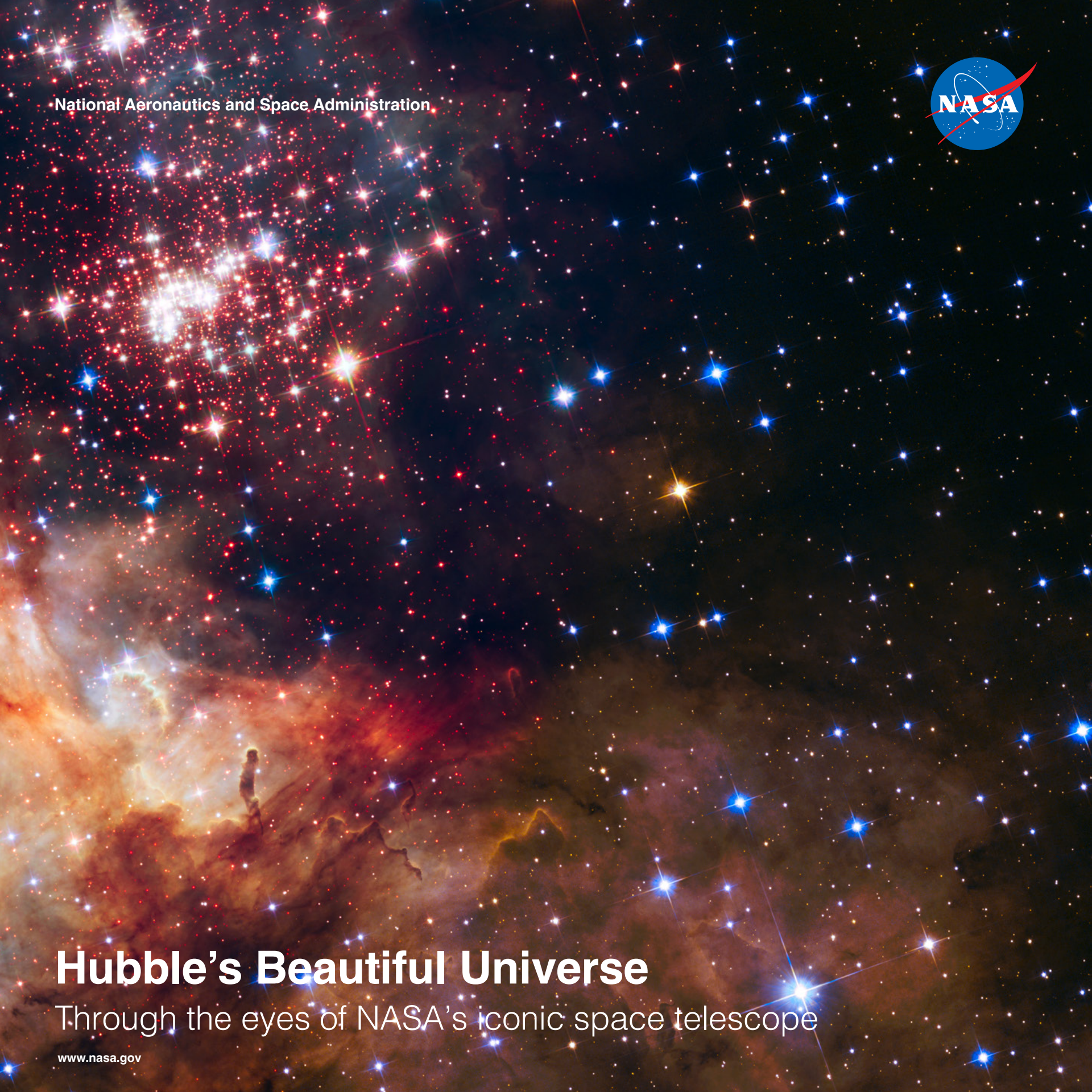
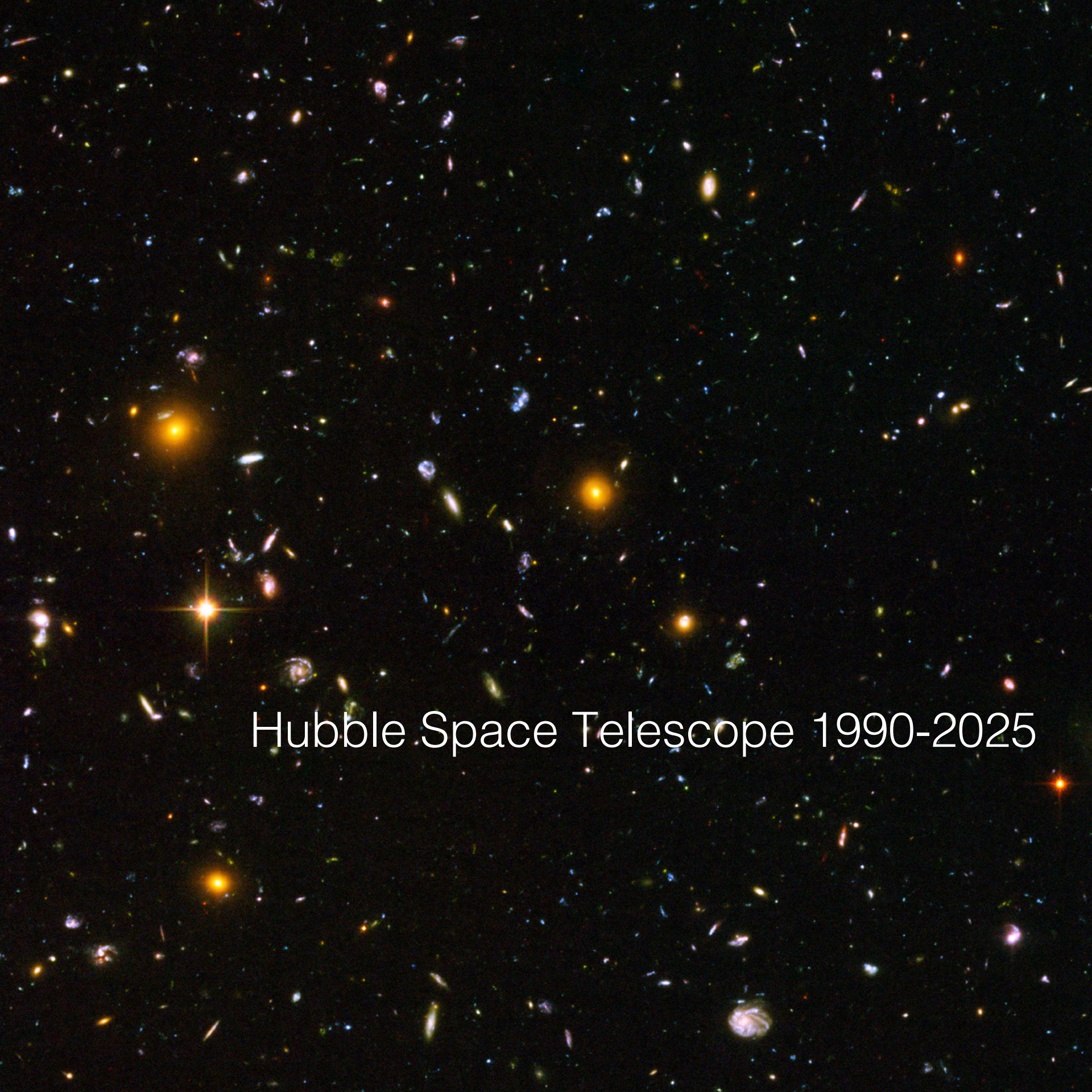

National Aeronautics and Space Administration
NASA
Hubble's Beautiful Universe
Through the eyes of NASA's iconic space telescope
www.nasa.gov

This book was produced by the Hubble Space Telescope project at NASA's Goddard Space Flight Center. The Hubble Space Telescope is a cooperative project between the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA).

This deep, detailed image is the result of a million-second-long exposure of a small portion of the sky equivalent to looking through the eye of a sewing needle held at arms-length. Called the Hubble Ultra Deep Field, this portion of the overall image shows some of the oldest galaxies ever seen – the first galaxies to emerge from the "dark ages," a time just after the big bang. The complete image contains over 10,000 galaxies.


Hubble Space Telescope 1990-2025

Inside

The Hubble Space Telescope was launched by the space shuttle Discovery on April 24, 1990. Avoiding distortions of the atmosphere, Hubble has an unobstructed view of planets, stars, and galaxies, some over 13 billion light-years away.

Introduction

In April 1990, the Hubble Space Telescope launched as a groundbreaking astronomical observatory. Its ambition was to study the universe in different wavelengths of light, providing profound discoveries that not only advanced humanity's knowledge of the known universe, but also uncovered phenomena not even imagined. Since its deployment 35 years ago, Hubble has accomplished and is far exceeding that mission — returning more than 1.6 million observations (and counting!) that touch every area of astronomy.

Despite its great success, Hubble is no stranger to a challenge. Shortly after launch, it became apparent that a spherical aberration in the telescope's primary mirror affected the clarity of its images. Luckily, Hubble was designed and built for servicing by astronauts while in orbit. NASA took advantage of this capability in December 1993 to install components that corrected for the flawed mirror and replaced problematic hardware. This marked the first of five successful servicing missions over a 16-year period.

These servicing missions proved critical to Hubble's continued operations and allowed the installation of new technology that increased its scientific potential. The final servicing mission in 2009 left Hubble at the apex of its scientific capability. It also left the spacecraft in great health, allowing it to continue making discoveries to this day. NASA anticipates that Hubble will continue collecting its unique scientific data into the next decade.

More than 25,000 scientists from nearly 40 countries have collected observational data with Hubble. That data is responsible for more than 20,000 scientific papers that have, in turn, been cited in other papers over one million times. Hubble data has also contributed to a Nobel prize in physics.

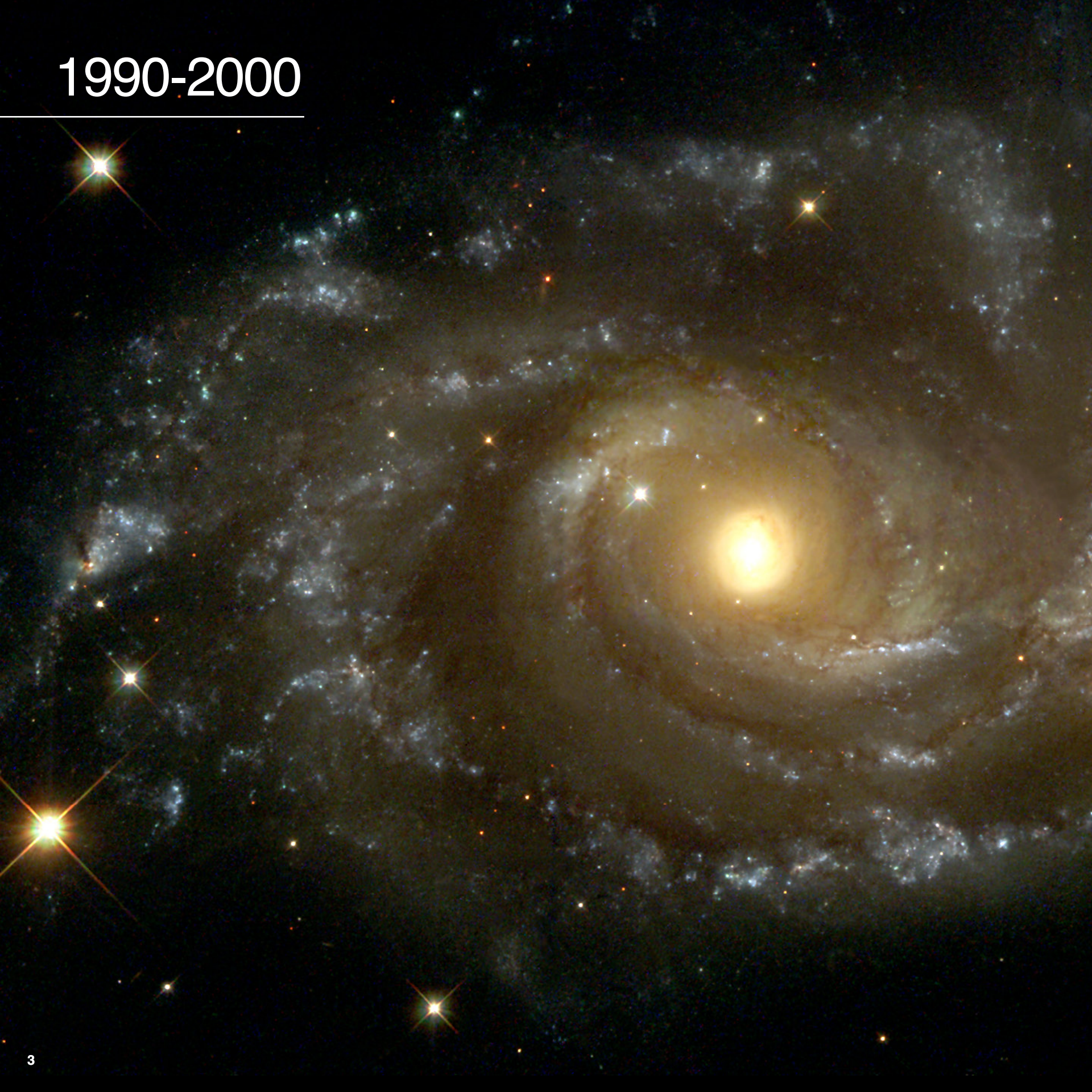
Thousands of people from around the world have been involved in developing, servicing, and operating Hubble. Their ingenuity and dedication have allowed Hubble to more than double its estimated lifespan of 15 years, advancing its grand mission to understand the cosmos even further.

This book is in honor of the success of this extraordinary telescope, the people who made it happen, and the public that has supported Hubble throughout the decades. The book shares many of its breathtaking images and scientific achievements, but represents just a fraction of its results, highlighting each decade's most stunning visuals and science. To learn more about any image, click on the underlined text.

Despite the plethora of data gathered by Hubble over the course of 35 years, the telescope has only looked at one-tenth of 1% of the universe. The remaining 99% awaits!

This Hubble view shows the dust surrounding a variable star that produces a light echo. The star, V838 Monocerotis, is located 20,000 light-years away on the periphery of our galaxy. For more images of V838 Monocerotis, see pages 57-58.

1990-2000



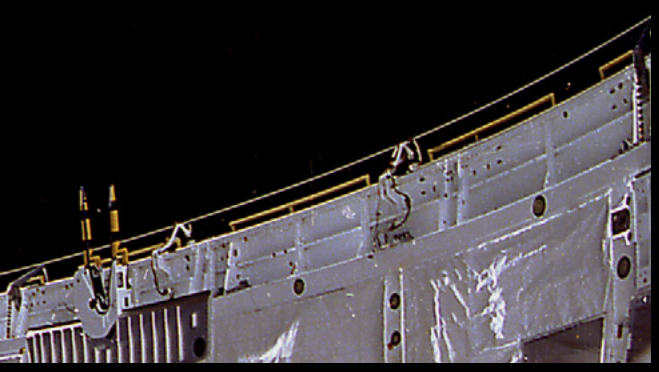
“The most important discoveries will provide answers to questions that we do not yet know how to ask and will concern objects we have not yet imagined.”

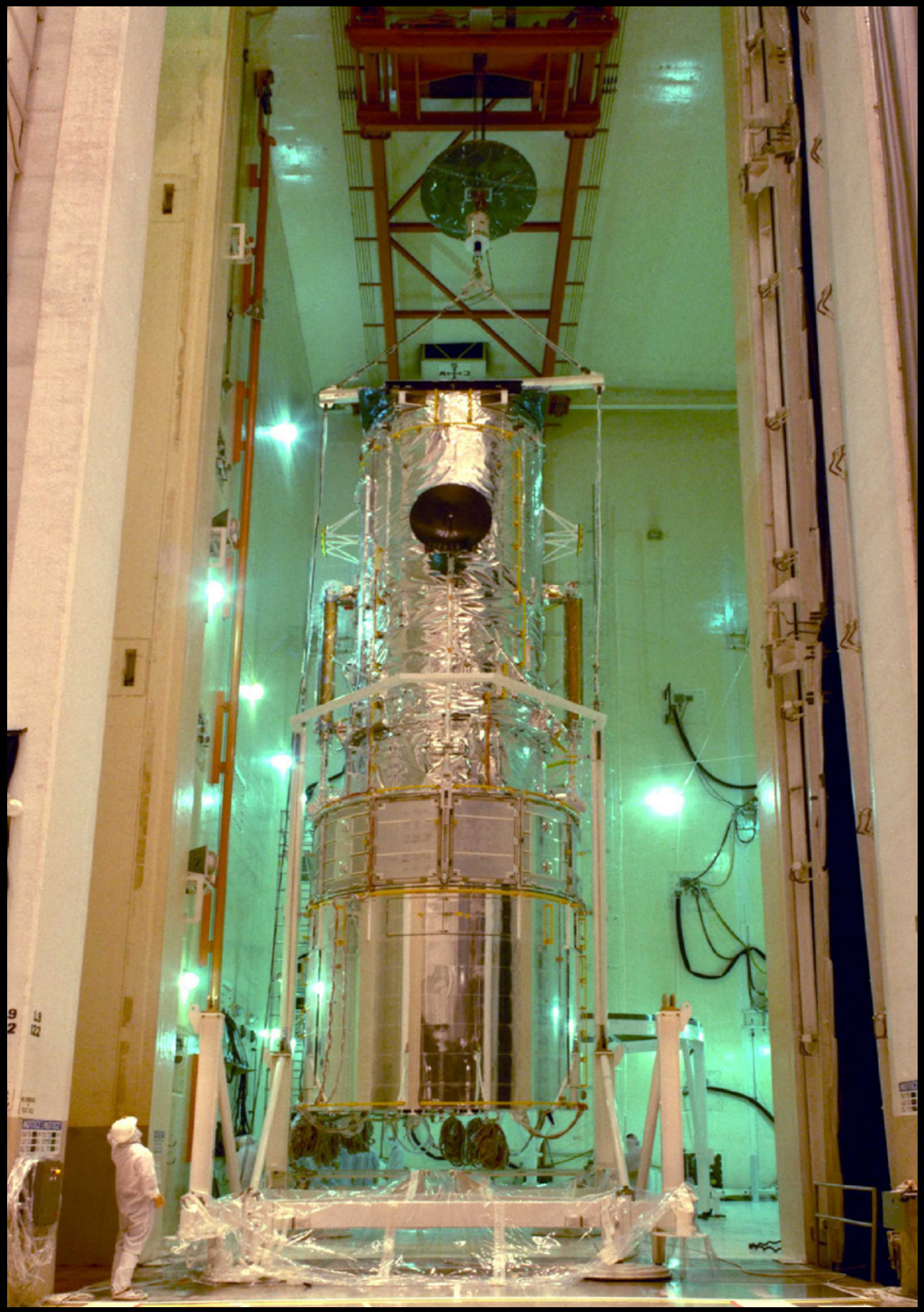
John Bahcall

President of the American Astronomical Society

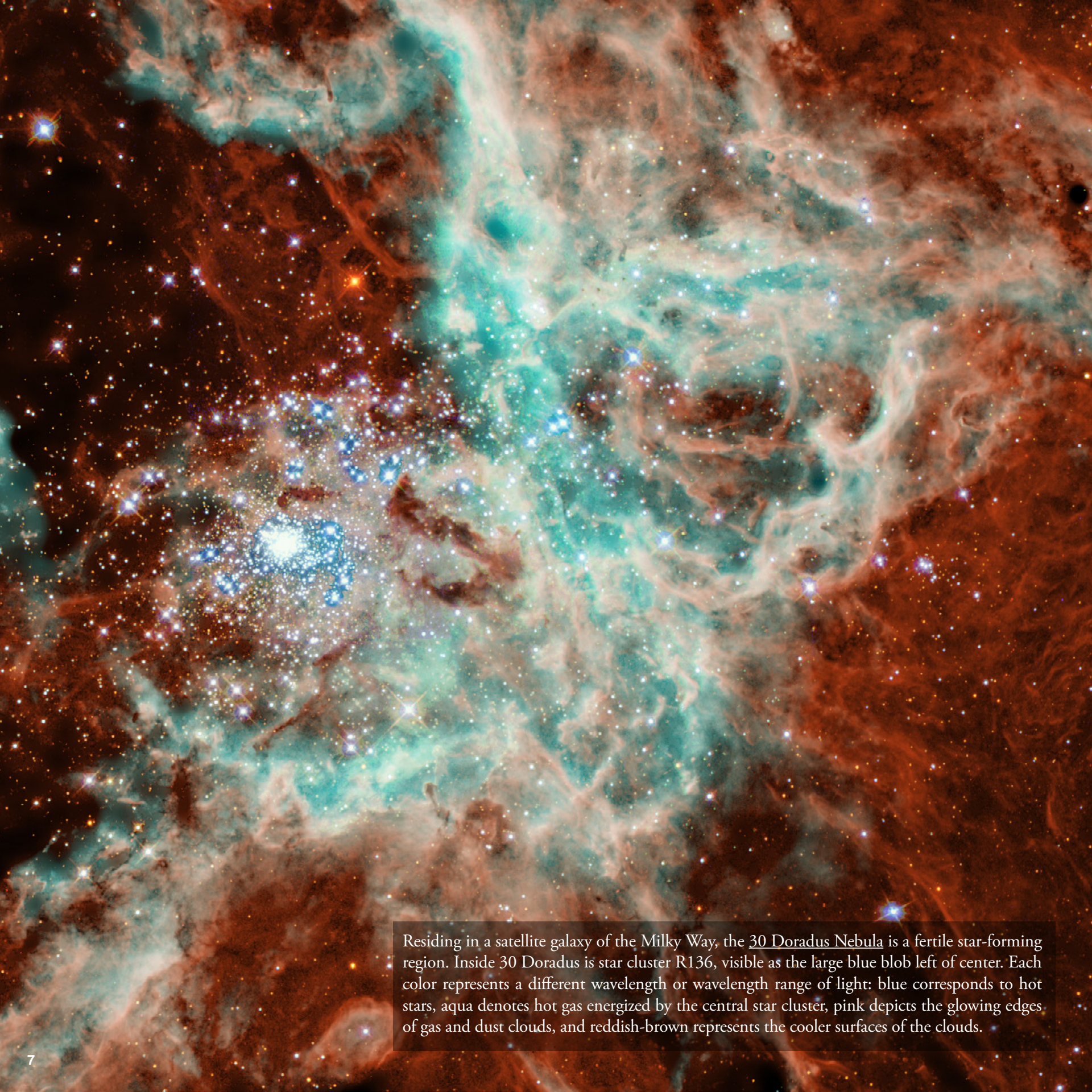
Two spiral galaxies, NGC 2207 (left) and IC 2163 (right), are captured passing by each other. Strong tidal forces from NGC 2207 distorted the smaller galaxy, flinging out stars and gas into long streamers stretching out a hundred thousand light-years.

The Hubble Space Telescope launched aboard space shuttle Discovery from NASA's Kennedy Space Center in Florida on April 24, 1990. Below, an image shows the telescope being released into space from the shuttle on April 25.



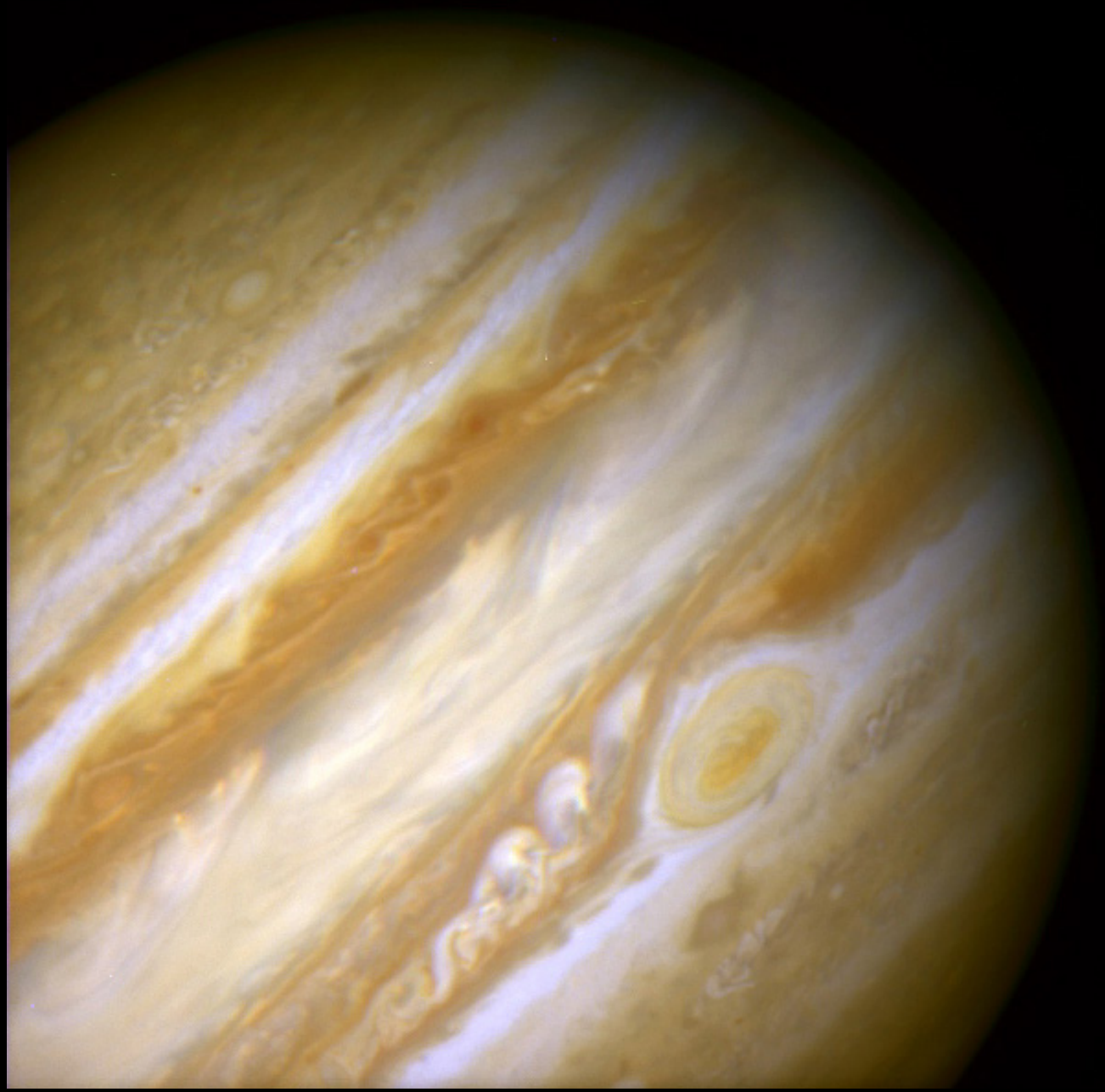


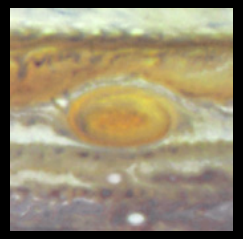
The Hubble Space Telescope lifted into an upright position in Lockheed Martin's acoustic vibration chamber for pre-launch testing.

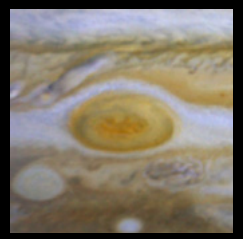


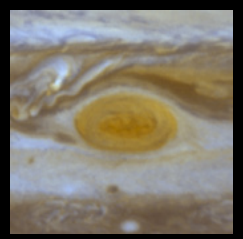
Residing in a satellite galaxy of the Milky Way, the 30 Doradus Nebula is a fertile star-forming region. Inside 30 Doradus is star cluster R136, visible as the large blue blob left of center. Each color represents a different wavelength or wavelength range of light: blue corresponds to hot stars, aqua denotes hot gas energized by the central star cluster, pink depicts the glowing edges of gas and dust clouds, and reddish-brown represents the cooler surfaces of the clouds.

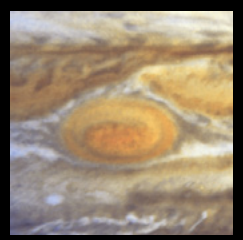
Swirling in Jupiter's atmosphere since at least the 17th century, Jupiter's Great Red Spot is a vast high-pressure storm nearly twice the size of Earth. Hubble regularly observes Jupiter to chart its ever-changing atmosphere. The series at right, taken between 1992 and 1999, shows changes in the storm's appearance over time. Hubble observations revealed that the Great Red Spot is shrinking and jiggling, and its outer winds are speeding up.

