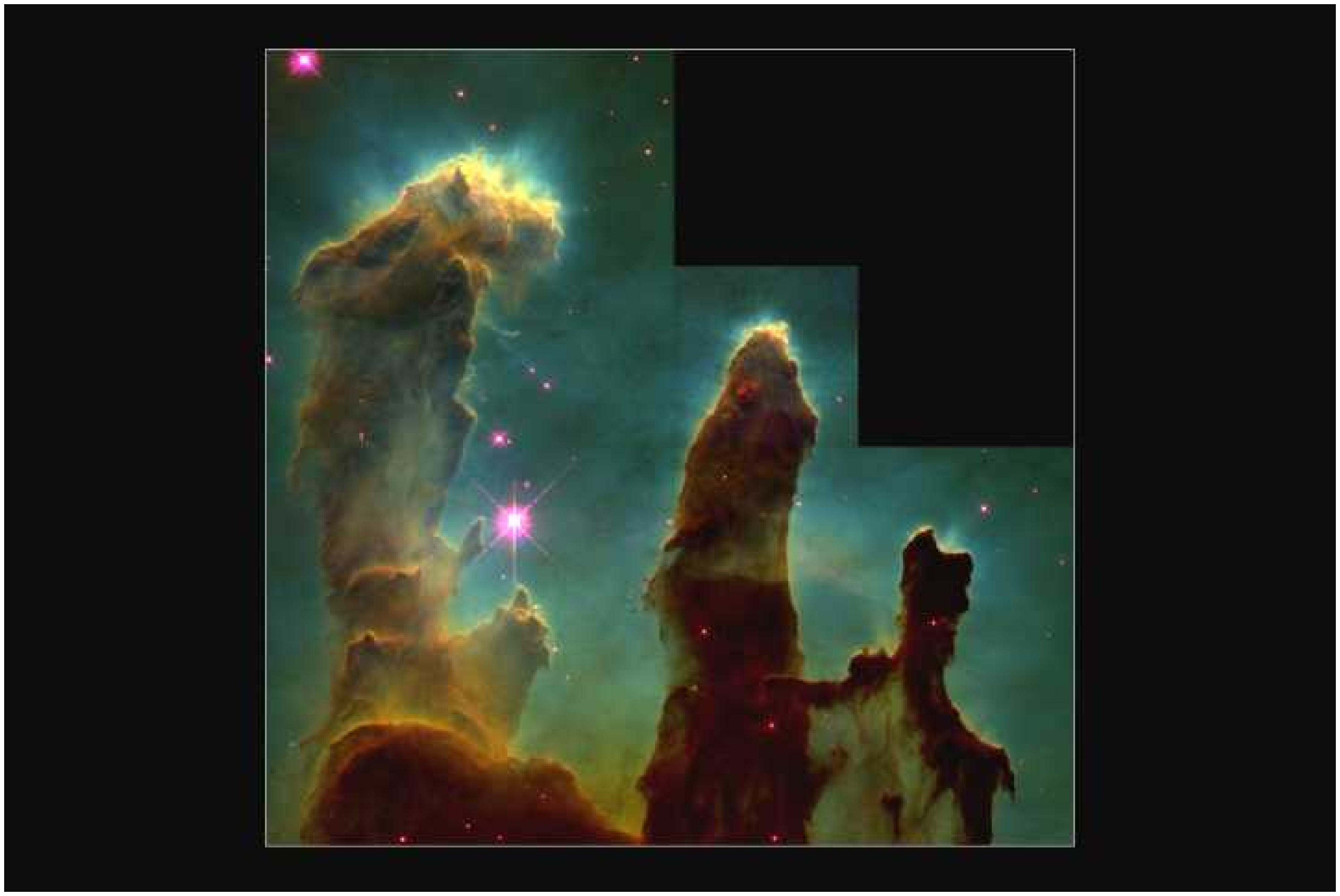

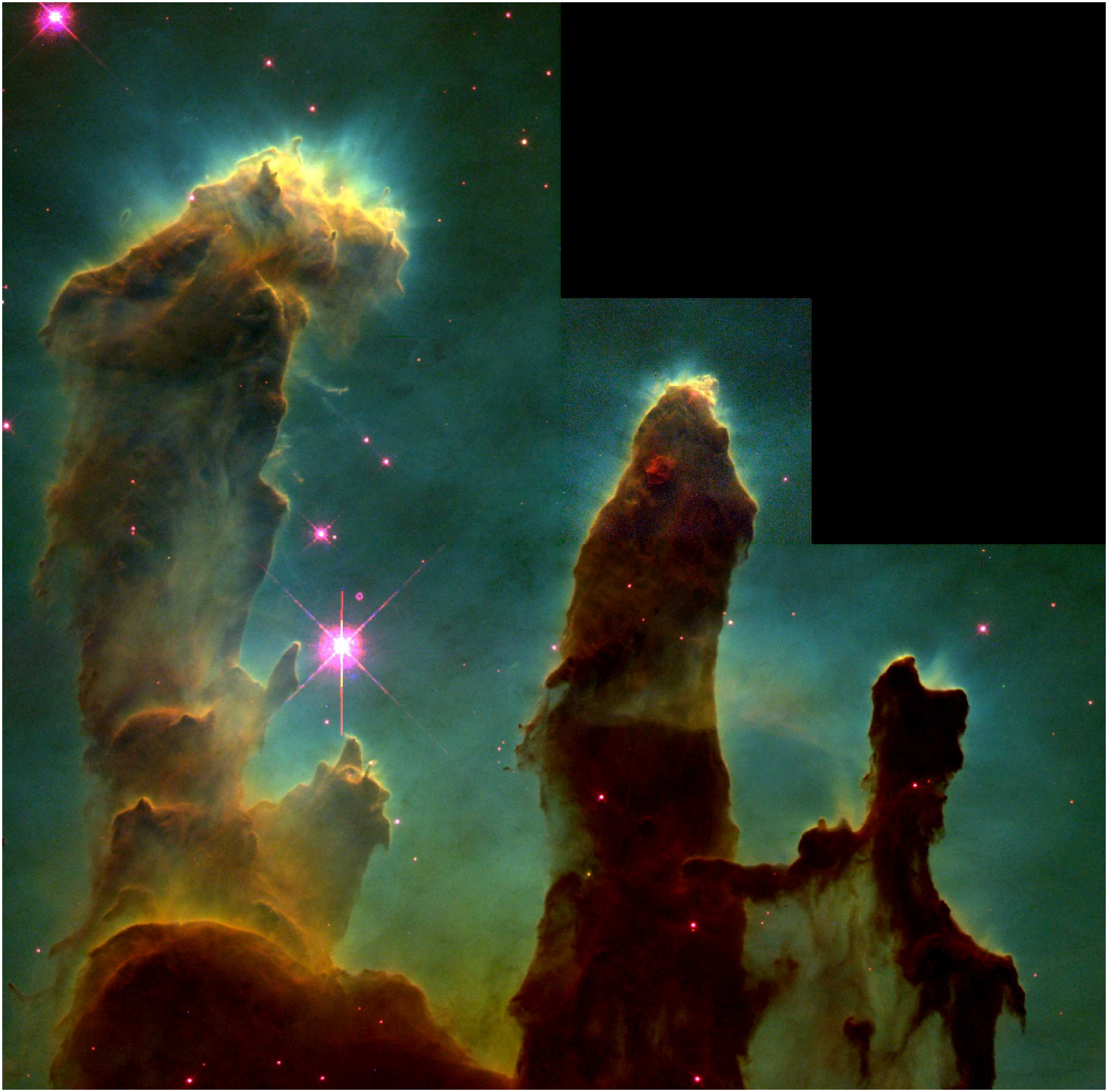

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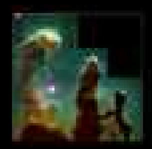
EAGLE NEBULA

BACK



The three columns of dust and gas in this Hubble Space Telescope image are located in the Eagle Nebula, a nearby star-forming region 7,000 light-years away in the constellation Serpens. The tallest pillar of cool hydrogen gas and dust (on the left) is about a light-year long. In many ways, these eerie-looking structures could be compared to desert buttes, which were formed by erosion. In this case, though, ultraviolet light from hot, massive newborn stars (off the top edge of the picture) sculpted the columns in a process called "photoevaporation." As the ultraviolet light slowly erodes away the pillars, small globules of even denser gas emerge from within the columns themselves. These globules, called EGGs for Evaporating Gaseous Globules, are actually the birthplace of embryonic stars. However, the same process that sculpted the columns will eventually cut off their food source, and these embryonic stars will eventually succumb to photoevaporation and stop evolving.

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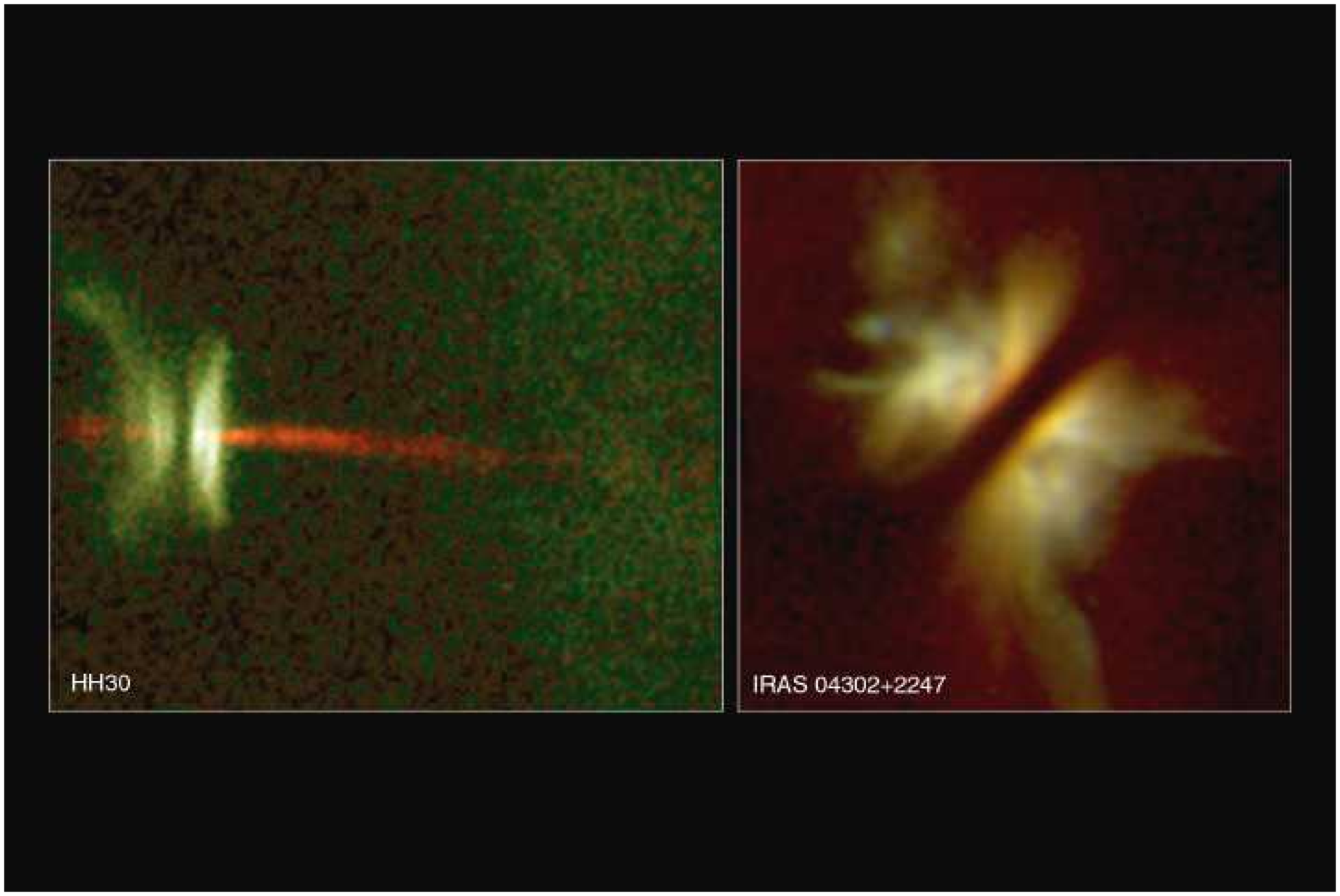
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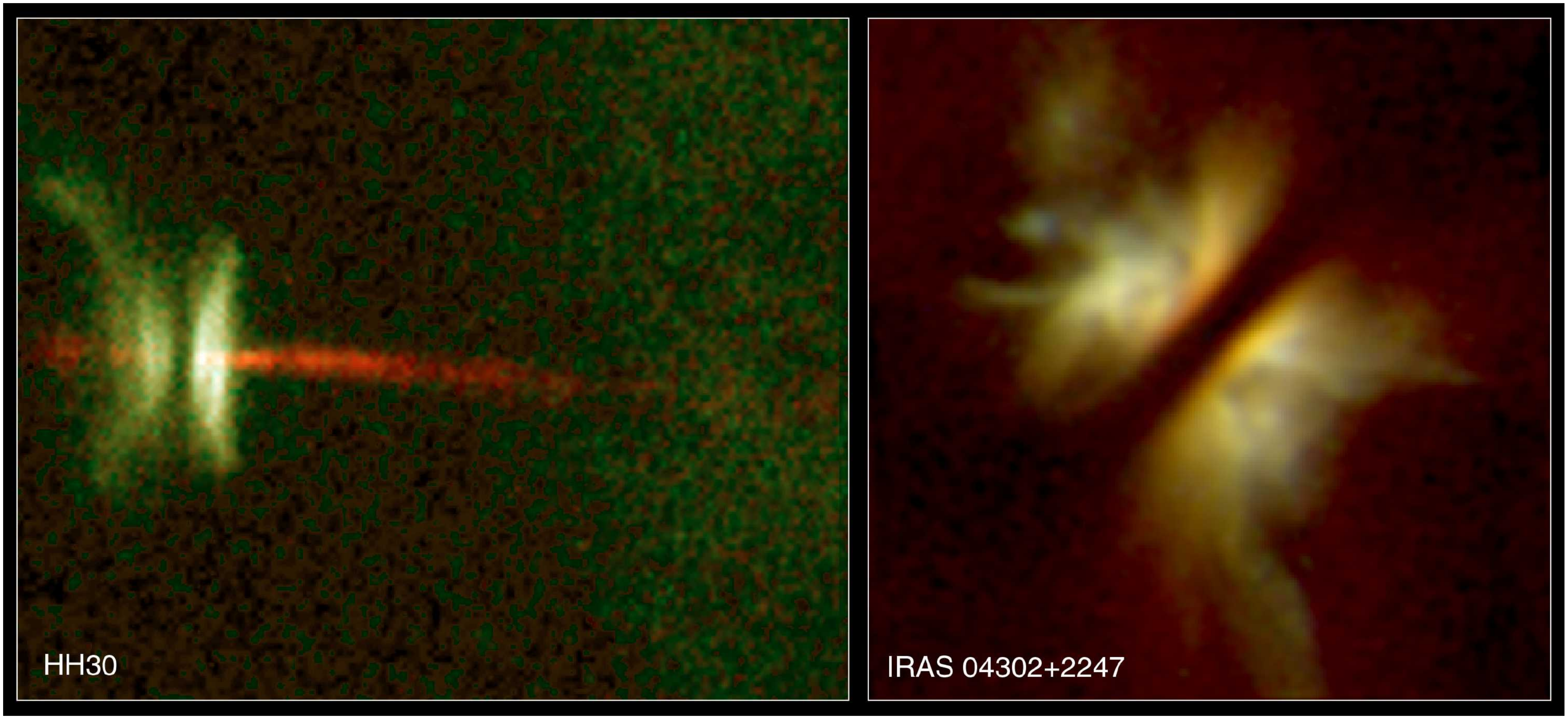
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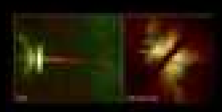
YOUNG STELLAR DISKS

BACK



These Hubble images don't show actual planets, but rather the edge-on disks of gas and dust that eventually condense to form planets around young stars. Although astronomers have discovered about 30 possible extrasolar planets over the past few years, they have never gotten such detailed pictures of the planet-forming environments around newborn stars. Located 450 light-years away in the constellation Taurus, the stars all sport dusty disks that appear as dark bands. The disks are believed to be eight to 16 times the diameter of Neptune's orbit. In addition, the images show that raw material is still falling into these disks and driving jets of gas from the forming stars.

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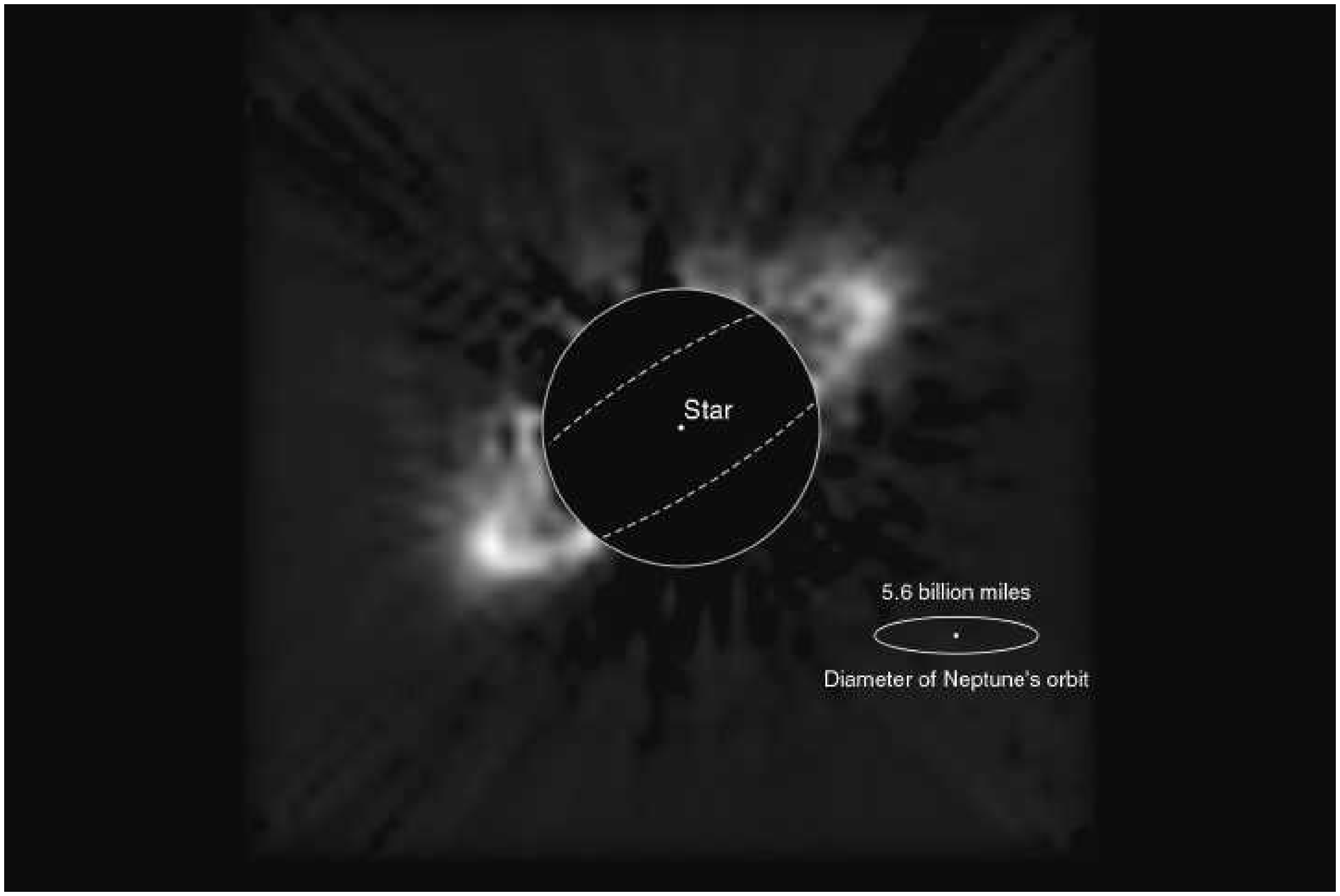
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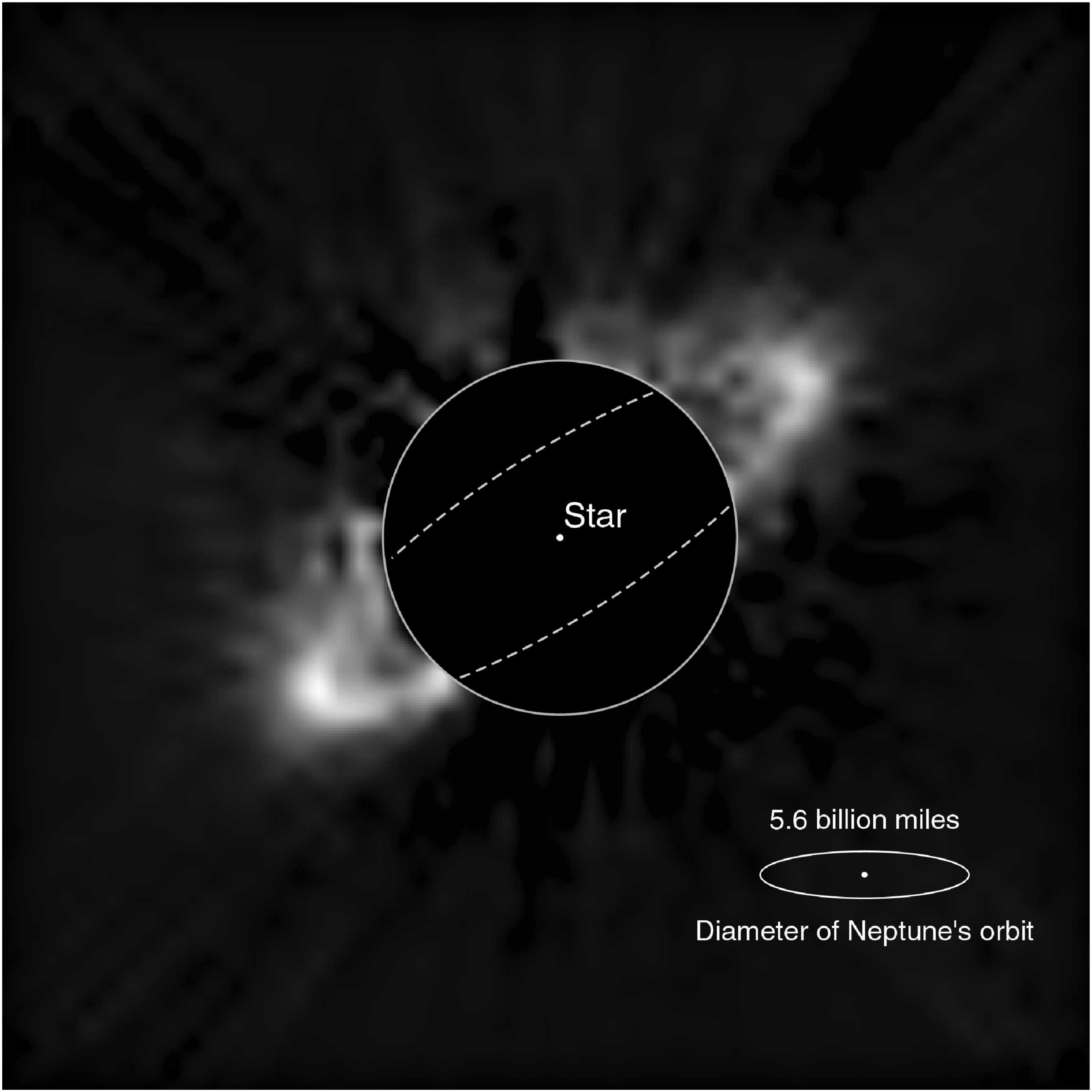
5.6 billion miles
Diameter of Neptune's orbit