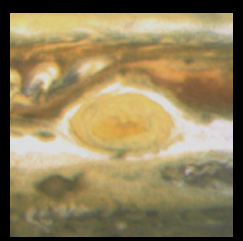


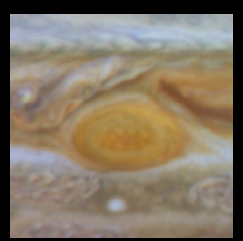


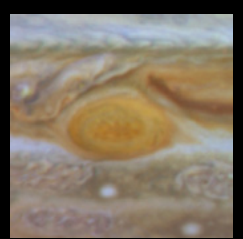




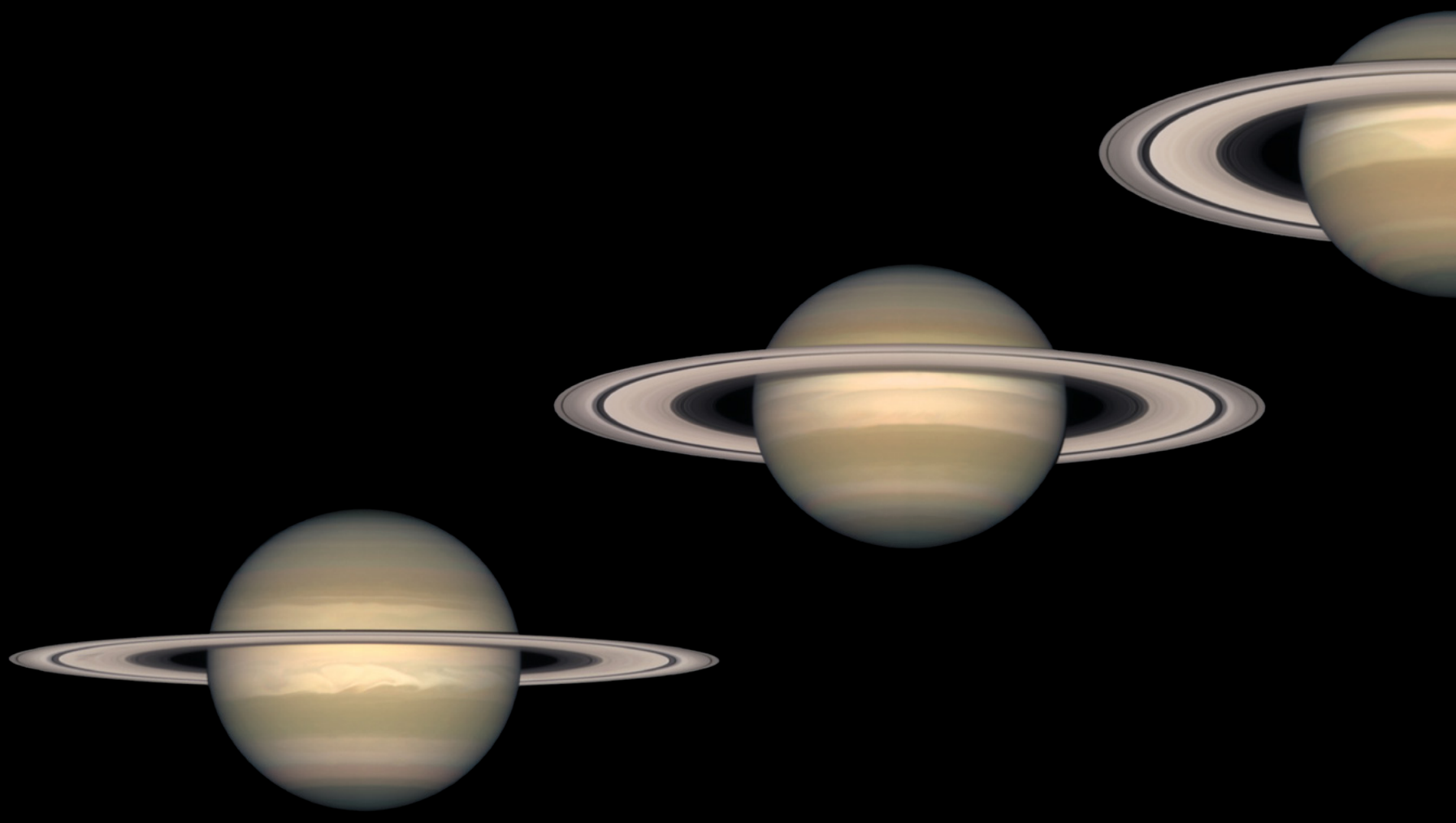


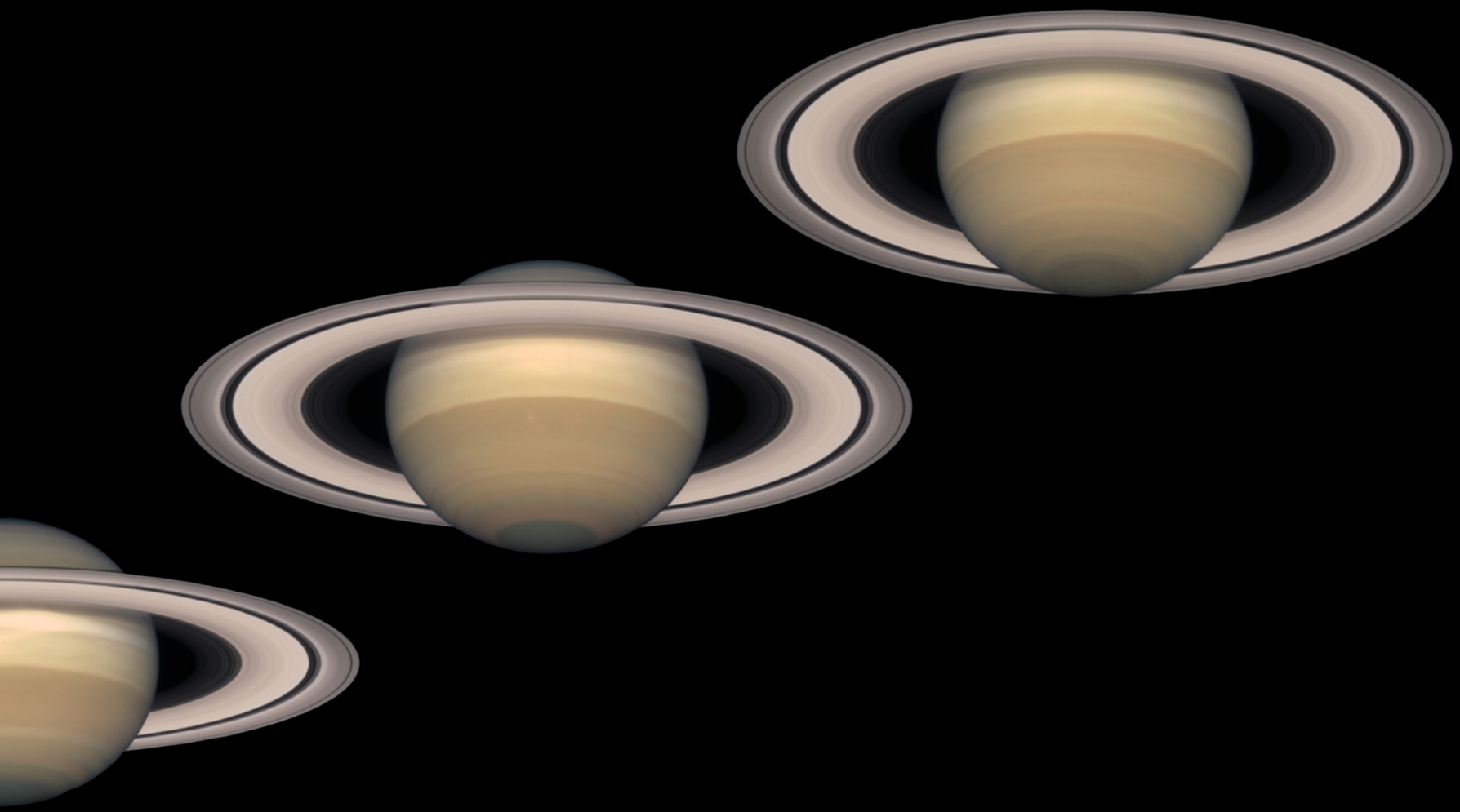






M51, also known as the Whirlpool galaxy and NGC 5194, is having a close encounter with a nearby galaxy, NGC 5195, which sits just out of the frame of this image. The companion galaxy's gravitational pull triggers star formation in M51, visible in brilliant detail as numerous bright clusters of blue, young, energetic stars near the pink nebulae that they energize. This image combines Hubble data with data from the 0.9-meter telescope at the National Science Foundation's Kitt Peak National Observatory in Arizona.

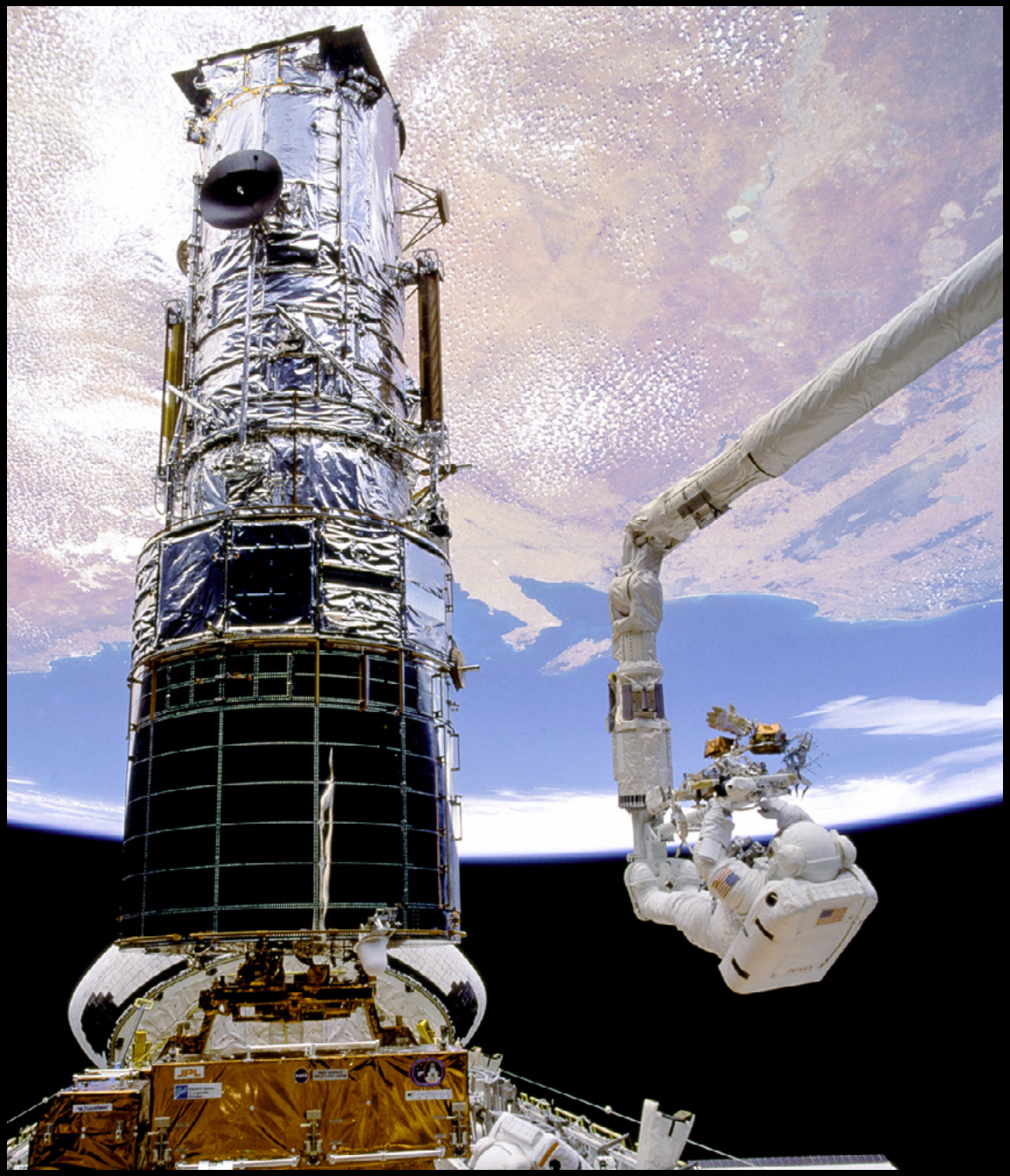




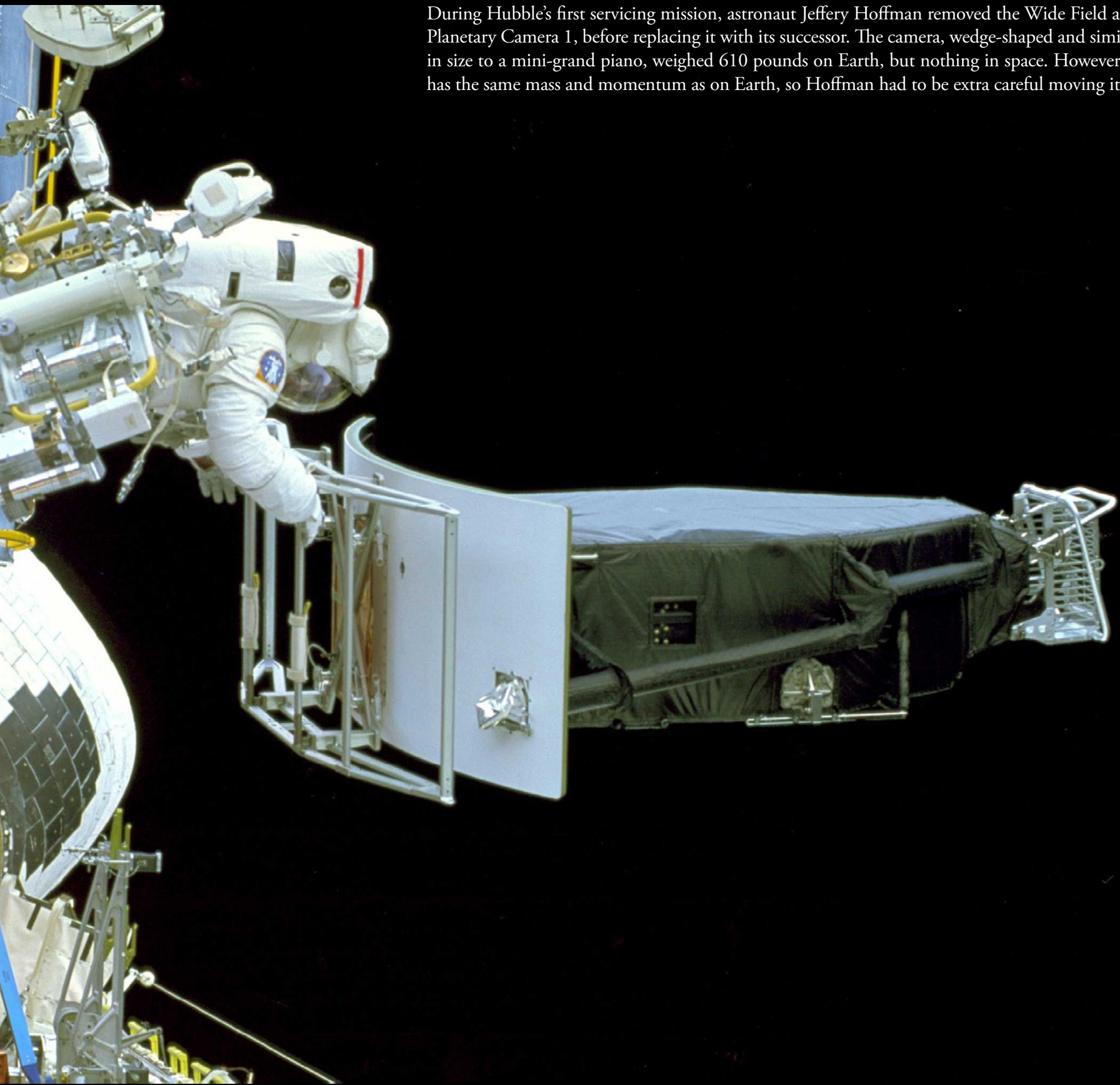
Like Earth, Saturn's axial tilt and orbit around the Sun causes seasons on the gas giant. This series of Hubble images, captured from 1996 to 2000, shows Saturn's rings from just past an edge-on view to nearly fully tilted as the planet moves from autumn toward winter in its northern hemisphere.

Shortly after Hubble was deployed in 1990, it was discovered that the telescope's primary mirror had an aberration that affected the clarity of images. Fortunately, Hubble was the first telescope designed to be serviced in space by astronauts, which first took place December 2-13, 1993.

During Servicing Mission 1, astronauts installed WFPC2 (the Wide Field and Planetary Camera 2) and COSTAR (the Corrective Optics Space Telescope Axial Replacement) to correct the optics for the flaw in the mirror. Astronauts also installed and replaced other components of the telescope, including solar arrays and gyroscopes.



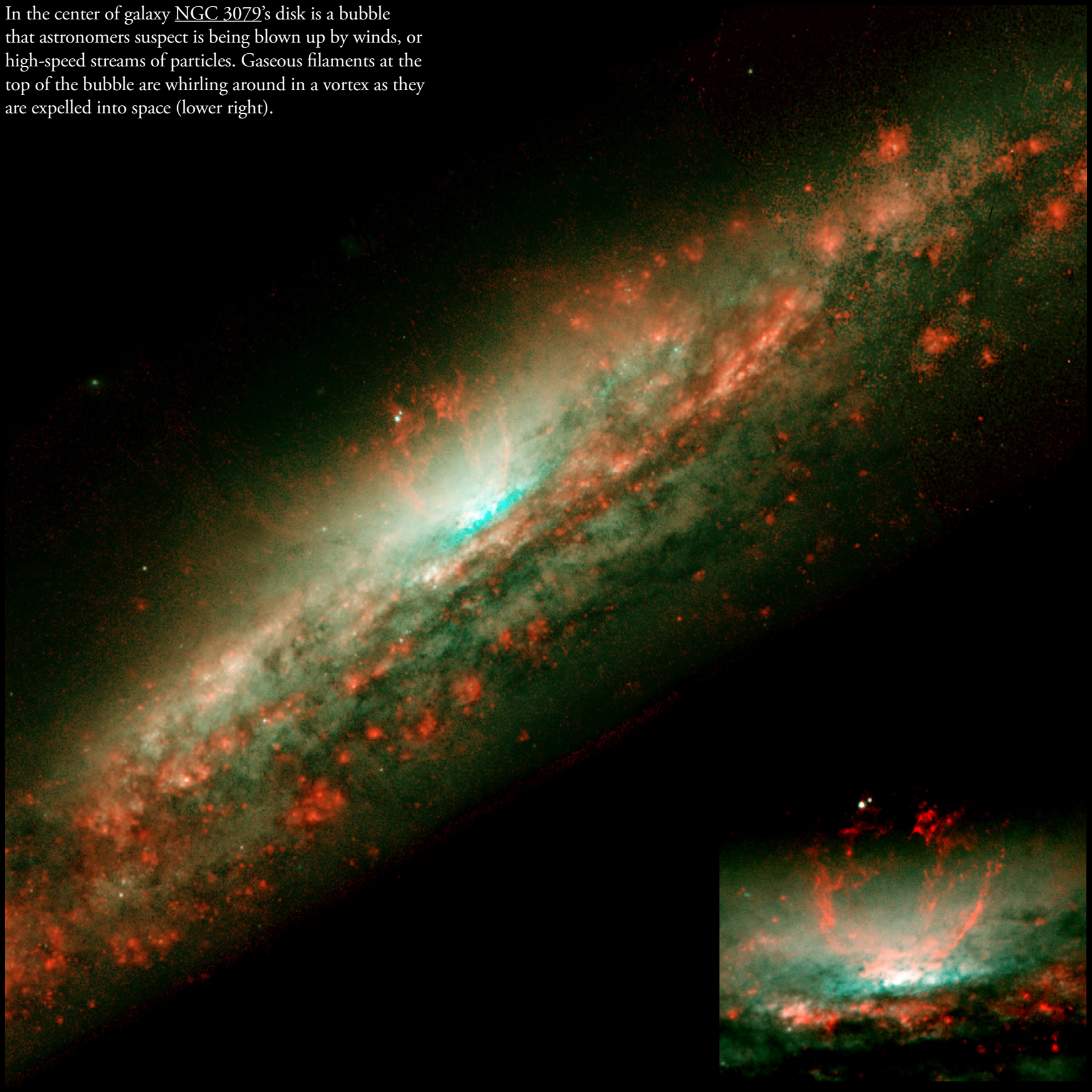
Astronaut F. Story Musgrave, anchored on space shuttle Endeavour's robotic arm, prepares to be elevated to the top of Hubble during the telescope's first servicing mission in December 1993.



During Hubble's first servicing mission, astronaut Jeffery Hoffman removed the Wide Field and Planetary Camera 1, before replacing it with its successor. The camera, wedge-shaped and similar in size to a mini-grand piano, weighed 610 pounds on Earth, but nothing in space. However, it has the same mass and momentum as on Earth, so Hoffman had to be extra careful moving it!

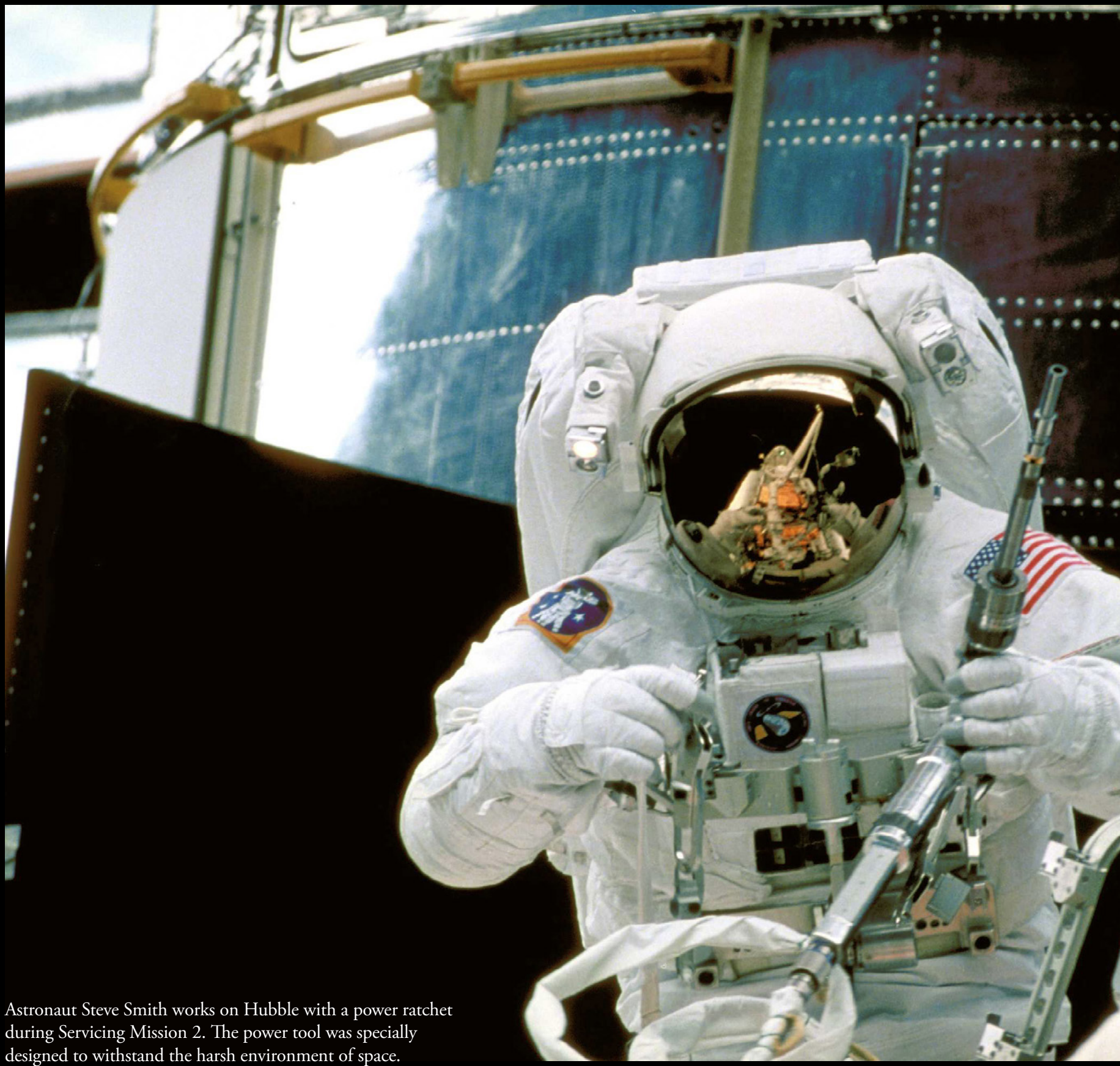
Messier 80 is one of the densest of the 147 known globular clusters in the Milky Way. Sitting about 32,600 light-years away from Earth, the cluster, also known as NGC 6093, contains hundreds of thousands of stars held together by their mutual gravitational attraction.

In the center of galaxy NGC 3079's disk is a bubble that astronomers suspect is being blown up by winds, or high-speed streams of particles. Gaseous filaments at the top of the bubble are whirling around in a vortex as they are expelled into space (lower right).

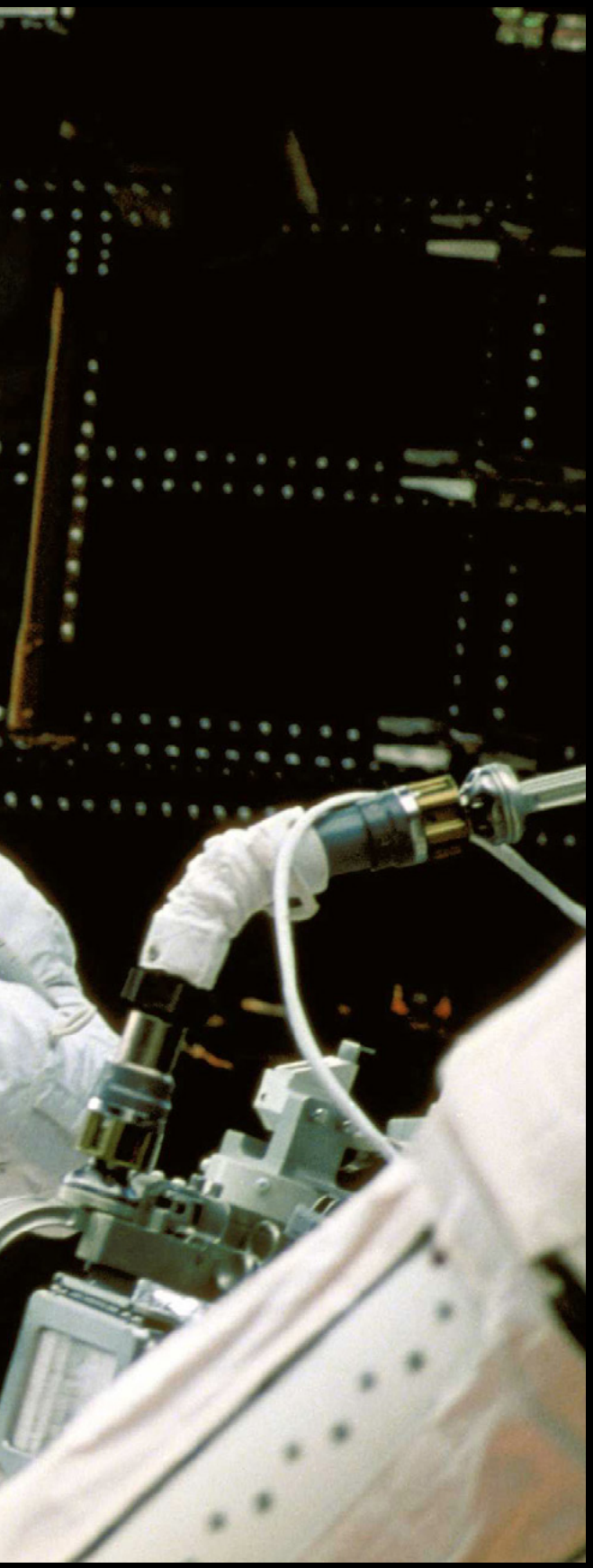


Above: In the so-called Ant Nebula, also known as Menzel 3, the ant's body is actually a pair of fiery lobes protruding from a dying Sun-like star.

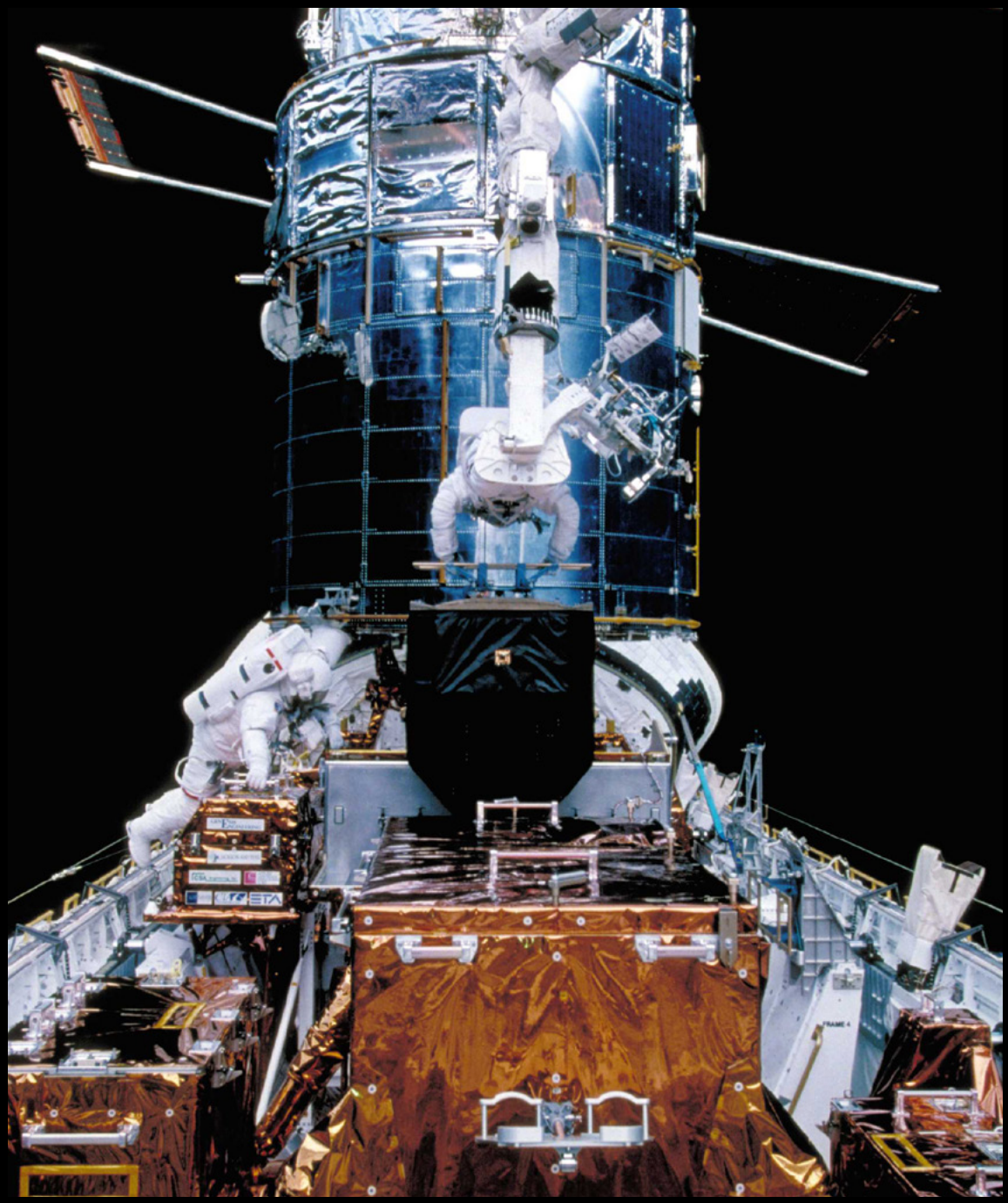
Left: M17, or the Omega or Swan Nebula, is a hotbed of star formation. Discovered in 1745, it's one of the largest star-forming regions in the Milky Way galaxy. This image is roughly three light-years across. The colors in this image represent various gasses. Red represents sulfur, green corresponds to hydrogen, and blue to oxygen.



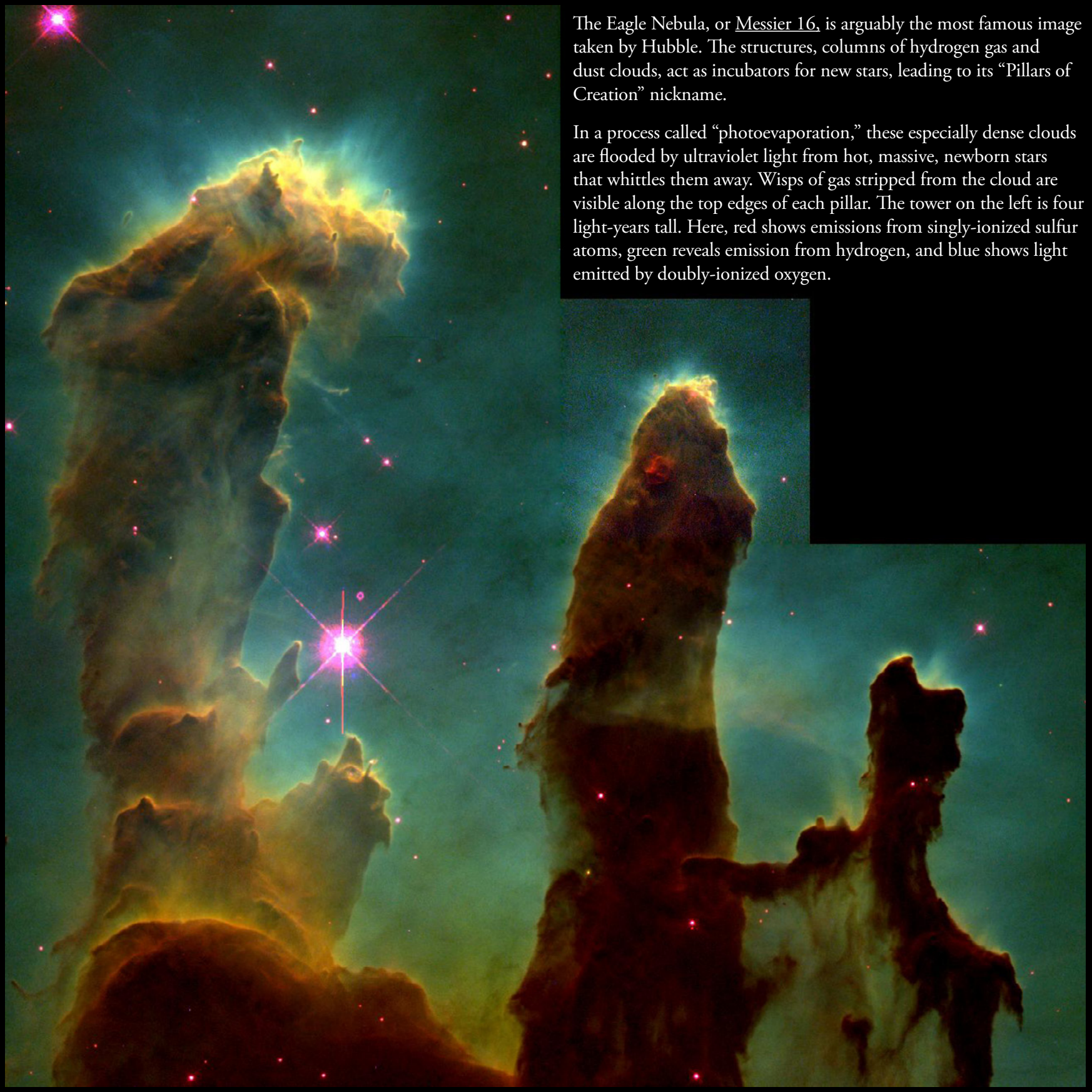
Astronaut Steve Smith works on Hubble with a power ratchet during Servicing Mission 2. The power tool was specially designed to withstand the harsh environment of space.



During Servicing Mission 2, from February 11-21, 1997, the crew installed new instruments. One extended Hubble's wavelength range into the near-infrared for imaging and spectroscopy, allowing the telescope to probe the most distant reaches of the universe. The other was an advanced imaging spectograph that can see ultraviolet, visible, and some near-infrared light. The astronauts also performed spacecraft maintenance items.

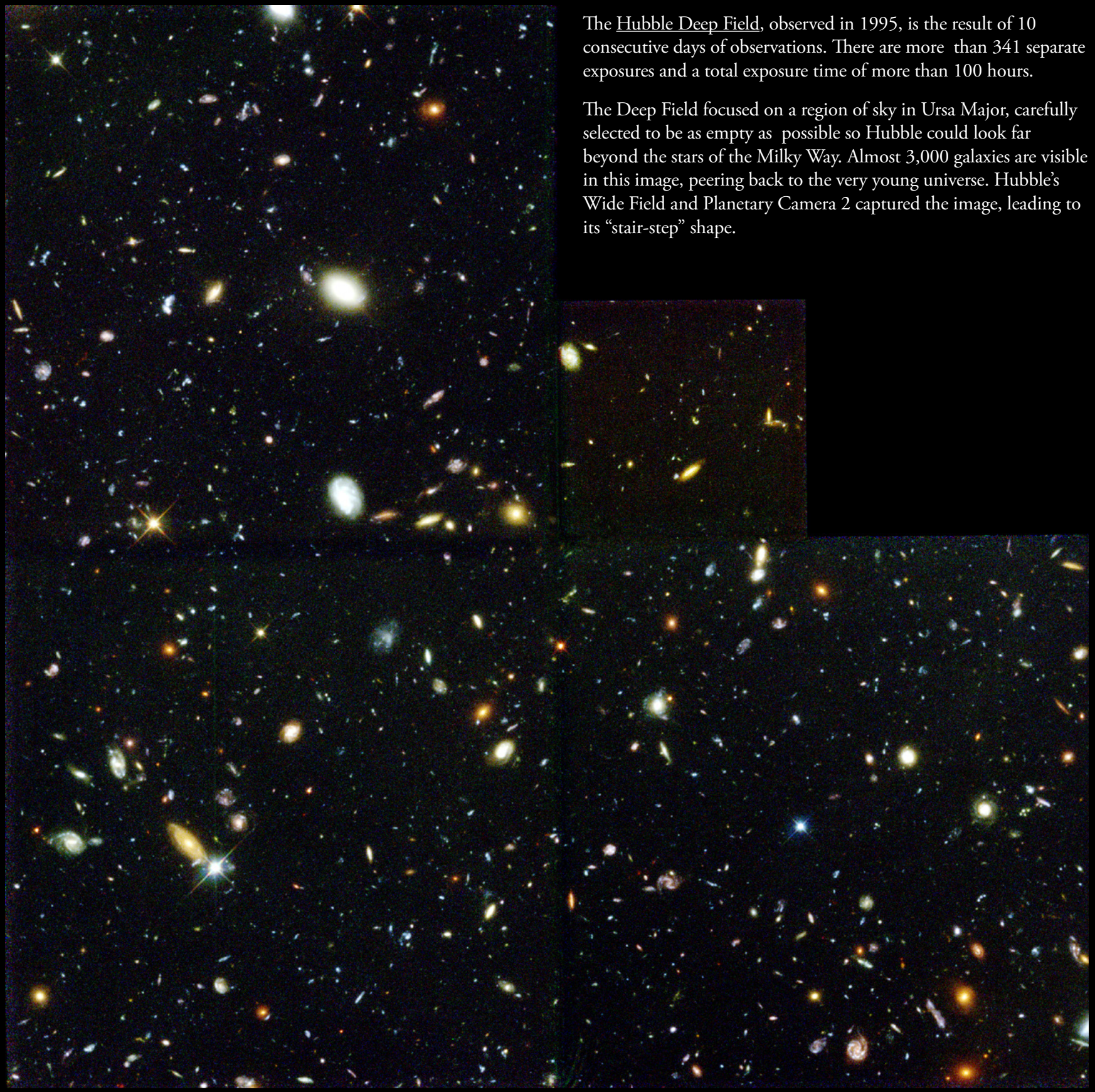


Astronauts Joseph Tanner and Gregory Harbaugh replaced Hubble's Fine Guidance Sensors during Servicing Mission 2. The Fine Guidance Sensors locate and lock onto a guide star while science instruments make observations of an astronomical object or phenomenon.



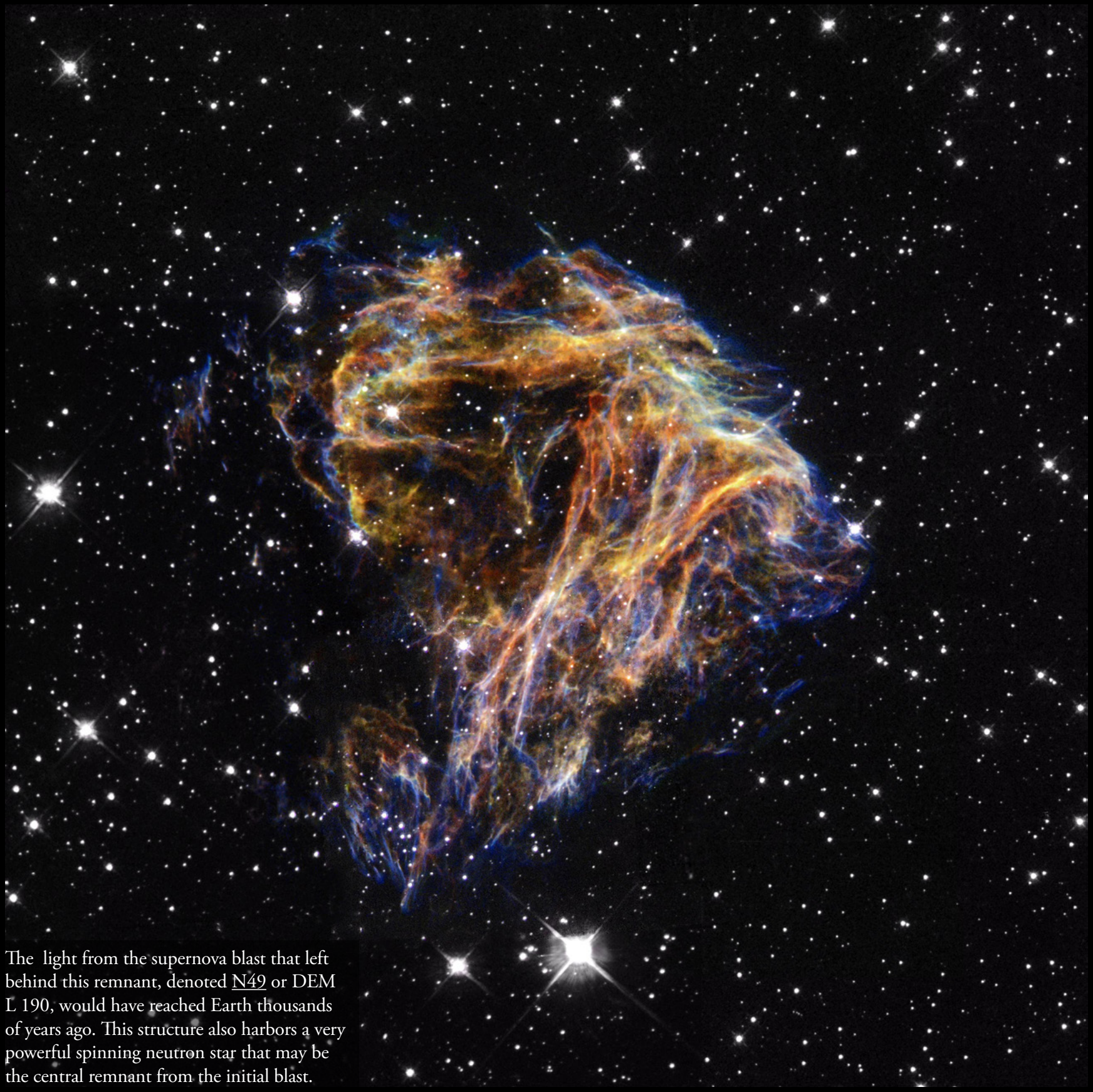
The Eagle Nebula, or Messier 16, is arguably the most famous image taken by Hubble. The structures, columns of hydrogen gas and dust clouds, act as incubators for new stars, leading to its "Pillars of Creation" nickname.

In a process called "photoevaporation," these especially dense clouds are flooded by ultraviolet light from hot, massive, newborn stars that whittles them away. Wisps of gas stripped from the cloud are visible along the top edges of each pillar. The tower on the left is four light-years tall. Here, red shows emissions from singly-ionized sulfur atoms, green reveals emission from hydrogen, and blue shows light emitted by doubly-ionized oxygen.



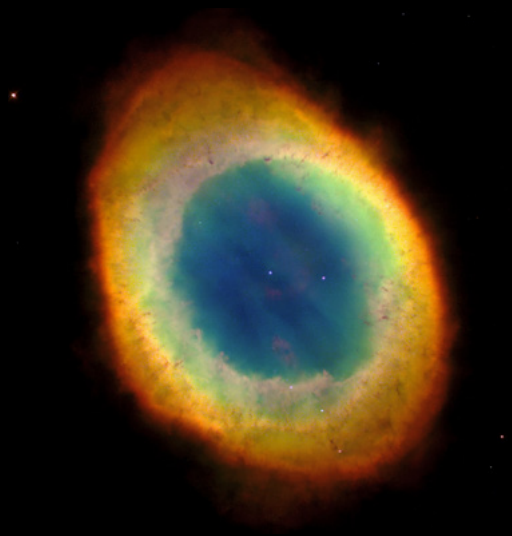
The Hubble Deep Field, observed in 1995, is the result of 10 consecutive days of observations. There are more than 341 separate exposures and a total exposure time of more than 100 hours.

The Deep Field focused on a region of sky in Ursa Major, carefully selected to be as empty as possible so Hubble could look far beyond the stars of the Milky Way. Almost 3,000 galaxies are visible in this image, peering back to the very young universe. Hubble's Wide Field and Planetary Camera 2 captured the image, leading to its "stair-step" shape.



The light from the supernova blast that left behind this remnant, denoted N49 or DEM L 190, would have reached Earth thousands of years ago. This structure also harbors a very powerful spinning neutron star that may be the central remnant from the initial blast.

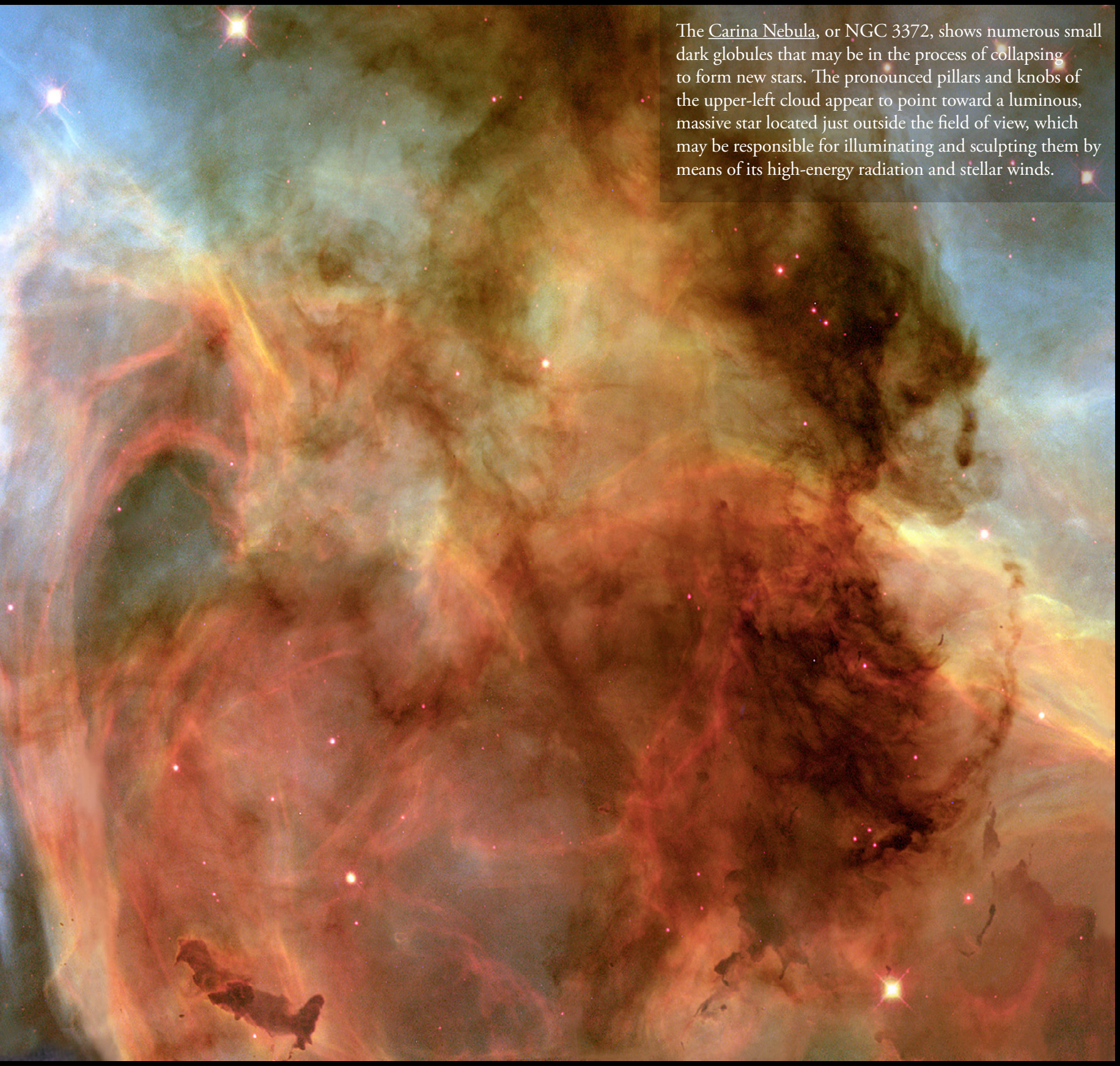
Supernova 1994D, the bright object seen in the lower left, lies on the outskirts of galaxy NGC 4526 in the Virgo cluster of galaxies. NGC 4526 is one of the brightest known lenticular galaxies, a type of galaxy between elliptical and spiral, and has hosted two known supernova explosions, one in 1969 and one in 1994.



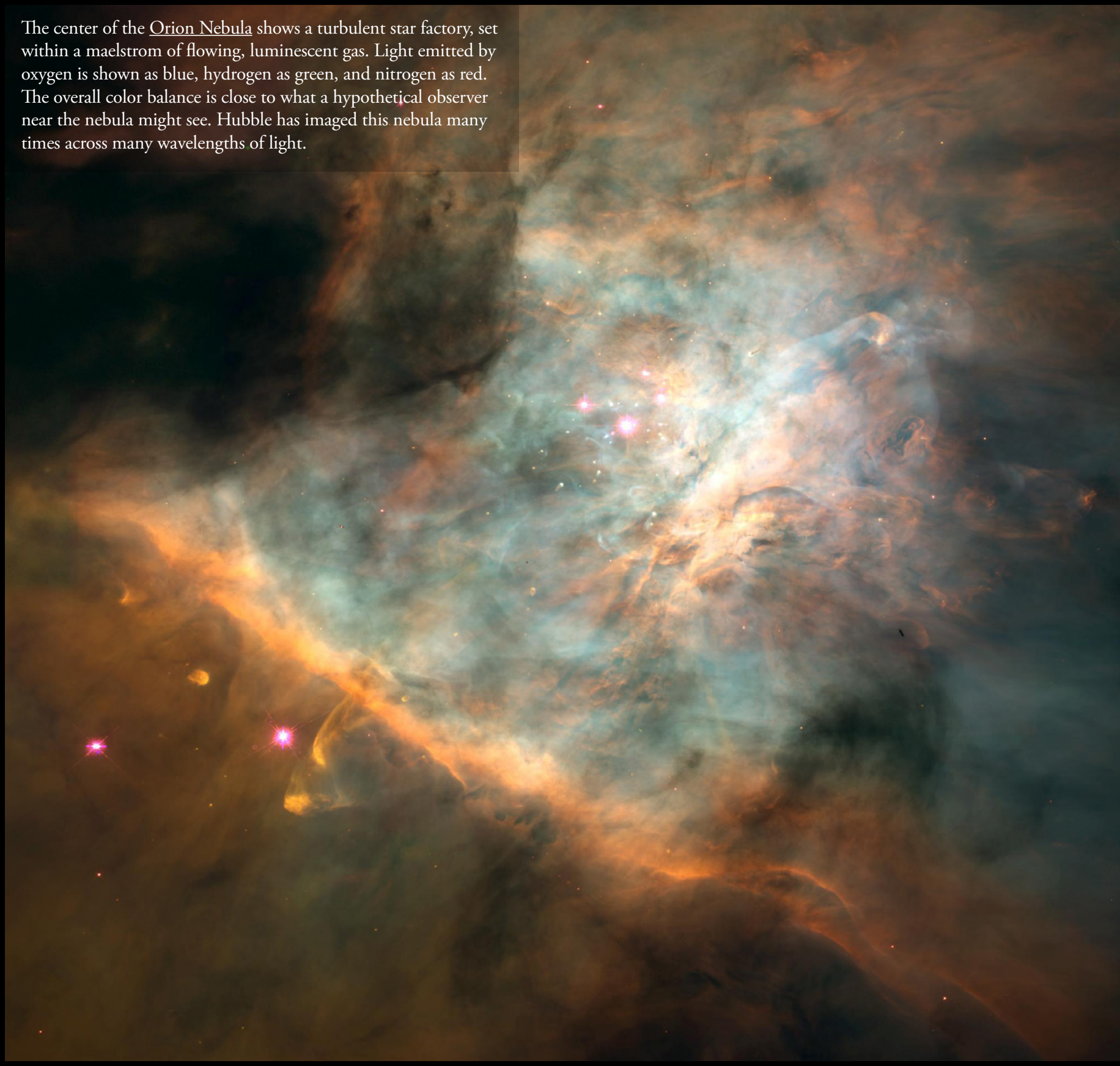
One of the most famous nebulae is the Ring Nebula. This true color image reveals the dying star at its center.

MyCn18, the Hourglass Nebula, is named after its distinctive shape. Its form is the result of a dying star shedding its outer layers in two directions.

The nebula NGC 6826's eye-like appearance is marred by two sets of red "fliers" where electrically charged atoms shoot off at supersonic speeds. The surrounding expelled faint green gas is almost half of the star's mass.



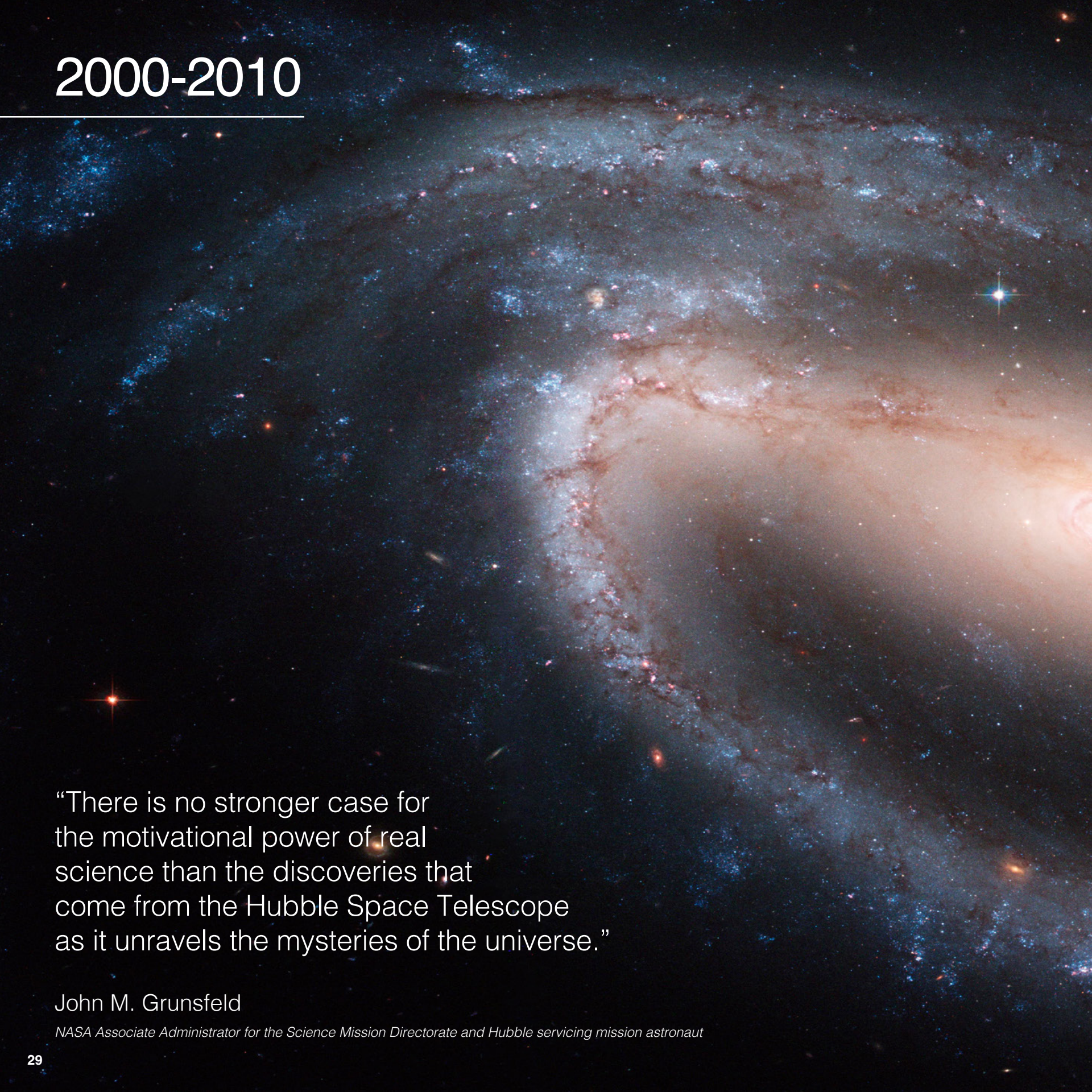
The Carina Nebula, or NGC 3372, shows numerous small dark globules that may be in the process of collapsing to form new stars. The pronounced pillars and knobs of the upper-left cloud appear to point toward a luminous, massive star located just outside the field of view, which may be responsible for illuminating and sculpting them by means of its high-energy radiation and stellar winds.