Star
5.6 billion miles
Diameter of Neptune's orbit

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STELLAR DUST RING AROUND STAR HR 4796A

BACK

Unlike the extensive disks of dust seen around other young stars, the ring around this young star is 6.5 billion miles from the star itself, which would be equivalent to the distance separating the orbits of Mars and Uranus in our own solar system. The dust rings intrigue astronomers because of what they signify. All dust rings, whether around stars or planets, only remain intact by some mechanism confining the dust. Otherwise, particle collisions would cause the ring to spread both inward and outward until it finally lost its identity. The mechanism holding together this ring is probably the formation of new planets, astronomers believe. Just visible to the naked eye, the star, HR 4796A, is located 220 light-years away in the southern constellation Centaurus.

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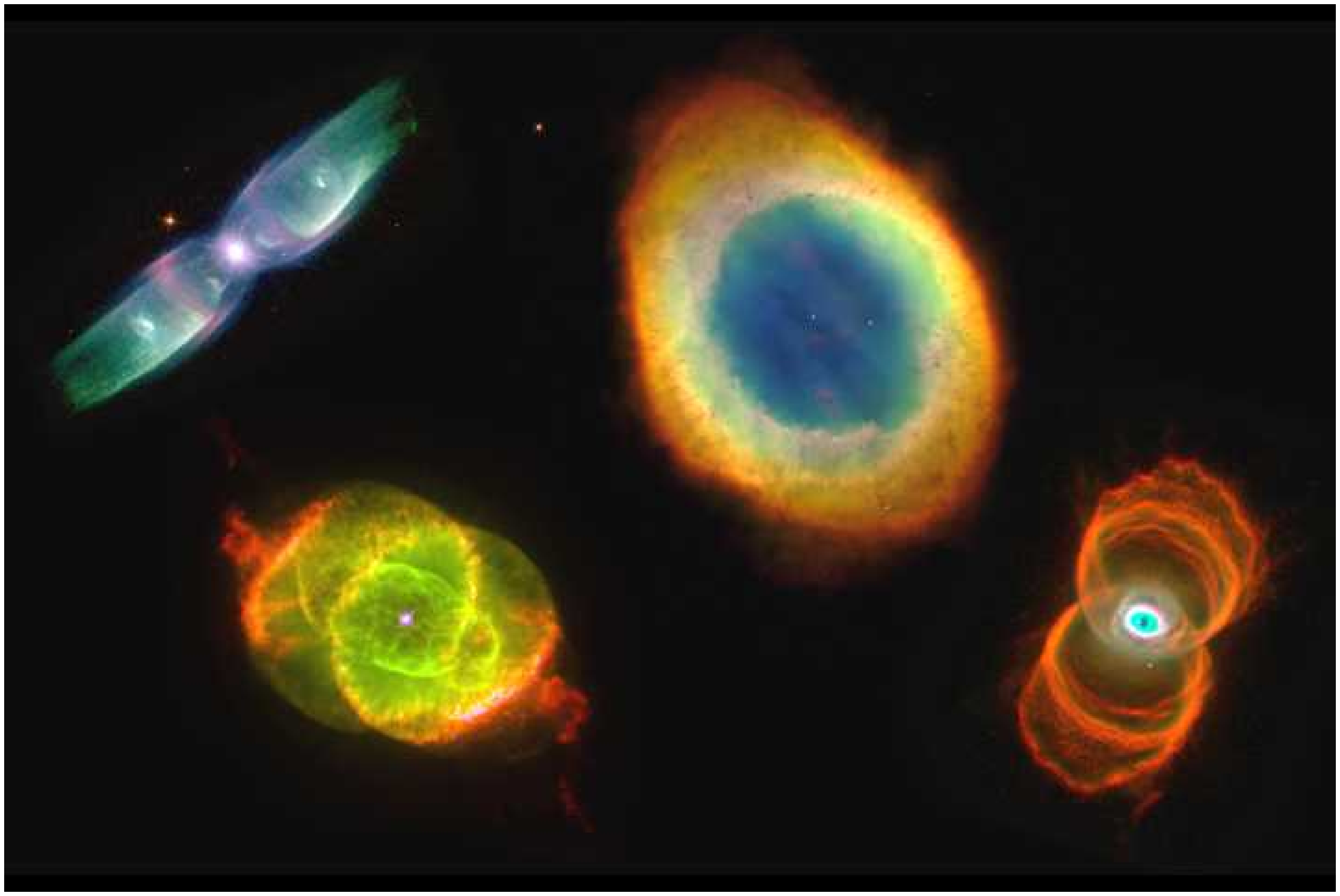

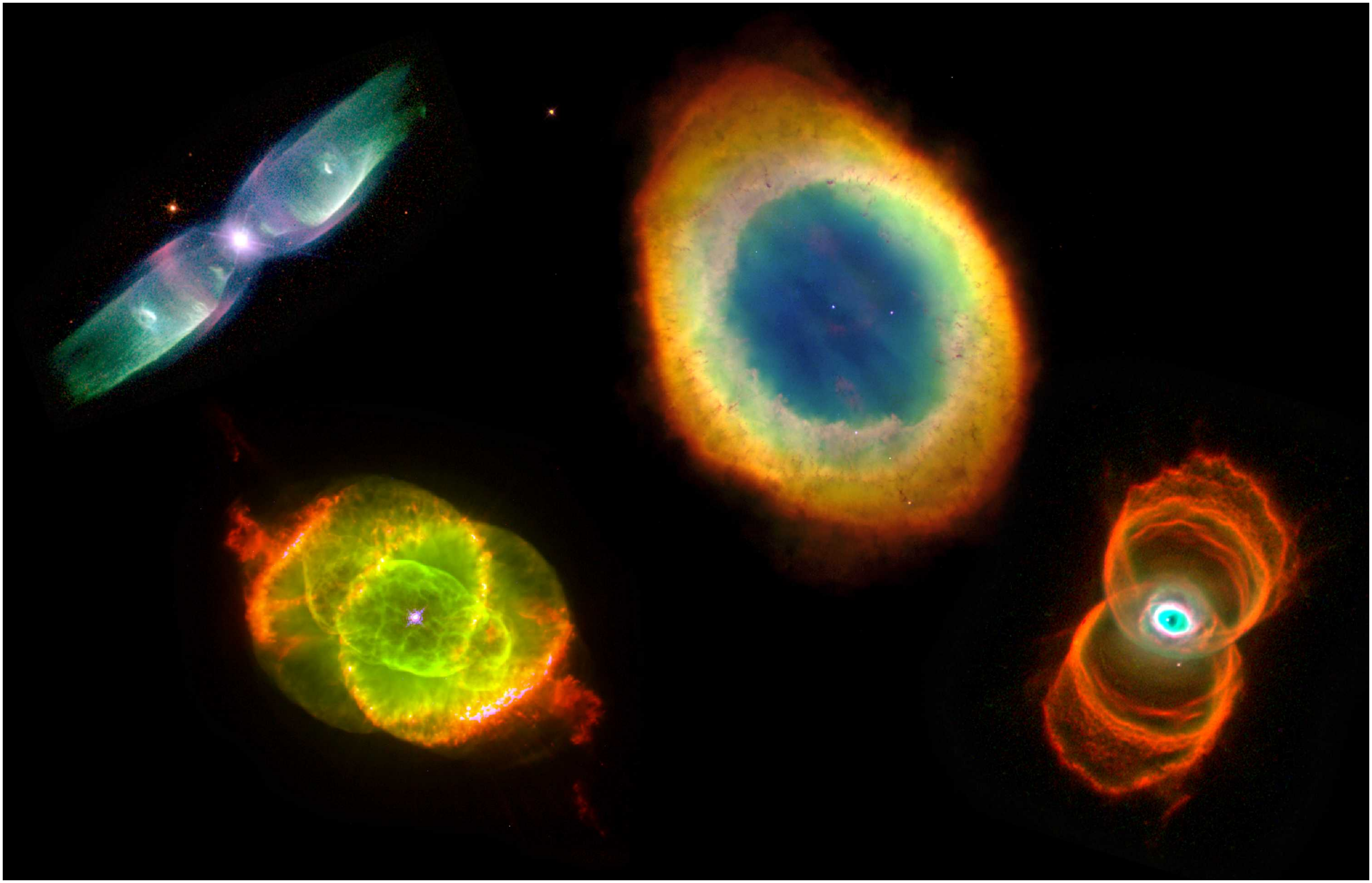

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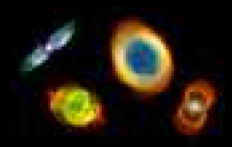
PLANETARY NEBULA GALLERY



BACK

A star's death was once thought to be a simple affair. The star cast off a shell of glowing gas and lived the remainder of its time as a white dwarf. This collection of images, however, is forcing researchers to rethink their theories of how Sun-like stars die. In particular, they believe the stars' intricate patterns, which resemble everything from lawn sprinklers to goblets, may be woven by a star's interaction with unseen companions, including planets, brown dwarfs or smaller stars. The question researchers now ask is how do so-called planetary nebulae (a name that was given them long before astronomers knew that these objects were actually dying stars) shape themselves. Hubble's ability to detect intricate details is giving researchers plenty to digest. From this collection, they found unexplained disks and "donuts" of dust girdling a star, strange glowing "red blobs" placed along the edge of some nebulae and jets of high-speed particles. Researchers say that these images give us a preview of our own Sun's fate some 5 billion years from now.

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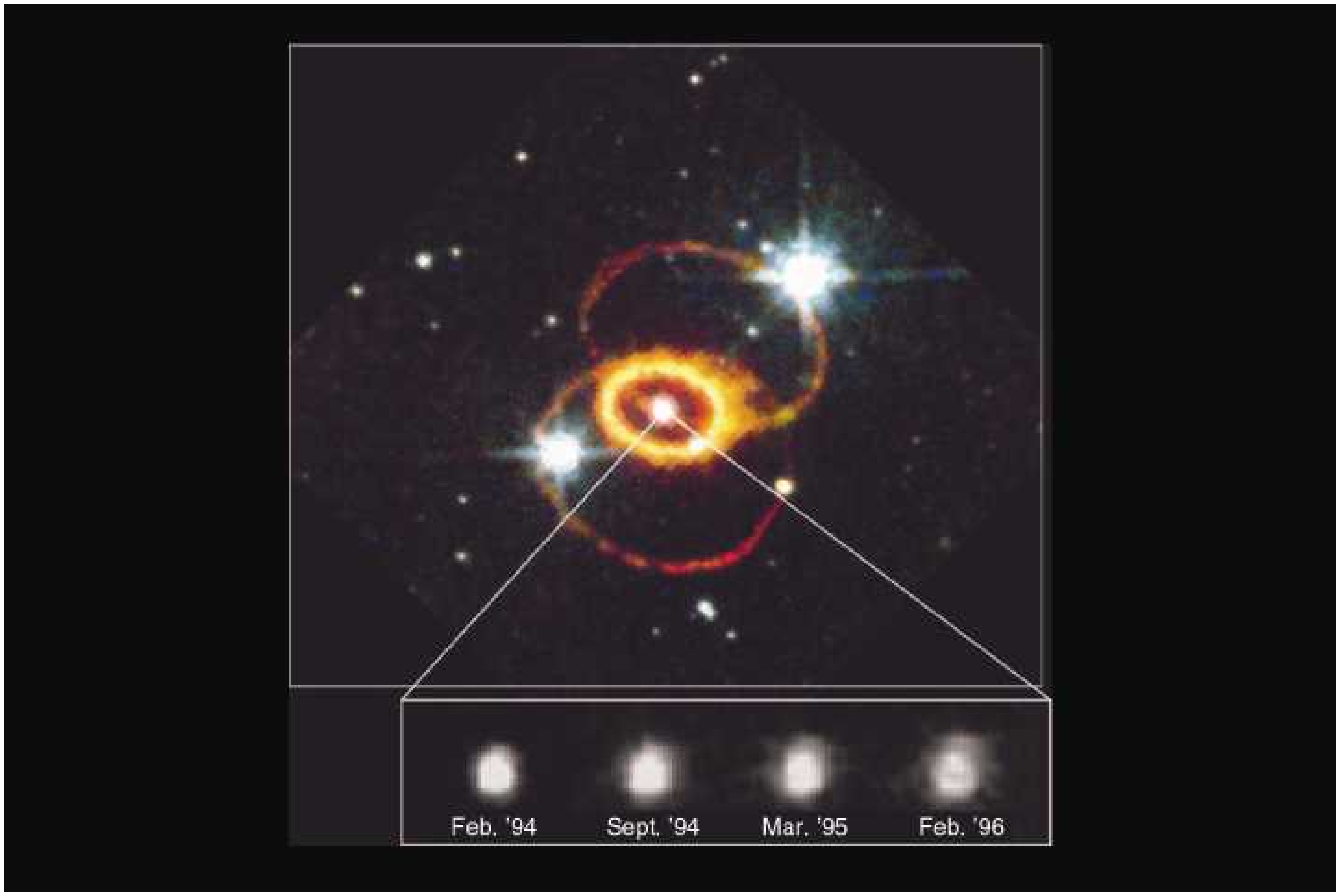
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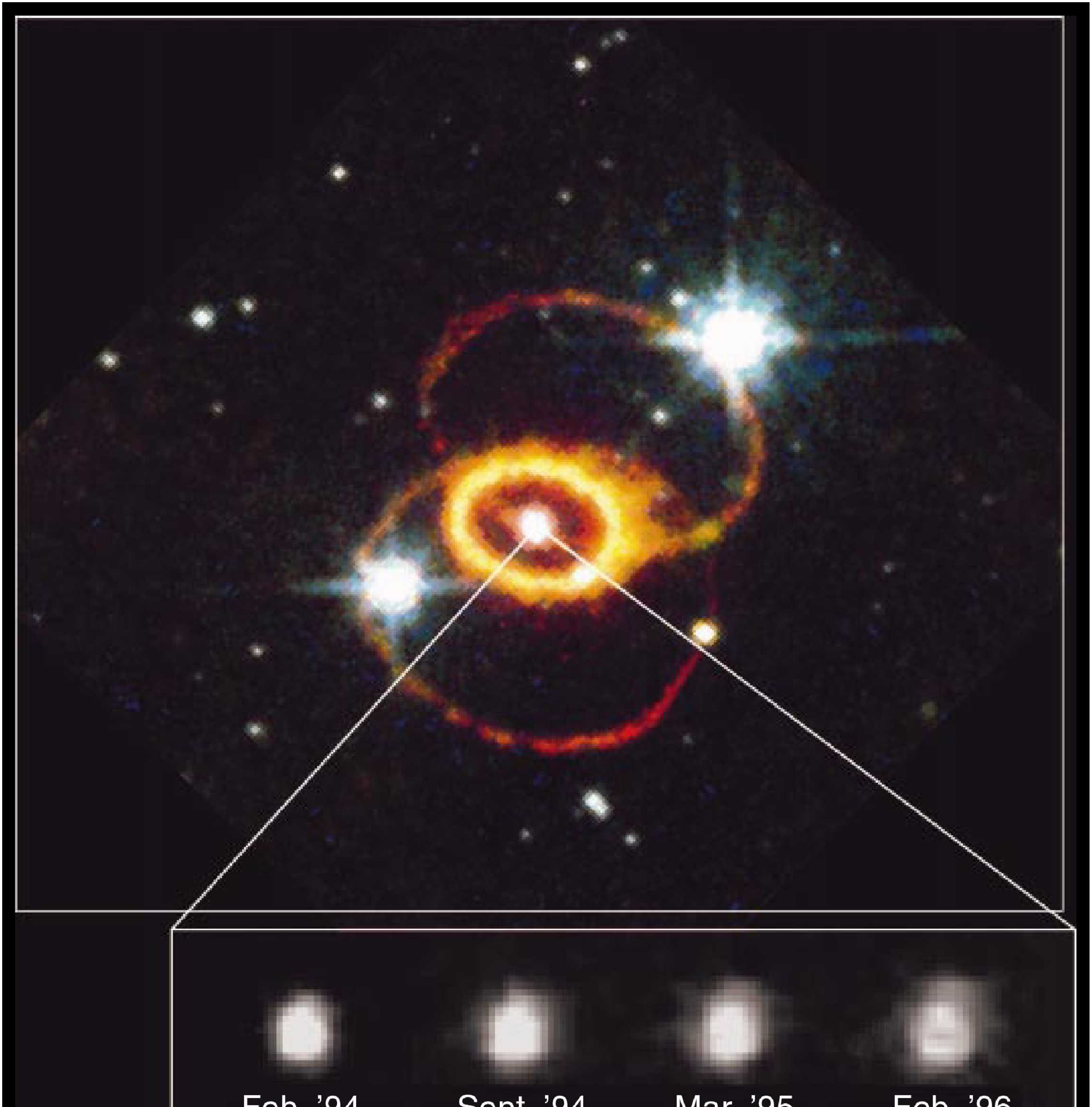
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A DECADE OF DISCOVERY

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BACK

SUPERNOVA 1987A

The brightest supernova in four centuries lit up the southern sky in 1987, but astronomers waited nearly a decade for the ballooning fireball to become large enough–about one-sixth of a light-year–to be resolved from Earth's orbit. With the Hubble Space Telescope astronomers have watched the remnant of the blast develop into a dumbbell-shaped structure consisting of two blobs of debris expanding away from each other at nearly 6 million mph. The structure surprised astronomers. They believe the dim area between the blobs may be related to the equatorial belt of material around the supernova that existed before the star exploded. The ring was illuminated by radiation from the supernova explosion and slowly faded thereafter. However, recently the ring has begun to light up again as debris from the blast crashes into it. The star exploded when its core collapsed and produced a blast wave of neutrinos, which heated the star's inner layers to 10 billion degrees Fahrenheit. This triggered a shockwave that then ripped the star apart and sent the debris hurtling into space. The fireball has since cooled down to a few hundred degrees Fahrenheit, and the debris is now heated by nuclear energy from the decay of the radioactive nuclei produced in the explosion.