The center of the Orion Nebula shows a turbulent star factory, set within a maelstrom of flowing, luminescent gas. Light emitted by oxygen is shown as blue, hydrogen as green, and nitrogen as red. The overall color balance is close to what a hypothetical observer near the nebula might see. Hubble has imaged this nebula many times across many wavelengths of light.

Hubble was the first telescope to resolve protoplanetary disks in the Orion Nebula. Protoplanetary disks, or proplyds, are pancake-like disks of mostly gas and some dust that surround a young star. They are a prerequisite for the formation of planetary systems. Hubble has imaged proplyds around nearly 200 stars in the Orion Nebula.

2000-2010

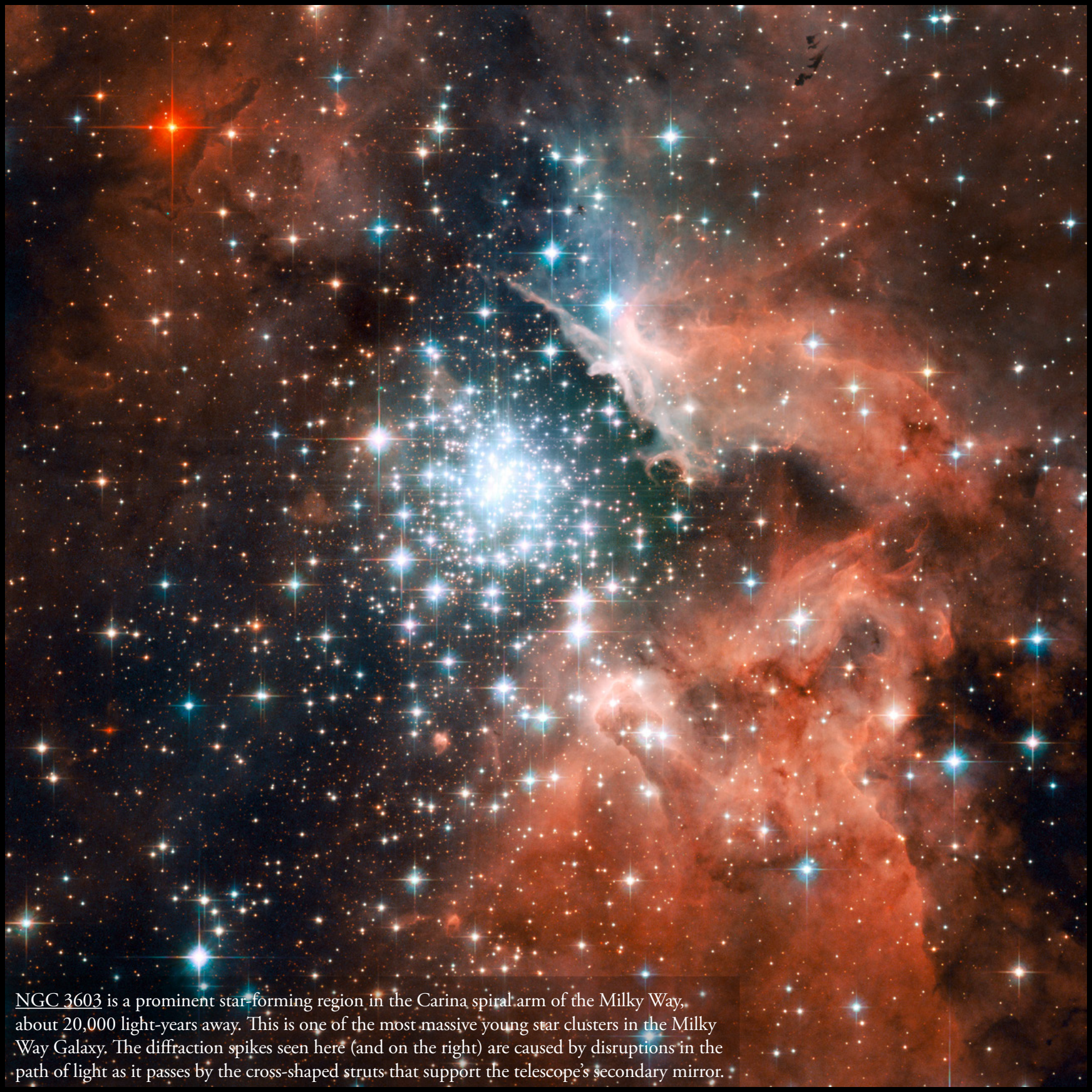


"There is no stronger case for the motivational power of real science than the discoveries that come from the Hubble Space Telescope as it unravels the mysteries of the universe."

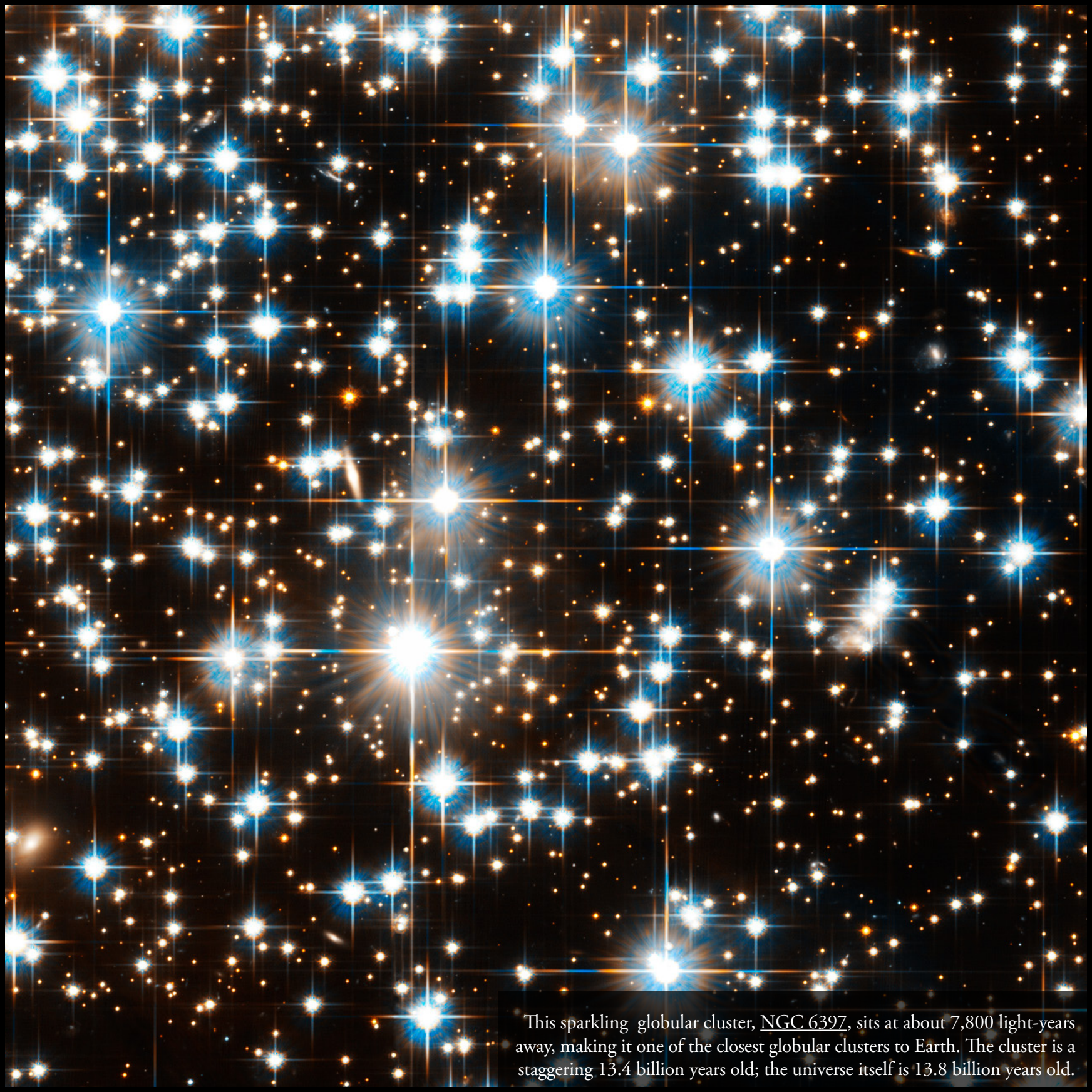
John M. Grunsfeld

NASA Associate Administrator for the Science Mission Directorate and Hubble servicing mission astronaut

This display of starlight (yellow and blue), glowing gas (pink), and silhouetted dark clouds (brown) of interstellar dust is the barred spiral galaxy NGC 1300.

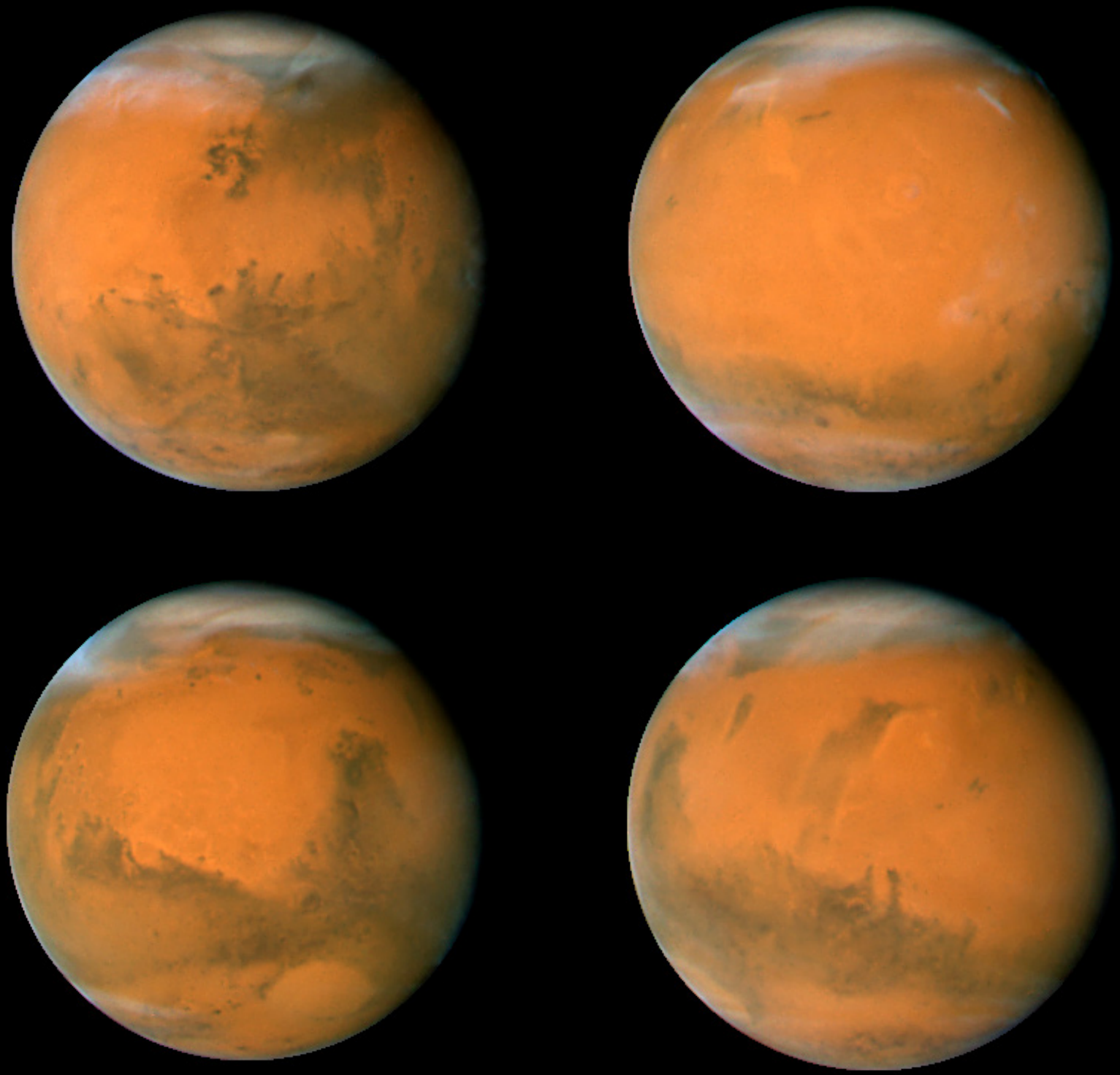


NGC 3603 is a prominent star-forming region in the Carina spiral arm of the Milky Way, about 20,000 light-years away. This is one of the most massive young star clusters in the Milky Way Galaxy. The diffraction spikes seen here (and on the right) are caused by disruptions in the path of light as it passes by the cross-shaped struts that support the telescope's secondary mirror.



This sparkling globular cluster, NGC 6397, sits at about 7,800 light-years away, making it one of the closest globular clusters to Earth. The cluster is a staggering 13.4 billion years old; the universe itself is 13.8 billion years old.

A maelstrom of star birth — and death — unfolds in this 50-light-year-wide view of the central region of the Carina Nebula. The nebula is sculpted by outflowing winds and scorching ultraviolet radiation from the large stars that call the nebula home. Learn more about the fantasy-like landscape of this nebula in Hubble's Inside The Image video.



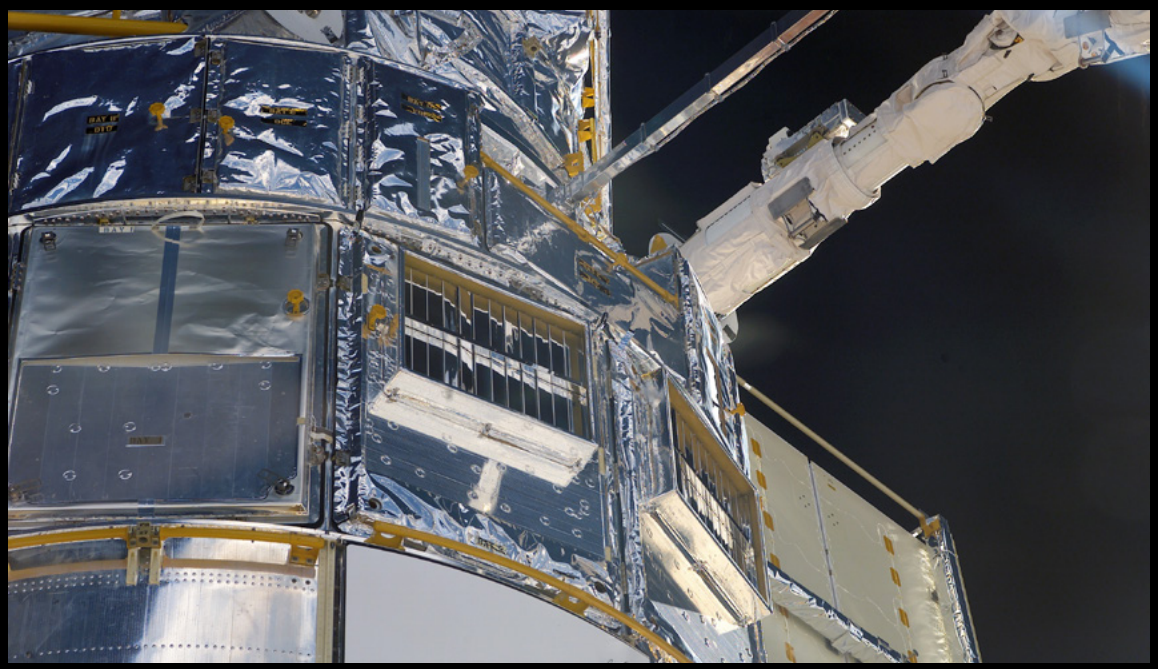
In December 2007, Mars' closest approach and opposition occurred within a week of each other. This series of images shows the planet rotating about 90 degrees from the last image, giving a full-globe look at the Red Planet. The planet appeared free of any dust storm, however, there are significant clouds visible in both the northern and southern polar cap regions.

Messier 74 is a stunning example of a “grand-design” spiral galaxy. Its symmetrical spiral arms emanate from the central nucleus and are dotted with clusters of young blue stars and glowing pink regions of ionized hydrogen (hydrogen atoms that have lost their electrons).

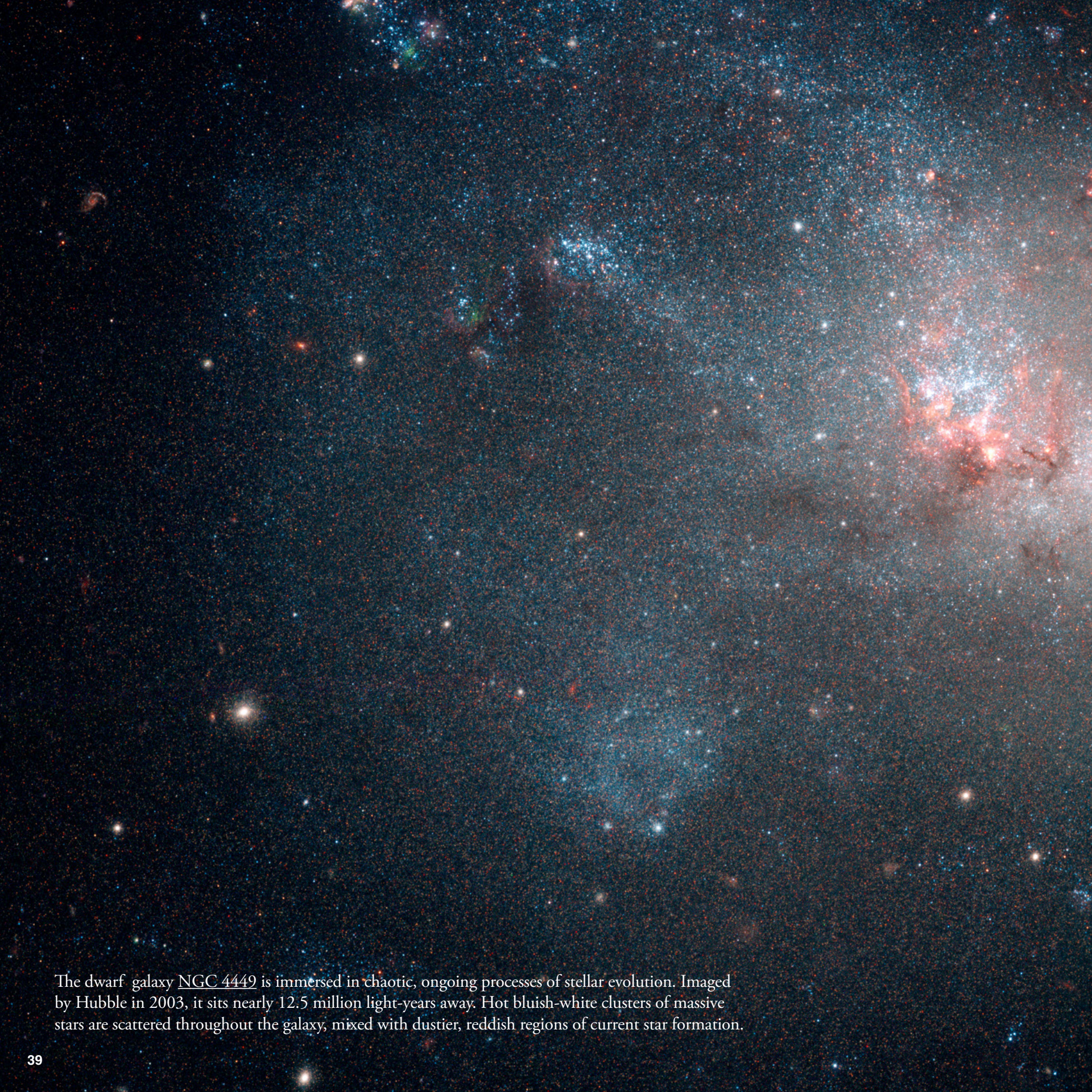
Servicing Mission 3B was the fourth visit to Hubble and took place March 1 through 12, 2002. Astronauts installed the Advanced Camera for Surveys, or ACS, which had 10 times more discovery power than the existing main camera. The mission also saw the installation of new solar arrays, a power control unit, and a cryocooler.

Top: The space shuttle Columbia's robotic arm, controlled from inside the shuttle, grasps the telescope. The robotic arm was used to capture Hubble from its orbit and place it into the shuttle's cargo bay, and then deploy it back into space at the end of the mission.

Bottom: Astronaut James H. Newman, mission specialist, waves to a crew mate during a spacewalk in which he and astronaut Mike Massimino replaced solar arrays and installed a new reaction wheel assembly that is used to turn Hubble and keep it steady.



Astronauts John M. Grunsfeld (top) and Richard M. Linnehan (bottom) conduct a 6-hour-and-48-minute spacewalk to install a new power control unit during Servicing Mission 3B.



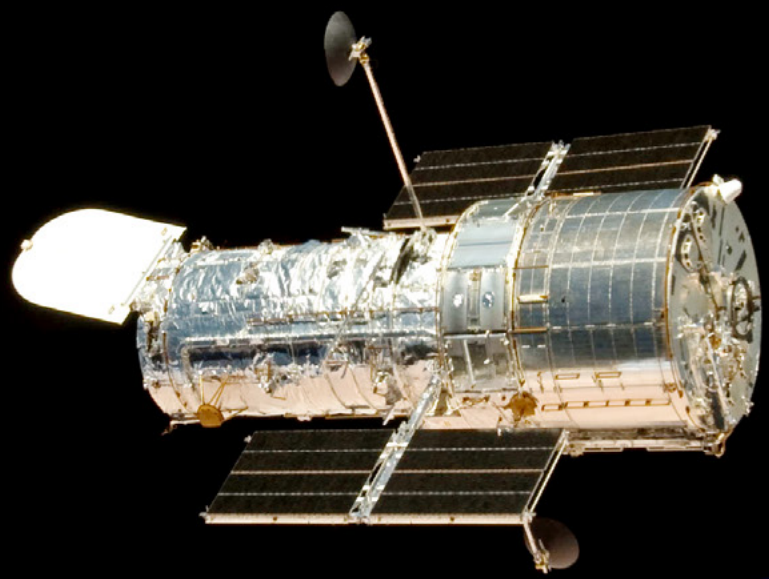
The dwarf galaxy NGC 4449 is immersed in chaotic, ongoing processes of stellar evolution. Imaged by Hubble in 2003, it sits nearly 12.5 million light-years away. Hot bluish-white clusters of massive stars are scattered throughout the galaxy, mixed with dustier, reddish regions of current star formation.

This mosaic image of the coil-shaped Helix Nebula offers a look down a trillion-mile-long tunnel of glowing gases. A forest of comet-like filaments line the inner rim of the nebula, pointing back its central star, a super-hot white dwarf (the remains of a low-mass star that has exhausted its fuel). These filaments represent high concentrations of dust and gas that the star's wind has not yet blown away.

One of the first planetary nebulae discovered, the Cat's Eye Nebula appears as a complex bull's-eye pattern of eleven or more concentric rings. Each ring is actually the edge of a spherical bubble of gas, each one puffed off at roughly 1,500-year intervals.

This cluster of blue stars is called NGC 602 and is found in a nearby galaxy called the Small Magellanic Cloud. The radiation being produced by these hot, young stars is sculpting the inner rim of the gaseous nebula, leaving some tall pillars pointing toward the stars.

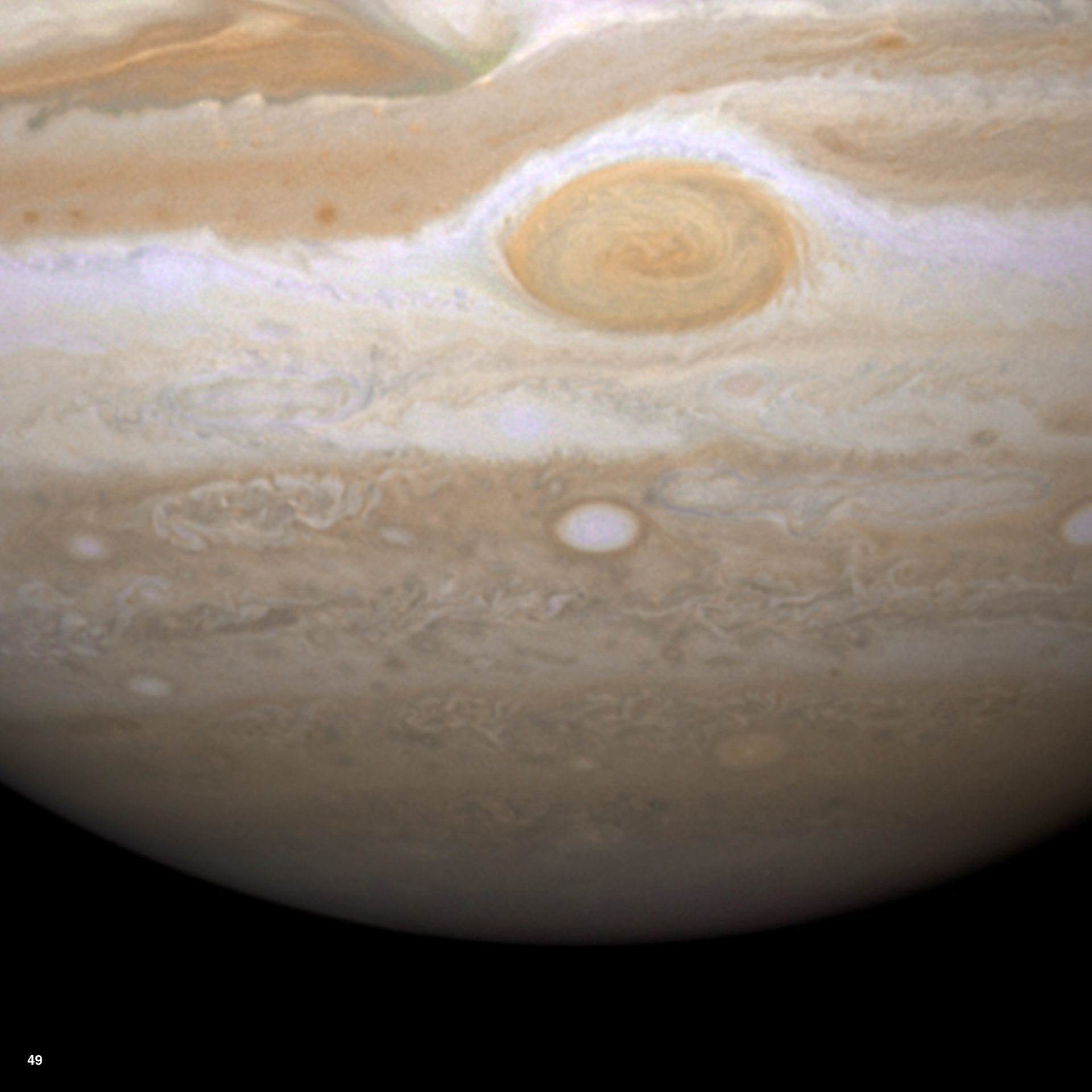
In May 2009, astronauts visited Hubble as part of Servicing Mission 4. Over the course of the 12-day mission, two new scientific instruments were installed and two failed instruments were brought back to life in the first ever on-orbit repairs, bringing Hubble to the apex of its scientific capabilities.