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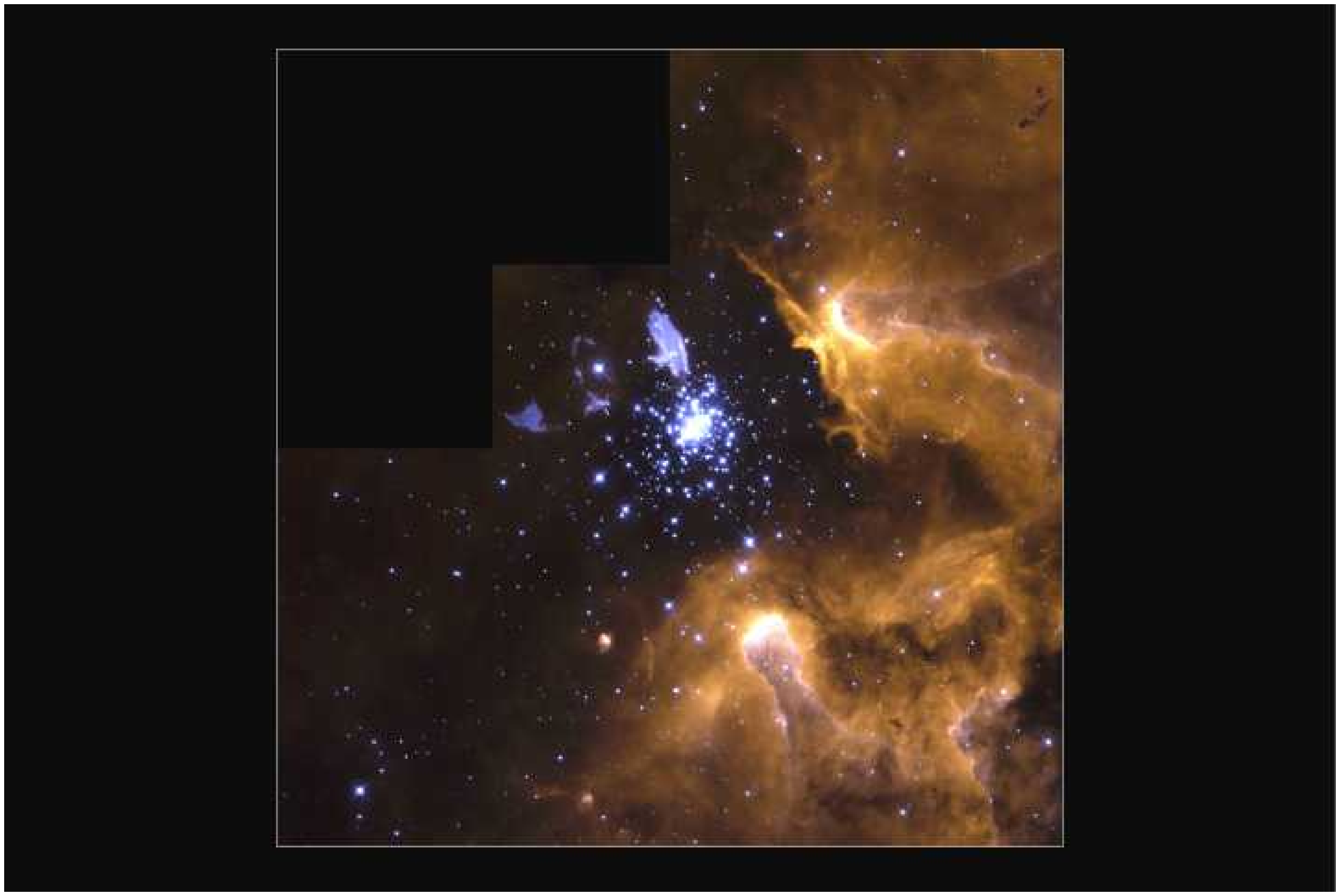

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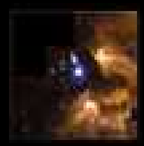

CLUSTER AND NEBULA NGC 3603

The Hubble Space Telescope captures in one single view the entire life cycle of stars. In the upper left of this picture of galactic nebula NGC 3603 is the evolved blue supergiant, called Sher 25. Like the famous 1987A supernova, a unique ring of glowing gas encircles it. The grayish-blue color of the ring and the blobs to the upper right and lower left of the star indicate the presence of chemically enriched material. Near the center, young, hot massive stars dominate the starburst cluster. Meanwhile, the dark clouds at the upper right, which are called Bok globules, probably are in the early stages of star formation. To the lower left of the cluster are two compact, tadpole-shaped emission clouds, which scientists believe may be evidence of protoplanetary disks, which eventually condense to form planets.

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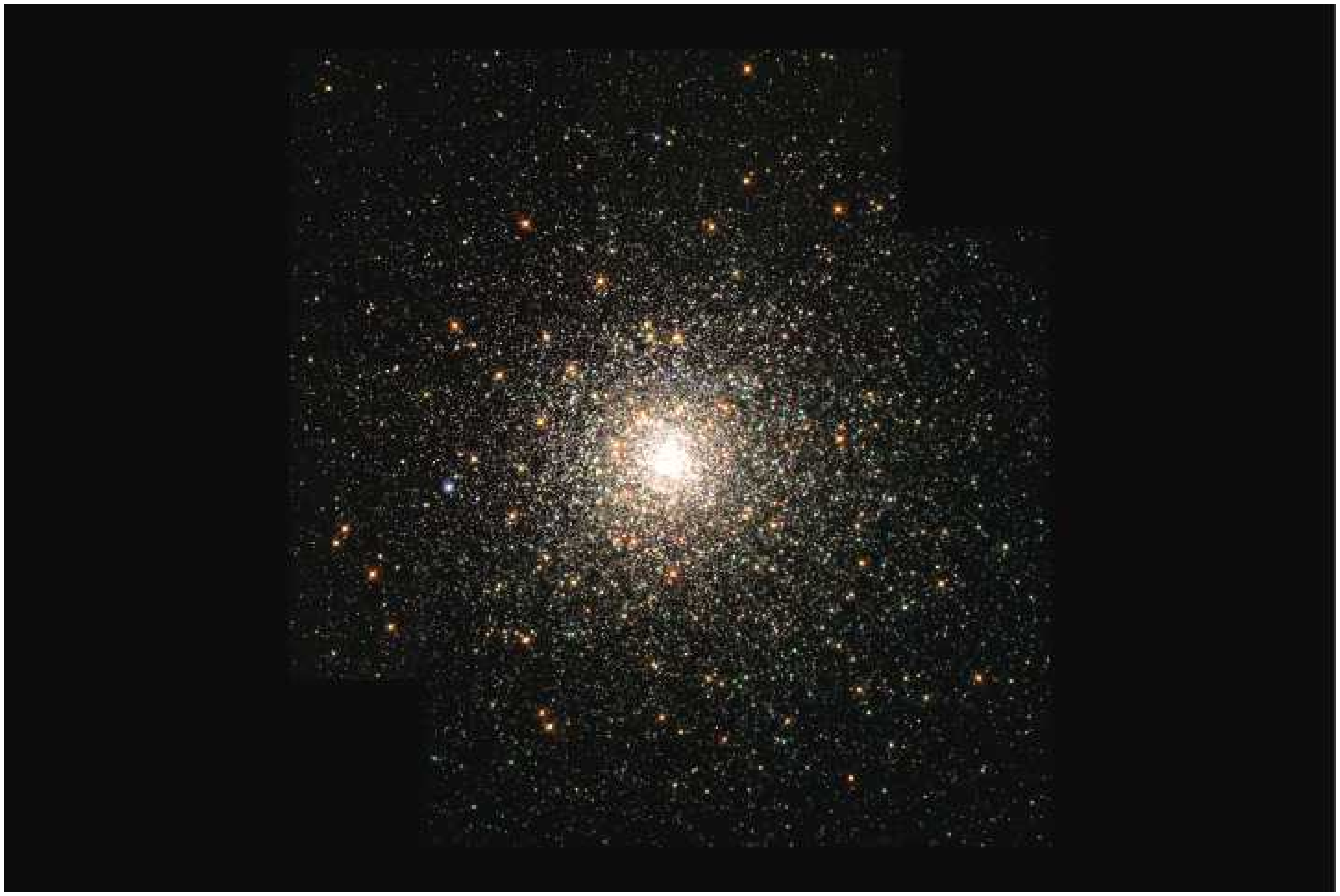

A DECADE OF DISCOVERY

GLOBULAR STAR CLUSTER M80

BACK

Located about 28,000 light-years from Earth, this swarm of stars, known as M80, is one of the densest globular star clusters in the Milky Way. The cluster contains hundreds of thousands of stars, all held together by their mutual gravitational attraction. In addition to being beautiful, clusters such as this one tell us much about stellar evolution and provide a means of measuring the ages of stars. All the stars in a cluster like this one were formed at the same time and so are of the same age. They are among the oldest stars in our galaxy. Yet they cover a range in terms of mass and size. The more massive stars in the cluster burn their nuclear fuel more quickly and evolve into red giants and ultimately white dwarfs. The less massive stars have longer lives and many are still burning their original hydrogen fuel in their central cores, much like our own Sun does.

Hubble is able to resolve individual stars in globular clusters, covering an unprecedented range of mass, size, and degree of evolution, and to accurately measure their brightness and colors. By comparing these accurate measurements to theoretical models describing how stars evolve, Hubble can measure the age of the entire cluster. A lot of work remains to be done. But Hubble's accurate measurements, coupled with recent improvements in the measurement of the clusters' distances, has led to revised estimates of the ages of the oldest stars in our galaxy — about 13-14 billion years.

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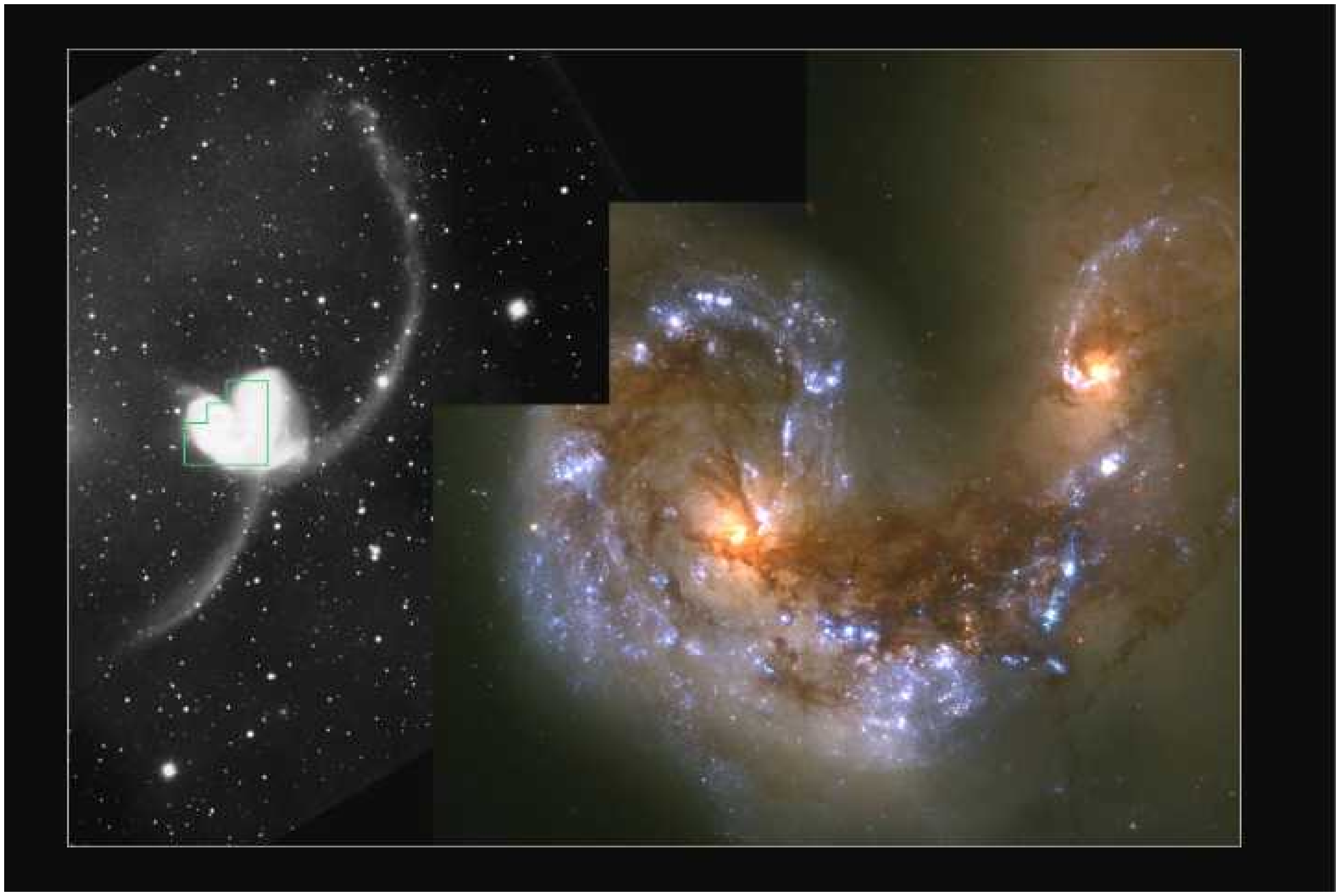

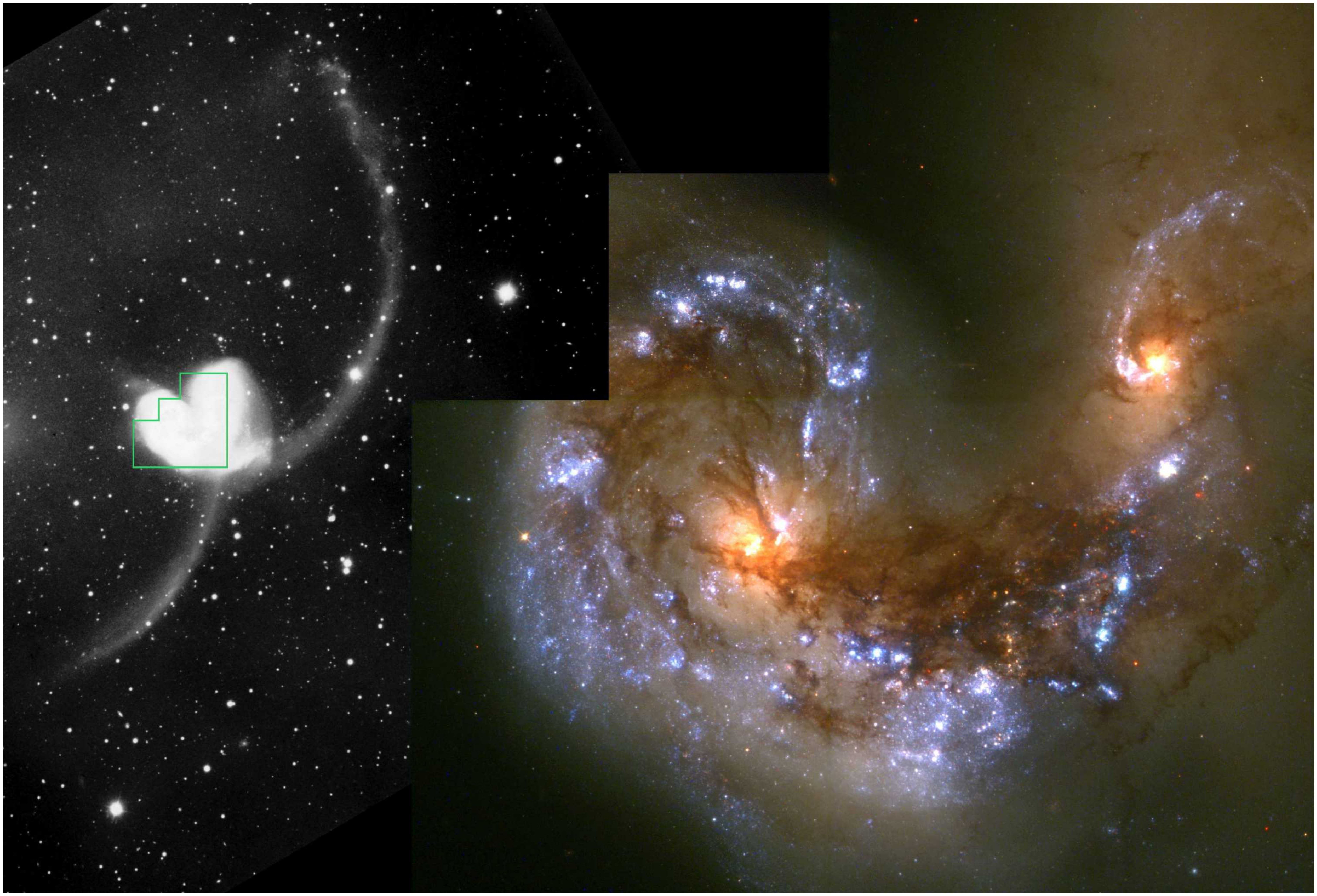

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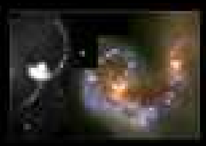

BACK

COLLIDING GALAXIES NGC 4038 AND 4039

Galaxies don't crash into one another as often as they used to. That's why scientists were so thrilled when they discovered this head-on collision and observed the results of the galactic smack-up – the creation of more than 1,000 bright, young star clusters. Star clusters are groups of stars born at almost the same time and place, and live together as units for billions of years because of the mutual gravitational attraction of their member stars. By studying the so-called Antennae galaxies, scientists hope to understand the evolution of colliding galaxies and why some galaxies are spiral shaped and others are elliptical or round. They also hope to get a better idea of how star clusters evolve, too. They once thought that these star-packed objects were the relics of the earliest generations of stars. It now appears that star clusters begin in giant molecular clouds that are squeezed by hot gas heated during a galactic collision. These clouds then light up in a great burst of star formation almost like a string of firecrackers. The Antennae galaxies, located 63 million light-years away in the constellation Corvus, got their unusual name because they have a pair of long tails of luminous matter that look like an insect's antennae.