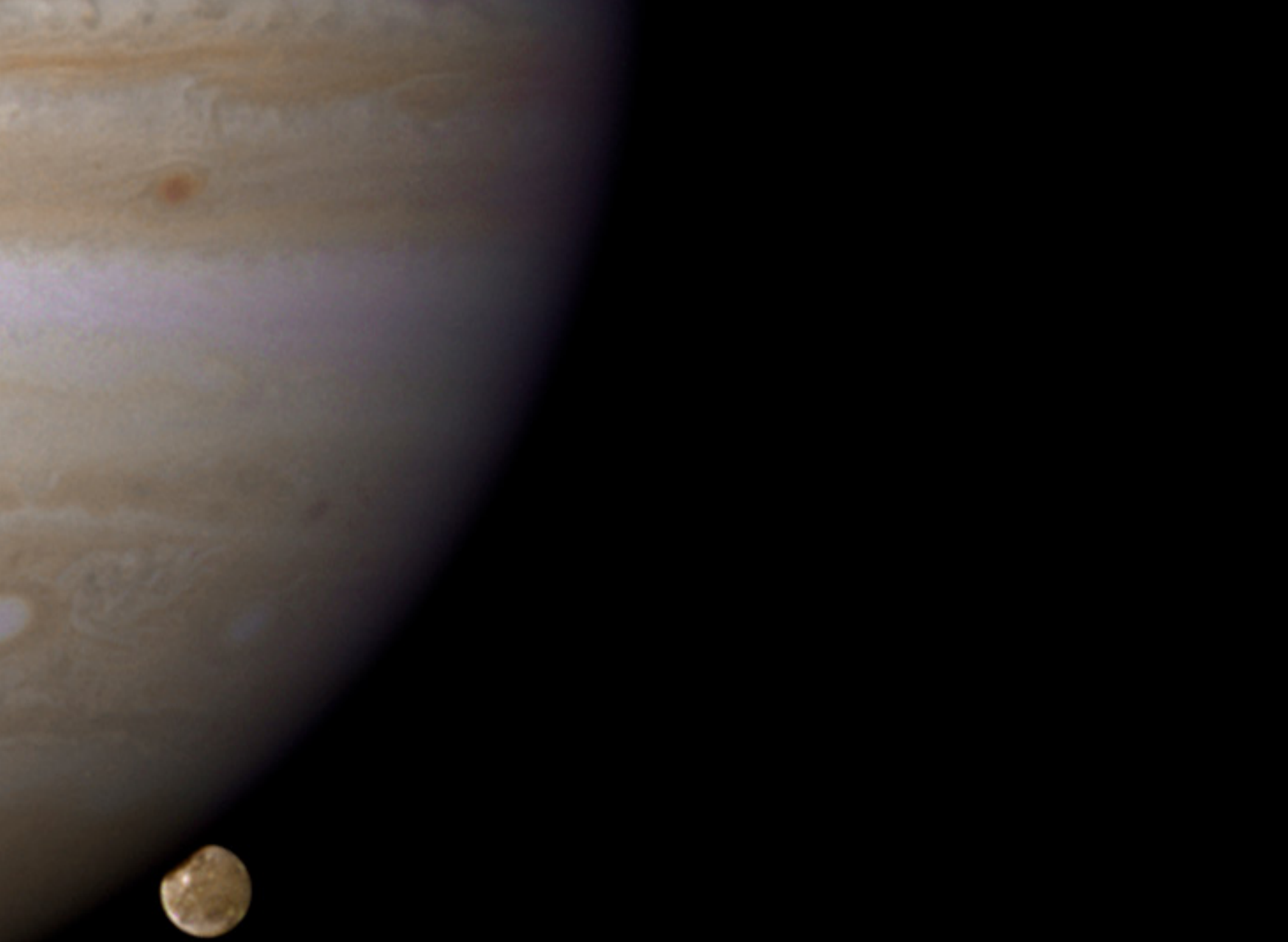


Above: Hubble is seen drifting over Earth after its final release on May 19, 2009.
Left: A close-up shot of astronaut John Grunsfeld that reveals the photographer (fellow astronaut Andrew Feustel) reflected in his helmet.

These spiral galaxies, known as the Antennae galaxies, started to interact a few hundred million years ago, making them one of the nearest and youngest examples of colliding galaxies. They are dotted with blue star-forming regions, surrounded by hydrogen gas that appears pink in the image.

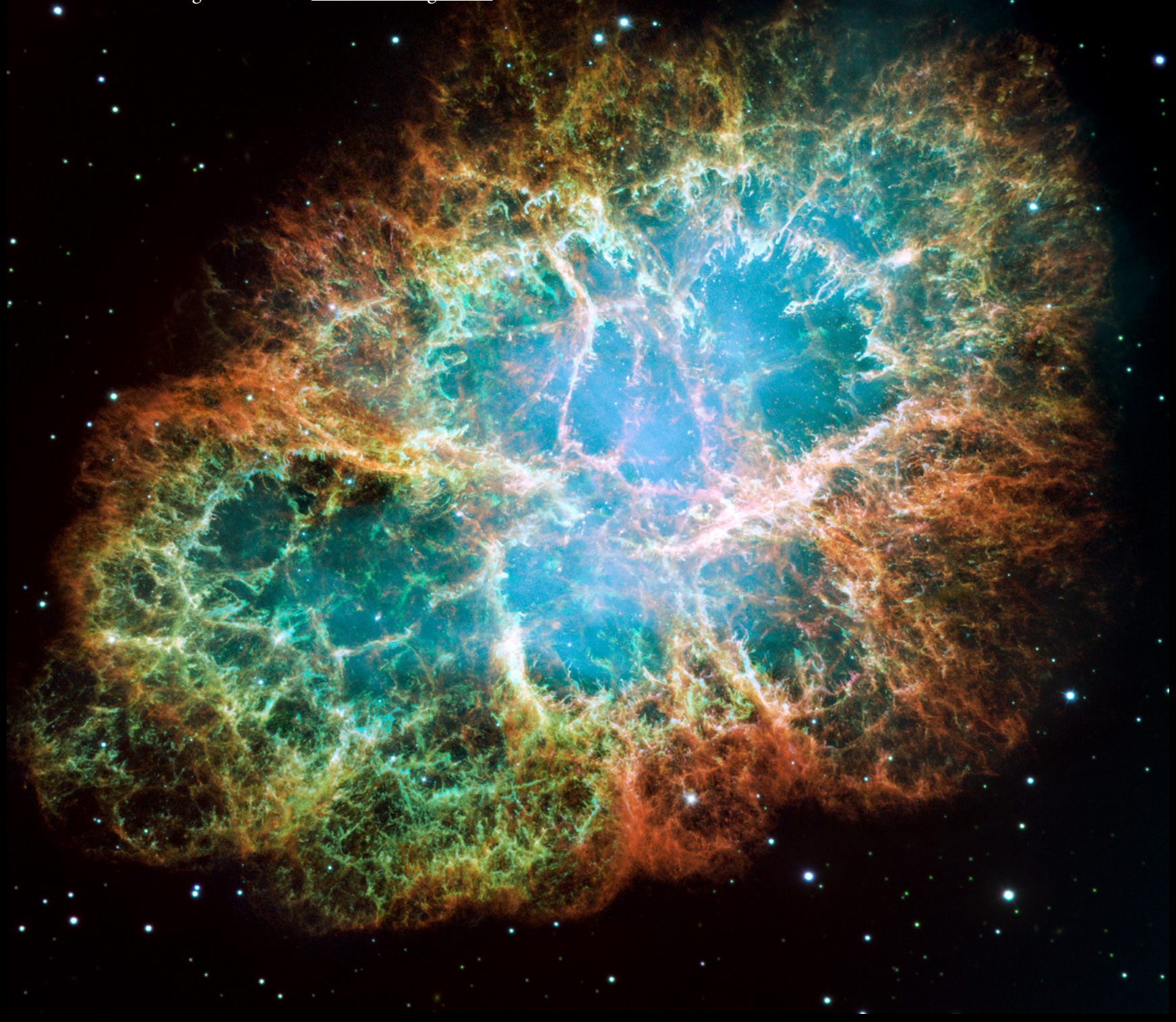
Messier 104's hallmark features include a brilliant white, bulbous core encircled by thick dust lanes comprising the spiral structure of the galaxy — earning it the nickname of "Sombrero Galaxy" for its resemblance to the broad rim and high-topped Mexican hat.



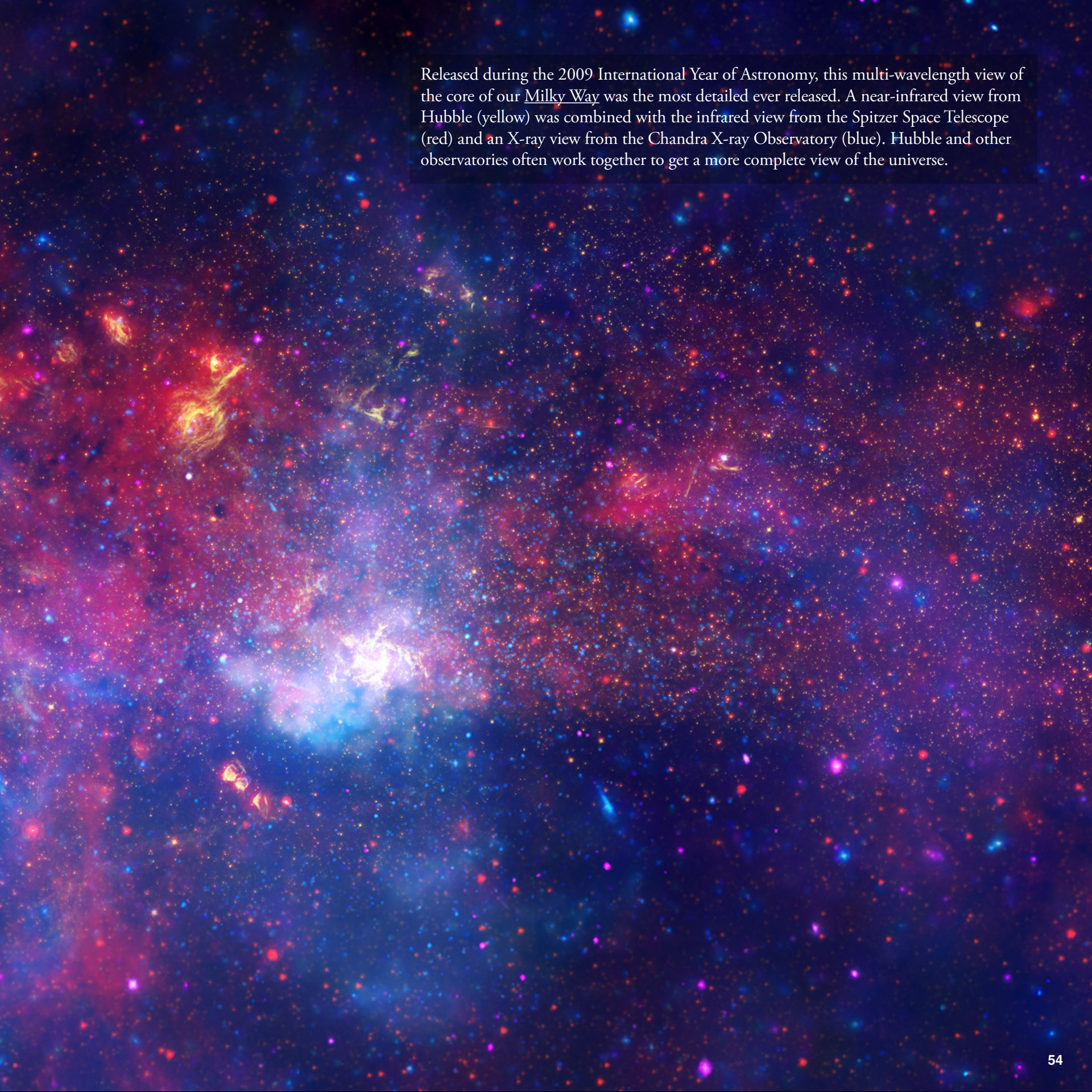


This 2007 image captures Jupiter and its moon Ganymede right before it ducks behind the giant plant. Ganymede, the largest moon in our solar system, completes an orbit around Jupiter every seven days.

The Crab Nebula, captured in this mosaic image, is a six-light-year-wide expanding remnant of a star's supernova explosion that took place in the year 1054. The orange filaments are tattered remains of the star made mainly of hydrogen. The blue light comes from electrons whirling at nearly the speed of light around the neutron star embedded in the center. Learn more about the science behind this image in Hubble's Inside the Image video.



More than 3,000 stars of various sizes appear in the full-resolution image of the Orion Nebula. The one-gigapixel image produced from 520 exposures is the sharpest view ever taken of this region. It's located 1,500 light-years away, making it the nearest massive-star-forming region to Earth.

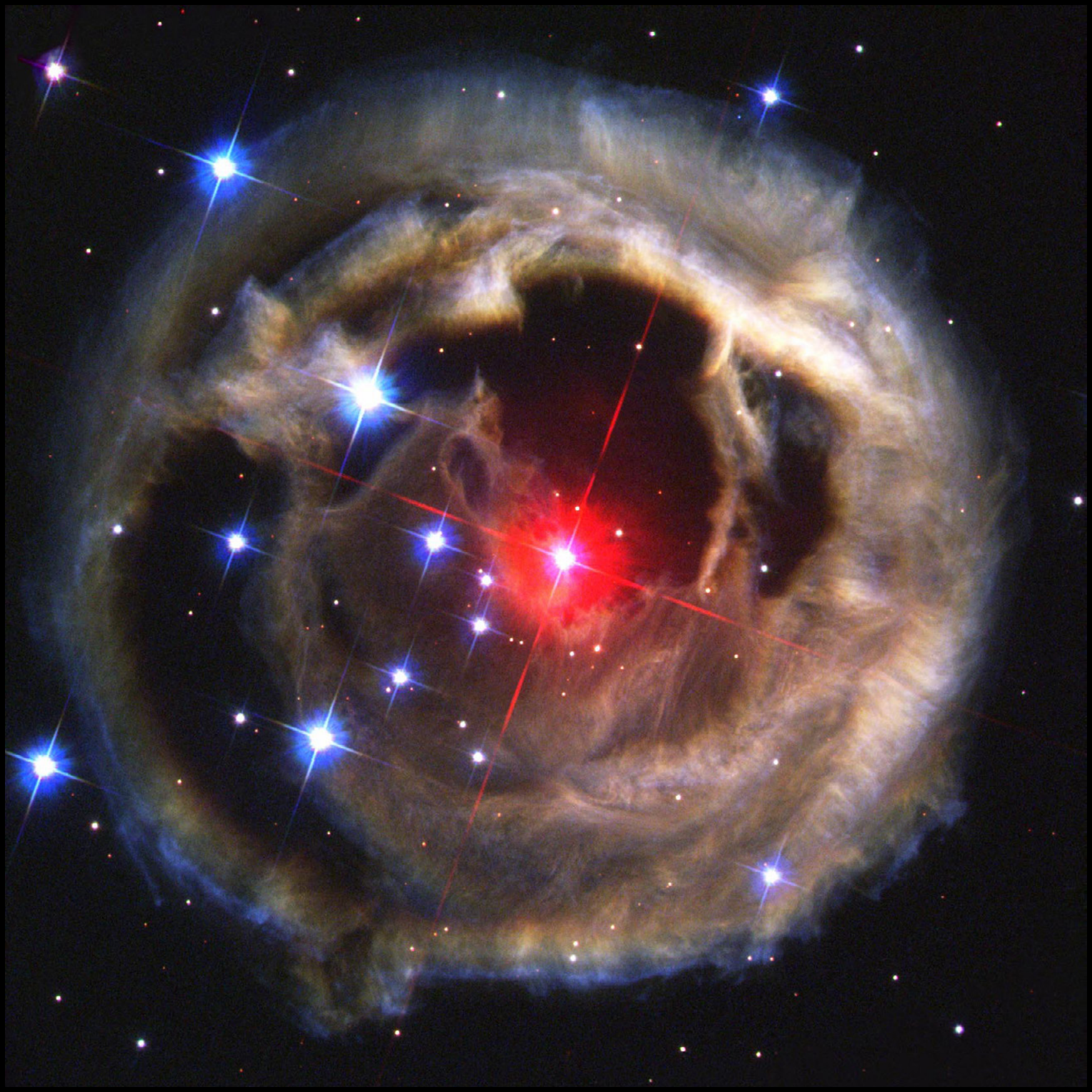


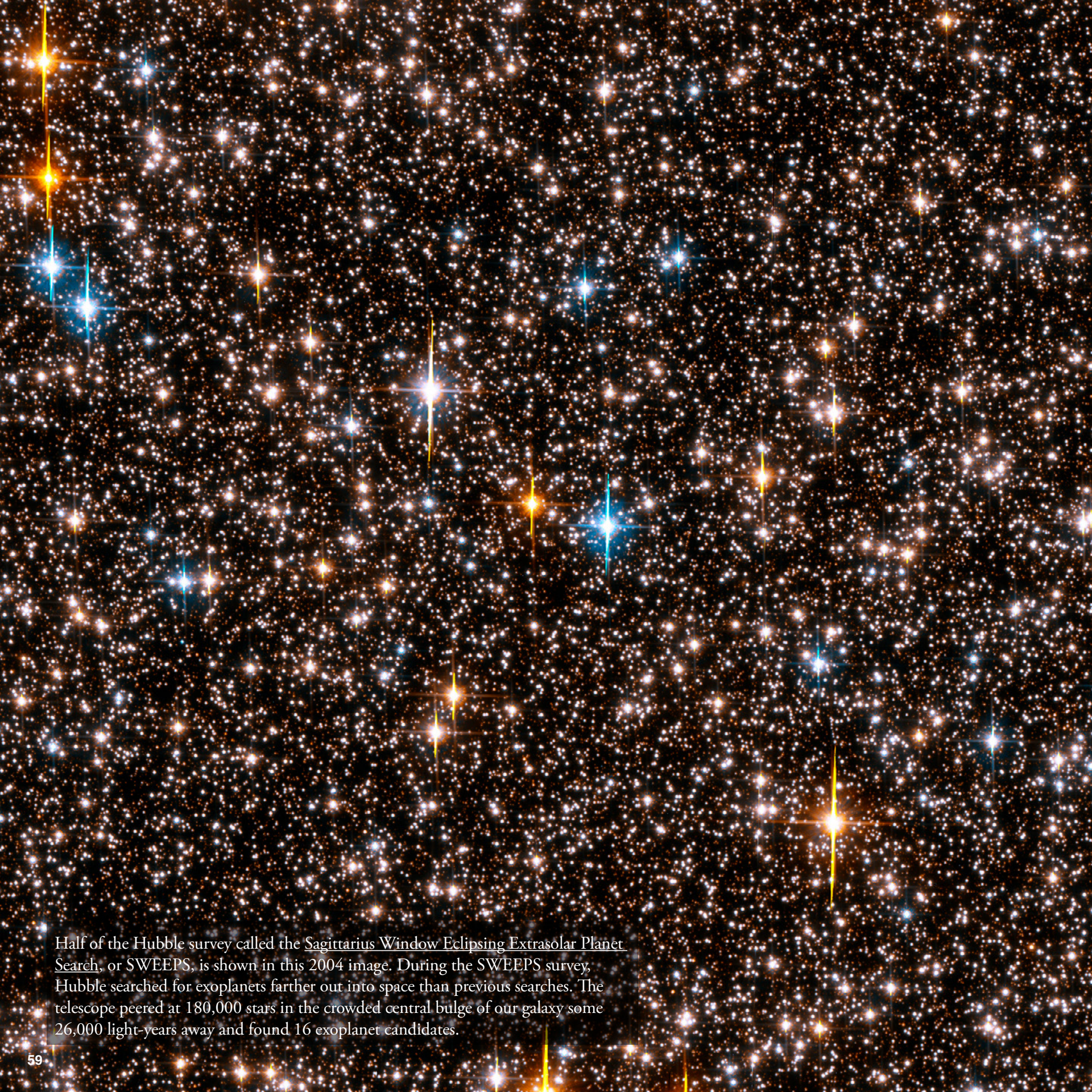
Released during the 2009 International Year of Astronomy, this multi-wavelength view of the core of our Milky Way was the most detailed ever released. A near-infrared view from Hubble (yellow) was combined with the infrared view from the Spitzer Space Telescope (red) and an X-ray view from the Chandra X-ray Observatory (blue). Hubble and other observatories often work together to get a more complete view of the universe.

Above: Messier 82 is a galaxy remarkable for its bright blue disk and webs of shredded clouds with fiery-looking plumes of hydrogen. Throughout the center of the galaxy, stars are forming 10 times faster than they are inside the Milky Way.

Left: The graceful, winding arms of the majestic Whirlpool Galaxy, also known as Messier 51, are on full display, along with the smaller, yellowish galaxy NGC 5195 (which is passing behind the Whirlpool Galaxy). Young stars reside in M51's spiral arms and older stars in the galaxy's core.

In early 2002, the star V838 Monocerotis suddenly brightened for several weeks, unveiling never-before-seen dust patterns. This series of images captures an effect known as a light echo around the star. The echoing of light through space is similar to the echoing of sound through air — as light from the stellar explosion propagates outwards, it illuminates and reflects off of different parts of the surrounding dust at different times, making the cloud appear as though it is expanding. Learn more about the structures in this dusty cloud in Hubble's Inside The Image video.





Half of the Hubble survey called the Sagittarius Window Eclipsing Extrasolar Planet Search, or SWEEPS, is shown in this 2004 image. During the SWEEPS survey, Hubble searched for exoplanets farther out into space than previous searches. The telescope peered at 180,000 stars in the crowded central bulge of our galaxy some 26,000 light-years away and found 16 exoplanet candidates.

This massive, young stellar grouping, called R136, is only a few million years old and resides in the 30 Doradus Nebula, a turbulent starbirth region in the Large Magellanic Cloud, a satellite galaxy of our Milky Way. Many of its bright blue stars are among the most massive stars known – several are more than 100 times more massive than our Sun.

This view of a star forming region called LH 95 in the Large Magellanic Cloud shows low-mass, infant stars and their much more massive stellar neighbors.

2010-2020

"The chief contribution of such a radically new and more powerful instrument would be … to uncover new phenomena not yet imagined, and perhaps to modify profoundly our basic concepts of space and time."

Lyman Spitzer, Jr.

Astrophysicist who first proposed the idea for a space-based observatory in 1946

These delicate, draped filamentary structures are a small section of the expanding remains of a massive star that exploded about 8,000 years ago. Called the Veil Nebula, it is the remains of a star that was 20 times more massive than our Sun. In this image, red corresponds to the glow of hydrogen, green from sulfur, and blue from oxygen.

30 Doradus, in the heart of the Tarantula Nebula, is the brightest star-forming region visible in a neighboring galaxy and home to the most massive stars ever seen. It's located about 170,000 light-years away, in the Large Magellanic Cloud. This image was released to commemorate Hubble's 22nd anniversary.

One of Hubble's frequent targets, the Orion Nebula is a turbulent stellar nursery that is the perfect laboratory to study how stars are born because it is 1,500 light-years away, a relatively short distance within our 100,000 light-year wide galaxy. The nebula reveals a tapestry of star formation, from dense pillars of gas and dust that may house fledgling stars, to hot, young, massive stars that are shaping the nebula with their powerful ultraviolet light.

The Bubble Nebula, or NGC 7635, is seven light-years across and resides 7,100 light-years away from Earth in the constellation Cassiopeia. The seething star responsible for this nebula is 45 times more massive than our Sun. Its escaping gas forms a "stellar wind" moving four million miles per hour, sweeping cold, interstellar gas in front, which forms the outer edge of the bubble. Learn more in Hubble's Inside the Image video.

One of the Milky Way's closest galactic neighbors is the Small Magellanic Cloud, a very bright galaxy that is visible with the naked eye from the Southern Hemisphere and near the equator. This image is a composite of data from Hubble (red, green, and blue), the Chandra X-Ray Observatory (purple), and the Spitzer Space Telescope (also red).

Planetary nebulae, like NGC 5189, represent the final stage in the life of a medium-sized star, when the dying star expels a large portion of its outer envelope. As a result of the mass-loss process, the nebula has two nested structures that expand away from the center in different directions.

About 30 million light-years away, NGC 3147 has majestic winding arms of young blue stars, pinkish nebulae, and dust. At the center is a malnourished black hole surrounded by a thin, compact disk of stars, gas, and dust that is caught up in a gravitational maelstrom.

This infrared-light portrait of a small part of the Monkey Head Nebula, also known as NCG 2174, shows a roiling region of starbirth. Located 6,400 light-years away, the nebula hosts dusky dust clouds silhouetted against glowing gas.

This image represents 16 years' worth of Hubble observations and is a combination of nearly 7,500 separate Hubble exposures. Called the Hubble Legacy Field, this ambitious endeavor presents a wide portrait of the distant universe and contains roughly 265,000 galaxies, stretching back through 13.3 billion years of time to just 500 million years after the big bang. The faintest and farthest galaxies are just one ten-billionth the brightness of what the human eye can see. This book can't capture the full resolution (650 megapixels!) of this image.

This bipolar star-forming region, called Sharpless 2-106, lies nearly 2,000 light-years away. Sharpless 2-106 looks a bit like a soaring, celestial angel and a massive, young star, Infrared Source 4, is responsible for the furious activity present. Twin lobes of super-hot gas, glowing blue in this image, stretch outward from the central star, creating the “wings” of the angel.

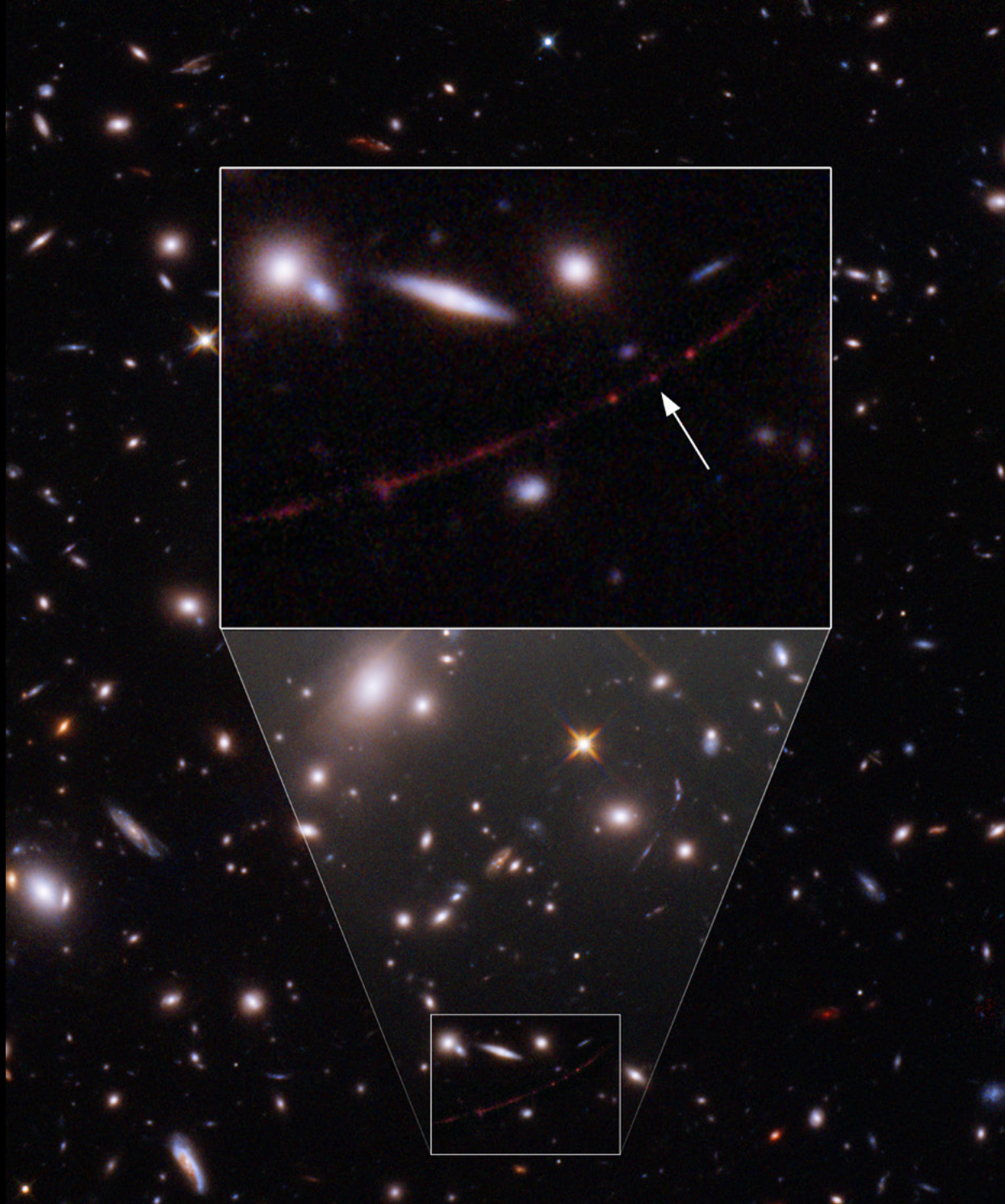
The Pillars of Creation in the Eagle Nebula (M16) stand five light-years tall and are giving birth to new stars buried in the dusty spires. The pillars first became famous after Hubble imaged them in 1995. This portrait, retaken in 2015 with a higher resolution camera, is in visible light.

This near-infrared portrait of the Pillars of Creation shows the silhouettes of the pillars against a background of stars. Near-infrared light can penetrate much of the gas and dust in the nebula, revealing the thousands of stars hidden behind and inside the nebula.

N44 is a complex nebula filled with glowing hydrogen gas, dark lanes of dust, massive stars, and many stars of different ages. One of its most distinctive features is a dark, starry gap called a "superbubble," visible in this image. The presence of the about 250-light-year-wide hole is still a bit of a mystery. Learn more about N44 in Hubble's Inside The Image video.

Dark lanes of dust crisscross the giant elliptical galaxy Centaurus A. The galaxy's disk has a warped shape, providing evidence for a past collision and merger with another galaxy. Centaurus A contains the closest active galactic nucleus to Earth, meaning the center of the galaxy is home to a supermassive black hole (not visible in this image).

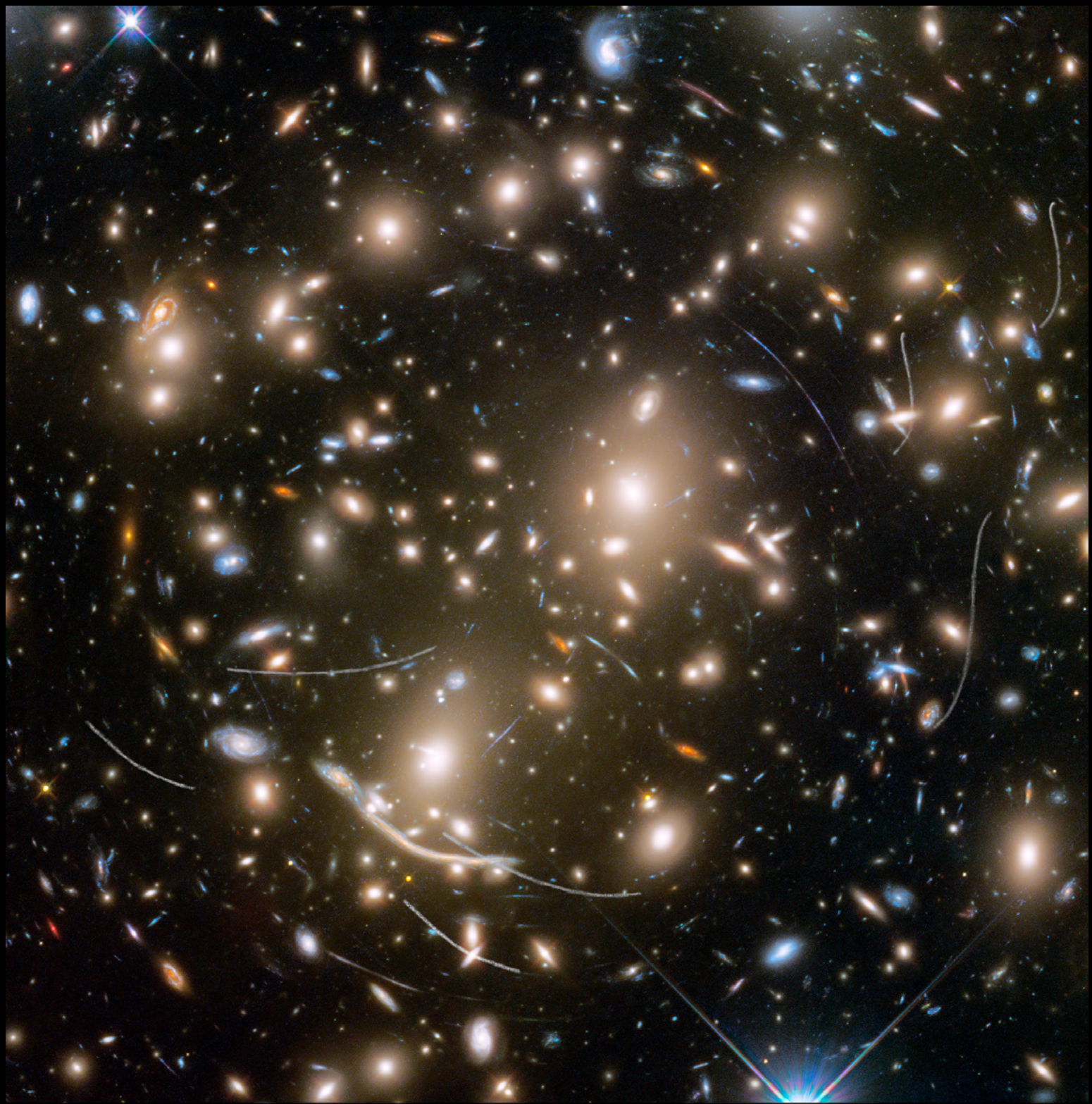
The spiraling dust lanes coming from the center of spiral galaxy NGC 2841 are silhouetted against a population of whitish middle-aged stars. Much younger blue stars trace the spiral arms. Notably missing are the pinkish emission nebulae that indicate new star birth. Radiation and supersonic winds from the super-hot blue stars likely cleared out the remaining gas and shut down further star formation.



Denoted with the arrow above is the farthest individual star ever seen. Nicknamed Earendel, the star is so far away that its light took 12.9 billion years to reach Earth, appearing to us as it did when the universe was only 7% of its current age. Scientists estimate that Earendel is at least 50 times the mass of our Sun and millions of times as bright. But even such a brilliant and high-mass star would be impossible to see without the aid of natural magnification by a huge foreground galaxy cluster whose mass is creating a gravitational lens. Earendel is a type of star that lives only around 500 million years, meaning that by the time its light reached us, it no longer existed. Learn more about this benchmark in Hubble's Inside the Image video.

This partial image of Messier 83, also known as the Southern Pinwheel Galaxy, contains stars, star clusters, and supernova remnants. The vibrant magentas and blues demonstrate how the spiral galaxy is ablaze with star formation. The newest stars are forming largely in clusters on the edges of the dark brown spiral dust lanes.

The bright, southern hemisphere star RS Puppis at the center of this image is ten times more massive than our Sun. RS Puppis rhythmically brightens and dims over a six-week cycle.

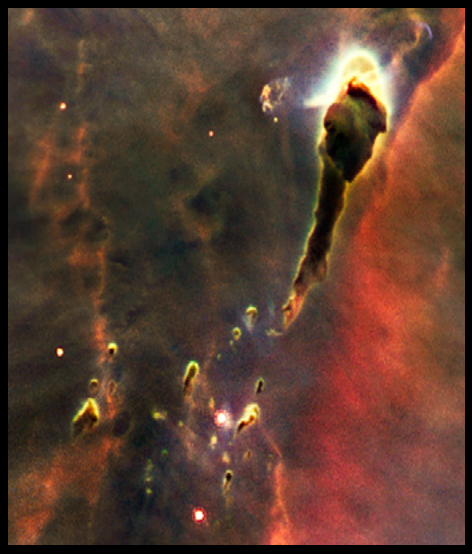


Galaxy cluster Abell 370 contains an astounding assortment of several hundred galaxies. Entangled among them are thin, white trails that look like curved streaks; theses are the trails from asteroids much closer to Earth. The trails should not be confused with the arcs of blue and yellow light that are actually distorted images of distant galaxies behind the cluster. This is an example of "gravitational lensing," when a galaxy cluster acts as a natural telescope.

A billowing cloud of cold interstellar gas and dust, known as Mystic Mountain, is rising from a tempestuous stellar nursery located in the Carina Nebula, about 7,500 light-years away. This pillar serves as an incubator for new stars. The pillars are sculpted by stellar winds and material evaporating off the edges of the pillars. On the left is Hubble's visible-light view, and above is Hubble's near-infrared view, piercing through the clouds of gas and dust.

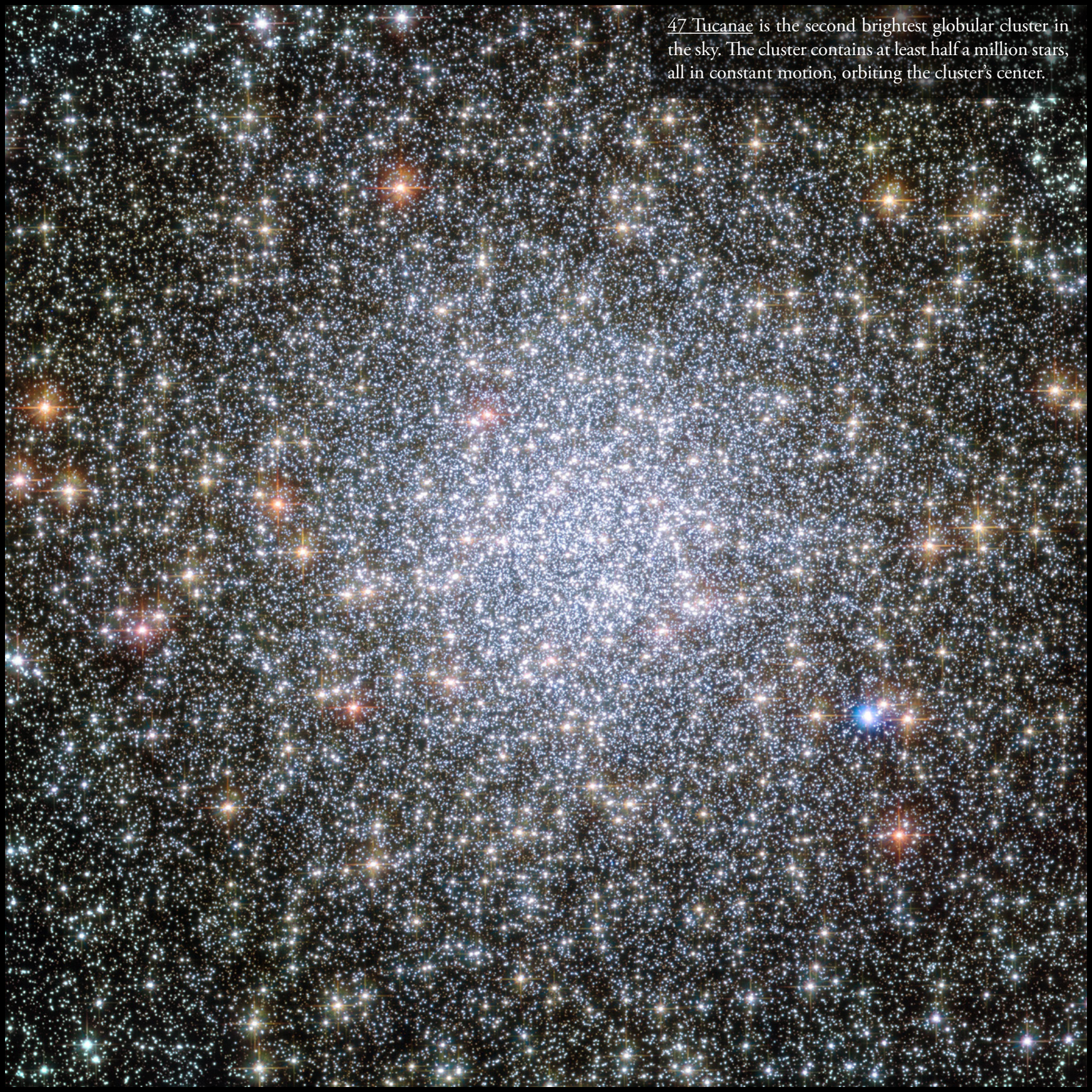
To the right are close-up views of small portions of the nebula. Dive into this dramatic landscape and learn more about the science behind it with Hubble's Inside the Image video.

The noteworthy feature in this image is a 3.5 trillion-mile-long horizontal jet. A young star hidden in the tip of the pillar-like structure is blasting the jet into space. A bowshock is visible on the left side of the jet.

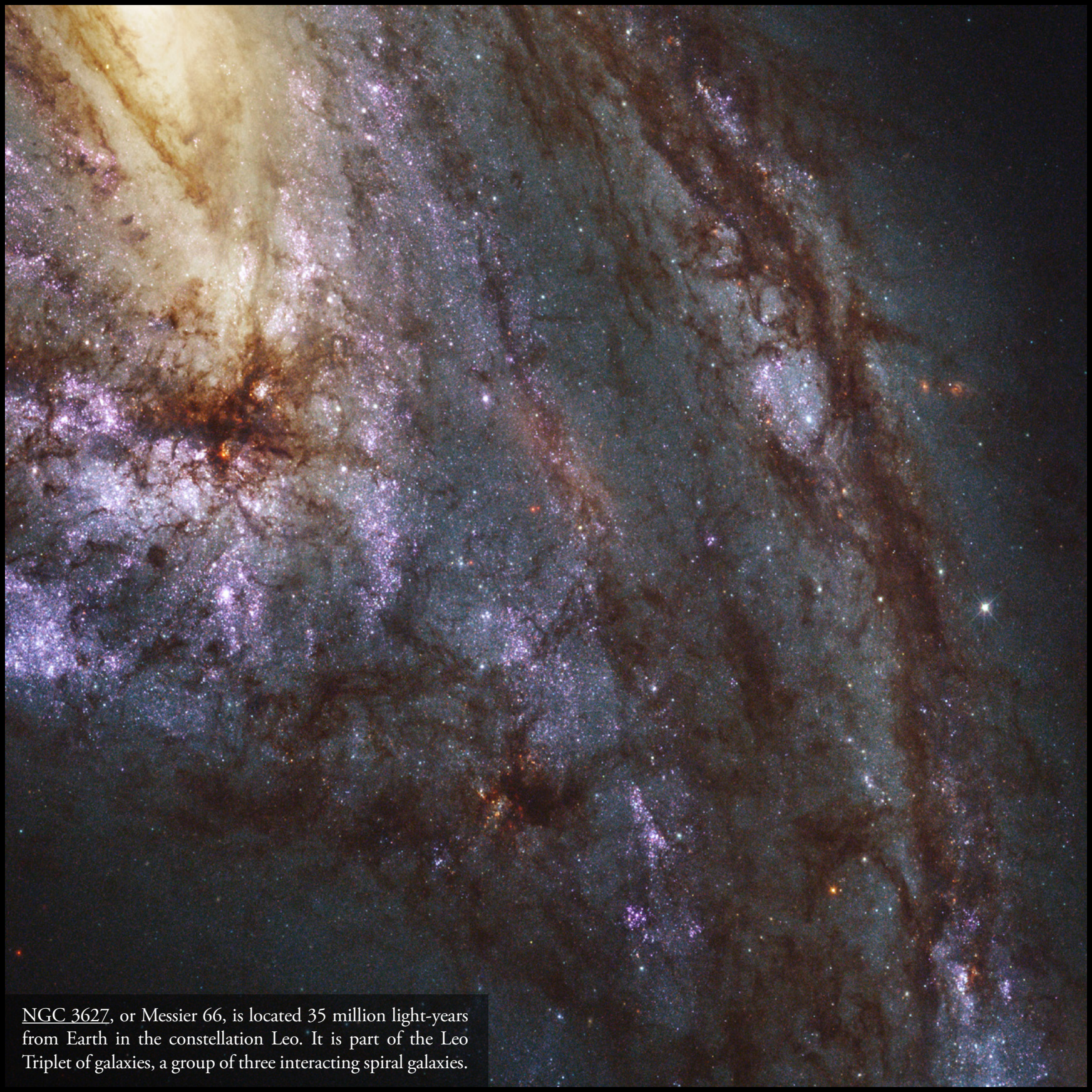


Mystic Mountain is a nebula made up of primarily cold hydrogen gas, laced with dust — which makes it opaque. Young stars in the region shed ultraviolet light, and this radiation erodes the gas into tadpole-like shapes.

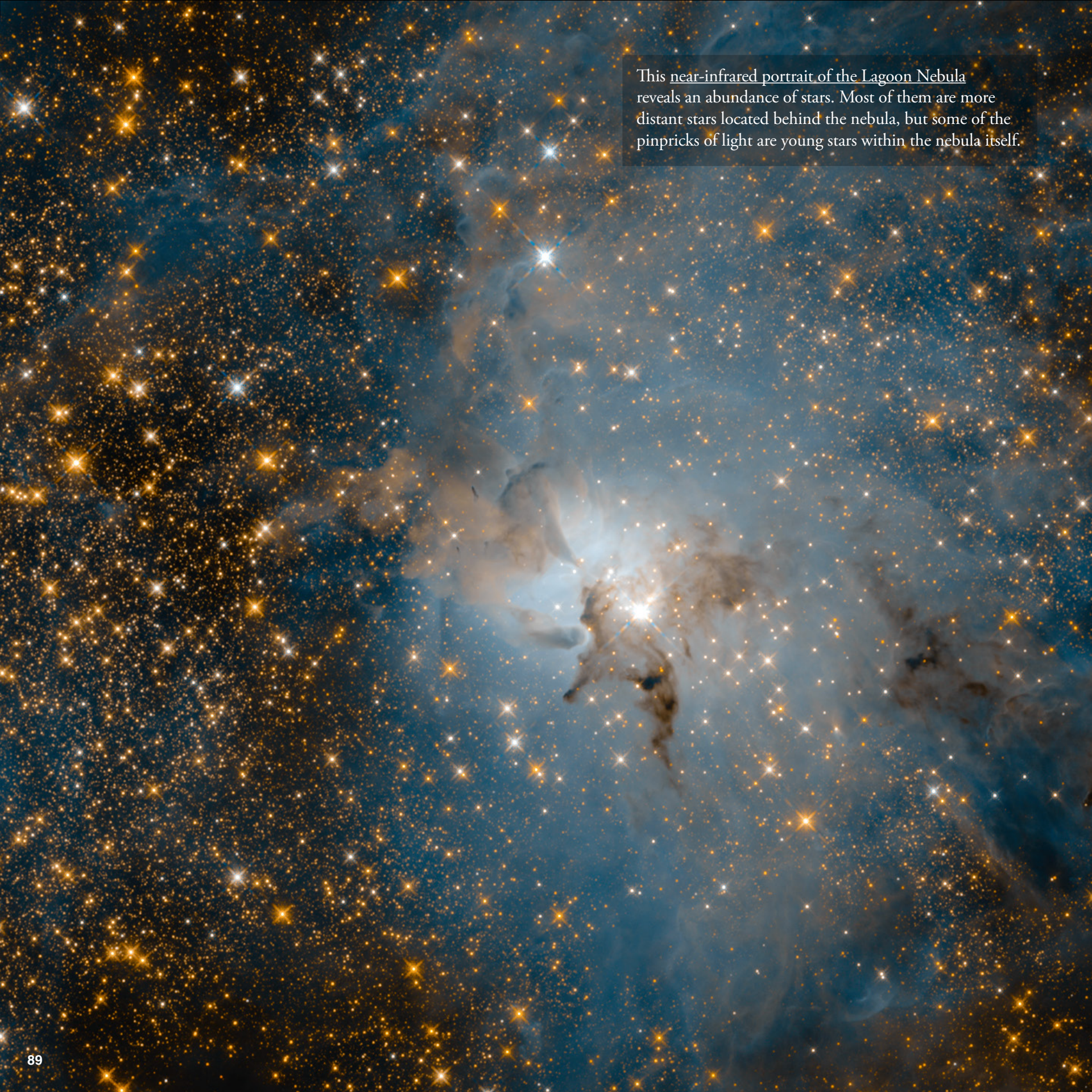
This free-floating cloud of gas and dust is a whopping 2.3 trillion miles long! Like the structure above, this was originally formed by erosion from ultraviolet light coming off nearby young stars.



47 Tucanae is the second brightest globular cluster in the sky. The cluster contains at least half a million stars, all in constant motion, orbiting the cluster's center.



NGC 3627, or Messier 66, is located 35 million light-years from Earth in the constellation Leo. It is part of the Leo Triplet of galaxies, a group of three interacting spiral galaxies.

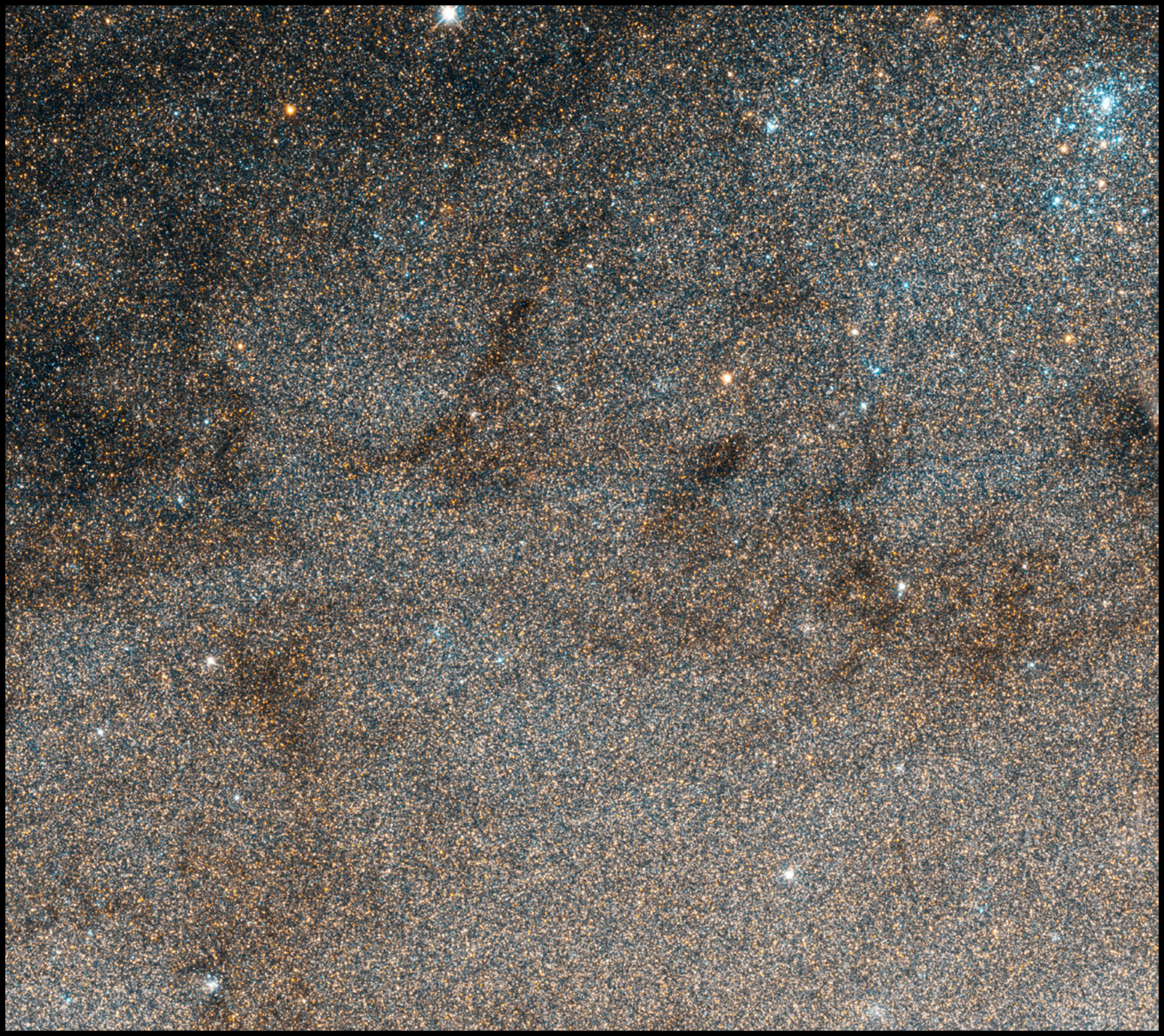


This near-infrared portrait of the Lagoon Nebula reveals an abundance of stars. Most of them are more distant stars located behind the nebula, but some of the pinpricks of light are young stars within the nebula itself.

At the center of this visible-light image of the Lagoon Nebula is a monster young star 200,000 times brighter than our Sun. The star, Herschel 36, is blasting powerful ultraviolet radiation and hurricane-like stellar winds that are carving out a landscape of ridges, cavities, and mountains of gas and dust. In this image, oxygen gas is in blue, yellow is matter illuminated by Herschel 36's brilliant light, the reddish hue is glowing nitrogen, and the dark purple areas represent a mixture of hydrogen, oxygen, and nitrogen.

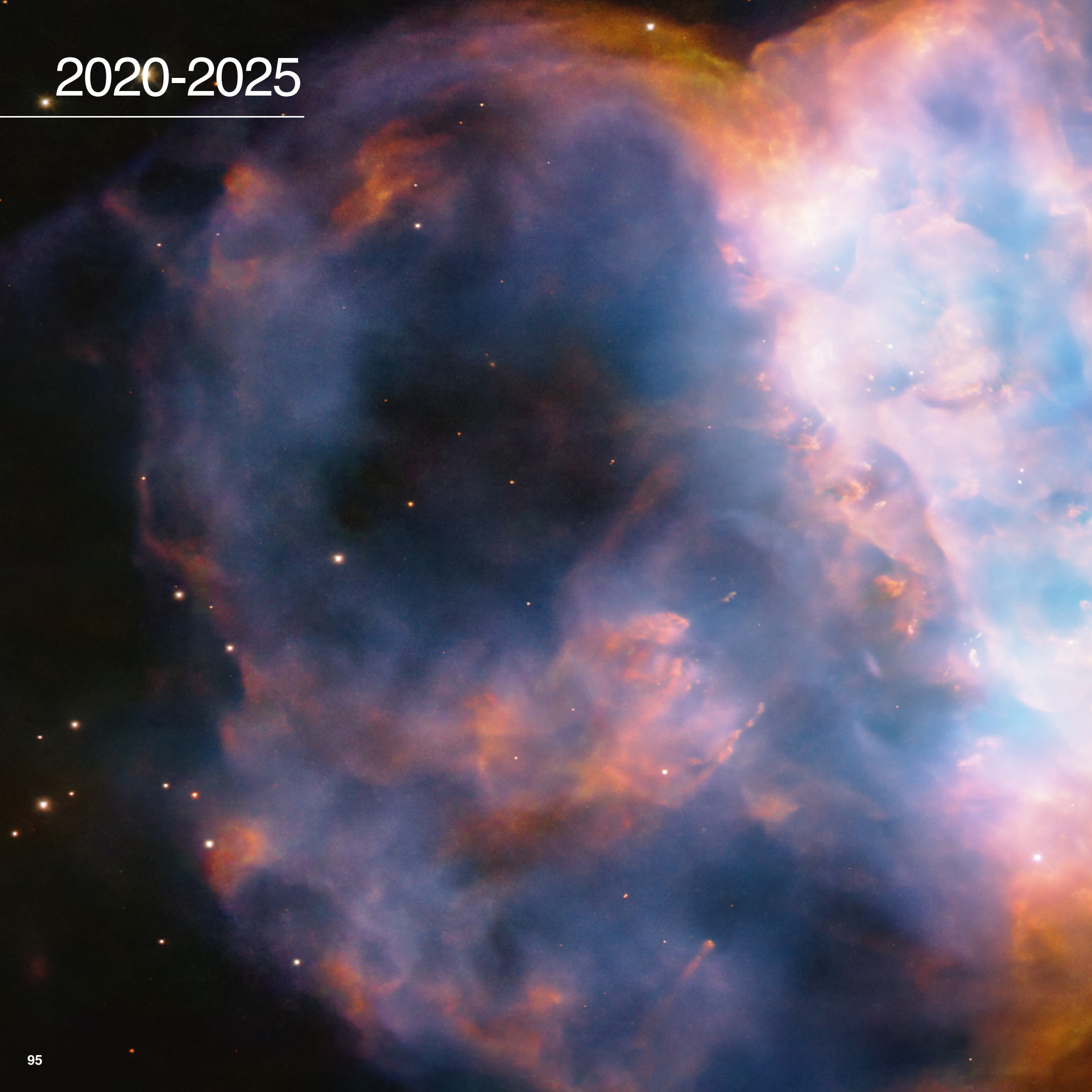
This sweeping bird's-eye view of a portion of the Andromeda Galaxy is the sharpest large composite image ever taken of our galactic next-door neighbor. The innermost hub of the galaxy is visible at bottom-left. The panorama then sweeps from the central bulge across lanes of stars and dust toward the sparser outer disk. Large groups of young blue stars indicate the locations of star clusters and star-forming regions. This is only a portion of a fuller image with 1.5 billion pixels, which would require over 600 HD television screens to display! It remains the biggest Hubble image ever released, and shows over 100 million stars and thousands of star clusters embedded in a section of the galaxy's pancake-shaped disk stretching across over 40 light-years.