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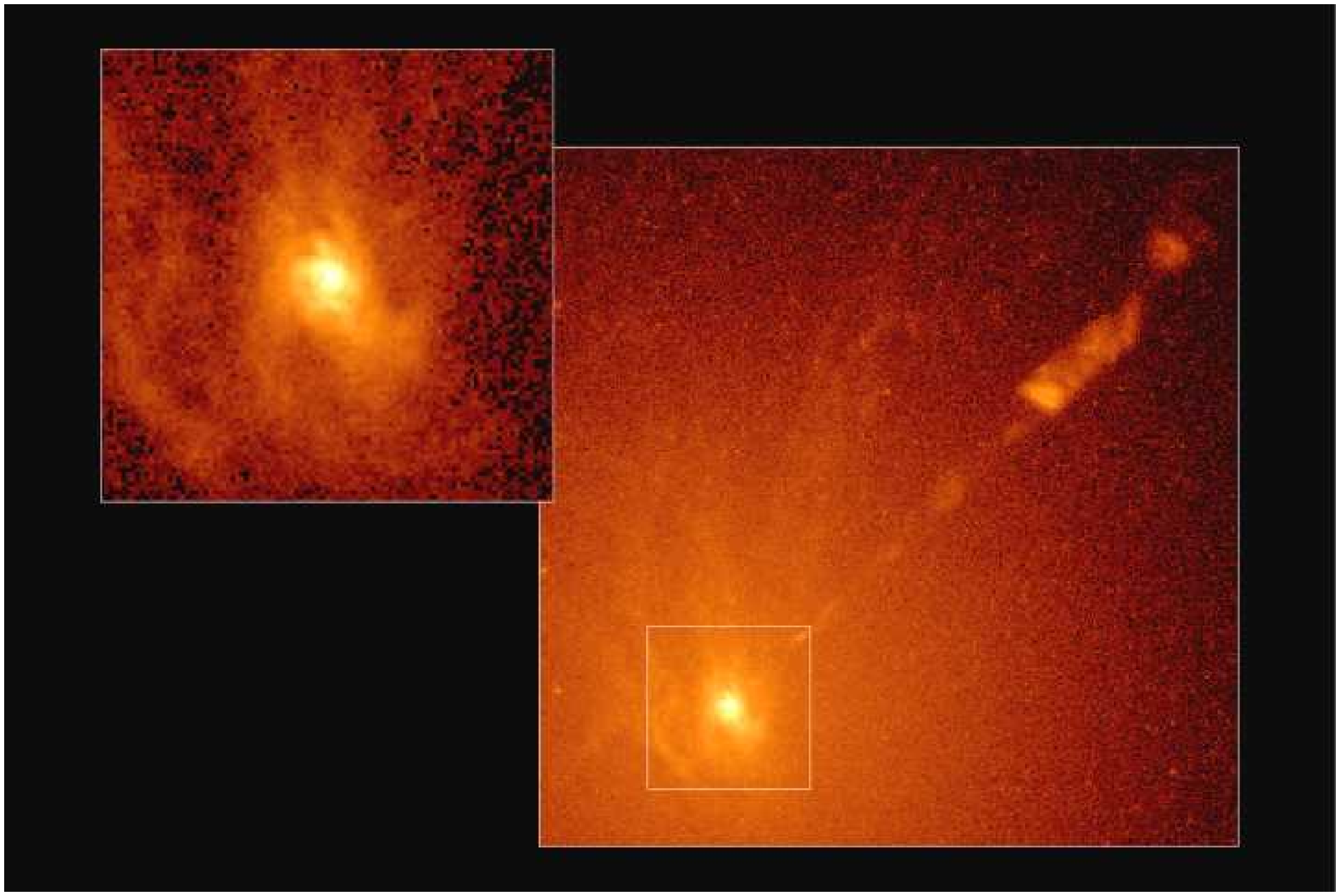

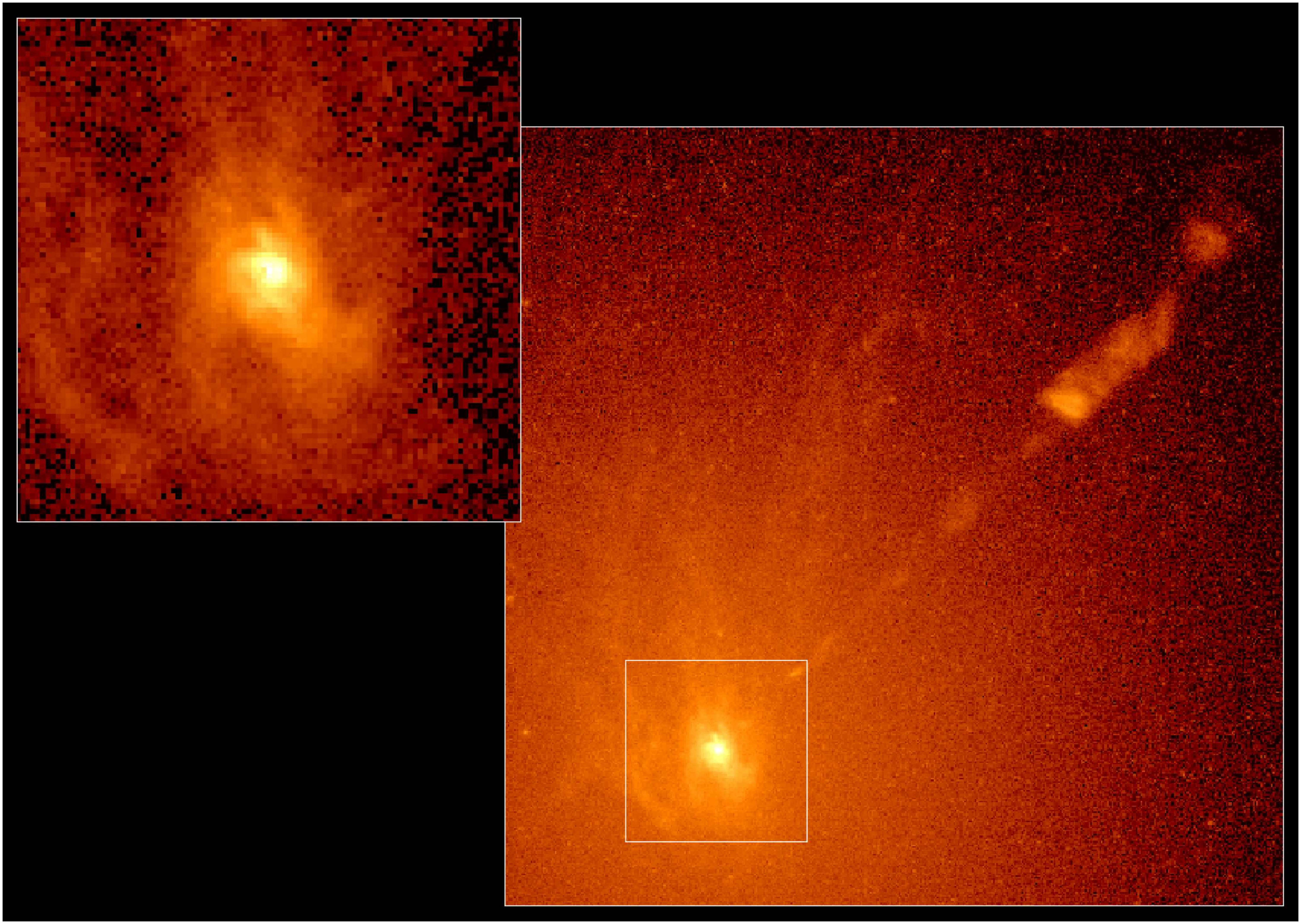

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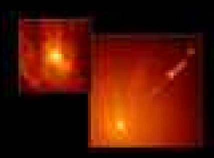

ACTIVE GALAXY M87 JET

BACK

Earlier Hubble observations suggested that a massive black hole lived in the center of M87, but this observation proved it practically beyond doubt. Astronomers discovered that a disk of hot gas in the galactic core is rotating so rapidly that it contains a massive black hole at its hub. A black hole, which Albert Einstein predicted in his general theory of relativity, is an object so massive and compact that nothing can escape its gravitational pull, including light. The object at the center of M87 fits that description. It weighs as much as three billion suns, but is concentrated in a space no larger than the solar system. The region contains only a fraction of the number of stars needed to create such a powerful attraction, leading astronomers to believe that there must be something else there that can't be seen. The giant galaxy is located 50 million light-years away in the constellation Virgo.

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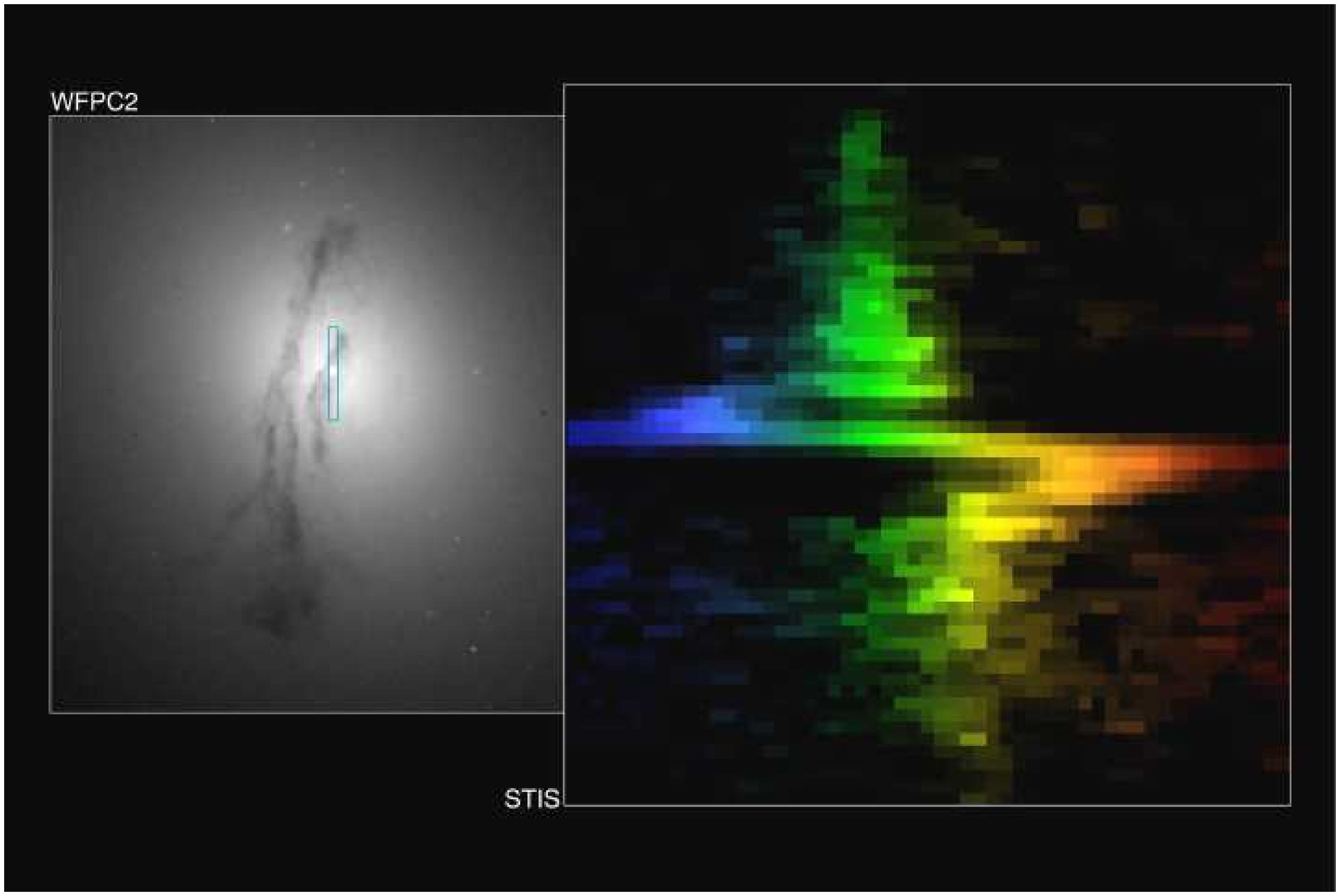
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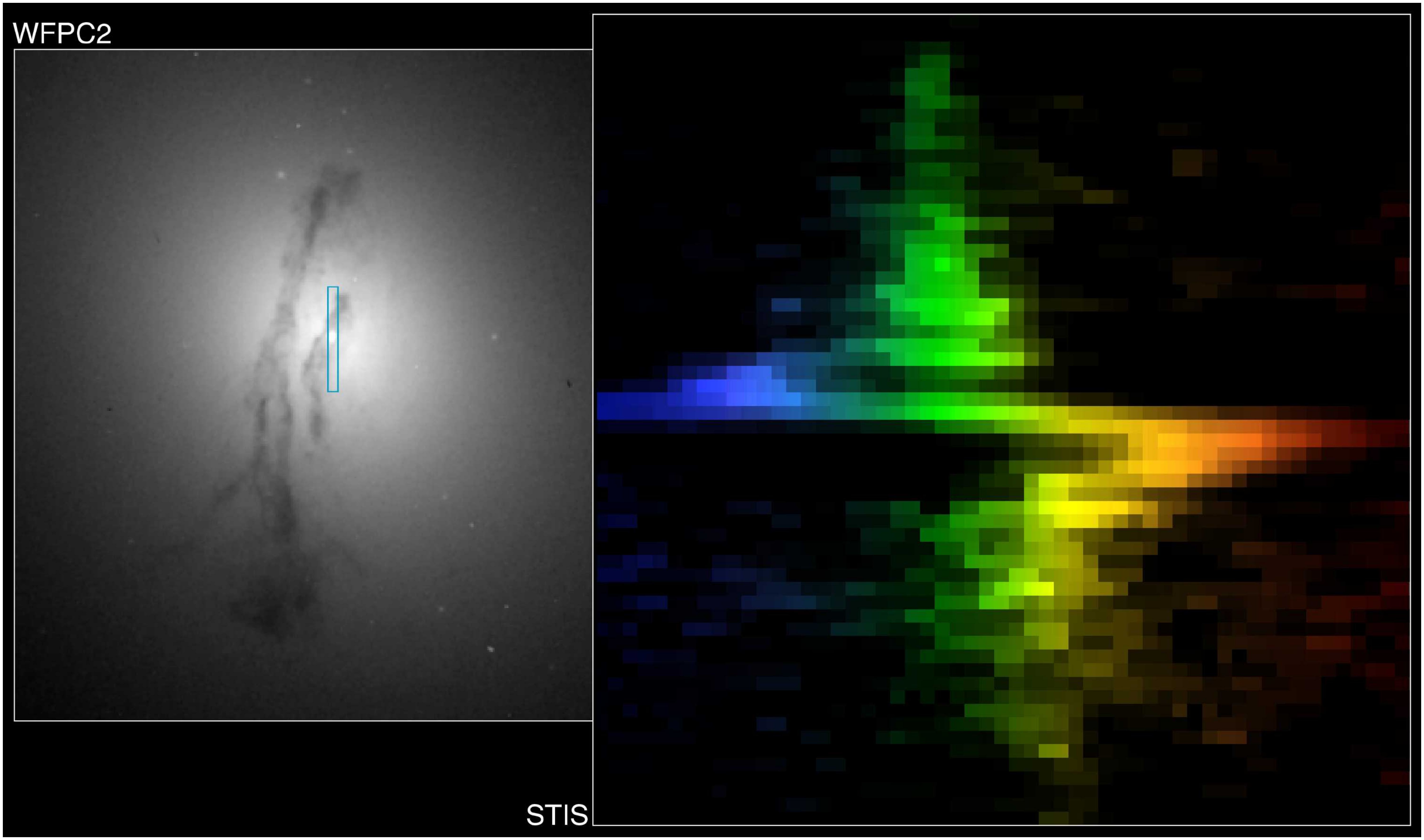
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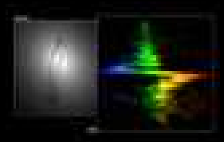
BLACK HOLE IN GALAXY M84



In a single exposure, astronomers were able to confirm the existence of a supermassive black hole in the center of galaxy M84. They did this by using the telescope's more powerful spectrograph to map the rapid rotation of gas at the galaxy's center. The colorful zigzag on the right provides the evidence. If no black hole were present, the line would be nearly vertical. The Space Telescope Imaging Spectrograph measured a velocity of 880,000 mph within 26 light-years of the galaxy's center. This measurement allowed astronomers to calculate that the black hole contains at least 300 million solar masses. M84 is located in the Virgo Cluster of galaxies, 50 million light-years from Earth, and a nearby neighbor to the more massive M87 galaxy, which also contains an extremely massive black hole. The image on the left shows the galaxy's center in visible light.

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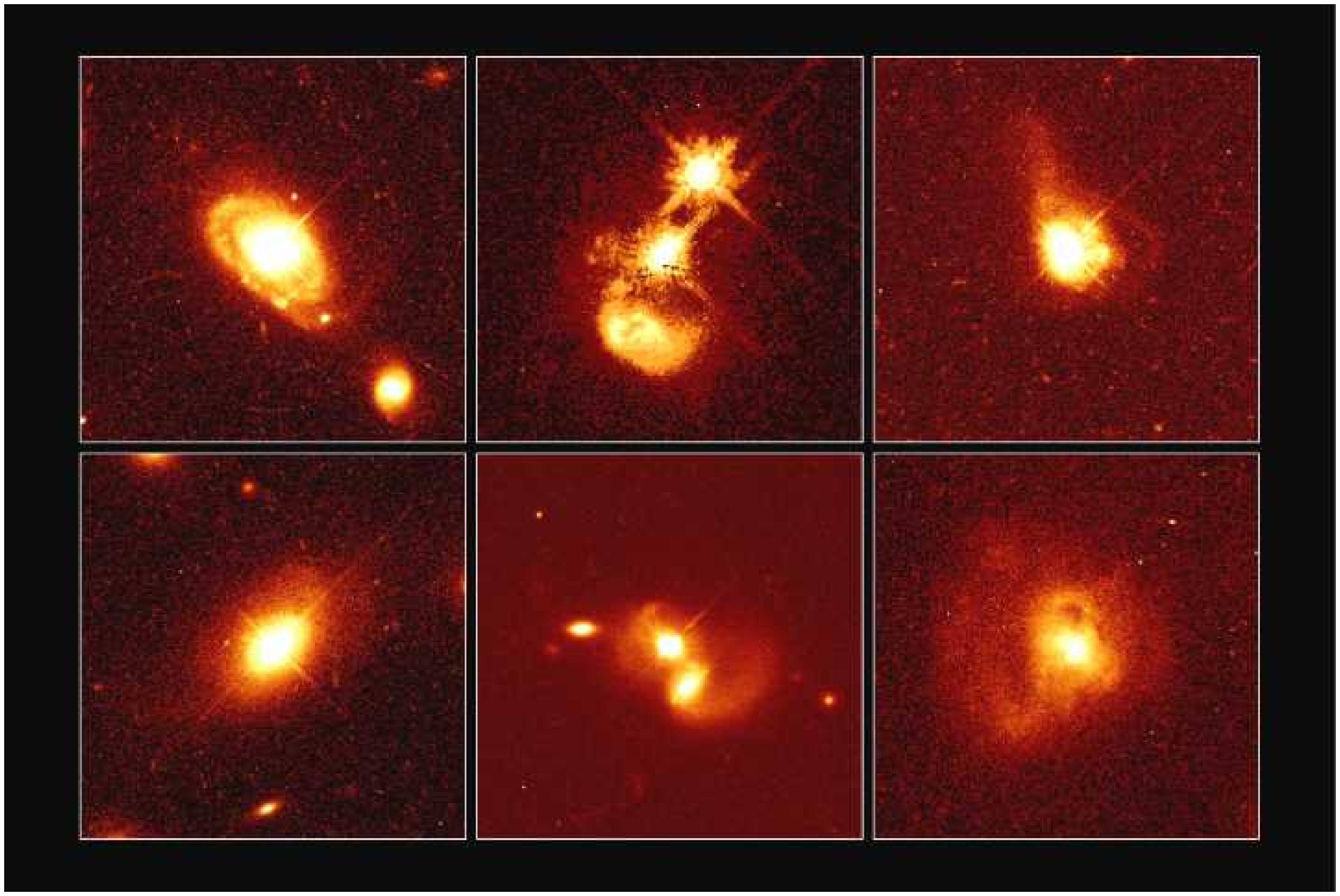

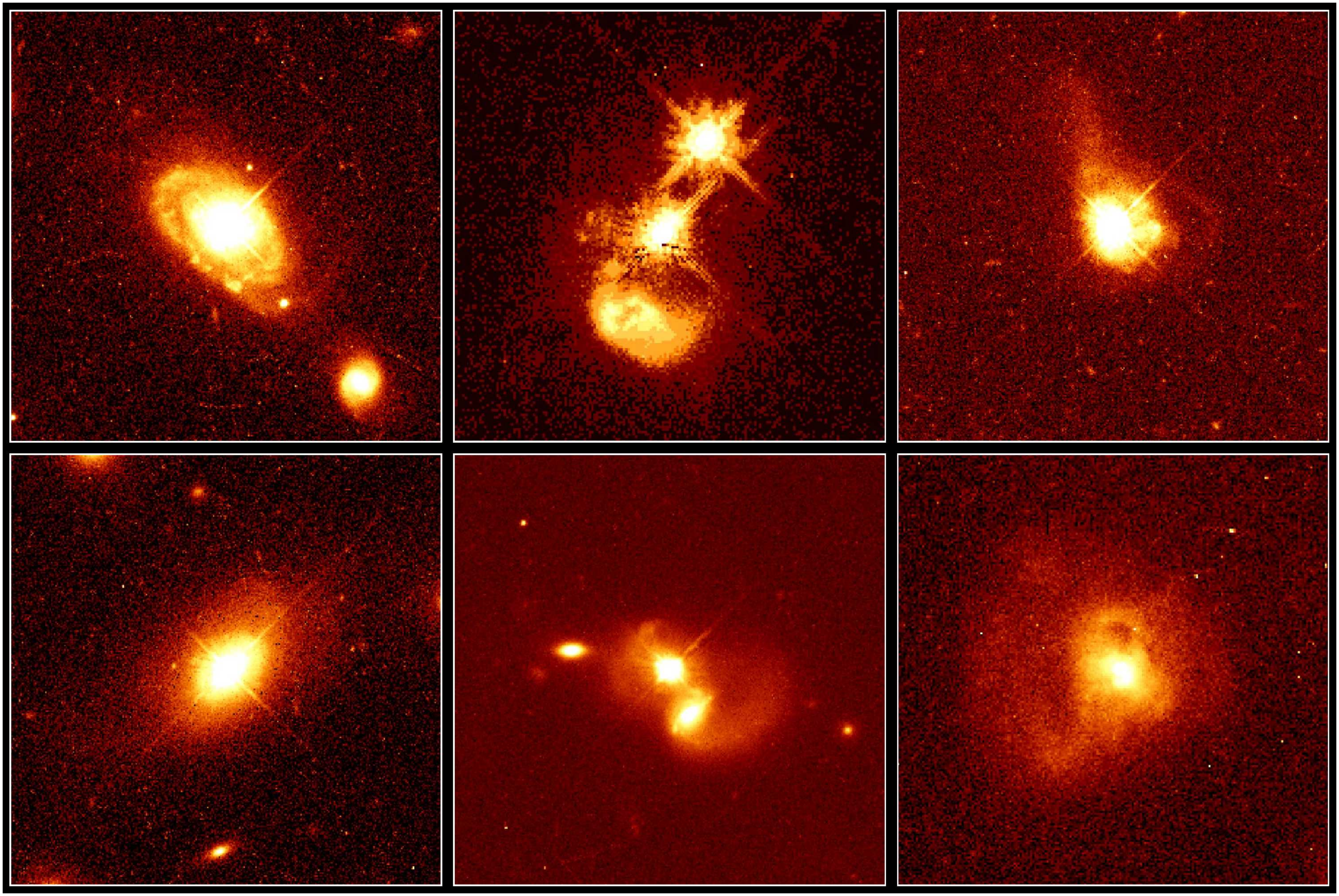

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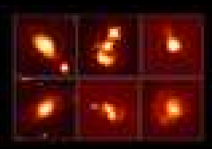
QUASAR HOST GALAXIES



When seen through ground-based telescopes, quasars are compact, mysterious light sources that resemble stars, yet they are billions of light-years away and several hundred billion times brighter than the average star. Some of these objects can emit the energy output of 10 billion suns. Given the incredible energy output, astronomers believe that quasars, which is short for quasi-stellar radio sources, turn on when a massive black hole at the center of a galaxy feeds on gas and stars. As the matter falls into the black hole, intense radiation is emitted. Eventually, the black hole will stop emitting radiation once it consumes all nearby matter. These Hubble images show different quasar homes, which range from normal to highly disturbed galaxies. The top left image, for example, is of a normal spiral galaxy, while the bottom right depicts the merger of two galaxies. Both quasars are more than a billion light-years from Earth.

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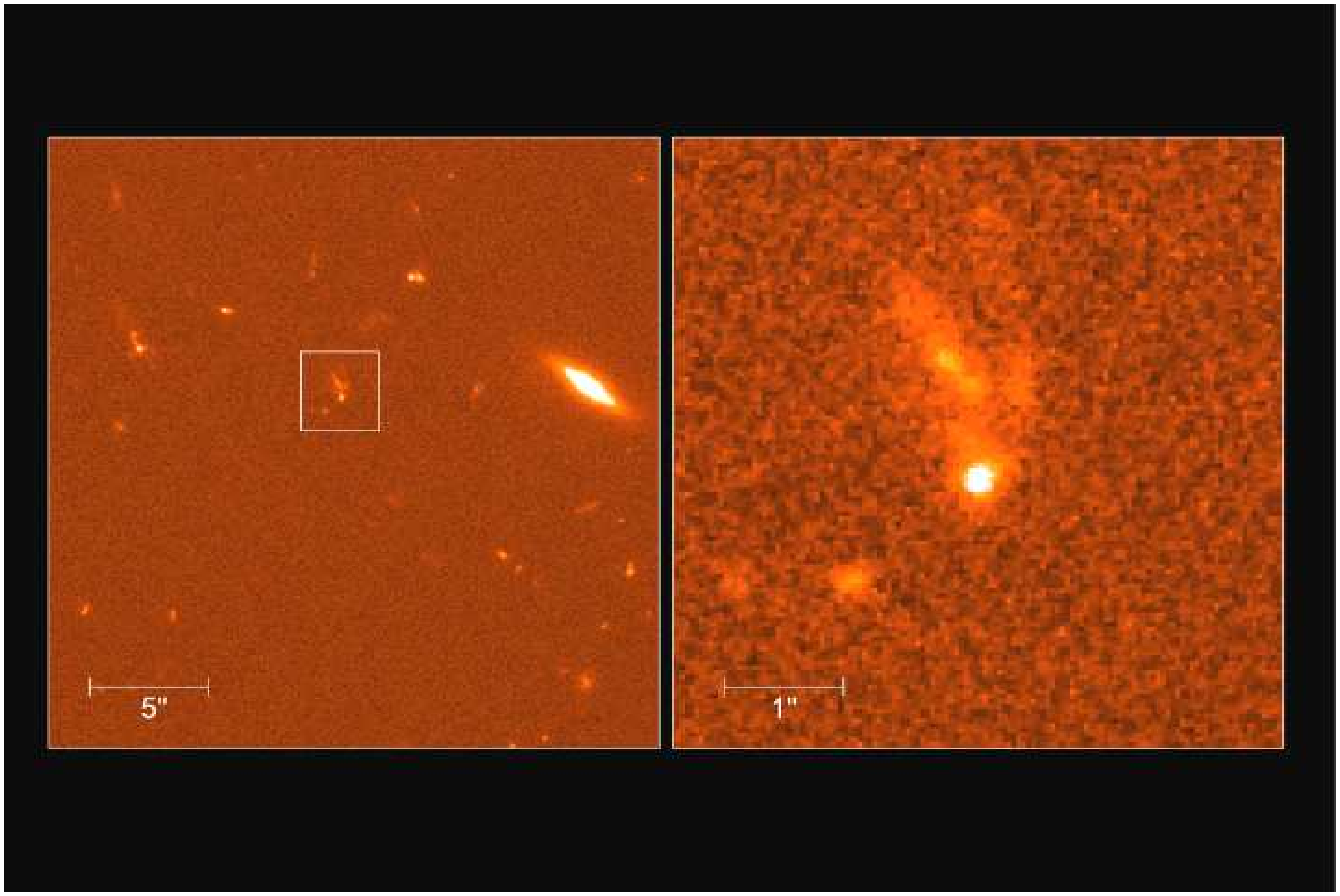

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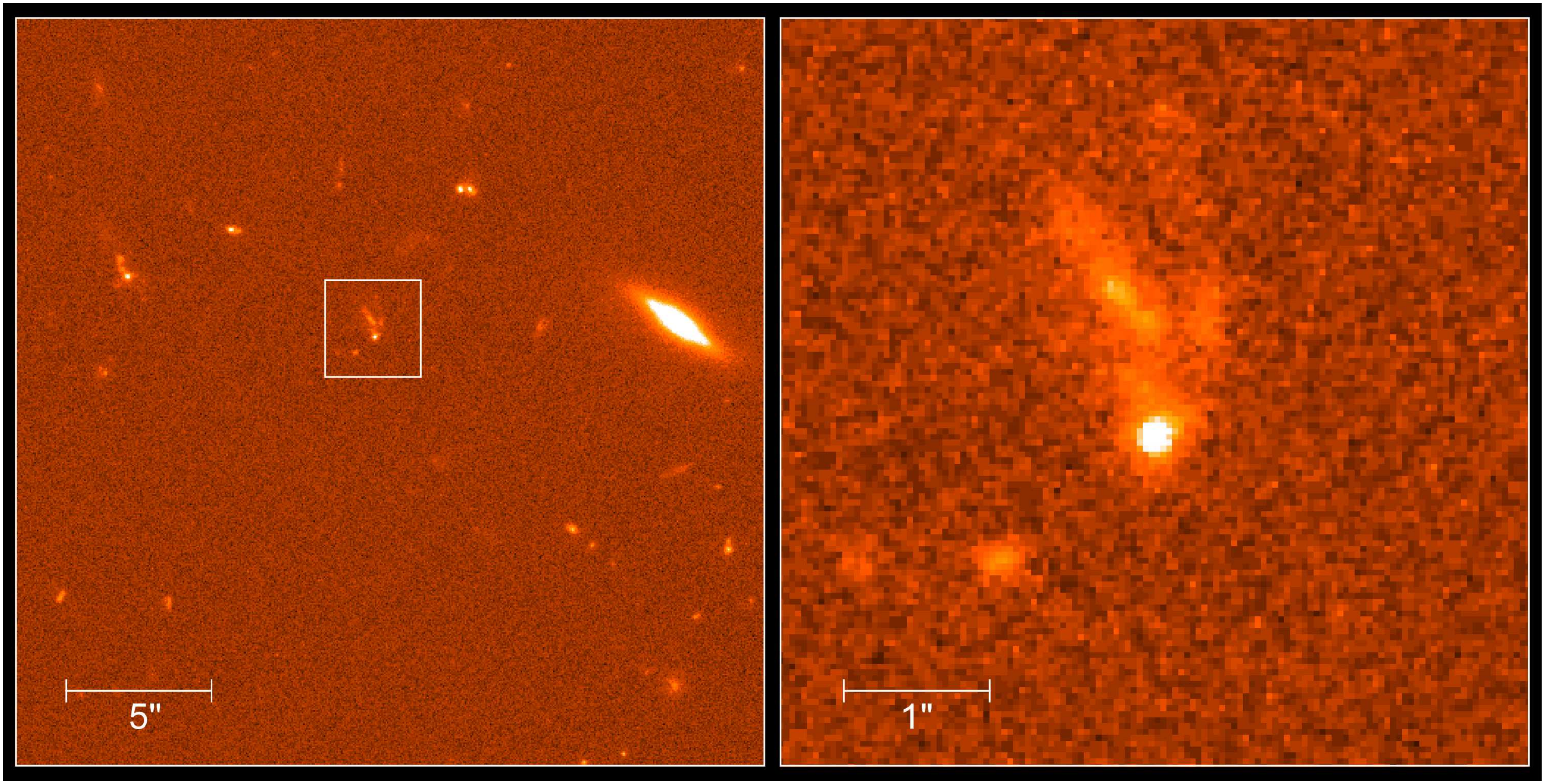
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TELESCOPE & SCIENCE
PHOTOS
VIDEO
THE VAULT

BACK

GAMMA RAY BURST GRB990123

Astronomers have known about gamma-ray bursts for more than 20 years; however, tracking them has always been difficult because they happen without warning and typically last for only a few seconds and come from any direction in the sky.

Within only the past couple years, astronomers have found that these mysterious bursts of radiation are extremely far away and are caused by tremendous, still unexplained explosions. But they got their first break in early 1999. Using orbiting observatories and ground-based telescopes, astronomers tracked the visible glow of the most energetic gamma-ray burst ever recorded. For a brief moment, the light from the blast was equal to the radiance of one million galaxies.

When the Hubble Space Telescope observed the target a few days after the burst (left image), the object had already faded to one four-millionth of its original brightness. The telescope captured the fading fireball embedded in a galaxy located two-thirds of the way to the horizon of the observable universe. Further Hubble observations showed that the galaxy was neither a classic spiral nor an elliptical. It looked distorted as if its shape had been changed due to a collision with another galaxy, which would induce rapid star birth. The observations support the idea that these mysterious powerful explosions happen where vigorous star formation takes place.

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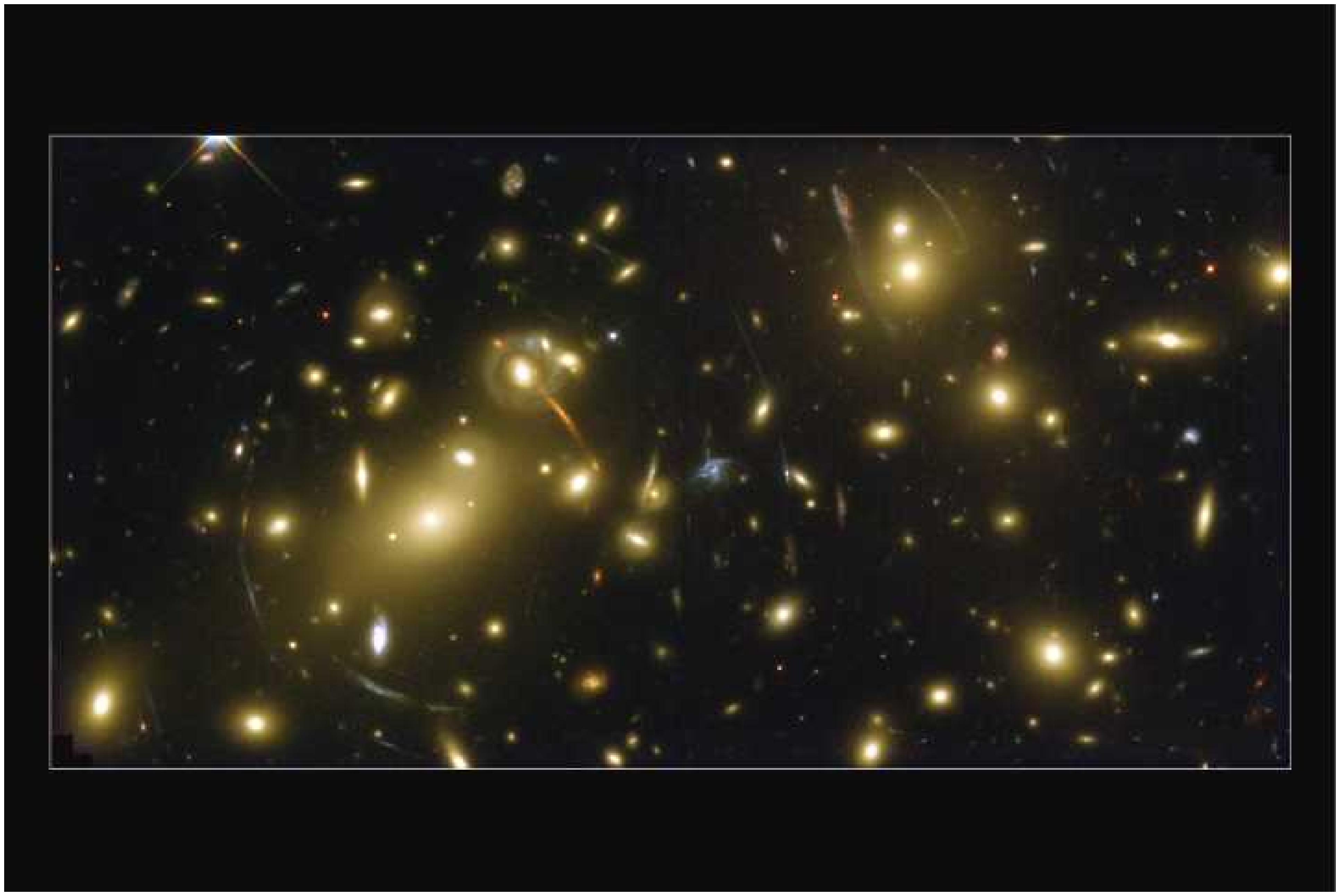

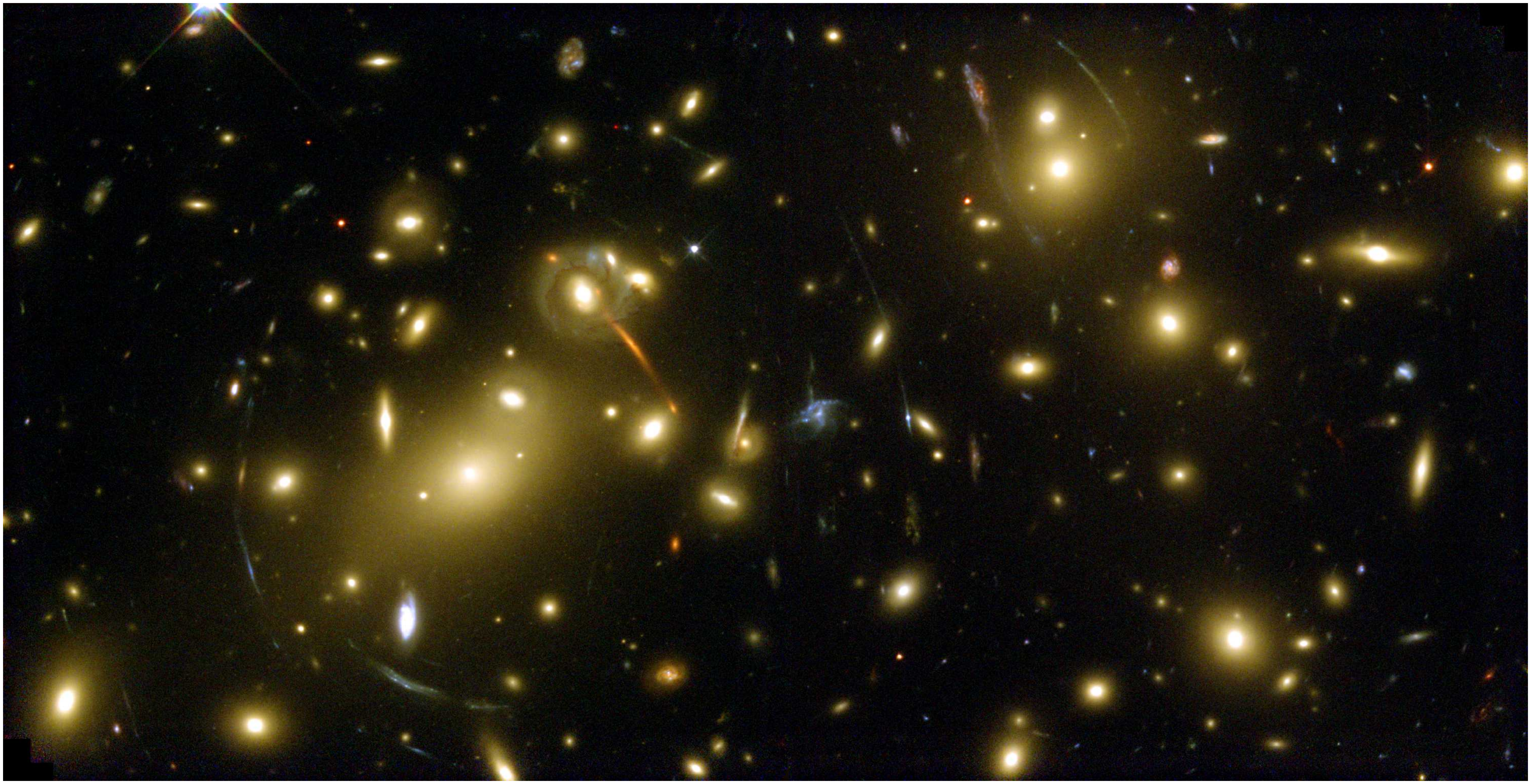

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GRAVITATIONAL LENSING IN GALAXY CLUSTER ABELL 2218

BACK

Abell 2218, an enormous cluster of galaxies that resides in the constellation Draco some 2 billion light-years from Earth, is so massive that its gravitational field magnifies, brightens, and distorts the light of more distant objects. The phenomenon, known as a gravitational lens, is evident by the arc-shaped patterns found throughout the Hubble image. These "arcs" are actually distorted images of very distant galaxies, which lie five to 10 times farther than Abell 2218. This distant population existed when the universe was just a quarter of its current age. The tiny red dot just left of top center also intrigues researchers. They believe it may be an extremely remote object made visible by the cluster's magnifying powers. This is the second time Hubble observed this cluster. In 1994, scientists analyzed a black-and-white Hubble image and discovered more than 50 remote, young galaxies. The color imagery shown here is even more useful. Colors yield clues to ages, distances, and temperatures of stars.