This close-up portrait shows a region of the Andromeda Galaxy, replete with star clusters seen in bright blue, which stretches about 4.4 light-years across. Andromeda is our nearest major galactic neighbor, at a distance of 2.5 million light-years from Earth.



The star V1, seen at lower left, is a special class of pulsating star called a Cepheid variable which astronomers use to make measurements of large cosmic distances. V1 helped astronomer Edwin Hubble show that the Andromeda galaxy lies beyond our home galaxy, the Milky Way. This Hubble image shows V1's surroundings.

2020-2025



Released for Hubble's 34th anniversary, this image of the Little Dumbbell Nebula shows expanding lobes of material cast off from a dying star.

"We're poised now for many years of discovery ahead. Hubble plays a powerful role in NASA's astronomical toolkit."

Dr. Jennifer Wiseman

Hubble's Senior Project Scientist

The giant red nebula (NGC 2014) and the smaller, nearby blue nebula (NGC 2020) are part of a vast star-forming region in the Large Magellanic Cloud. Nicknamed the Cosmic Reef for its resemblance to an undersea world, this image shows a grouping of bright stars, each 10 to 20 times more massive than our Sun.

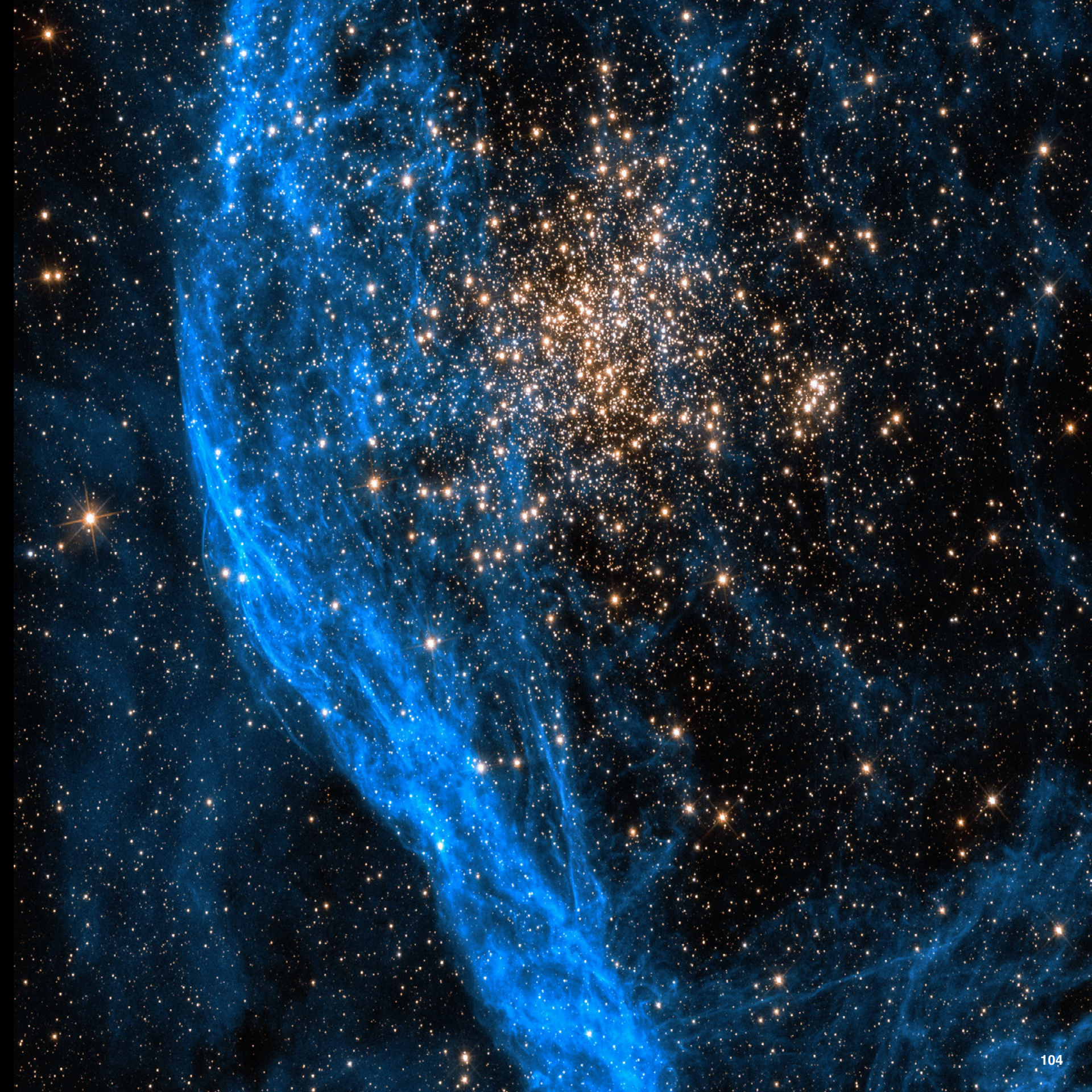
Left: This triangle-shaped star birthing frenzy (called Arp 143) is fueled by a head-on collision between two galaxies, NGC 2445 at the right and NGC 2444 at the left. NGC 2445 is awash in starbirth because it is rich in gas, the fuel that makes stars.

Below: One of the brightest stars seen in our galaxy, AG Carinae, is waging a tug-of-war between gravity and radiation to avoid self-destruction. The structure is the result of one or more giant eruptions about 10,000 years ago. The expanding shell of gas and dust that surrounds the star is about five light-years wide – the same distance from Earth to the nearest star beyond our Sun, Proxima Centauri.

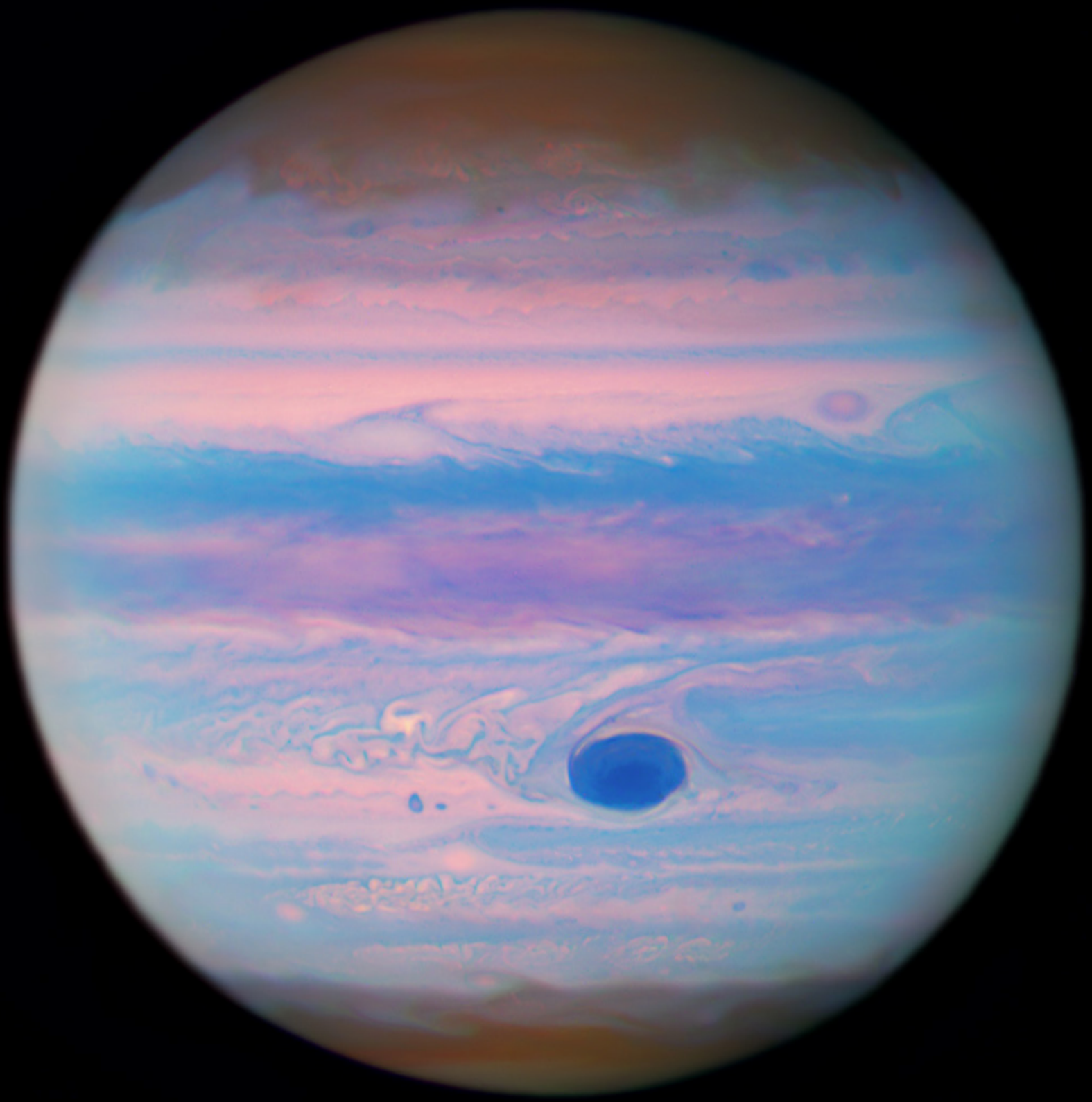
The Butterfly Nebula, captured here across near-ultraviolet to near-infrared light, lies in the constellation Scorpius. The stars at the center are responsible for the nebula's appearance — in their death throes, they have cast off layers of gas that create the "wings".

This visibly diffuse region of gas and dust may be the result of ejections by closely orbiting binary stars that first started slowly sloughing off material thousands of years ago and then entered a phase of more violent mass ejections. Hubble observed NGC 7027 on more than one occasion, revealing changes in the nebula over time.

These Hubble images show two views of the same star cluster, NGC 1850, taken in different wavelengths of light, from different pointings of the telescope. This star cluster is about 100 million years old, and is located in the Large Magellanic Cloud. NGC 1850 is about 160,000 light-years from Earth.



With Hubble's unique ability to observe in ultraviolet light, the planet Jupiter looks different than how we're used to seeing it. Its Great "Red" Spot storm appears dark blue because high altitude haze particles absorb ultraviolet light. The reddish, wavy polar hazes are absorbing slightly less of this light due to differences in either particle size, composition, or altitude.



This cosmic spiderweb, located 400 light-years away, is called CW Leonis. It's a red giant star, and its "cobwebs" are actually dusty clouds of carbon engulfing this dying star.

NGC 6951 resides 78 million light-years away. This galaxy had its highest rates of star formation about 800 million years ago, then sat quietly for 300 million years before beginning to birth stars again.

Located about 700 light-years away, a binary star system called R Aquarii undergoes violent eruptions that blast out huge filaments of glowing gas.

Terzan 12 is a glittering star cluster about 15,000 light-years from Earth. The brightest red stars in this image are bloated, aging giants that actually lie between Earth and Terzan 12. The very brightest blue stars are also along Hubble's line-of-sight, and not inside the cluster.

The FS Tau star system is made up of FS Tau A, the bright star-like object near the middle of this image, and FS Tau B, the bright object to the far right obscured by a dark, vertical lane of dust. FS Tau B ejects the blue jet of material seen here. This system is only 2.8 million years old – very young for a star system. For example, our Sun is 4.6 billion years old.

Science Highlights

Jupiter's Great Red Spot is a large storm rolling counterclockwise.

Since its launch in 1990, Hubble has offered up thousands and thousands of awe-inspiring images of the universe. But Hubble's breathtaking images are just a small part of its accomplishments. The telescope has amassed more than 1.6 million observations with its suite of scientific instruments. Hubble gathers wavelengths of light from ultraviolet, through visible, and into the near-infrared part of the electromagnetic spectrum, making it one of the most valuable and productive observatories in the history of astronomy.

Hubble's instruments can view objects near and far – from small colliding asteroids to distant star-forming galaxies that date back to the universe's early days. The telescope's observations have been the basis for more than 20,000 peer-reviewed scientific papers and references in more than 1.1 million publications, a figure that is constantly increasing.

With more than three decades of observations under its belt, Hubble has expanded our understanding of the universe in ways that were never imagined – both answering and raising questions about the cosmos. The following section showcases some of Hubble's scientific milestones in various areas of astronomy.

Planets and Moons

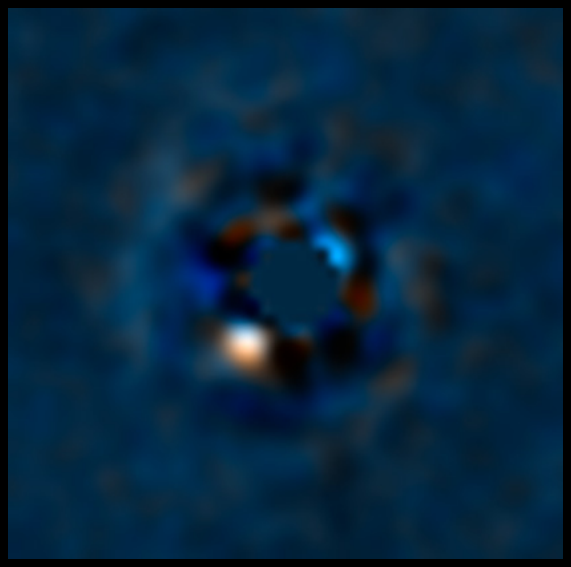
Hubble regularly measures and monitors features on Jupiter, Saturn, Uranus, and Neptune to chart their changing environments over time. For example, Hubble consistently checks in on Jupiter's Great Red Spot, a giant storm that has been shrinking over the last 90 years. Hubble also captures bright aurorae on Jupiter, Saturn, and Uranus.

Just four years into its long tenure collecting data, Hubble watched as 21 fragments of Comet Shoemaker-Levy 9 bombarded Jupiter with a sequential train of impacts. Hubble's 1994 series of observations was the first time astronomers witnessed such an event.

The telescope also sets its sights on the gas giants' moons. Jupiter's moons can provide clues in the search for life beyond Earth — in fact, Hubble found the best evidence yet for an underground saltwater ocean on the moon Ganymede.

Images of asteroid P/2013 P5 revealed it was changing appearance with time.

Pluto and its moons Charon, Nix, and Hydra are found in the Kuiper Belt.



Located about 370 light-years away, exoplanet PDS 70b (seen as the yellow dot) is about five times the mass of Jupiter.

Evolution in the Asteroid Belt

Asteroids don't just collide with planets, they also run into each other — something astronomers used Hubble to witness.

Hubble observations showed an X-shaped pattern of filamentary structures in P/2010 A2 that suggested the previous head-on collision of two asteroids, supporting the idea that the asteroid belt is slowly eroding through collisions.

Hubble's observations have also revealed more details about asteroids, including observing the first known binary asteroid (which looks like a comet), and documenting the slow break-up of asteroids into smaller pieces.

Observations of two of the most massive objects in the belt, Ceres and Vesta, revealed bright and dark regions on Ceres' surface which could indicate topographic features or different surface materials. Hubble's data was used to map Vesta's southern hemisphere.

Kuiper Belt

The Kuiper Belt is a region of our solar system beyond the orbit of Neptune that contains icy objects.

In July 2015, NASA's New Horizons spacecraft shot past Pluto, making detailed observations of its surface. With repeated observations of Pluto from the early 1990s to 2010, scientists were able to refine maps of the dwarf planet's surface and plan for the spacecraft's rendezvous with Pluto. Plus, Hubble found four previously unknown moons of Pluto, which aided in planning for New Horizons' fly-by.

Prior to the mission, Hubble discovered two Kuiper Belt objects the spacecraft could potentially target on its continual outward journey. The mission focused on one of the candidates, now named Arrokoth, capturing up-close imagery of the ancient cosmic object, which consists of two lobes of material.

Hubble also discovered a 100-mile-wide moon in orbit around the second-brightest icy dwarf planet in the Kuiper Belt.

Worlds Beyond our Sun

When Hubble launched, there were no confirmed planets outside of our solar system. Since then, scientists have confirmed the existence of more than 5,000 exoplanets. Hubble took the first measurements of the atmospheric composition of exoplanets.

The telescope's observations identified atmospheres containing sodium, oxygen, carbon, hydrogen, carbon dioxide, methane, helium, and water vapor. While most of the planetary bodies studied to date are too hot for life as we know it, Hubble's observations show we can detect basic organic components for life.

Hubble observed the first known system of seven Earth-size planets around a single star, an ultra-cool dwarf that would allow liquid water to survive on planets orbiting it. The telescope's observations revealed that at least three of the exoplanets appear not to have a puffy, hydrogen-rich atmosphere similar to gaseous planets, favoring more compact atmospheres like those found on Earth and Venus.

The Butterfly Nebula is the result of a dying star about five times the mass of the Sun.

Death of Stars

Ground-based observations predating Hubble's launch suggested that planetary nebulae, or the shells of gas and dust around a dying star, had simple, spherical shapes. Hubble's observations, however, showed in unprecedented detail that the shapes of dying stars are much more complex. Some planetary nebulae look like pinwheels, others like butterflies, and still others like hourglasses.

Hubble's detailed observations offer a glimpse into the complex dynamics that accompany a star's release of its outer gaseous layers before it collapses.

Hubble's first observations of a supernova came just 4 months after its launch when Hubble's Faint Object Camera resolved an elliptical ring of material around Supernova 1987A (SN1987A). SN 1987A was the brightest exploding star astronomers saw in 400 years, and Hubble's sensitivity, resolution, and longevity allow it to keep track of its evolution, collecting 7,000 data sets for some 250 scientific proposals as of July 2024.

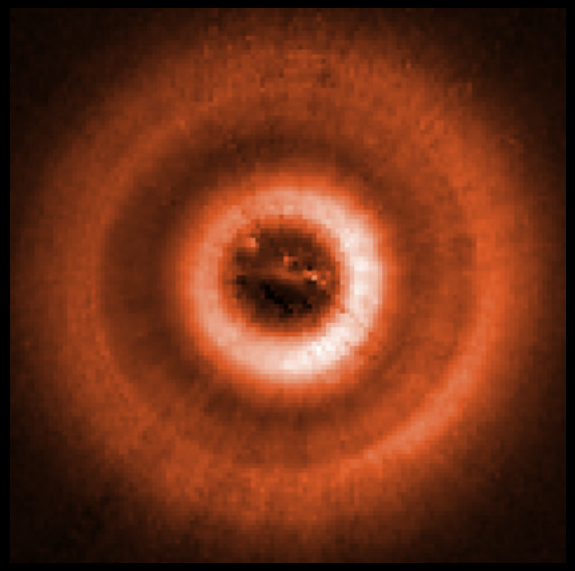
An infant star in the Carina Nebula is seen firing off jets of gas.

Birth of Stars

Hubble's observations of infant stars reveal the violent process of star birth that produces intense ultraviolet radiation and shock fronts. Stars form in large clouds of gas and dust called nebulae that scatter the visible wavelengths of light. Hubble's near-infrared capabilities and high resolving power make it an important tool in the study of star formation.

The radiation and winds released in the process of star birth create cavities in stellar nursery clouds and erode material from giant gas pillars.

Hubble has also captured the jets of glowing gas emitted by young stars in unprecedented detail. Jets form when the star's magnetic field channels gas toward the spinning star's poles, shooting the gas out at supersonic speeds in opposite directions. Hubble is able to observe these jets over time, helping astronomers untangle the complicated physical processes associated with the newborn stars.



Hubble imaged a protoplanetary disk around the young star TW Hydrae.

Planetary Construction Zones

Hubble's sensitivity means it can reveal great disks of gas and dust around stars, a prerequisite for the formation of planetary systems.

In 1992, Hubble was the first telescope to resolve disks of gas and dust around stars, also known as protoplanetary disks or proplyds, around stars in the Orion Nebula. Hubble's high resolution and sensitivity have allowed the telescope to image proplyds around nearly 200 stars in the nebula.

Hubble is also responsible for the most sensitive and largest visible-light survey of debris disks around stars, including the star TW Hydrae. The telescope used a mask to block the star's bright light, revealing a gap in the disk of dust and gas, likely caused by a growing planet gravitationally sweeping up material.

Hubble research has also contributed to detecting changes in material orbiting stars, as well as radiation falling onto newly formed planets.

Hubble captured the light echo from V838 Monocerotis in 2002 and 2004.

Light Echoes

Pulses of light reverberating through cosmic clouds create phenomena called light echoes. In 2002, Hubble observed the star V838 Monocerotis when its brightness flared to roughly 600,000 times that of our Sun. Since light travels at a finite speed, the flash took years to reach the most distant clouds and expose them, creating the echo effect.

Light echoes are common around supernovae, but V838 Monocerotis did not detonate itself — the reasons for the flash are not totally understood. The star may have swallowed a companion star or planet.

Hubble also captured a light echo around the star RS Puppis in 2013.

Spiral galaxy NGC 6951 sits 78 million light-years away.

Galaxy Details and Mergers

Hubble's namesake, astronomer Edwin Hubble, pioneered the study of galaxies and categorized them into three basic categories: spiral, elliptical, and irregular. Today, the telescope named in his honor reveals unprecedented details in galaxies and helped discover that supermassive black holes live at the center of most galaxies.

Galaxy collisions take place at a snail's pace, with time frames that span several hundred million years. Hubble captures snapshots of these mergers.

The telescope's images of the "tadpole-like" Antennae and Mice galaxies reveal the gravitational turbulence these galaxies endure. Mergers like the ones Hubble captures preview the coming collision between the Milky Way and the neighboring Andromeda galaxy in four billion years.

Hubble's Ultra Deep Field had an 11-day exposure time.

Tracing the Growth of Galaxies

The deeper Hubble peers into space, the farther back it looks in time, allowing the telescope to learn more about how galaxies evolve. This occurs because light travels at a finite speed, meaning it takes time to travel the incredible distances from galaxies back to Earth. When light reaches Earth, it shows the object as it appeared when it was emitted. The most distant galaxies spied by Hubble are smaller and more irregularly shaped than today's galaxies, providing evidence that galaxies grew over time by merging with other galaxies.

Careful study of galaxies at different epochs can reveal clues about galactic evolution in our universe. Astronomers investigate relative amounts of stars and gas in galaxies, types and amounts of identifiable chemical elements, and star-formation rates.

The bright spots in this image of NGC 2292 and NGC 2293 show each galaxy's core, which hold supermassive black holes.

This supernova remnant called DEM L 190 contains a soft gamma-ray repeater.

Our universe is growing, and that expansion rate is accelerating.

Monster Black Holes

Before Hubble, astronomers theorized about the existence of supermassive black holes, but had no conclusive evidence to back it up. Direct evidence of black holes didn't come until 1994 when Hubble observed the heart of M87, a giant elliptical galaxy. The observation found a whirlpool of hot, ionized gas orbiting the heart of the galaxy at a speed that only the gravity of a supermassive black hole could generate.

Supermassive black holes are millions to tens of billions times the mass of the Sun. A Hubble census showed that larger galaxies are host to larger black holes — the mass of the black hole is dependent on the mass of the galaxy's central bulge.

Gamma Ray Bursts

Gamma-ray bursts are short-lived explosions of the most energetic form of light, also known as gamma rays. Bursts often shine hundreds of times brighter than a typical supernova and about a million trillion times as bright as the Sun.

They are the brightest electromagnetic events known to exist in the universe and release enormous amounts of energy.

If gamma-ray emissions last more than two seconds, they are called a long gamma-ray burst and are the result of the core collapse of a massive star. Scientists expect a supernova to accompany this type of burst.

Short bursts, or those that last less than two seconds, are likely the result of two neutron stars merging, or a neutron star and a black hole merging.

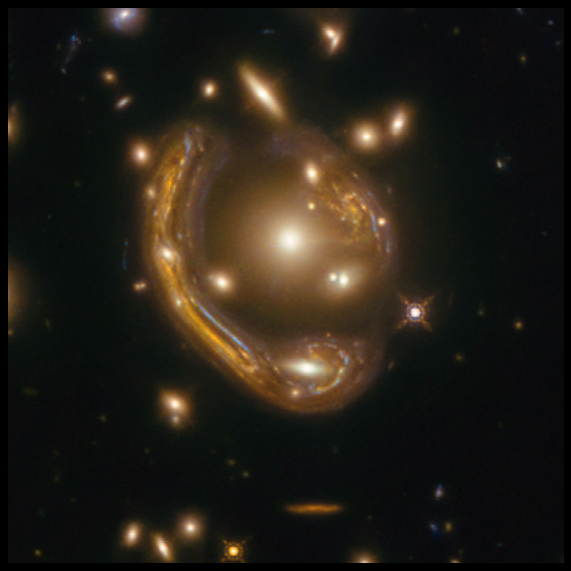
It wasn't until Hubble began observing the visible source of these events that astronomers began to better understand their origins.

A Runaway Universe

In 1929, astronomer Edwin Hubble discovered that the farther a galaxy is from us, the faster it appears to be receding into space away from us.

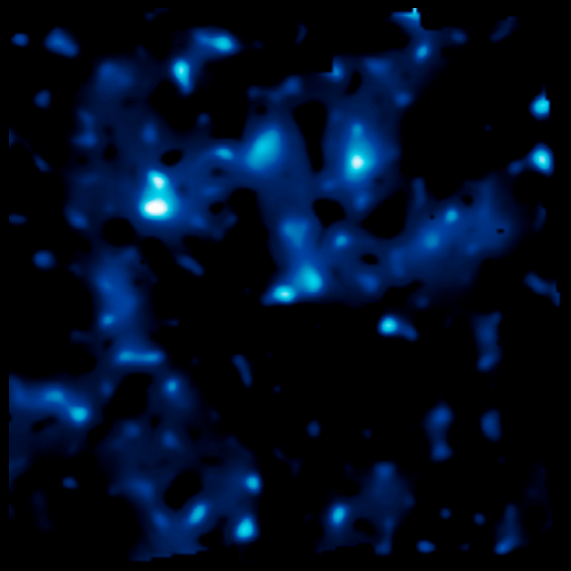
Nearly a century after Edwin Hubble's momentous discovery, the telescope named in his honor refined his measurements. Teams using Hubble's extraordinary capabilities measured the expansion rate to a precision of just over 1%, about eight times more precise than they originally anticipated! This value for the Hubble Constant puts the age of the universe at about 13.8 billion years old.

But in 2011, Hubble observations, along with those of ground-based observatories, surprised astronomers by revealing that the universe is not just expanding, but accelerating – a discovery that won the 2011 Nobel Prize in Physics. Many scientists believe an invisible force, called "dark energy," causes this acceleration.



The "Molten Ring" galaxy's unusual shape is attributed to gravitational lensing.

This Hubble image shows four major arcs from gravitational lensing.



This is a dark matter distribution map from the Cosmological Evolution Survey Field.

Gravitational Lensing

Gravitational lensing is a phenomenon that operates much like a giant magnifying glass. It allows Hubble to see and study the details of early galaxies that are too far away to see otherwise.

The phenomenon occurs when a huge amount of matter, like a whole cluster of galaxies, creates a gravitational field that distorts and magnifies light. This allows Hubble to see distant objects that are in the same line of sight as the galaxy cluster, and also behind and well beyond its strong gravitational field. The gravitational lens redirects light around the cluster, often creating multiple images of distant background objects.

Gravitational lenses extend Hubble's view deeper into the universe. The phenomenon helps astronomers probe the distribution of matter in galaxies and galaxy clusters, indicating the likely location of dark matter.

Dark Matter

Nearly 85% of the matter in the universe is made of stuff we have never seen. This invisible form of matter is called dark matter. Its existence is confirmed by the effects it has on visible matter.

Dark matter's gravity drives gas and dust to collect and build up into stars, galaxies, and galaxy clusters. The structure of dark matter may center on an immense network of filaments that stretch between galaxies and grow over time.