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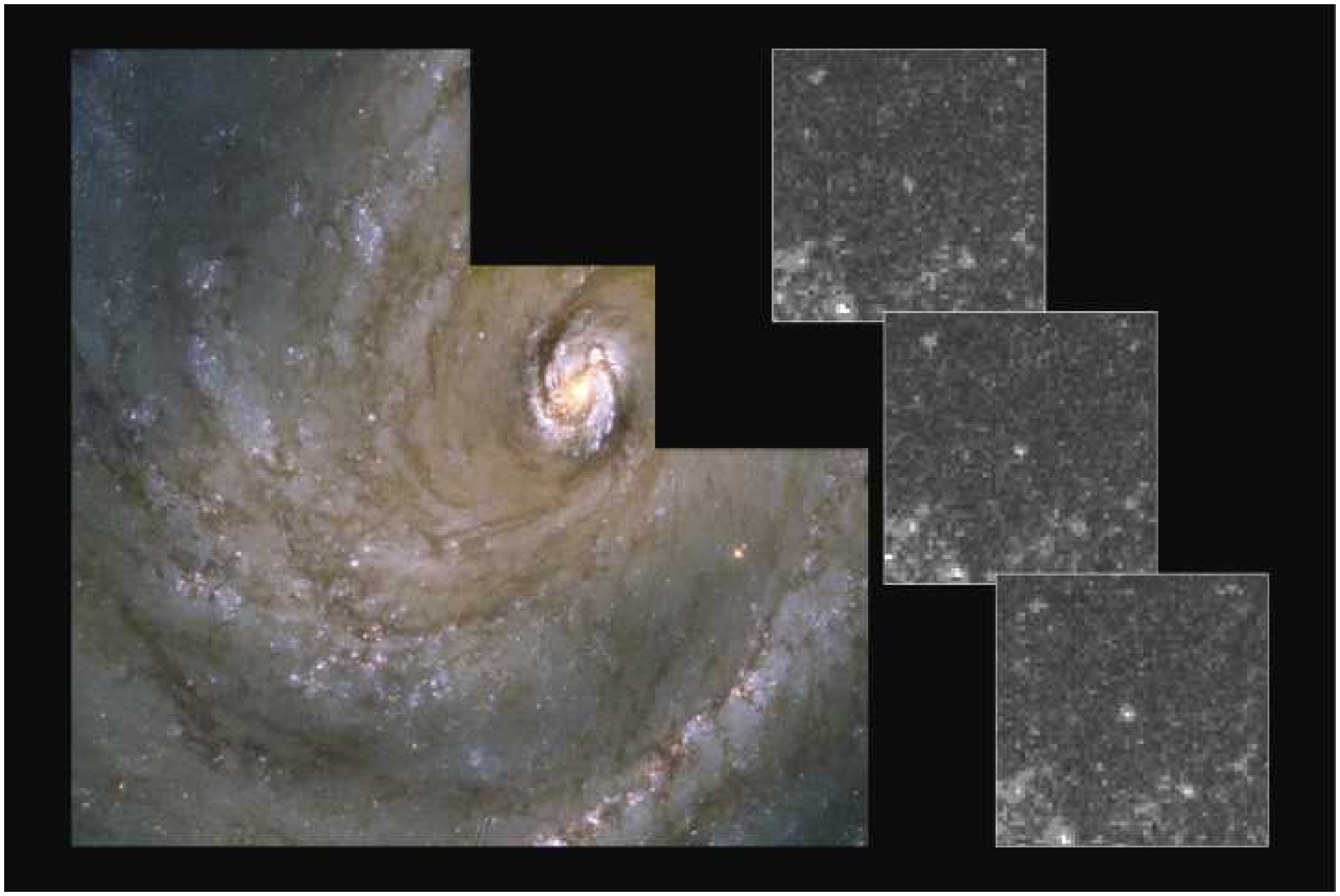

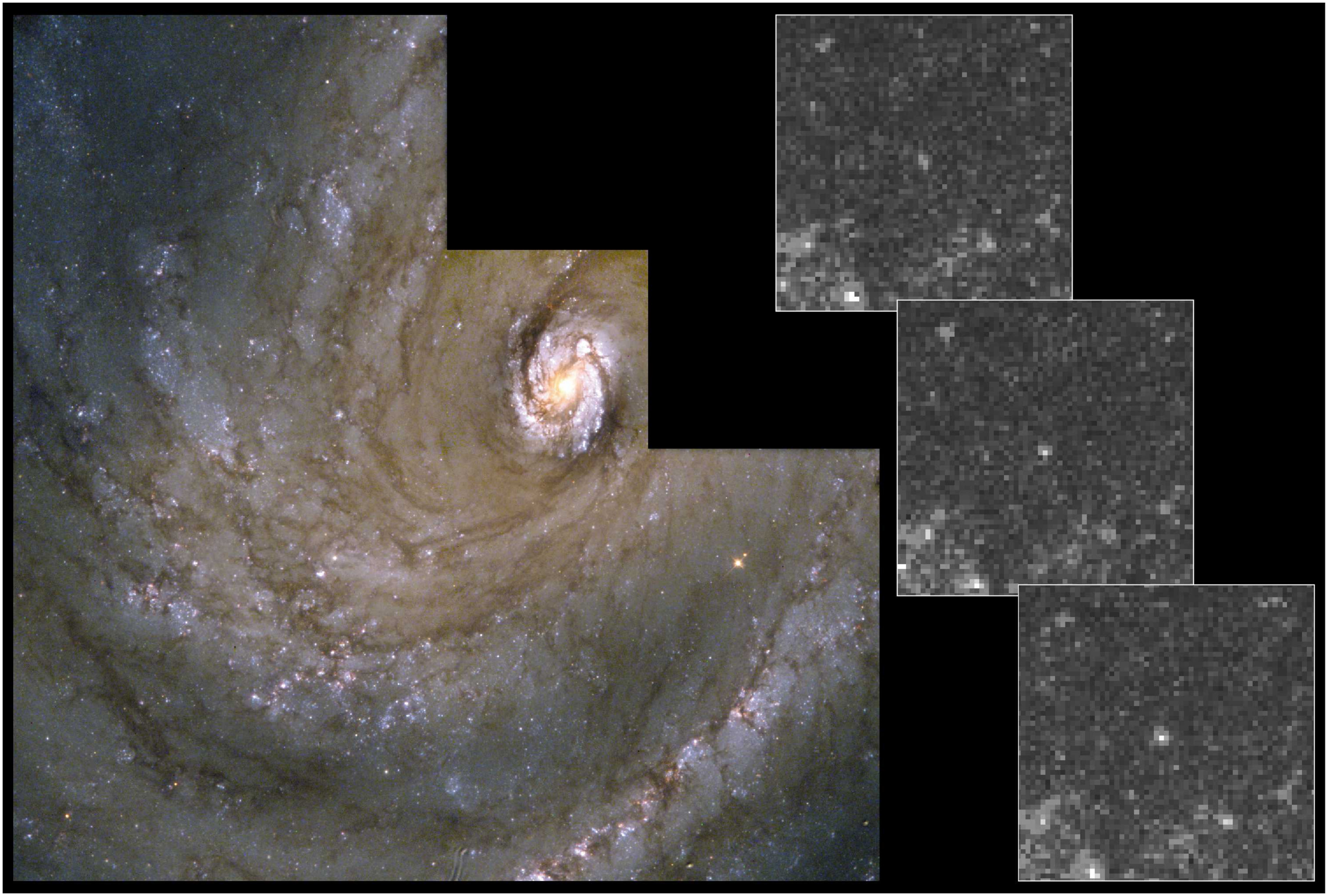

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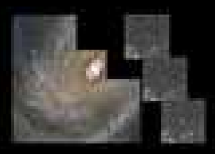

CEPHEID VARIABLE STARS IN GALAXY M100

BACK

M100, a majestic spiral in the Virgo Cluster of Galaxies, contains a rare class of pulsating stars called Cepheid variable stars. Cepheids, which Hubble detected within M100's spiral arms, are reliable cosmic distance mileposts. This is demonstrated in the top three frames of this image. The star in the center of each box changes brightness. The interval it takes for the Cepheid to complete one pulsation is a direct indication of the star's intrinsic brightness. This value can then be used to make a precise measurement of the galaxy's distance, which turns out to be 56 million light-years, making M100 the most distant galaxy in which Cepheids have been measured accurately. By understanding M100's distance from Earth, astronomers can calculate how fast the universe is expanding, which is crucial for understanding the age and size of the universe.

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SPIRAL GALAXY NGC 4414

In 1995, Hubble observed this majestic spiral galaxy, known as NGC 4414, as part of a key astronomical mission to accurately determine distances of many galaxies from Earth. The key was to find stars that vary in brightness. Called Cepheids, astronomers use these stars as standard distance indicators. Knowing distances allows astronomers to more accurately determine the universe's rate of expansion. This value is used to calculate distances, sizes, and the luminosity of other objects in the universe, as well as the age of the universe itself. However, the observation was incomplete. Given the galaxy's very large size, Hubble could only view half the galaxy, requiring a return visit to capture the other half. In 1999, the telescope did just that, producing this stunning, full-color portrait. The new image shows that the central region of the galaxy is typical of most spiral-shaped galaxies: it contains mostly yellow and red stars, an indication that they are much older than the blue-colored stars residing in the galaxy's spiral arms. The arms also are rich in interstellar dust, which is seen as dark patches and streaks silhouetted against the starlight.

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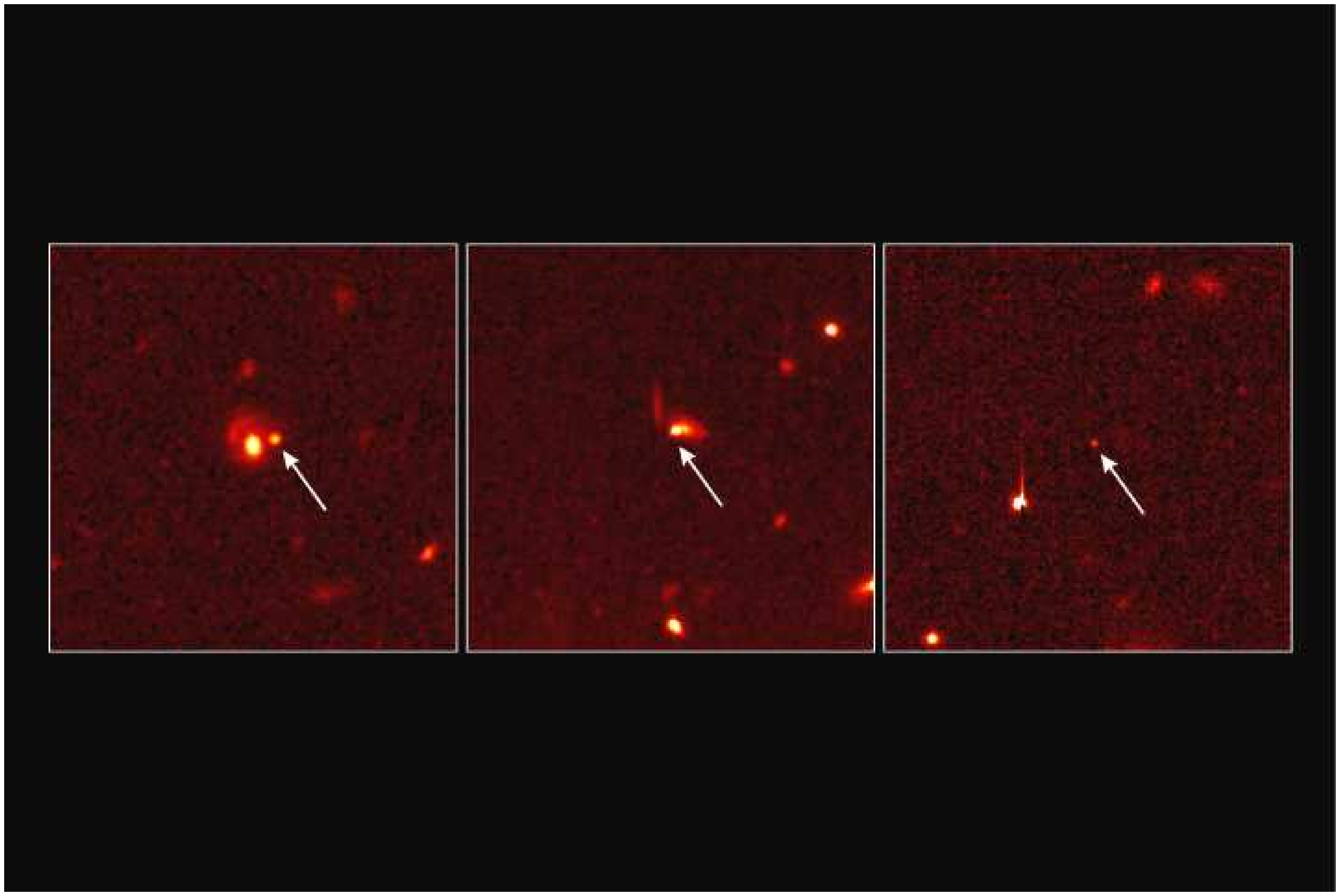

A DECADE OF DISCOVERY

BACK

DISTANT SUPERNOVAE

Researchers are studying very distant supernovae to determine whether the expansion of the universe was decelerating long ago but now is accelerating. Between May and June 1997, Hubble observed the three supernovae to measure their brightness and create a light curve. Researchers then used the light curve to make an accurate estimate of the distances to the supernovae. They combined the estimated distance with the measured velocity of the supernova's host galaxy to determine the expansion rate of the universe in the past (5 to 7 billion years ago) and compare it with the current rate. SN 1997ck (right) exploded when the universe was half its current age, erupting 7.7 billion years ago making it the most distant supernovae ever discovered; the other two supernovae – SN 1997cj (left) and SN 1997ce (center) – exploded about 5 billion years ago.

BACK

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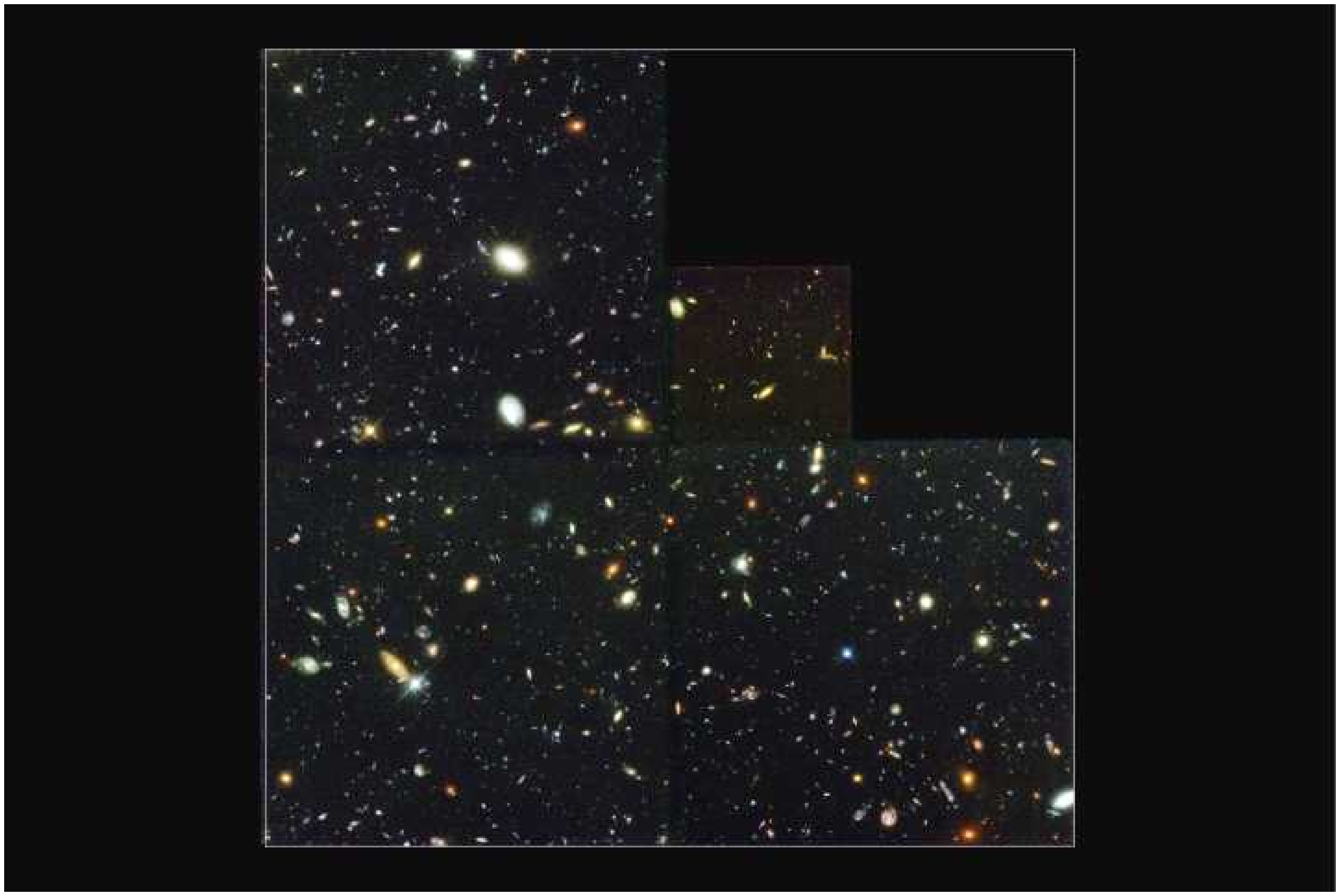

A DECADE OF DISCOVERY

Investigating Space
The Hubble Story

HUBBLE DEEP FIELD NORTH

BACK

In late 1995, researchers trained the Hubble Space Telescope on a speck-sized spot in the sky to produce this "deep field" view of the heavens – the most detailed optical view ever taken of the universe. Although the10-day observation covers just a fraction of the sky, researchers consider it fairly representative of the universe, which statistically looks largely the same in all directions. In this particular view, researchers found a bewildering assortment of at least 1,500 galaxies at various stages of evolution. Most are nearly four billion times fainter than can be seen with the human eye, and date back to nearly the beginning of time. In that sense, this image is like using a time machine to look into the past to witness the early formation of galaxies, perhaps less than one billion years after the universe's birth in the Big Bang.

BACK

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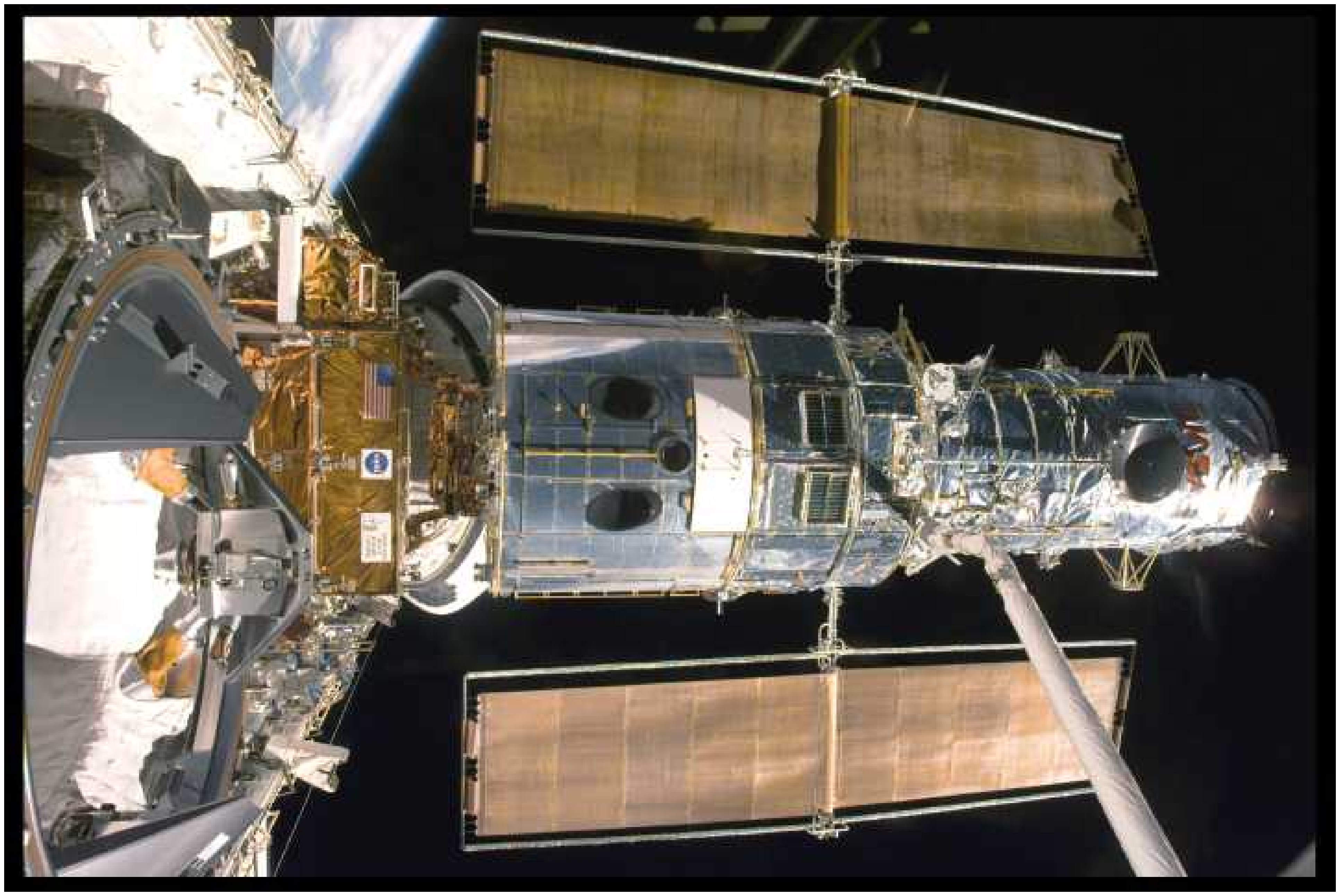

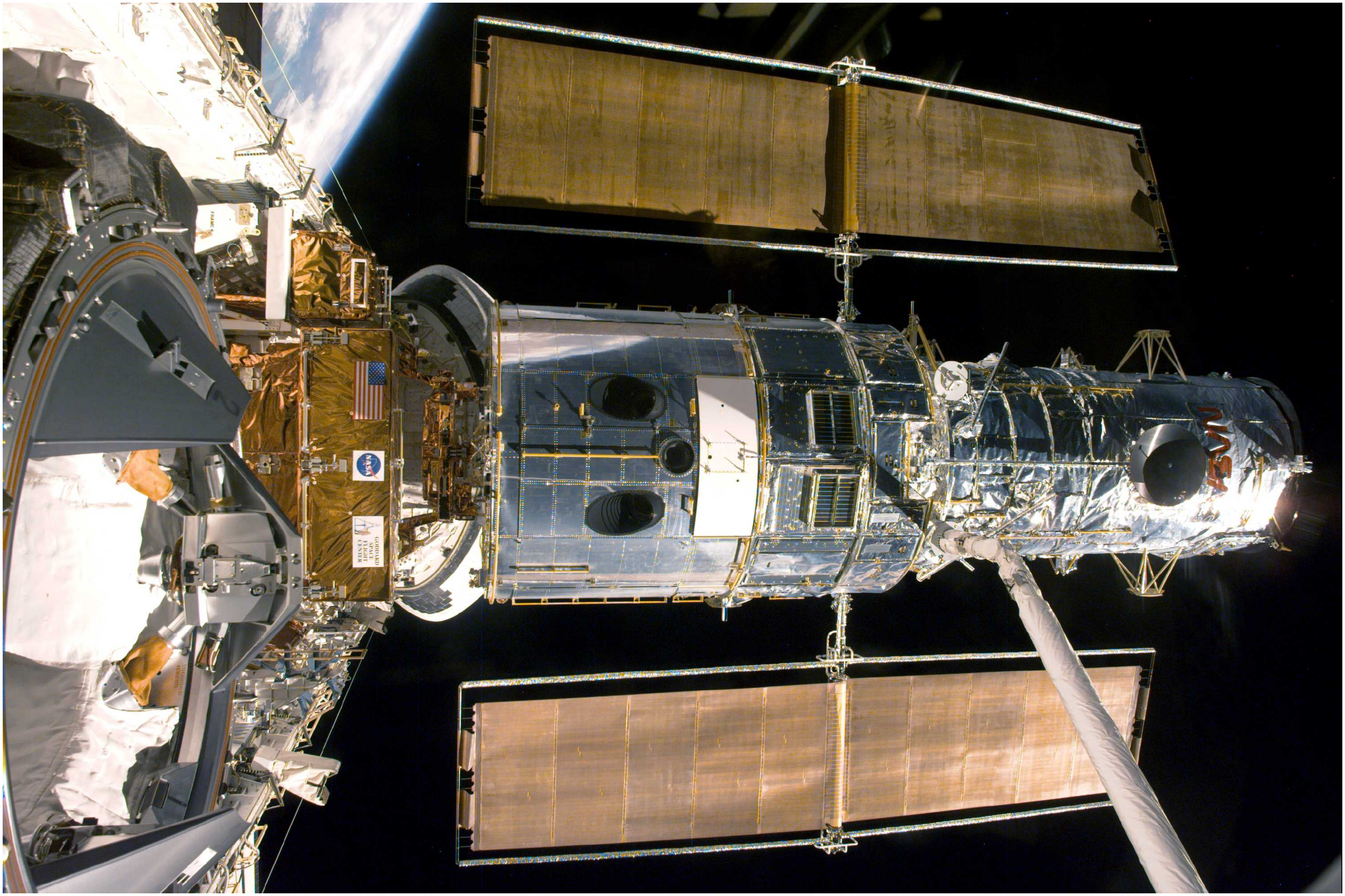
NASA
GODDARD SPACE FLIGHT CENTER

A DECADE OF DISCOVERY

BACK

SCHOOL BUS IN THE SKY

The Hubble Space Telescope is very big — about the size of a large school bus or tanker truck. The tubular part of Hubble's body is 14 feet across, and the telescope stands 43 feet tall — about as high as a five-story building. On the ground, it would weigh over 25,000 pounds, but in space it weighs nothing. When the space shuttle Discovery carried Hubble into orbit, the telescope completely filled Discovery's cargo bay. Hubble is pictured in Discovery's cargo bay during the December 1999 servicing mission.

Hubble orbits about 368 miles above the Earth, and it takes about 90 minutes to complete one orbit. It is designed to receive regular tune-ups from the astronauts, who keep Hubble healthy and fit it with the latest technology. It is about halfway through its 20-year mission. The Hubble Space Telescope is a joint effort between NASA and the European Space Agency.

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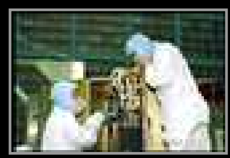
THE HUBBLE STORY

WFPC 

STIS 

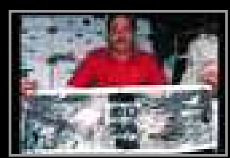
Simulating Weightlessness 

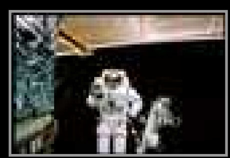
Hubble's Optics 

Training in the Clean Room 

Astronaut Tools 

Replacing a Data Recorder 

Insulation Repair 

Photos of Hubble 

Hubble Returns to Duty 

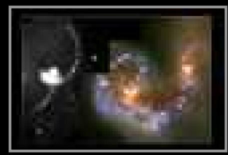
< PREVIOUS

A DECADE OF DISCOVERY

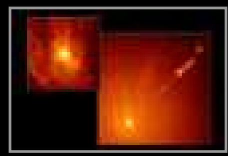
Investigating Space
The Hubble Story

INVESTIGATING SPACE

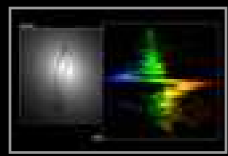
Colliding Galaxies NGC 4038 and 4039



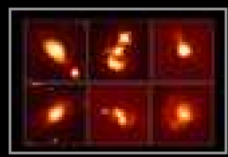
Active Galaxy M87 Jet



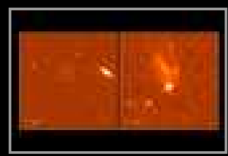
Black Hole in Galaxy M84



Quasar Host Galaxies

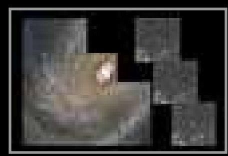


Gamma Ray Burst GRB990123



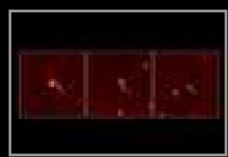
Gravitational Lensing in Galaxy Cluster Abell 2218

Cepheid Variable Stars in Galaxy M100



Spiral Galaxy NGC 4414

Distant Supernovae



Hubble Deep Field North

< PREVIOUS

A DECADE OF DISCOVERY

WHAT A VIEW: HUBBLE'S "EYE" ON THE COSMOS

HOUSE CALLS TO HUBBLE

Regular maintenance visits to the telescope keep the steady stream of pictures rolling off the Hubble assembly line. In fact, NASA designed the telescope for servicing in space. Earthbound telescopes receive routine checkups to ensure they're functioning properly; they also receive regular upgrades when new advances in technology come around. Hubble is no different. That's why astronauts visit the telescope every few years, replacing older equipment and adding state-of-the-art science instruments. Future servicing missions are planned for 2001 and 2003. In 2001 astronauts will install the Advanced Camera for Surveys, which will capture an even wider swath of the sky and will yield even sharper pictures than Hubble's current wide-field camera.

IN THE BEGINNING

Orbiting space observatories like Hubble can trace their roots to the 1920s. While most scientists considered a space telescope as pure science fiction, some were seriously exploring the idea. Rocket pioneer Hermann Oberth, for example, speculated about orbiting telescopes in his writings, and scientist Robert Goddard began testing his newly invented liquid-fuel rockets. As these men were pushing the technological envelope, Edwin Hubble was unveiling new heavenly horizons. Before Hubble came along, astronomers had a restricted view of the universe, believing that the only galaxy in the heavens was our Milky Way. But Hubble used the latest technology, a powerful 100-inch telescope, and made some startling discoveries that changed our concept of the cosmos.

First, he observed that galaxies exist beyond the Milky Way. Then he found that those galaxies are flying away from each other, an observation that helped him determine that the universe is expanding.

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THE VAULT

A DECADE OF DISCOVERY

WHAT A VIEW: HUBBLE'S "EYE" ON THE COSMOS

It takes powerful telescopes to study the uncharted territories of the vast cosmos. But it became increasingly clear to astronomers that Earth's atmosphere distorted starlight, which made it difficult to obtain razor-sharp views of celestial objects. The idea of placing a telescope in space, above Earth's turbulent air, had been kicked around for several years. But scientists pondered how to transport a telescope into space. The rocket technology pioneered by Oberth and Goddard and revolutionized by the Germans during World War II became the means of transportation.

DREAM BECOMES REALITY

After scientists figured out the means, they focused on coming up with the money to develop and build a space telescope. The newly established NASA (created in 1958) and well-known American astronomers such as Lyman Spitzer began championing the cause, trying to convince Congress that such a project was useful. In 1977 Congress finally agreed to allocate the money. But it took a decade of research, planning, and testing before NASA successfully launched its first space observatory. And two more decades passed before NASA launched the Hubble telescope, which has expanded our heavenly vistas far more than its namesake ever dreamed.

< **BACK** |

A DECADE OF DISCOVERY

OPENING NEW HEAVENLY VISTAS

Nearly 400 years ago, the Italian scientist Galileo opened a whole new world when he pointed the newly invented telescope toward the heavens. His crude telescope detected pockmarks on the moon and satellites around Jupiter, proving that the Earth wasn't the only special place in the cosmos. Galileo's discoveries revolutionized our view of our place in the universe.

The launch and deployment of NASA's Hubble Space Telescope, likewise, has changed our understanding of the heavens. From capturing the nearby, violent death of a massive star to staring far back in time to see embryonic galaxies, Hubble's many awe-inspiring moments have brought the beauty and mystery of space to homes all over the world.

The Earth-orbiting observatory collects and analyzes light from visible to near infrared, seeing more sharply than any previous telescope. The telescope has a much clearer view of the heavens because of its unique position above Earth's roily atmosphere, which distorts starlight, making it dance and wiggle. Its razor-sharp vision of celestial objects has turned the "hints and suspicions" of terrestrial observations into certainties, forcing theorists to rewrite broad-brush theories.

By observing 14,000 astronomical targets, Hubble has contributed significantly to astronomical research, from our solar system to the most distant galaxies.

| **NEXT** >

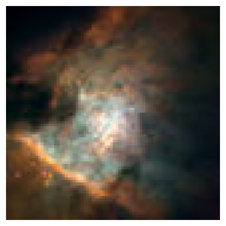
A DECADE OF DISCOVERY

OPENING NEW HEAVENLY VISTAS

INVASION OF JUPITER

In the solar system, the observatory witnessed an invasion of Jupiter in 1994 as pieces of Comet Shoemaker-Levy 9 plunged into the planet's atmosphere and exploded. The telescope's sharp "eyes" provided exquisite details on the plumes of debris kicked up by the explosions and for several days followed the expansion of the impact sites. This collision is a once-in-a-millenium occurrence.

LIFE CYCLE OF STARS



Moving from planets to stars, the telescope documented in colorful detail the births and deaths of these bright celestial objects. It provided visual proof that pancake-shaped dust disks around young stars are common, suggesting that the raw materials for planet formation are in place. The orbiting telescope showed for the first time that jets of material rising from embryonic stars emanate from the centers of disks of dust and gas, thus turning what was previously merely theory into an observed reality.

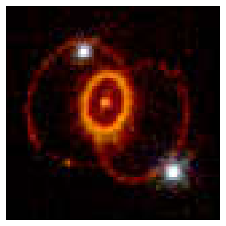
DYING IN STYLE

Hubble delivered many stunning pictures of stellar deaths, such as the glowing shrouds surrounding Sun-like stars (called planetary nebulae), the mysterious rings of material around the exploding, massive star called Supernova 1987A, and the twin lobes of matter billowing from Eta Carinae. Ground-based images suggested that many of these objects had simple shapes, but Hubble revealed that their shapes are more complex.

A DECADE OF DISCOVERY

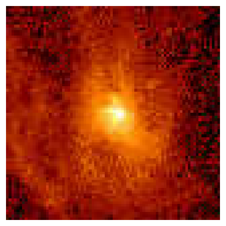
OPENING NEW HEAVENLY VISTAS

A COSMIC COLLISION



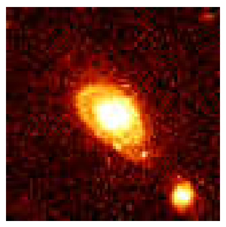
The telescope monitored Supernova 1987A, the closest exploding star in four centuries, providing (for the first time) pictures of a collision between a wave of material ejected from the doomed star and a ring of matter surrounding it. The collision has already begun to illuminate the central ring. In the next decade astronomers expect even more material to hit the ring, illuminating the surrounding material, and thereby literally throwing light on the exploding star's history.

A FEEDING FRENZY



Hubble also is yielding clues to what is causing the flurry of activity in the hearts of many galaxies. These central regions are very crowded, with stars, dust, and gas competing for space. But Hubble managed to probe these dense regions, providing decisive evidence that supermassive black holes — compact "monsters" that gobble up any material that ventures near them — reside in the centers of many galaxies. These elusive "eating machines" cannot be observed directly, because nothing, even light, escapes their stranglehold. But the telescope provided indirect, yet compelling, evidence of their existence. Hubble's crisp images revealed a doughnut-shaped structure composed of dust and gas around a central object, presumably a black hole. The telescope also helped astronomers determine the masses of several black holes by measuring the velocities of material whirling around them.

NATURE'S "LIGHTBULBS"



Most scientists believe that black holes are the "engines" that power quasars, powerful light beacons located more than halfway across the universe. Hubble has surveyed quasars, confirming that nature's brightest "lightbulbs" reside in galaxies. The observations also revealed that many of these galaxies are merging with other galaxies. The mergers kick up lots of dust and gas, providing an important clue for how black holes feed and power quasars.

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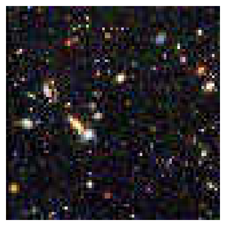
A DECADE OF DISCOVERY

OPENING NEW HEAVENLY VISTAS

GALAXY BUILDING BLOCKS

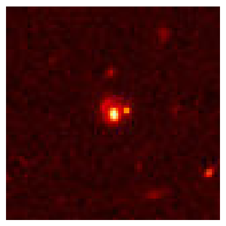


Hubble also peered across space to study galaxies in an infant universe. (Probing the distant cosmos means looking back in time.) Hubble's observations indicate that the young cosmos was filled with much smaller and more irregularly shaped galaxies than those astronomers see in our nearby universe. These smaller structures, composed of gas and young stars, may be the building blocks from which the more familiar spiral and elliptical galaxies formed, possibly through processes such as multiple galaxy collisions. The Hubble observations also show that the early universe more vigorously manufactured stars than it does today.

AN EXPANDING UNIVERSE

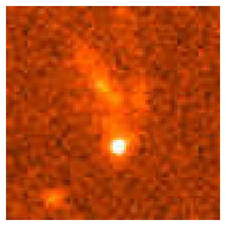
The universe doesn't remain still: it's expanding. Astronomer Edwin Hubble made that observation in the 1920s. Since then, astronomers have debated how fast it is expanding, a value called the Hubble constant. In May 1999 a team of astronomers announced they had obtained a value for the Hubble constant, an essential ingredient needed to determine the age, size, and fate of the universe. They did it by measuring the distances to 18 galaxies, some as far as 65 million light-years from Earth. By obtaining a value for the Hubble constant, the team then determined that the universe is 12 to 14 billion years old.

A SPEEDY UNIVERSE



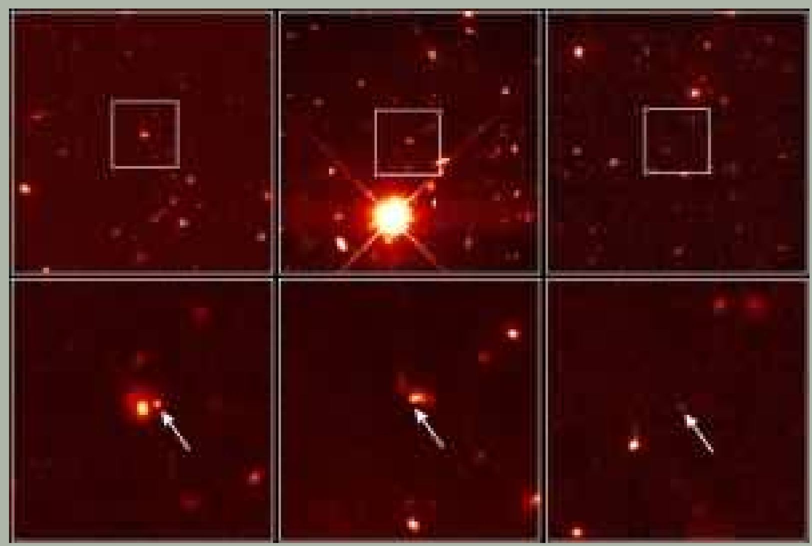
One of the most dramatic astronomical discoveries of this century came in 1998, when two independent teams, using Hubble and other telescopes, found strong evidence that the cosmic expansion is accelerating. The orbiting observatory's major contribution was the accurate measurement of the luminosities of some of the most distant exploding stars, called supernovae.