One way astronomers observe dark matter is by mapping how light moves through a gravitational lens. Each distortion directly relates to the amount of matter needed to produce the gravitational field that causes the distortion.

By looking at massive galaxy clusters, astronomers can identify background galaxies that are gravitationally lensed by the cluster. Astronomers can then reverse engineer the cluster's proportions and locate its dark matter.

Mapping the Cosmic Web

Hubble data was used to create the first three-dimensional map of the large-scale distribution of dark matter throughout the universe.

The map, released in 2007, stretches halfway back in time to the beginning of the universe. It reveals a network of dark matter filaments and provides evidence that normal matter (which includes all stars and galaxies) collect within the densest concentrations of dark matter.

Astronomers constructed the map by measuring the shapes of half a million faraway galaxies. As light from the galaxies traveled toward Hubble, it was deflected slightly by dark matter's gravity. Researchers used this subtle distortion to generate the dark matter map.

Pushing the Bounds

Hubble has expanded our knowledge of the universe for more than three decades, capturing noteworthy first-ever observations of cosmic phenomena and seeing objects deeper and further than ever before.

First time elements detected from early universe

In 1992, astronomers announced they had detected boron, a rare element, in an ancient star. The light from boron only appears in the ultraviolet spectrum and so does not penetrate Earth's atmosphere. Hubble was able to see it because of its position above the atmosphere.

First to confirm supermassive black holes exist

By studying the rapid rotation of a spiral-shaped disk of hot gas in the galaxy M87's core, Hubble's observations showed that black holes of a supermassive size exist.

First collision of two solar system objects

In July 1994, Hubble observed fragments of Comet Shoemaker-Levy 9 crashing into Jupiter's atmosphere.

First to detect oxygen in a satellite's atmosphere

Using Hubble, astronomers identified the presence of a tenuous atmosphere of molecular oxygen around one of Jupiter's moons, Europa. Europa was the first satellite ever found to have an oxygen atmosphere.

First images of star's surface other than our Sun

Hubble captured the first direct image of the surface of a star other than our Sun in 1996. The telescope revealed a huge ultraviolet atmosphere with a mysterious hot spot on the star Betelgeuse's surface.

First visual evidence of planetary building blocks

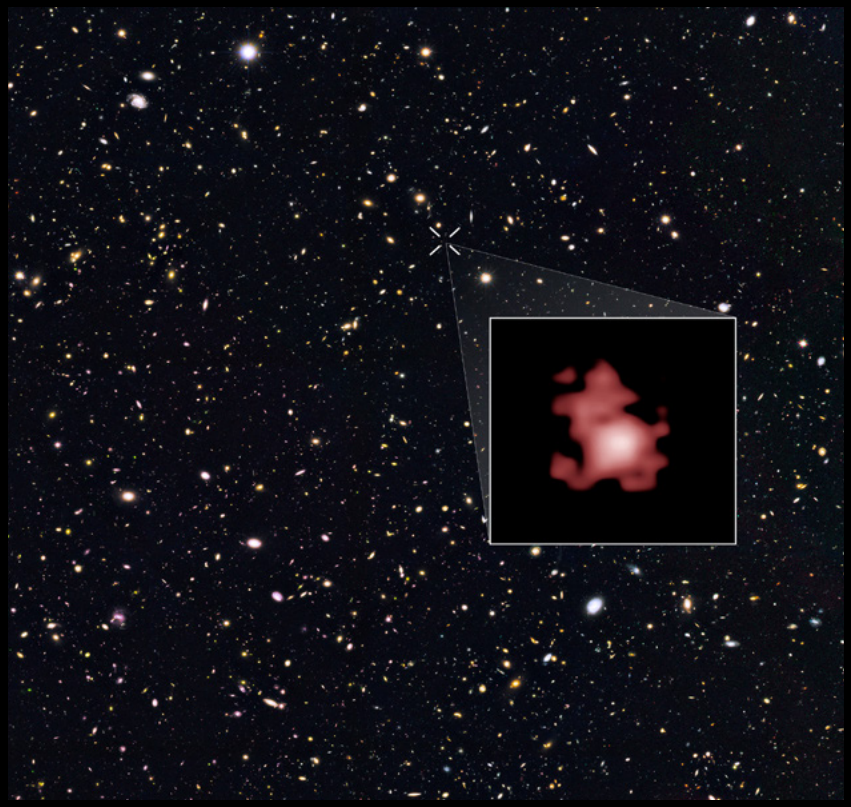
Observations by Hubble provided the first direct visual evidence of planetary building blocks with observations of the Orion Nebula. Protoplanetary disks, or proplyds, are dusty disks around young stars.

First exoplanet atmosphere detected and elements determined

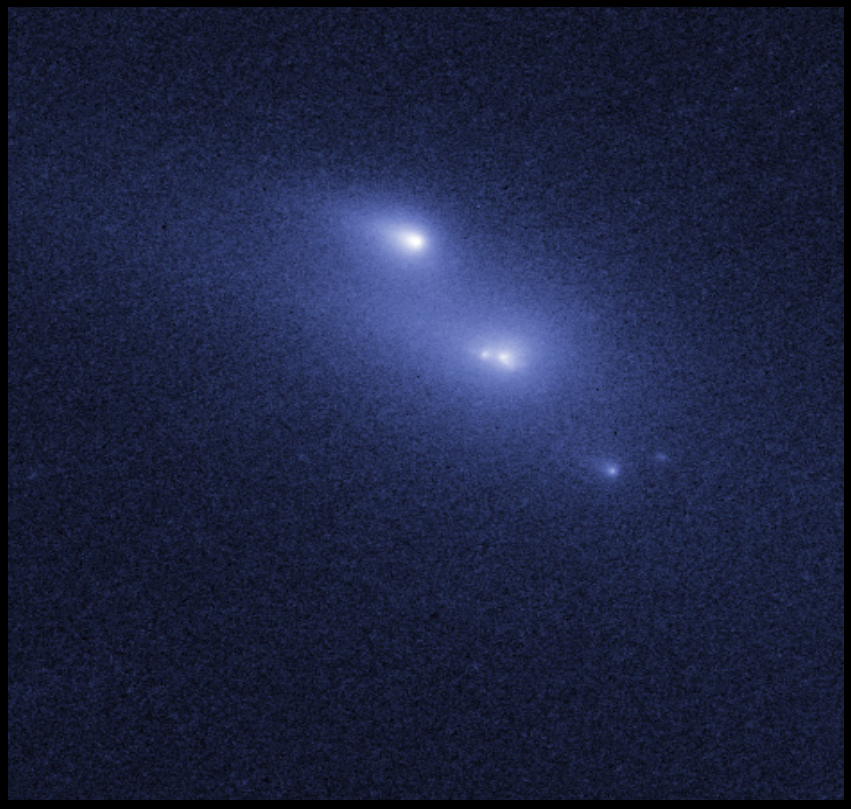
Astronomers made the first direct detection of the atmosphere of a planet orbiting a star outside our solar system in 2001. This planet is named HD 209458b.

Hubble found evidence of a supermassive black hole in M87.

Twenty-one pieces of Comet Shoemaker-Levy 9 crash into Jupiter.



The infant galaxy GN-z11 is seen as it was 13.4 billion years ago.



Comet P/2013 R3 broke up into as many as 10 pieces.

First visual evidence of a planet's atmosphere evaporating away into space

In 2003, the telescope observed the atmosphere of exoplanet HD 209458b evaporating into space. Most of the exoplanet may eventually disappear, leaving only its dense core.

First organic molecules detected in an exoplanet atmosphere

Hubble found methane, an organic molecule, in the atmosphere of exoplanet HD 189733b. Under the right circumstance, methane can play a key role in the chemical reactions considered necessary to form life as we know it.

First asteroid with tails

Until Hubble captured P/2013 P5 in 2013, all known asteroids appeared as tiny points of light. P/2013 p5, by contrast, has six comet-like tails of dust radiating out from it like a rotating lawn sprinkler.

First to detect water vapor plumes off of Europa

Hubble provided the first strong evidence of water plumes erupting off of Jupiter's moon Europa in 2012. The telescope's spectroscopic observations were used to distinguish between plumes and other particles.

First space-based images of asteroid breaking up

Starting in late 2013, Hubble observed the never-before-seen break-up of an asteroid into as many as 10 pieces. The crumbling asteroid, designated P/2013 R3, was first spotted by the Catalina and Pan STARRS sky surveys and further imaged by M. Keck Observatory on the summit of Mauna Kea. Hubble data showed the fragments drifting away from each other at a speed of one mile per hour.

First image of the first-ever predicted supernova

Hubble captured an image of the first-ever predicted supernova in 2015. Seen multiple times in a gravitationally lensed image, the timing and location of the Refsdal supernova were calculated using different models of dark matter and the galaxy cluster.

Farthest galaxy ever imaged at the time

In 2016, a team of astronomers measured the farthest galaxy ever seen in the universe, shattering the cosmic distance record of the time. The galaxy, called GN-z11, was seen as it was 13.4 billion years in the past.

First detection of possible moon around an exoplanet

Hubble, with the help of the Kepler Space Telescope, uncovered strong evidence for a potential moon orbiting a planet beyond our solar system. This possible "exomoon" is about 8,000 light-years away and orbits a planet that, in turn, orbits the star Kepler-1625.

First precision measurement of the expansion rate of the universe

Many Hubble observations of cosmic mile-markers helped astronomers more precisely measure the expansion rate of the universe. The reliable brightness of Cepheid variable stars and Type Ia supernovae helped make these calculations.

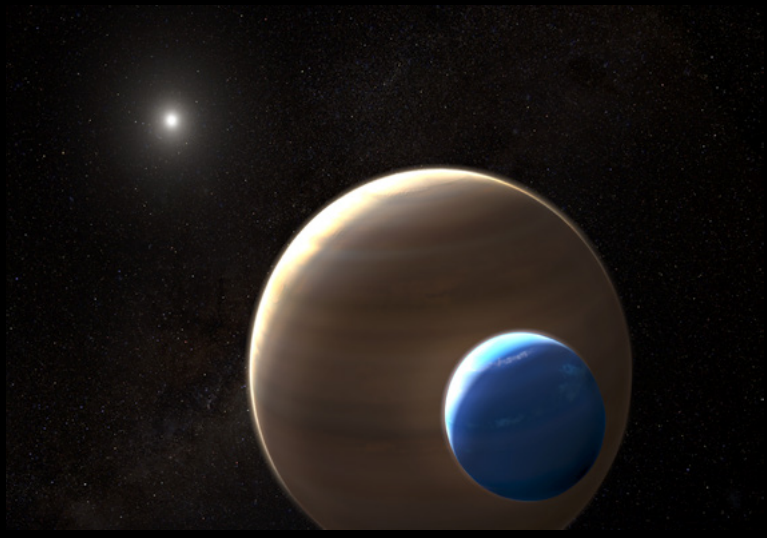
First confirmation that the Andromeda Galaxy will collide with our Milky Way Galaxy

Hubble's painstaking measurements of the movement of nearby major galactic neighbor Andromeda confirmed that in approximately four billion years, it will collide with the Milky Way. This is due to the mutual pull of gravity between both galaxies. Although the galaxies will collide, the stars inside each of them are so far apart that it's unlikely any will directly crash into each other.

First to prove that black holes are at the cores of almost all galaxies

Through several studies of many galaxies, Hubble confirmed that most galaxies have a supermassive black hole at their centers, and that the larger a galaxy is, the larger its black hole is as well.

Hubble's Ultra Deep Field had an 11-day exposure.



This artwork depicts an "exomoon" candidate 8,000 light-years away.

The Andromeda Galaxy is headed toward our Milky Way Galaxy.

Farthest individual star ever imaged at the time

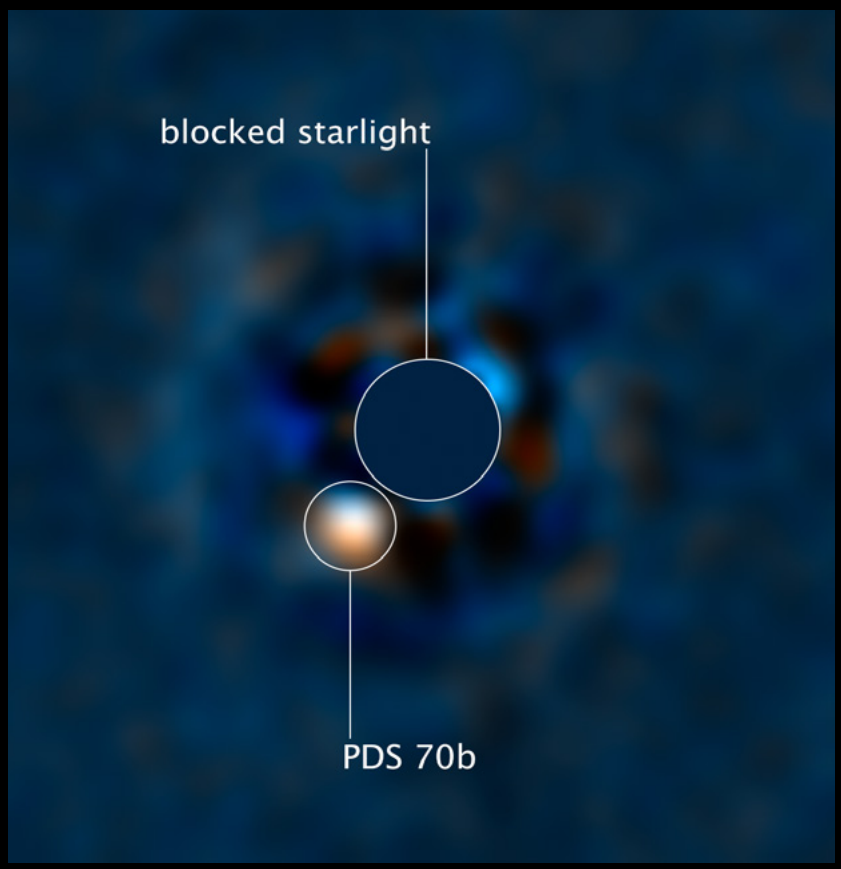
With the help of gravitational lensing, Hubble detected the light of a star that existed within the first billion years after the universe's birth in the Big Bang, making it the farthest individual star seen at the time (2022). The light from Earendel took 12.9 billion years to reach Earth.

First detection of water vapor on an exoplanet in the habitable zone

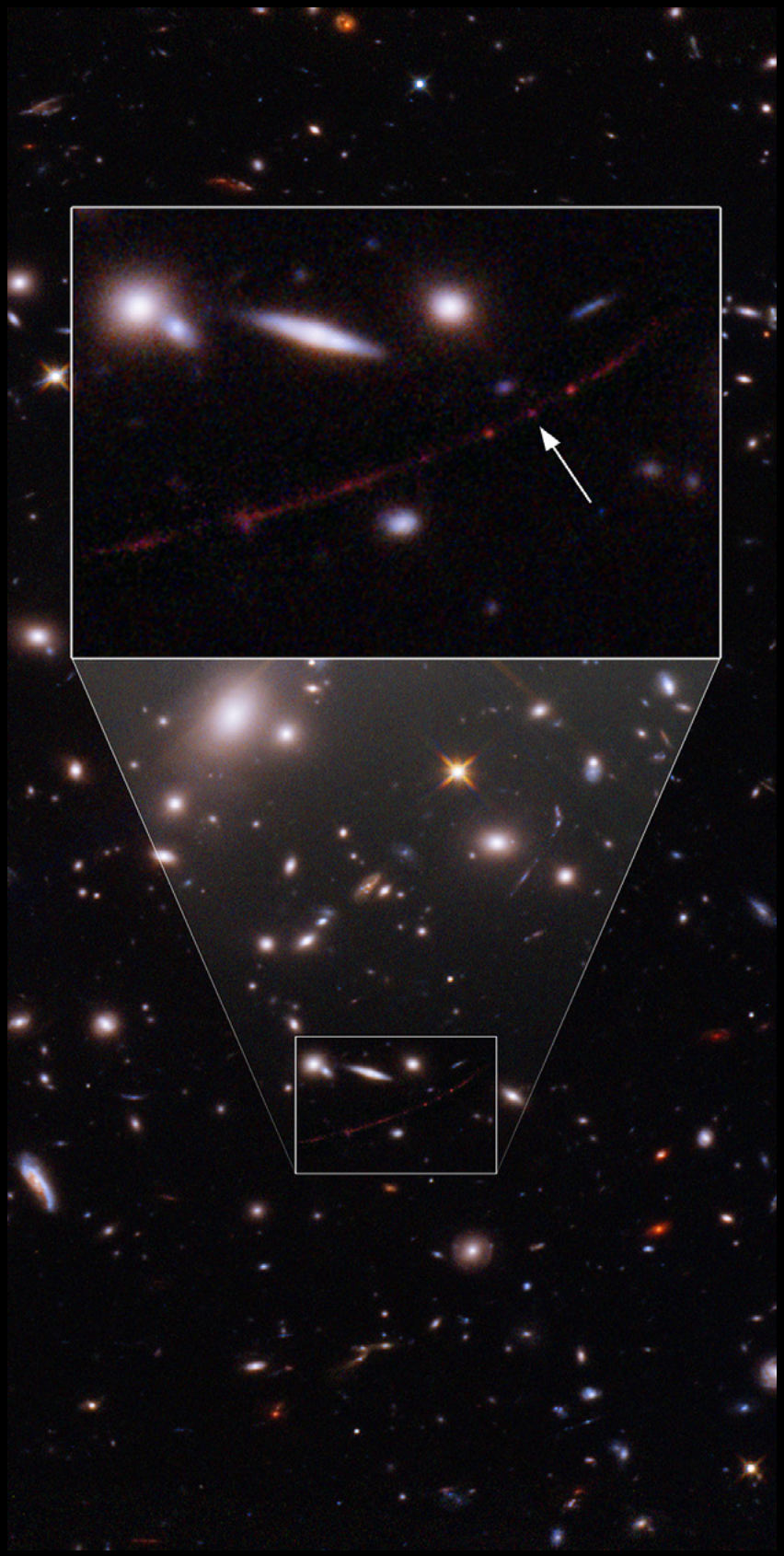
For the first time, in 2019 researchers detected water vapor signatures in the atmosphere of exoplanet K2-18b, which resides in the "habitable zone," or the zone around a star in which liquid water could potentially pool on the surface of a planet.

First ultraviolet image of an exoplanet in formation

Researchers using Hubble directly measured the mass growth rate of a planet in a far-flung solar system in 2021. The research team's new approach to using Hubble to image this exoplanet paved the way for further exoplanet research. Image below.



Exoplanet PDS 70b is about 370 light-years from Earth.



Earendel existed when the universe was less than 1 billion years old.

Acknowledgments

The Hubble Space Telescope's expansive mission wouldn't be possible without the dedicated work of thousands of people and organizations. From the teams behind Hubble's servicing missions to the support from an enthusiastic public, Hubble's success is owed to everyone involved.

The mission is a joint effort of NASA and the European Space Agency.

Astronauts from both organizations successfully completed complex and challenging servicing missions. Their efforts and expertise helped keep the telescope at peak scientific performance.

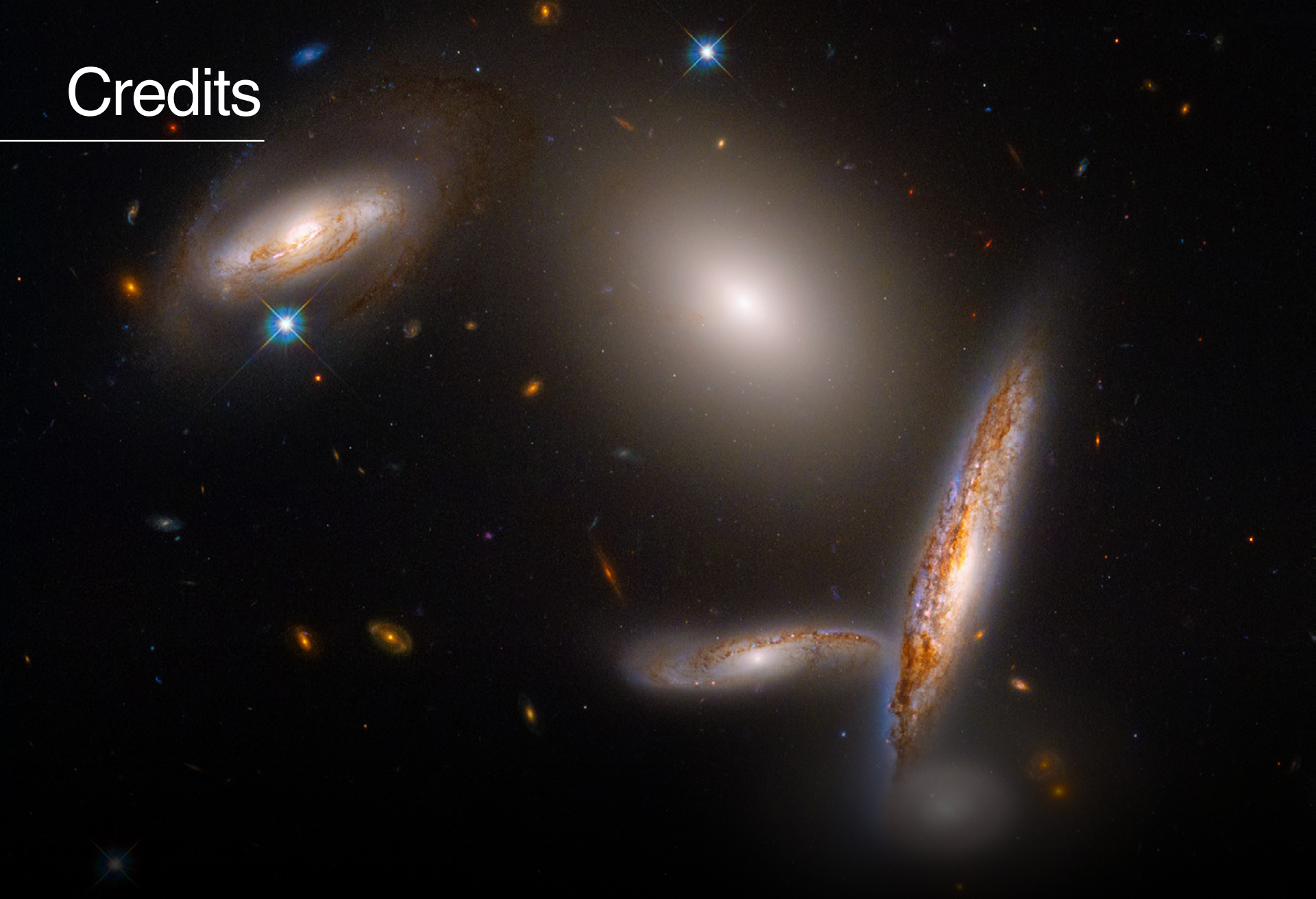
The project is under the Science Mission Directorate at NASA Headquarters while the Hubble Space Telescope Project Office at Goddard Space Flight Center has managed the on-orbit operations, spacecraft hardware development, and astronaut tool development since launch. The dedicated personnel at Kennedy Space Center and Johnson Space Center made the launch and servicing missions possible, while the Marshall Space Flight Center originally built Hubble and NASA's Jet Propulsion Laboratory played a significant role in the development of several critical scientific instruments.

Hubble's mission operations have kept the spacecraft operating at top performance for years. This work, which includes flight operations and engineering, has been conducted by Lockheed Martin under contract with NASA. Hubble's prolific science program is organized and guided by the Space Telescope Science Institute, operated by the Association of Universities for Research in Astronomy, under contract with NASA.

The mission continues to be supported by the enthusiasm and tax dollars of the citizens of the United States and Europe. This support has enabled thousands of astronomers from around the world to discover more about our universe. Through the thousands of scientific papers published using Hubble data, some of the universe's farthest corners and deepest reaches are now known, and invite further questions.

Caldwell 5, also known as IC 342, is a spiral galaxy located about 11 million light-years away. The galaxy appears near the equator of the Milky Way's pearly disk, making it hard to spot. The glowing red regions are places where new stars are forming.

Credits



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22 R. Williams (STScI), the Hubble Deep Field Team and NASA

Left: The Hickson Compact Group 40 contains a close-knit collection of five galaxies, pictured here by Hubble before they eventually merge together.

23 Hubble Heritage Team (STScI / AURA), Y. Chu (UIUC) et al., NASA

24 NASA, ESA, The Hubble Key Project Team, and The High-Z Supernova Search Team

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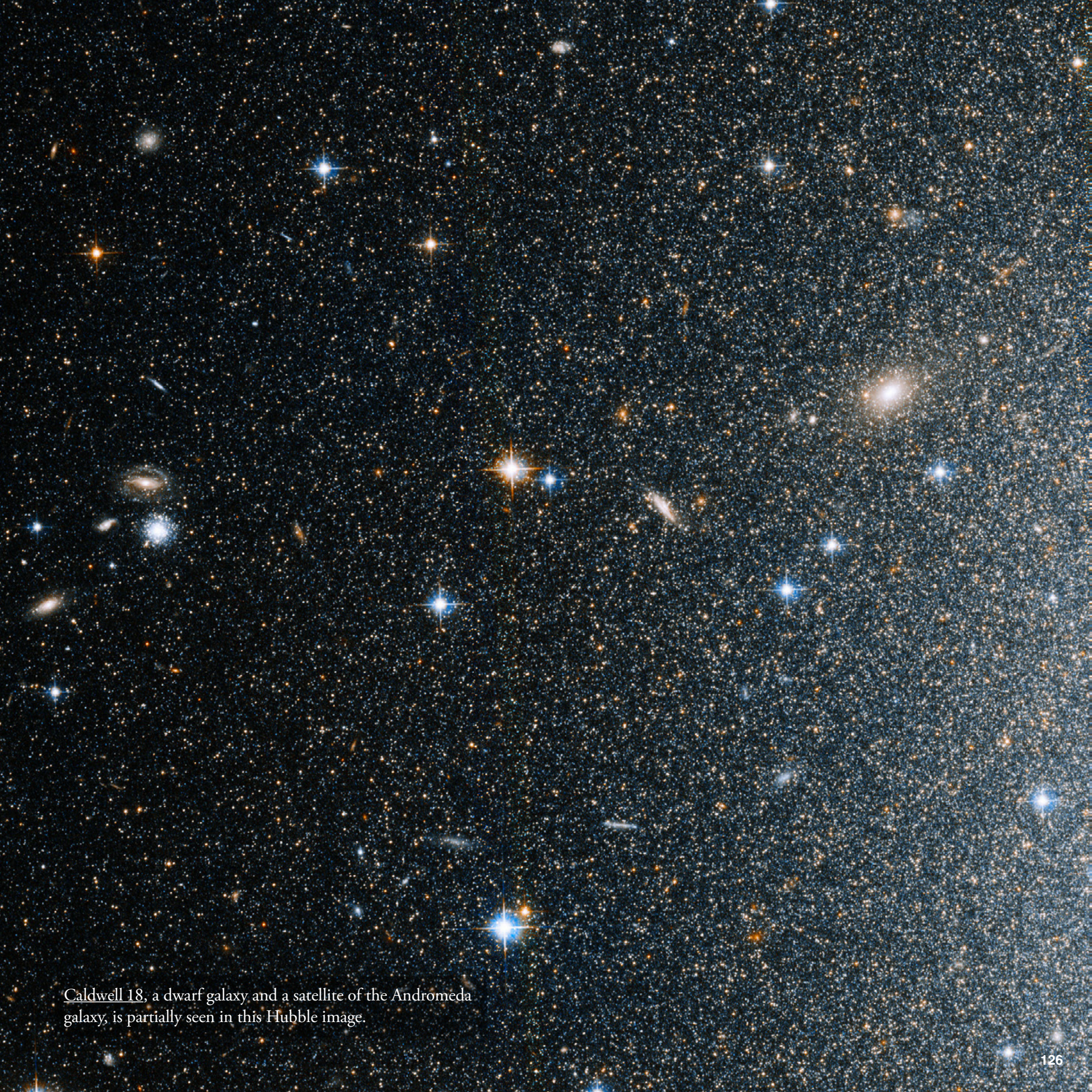

Caldwell 18, a dwarf galaxy and a satellite of the Andromeda galaxy, is partially seen in this Hubble image.

The galaxy NGC 5068 is full of thousands of star-forming regions and large amounts of interstellar dust. Located about 20 million light-years away, it resides in the constellation Virgo.

More Information

For more information about NASA's Hubble Space Telescope mission and its discoveries, visit Hubble's website at nasa.gov/hubble.

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Westerlund 2 is a giant cluster of thousands of stars that resides inside the busy star-forming region Gum 29. The cluster is about 20,000 light-years away.

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