COSMIC EXPLOSIONS



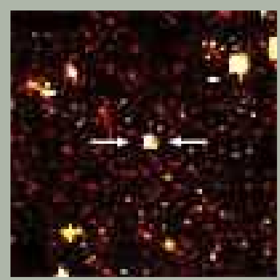
Hubble teamed up with a fleet of X-ray, gamma-ray, and visible-light observatories in a quest to analyze the sources of gamma-ray bursts. Gamma-ray bursts may represent the most powerful explosions in the universe since the Big Bang. Before 1997 astronomers were stumped: although they had observed more than 2,000 "bursts," they couldn't determine whether these fireballs occurred in our galaxy or at remote distances. Hubble images showed unambiguously that the bursts actually reside in far-flung galaxies rife with star formation.

Hubble Pinpoints Distant Supernovae



Peering halfway across the universe to analyze light from exploded stars that died long before our Sun even existed, the Hubble telescope has allowed astronomers to determine that the expansion of the cosmos has not slowed since the initial impetus of the Big Bang. Thus, the universe's expansion should continue to balloon outward indefinitely.

These results are based on unprecedented distance measurements to supernovae that are so far away they allow astronomers to determine if the universe was expanding at a faster rate long ago. These images showcase three of the supernovae used in the survey. The arrows in the bottom row of pictures pinpoint these exploding stars; the top row of images shows the regions where the supernovae reside.



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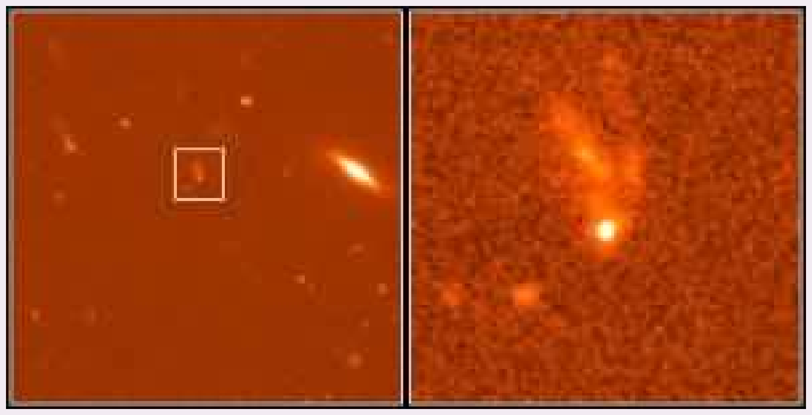
Cosmology, Stars

news & views

Hubble Views Home Galaxy of Record-Breaking Explosion



Here are Hubble telescope views of the rapidly fading visible-light fireball from the most powerful cosmic explosion recorded to date. For a brief moment the light from the blast was equal to the radiance of 100 million billion stars. The initial explosion began as an intense burst of gamma rays, which happened on Jan. 23, 1999.

The blast had already faded to one four-millionth of its original brightness when Hubble made observations on February 8 and 9 [image on left]. Hubble captured the fading fireball embedded in a galaxy located two-thirds of the way to the horizon of the observable universe. The picture on the right is a close-up view of the galaxy, the finger-like filaments extending above the bright white blob of the gamma-ray fireball.

Get the Full Scoop! HIGH-RES IMAGES ANIMATIONS VIDEO (if available)

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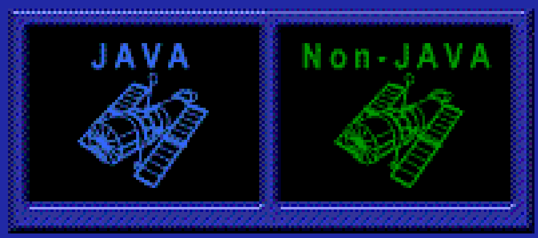
Where's Hubble now?. . . .



Track the Hubble Space Telescope!
Note the latitude, longitude, and altitude of the Telescope as it orbits the Earth.

HUBBLESITE

Where's Hubble now?. . . .

LIFTOFF Sponsored by Liftoff to Space Exploration

You do not have JAVA, try our non-JAVA version.

Click on craft	Change orbital data in lower right
Ctrl+Click on craft	Toggles on/off ground trace
Shift+Click on craft	Goes to web page about craft
Click+hold on map	Display first visible at longitude

Weather by INTELLICAST

Where's Hubble now?. . . .

LIFTOFF

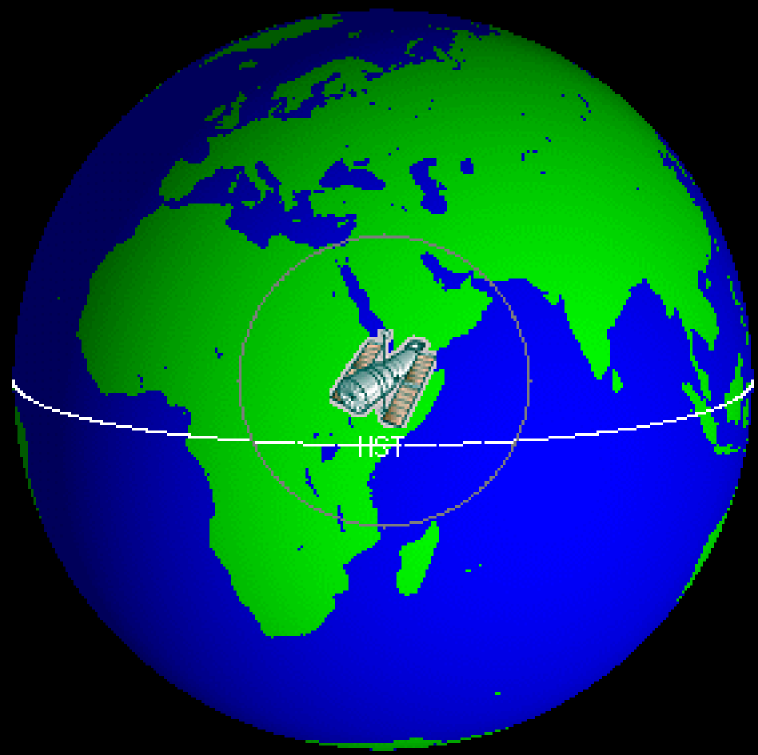
Sponsored by
Liftoff to Space Exploration

02 Mar 2002 08:33 UTC

Latitude (Degrees)	Longitude (Degrees)	Altitude (Kilometers)
10.2	41.2	560.5

FUN FACTS

- Hubble whirls around Earth at 5 miles per second. If a car could travel that fast, a road trip from Los Angeles to New York City would take only 10 minutes.
- Hubble completes one full orbit every 97 minutes.
- Hubble is nearly the size of a large school bus, but it can fit inside the cargo bay of a space shuttle.
- In an average orbit, Hubble uses about the same amount of energy as 24 100-watt light bulbs.
- In nearly 10 years, Hubble has traveled over 1 billion miles.



Current Hubble Location

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About Us...

About Us
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Maryland Science Ctr.
Media Kit
Credits

Detail of approach from east, west or north

See step-by-step directions below map.

1. Take Cold Spring Lane east to Roland Ave. and turn right.

2. At the fork at the first light on Roland, bear left, proceeding south on University Pkwy.

3. Follow University Pkwy. for four additional lights; turn right at the fourth light, into the woods on San Martin Drive. (If you cross Charles St., you have missed the turn onto San Martin.)

4. The Institute is the first building on the right.

[TOP]

About Us...

Detail of approach from south

Enter Martin Luther King Blvd. in Baltimore from either route A or B.
See step-by-step directions below map.

From route A to MLK Blvd:

1. From I-95 north, take Exit 53 onto I-395 north.
2. Take I-395 to exit for Martin Luther King Blvd. north.

From route B (see circular inset) to MLK Blvd:

1. Md. 295 north becomes Russell St. in Baltimore; from Russell, take exit for Martin Luther King Blvd. north. (NOTE: The signs are small!) This puts you briefly on a service road that runs parallel to Russell.

2. On service road, stay to the left to avoid being forced onto I-395 exit; take ramp for Martin Luther King Blvd.

From Martin Luther King Blvd. to the Institute

1. Take MLK Blvd. north until it ends at the light at Howard St. (Remain in one of the middle lanes of MLK Blvd. to avoid a premature forced right or left turn.)

2. Turn left at Howard and proceed north about two miles to 29th St.

3. One block past the light at 29th St., where Howard curves to the right and turns into Art Museum Dr., turn left at the traffic island onto Wyman Park Dr. (For more detail on this area, see map for approach from the north.)

4. Where Wyman Park Dr. curves hard to the left, bear right, into the woods on San Martin Drive.

5. Follow San Martin Drive north approximately one mile to the Institute, the second building on the left.

[TOP]

news & views

HUBBLESITE

Pick a category

black holes *(16 entries)*
cosmology *(23 entries)*
exotic phenomena *(24 entries)*
galaxies *(55 entries)*
miscellaneous *(23 entries)*
nebulae *(56 entries)*
solar system *(72 entries)*
star clusters *(36 entries)*
stars *(86 entries)*

HUBBLESITE

the hubble deep field

a multimedia journey

LAUNCH
in a small window

- OR -

LAUNCH
in a window which will take up the entire screen

You can also go directly to the links page

in order to view the hubble deep field multimedia
you will need the flash plugin, speakers
and a PENTIUM II cpu or the equivalent

edu•space

The Space Telescope Science Institute's Office of Public Outreach Education Group supports astronomy and space science education for grades K-12.

let hubblesite launch you to edu.space

the following is a list of educational projects which are affiliated with hubblesite

AMAZING SPACE: Taking Education to the Farthest Reaches of Space! A collection of online, interactive, educational resources for grades K-12. Using spectacular Hubble images, students explore the universe while learning the principles of math and science.

ORIGINS: Galaxies, Stars, Planets....and Life. Join NASA on the search for astronomical origins and planetary systems.

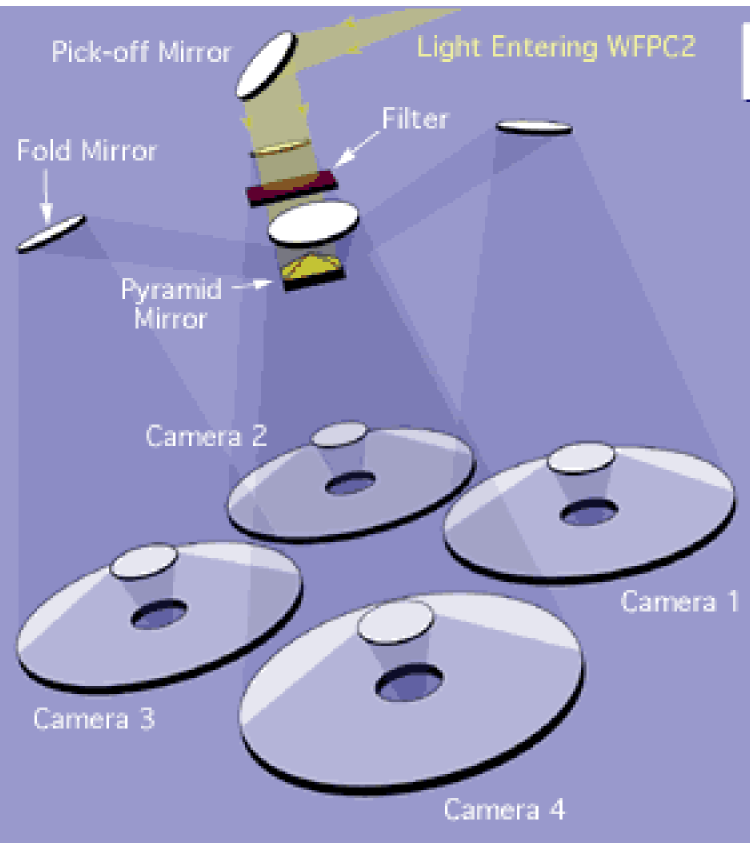
GRANTS: IDEAS and HST Cycle E/PO. Funding for the development of educational outreach projects that team educators with scientists.

INFORMAL SCIENCE: Resources for museums, planetariums and others.

EDUCATION RESOURCES: A variety of educational materials and information about Hubble Space Telescope and more!

EDUCATION PROJECTS: Other education projects in and around the Space Telescope Science Institute

Dividing Light



CHOOSE A CAMERA:

Camera 1

Camera 2

Camera 3

Camera 4

More on WFPC2

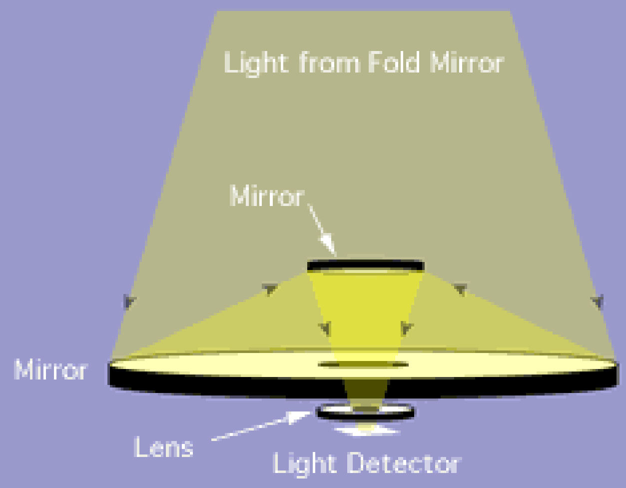
The Wide Field and Planetary Camera 2's four-camera design allows it to view more of the sky than a single camera could.

An intricate system of mirrors divides the beam of incoming light into four separate streams, each of which goes to a different camera.

Click on the camera buttons at left to see the light path and resulting image portion for each of WFPC2's four cameras.

next >>

Side View of Light Path Through a Camera



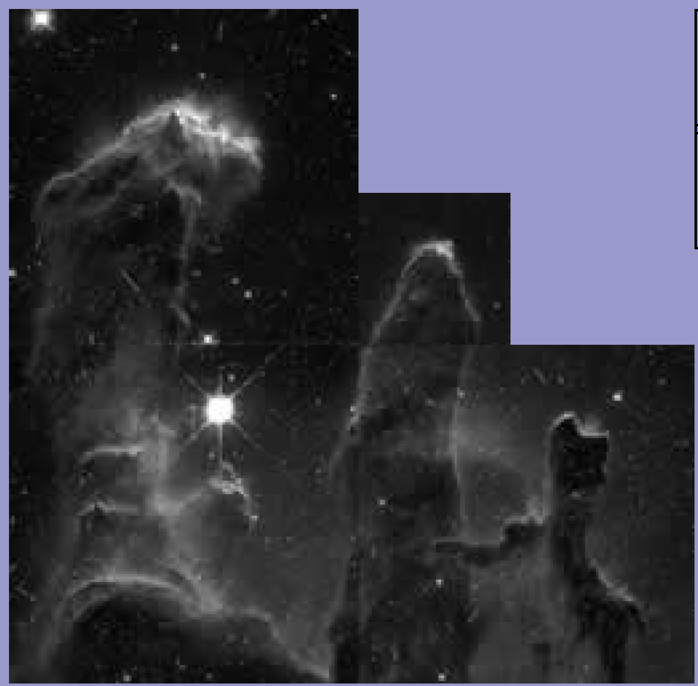
Getting It Together

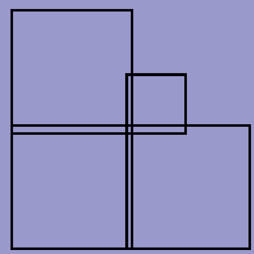
The Wide Field and Planetary Camera 2's cameras are trained on four neighboring regions of the sky.

To ensure that there are no gaps in the overall view, the four cameras are aimed so that each image slightly overlaps its neighboring images.

Image processing software compares and cleans up the overlapping edges as it stitches the four images together.

Assembled Image





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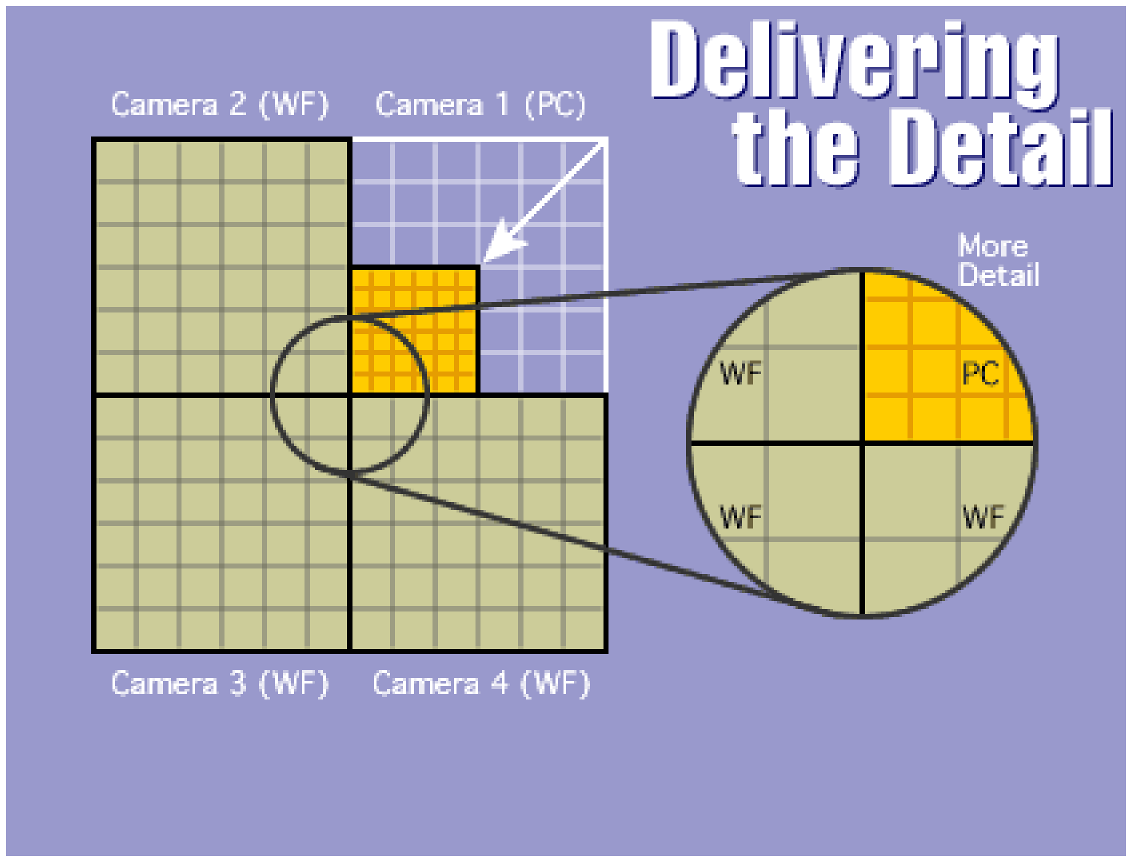
BEHIND THE PICTURES
WACKY SHAPE
CONSTRUCTING THE VIEW
DIVIDING LIGHT
GETTING IT TOGETHER
DELIVERING THE DETAIL



Hubble's Wide Field and Planetary Camera 2 (WFPC2) has a unique feature which is responsible for the oddly-shaped images it produces. One of its four cameras records a magnified view, which must then be resized (scaled down) to be in proportion with the other three images.

The magnified view falls on WFPC2's planetary camera (PC), which is the same physical size as the three wide field (WF) cameras. Because the image falling on the planetary camera is magnified, that camera views a region of the sky four times smaller than those seen by the wide field cameras, but it records four times as much detail in that smaller region of the sky. This results in a finer grid size in the detailed image. The added detail helps astronomers "zoom in" on a particular section of the object being observed.

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