HUBBLE 25

A Quarter-Century of Discovery with the Hubble Space Telescope

HubbleSite & WebbTelescope

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INTRODUCTION

The astronauts of Hubble's final servicing mission captured this view of the telescope orbiting Earth after completing their repairs and upgrades to the spacecraft in May 2009.

25 Years of Hubble

On April 24, 1990, NASA's Space Shuttle Discovery blasted off from the Florida coast carrying precious cargo that was destined to revolutionize the way humans see the cosmos. The Hubble Space Telescope had been decades in the making, the dream of astronomers who yearned to study the universe with a clear view unhindered by the distorting influence of Earth's atmosphere. A day after launch, Discovery's astronauts fulfilled that dream by releasing Hubble into orbit hundreds of miles above the ground, and more importantly, above the bulk of our planet's atmosphere.

Hubble was not the first telescope launched into space, nor is it the largest telescope at astronomers' disposal. Hubble's exceptional and ongoing capacity to help unveil the secrets of the universe comes not just from its position beyond Earth's atmosphere and, as a result, its exquisite image quality, but also its ability to be upgraded with new science instruments — a unique feature among space-based telescopes. After Hubble's launch, shuttle astronauts returned to the telescope five times to install new cameras, detectors, and other equipment built with ever-more advanced technology, keeping Hubble on the leading edge of astronomy. Hubble's suite of instruments also allows the observatory to record wavelengths of light not just in the visible range but in ultraviolet and near-infrared wavelengths (which are not visible to our eyes), including some wavelength ranges that cannot be observed from the ground.

Hubble Telescope Facts

Hubble captures pictures of stars, planets, galaxies, and more orbiting Earth at 17,500 miles per hour (8 kilometers per second).

Hubble has made more than 1 million observations since its mission began in 1990.

Hubble has traveled more than 3 billion miles (4.8 billion km) along a circular, low Earth orbit of about 340 miles (550 km) altitude.

Hubble's observations have produced more than 100 terabytes of data.

Hubble currently generates an average of 830 gigabytes of data per month.

About 4,000 astronomers from all over the world have used the telescope to probe the universe.

Astronomers using Hubble data have published more than 12,700 scientific papers, making it one of the most productive scientific instruments ever built.

Hubble weighs 24,500 pounds — as much as two full-grown elephants.

Hubble's primary mirror is 2.4 meters (7 feet, 10.5 inches) across.

Hubble is 13.3 meters (43.5 feet) long — the length of a large school bus.

Now 25 years into its trailblazing mission, Hubble's greatest accomplishments to date include helping to uncover black holes in the centers of galaxies, observing changes on planets in our solar system, investigating the atmospheres of planets around stars other than the Sun, seeing disks that are possibly forming new solar systems, and hunting down nascent galaxies in the very early universe. Astronomers have also used Hubble to follow up on the work done almost a century ago by the telescope's namesake, the astronomer Edwin Hubble, whose observations of galaxies revealed that the universe was expanding. Observing with the Hubble telescope, astronomers have refined their calculation for the universe's expansion rate and discovered the existence of a force called dark energy, which is causing the universe to expand faster and faster as time goes on.

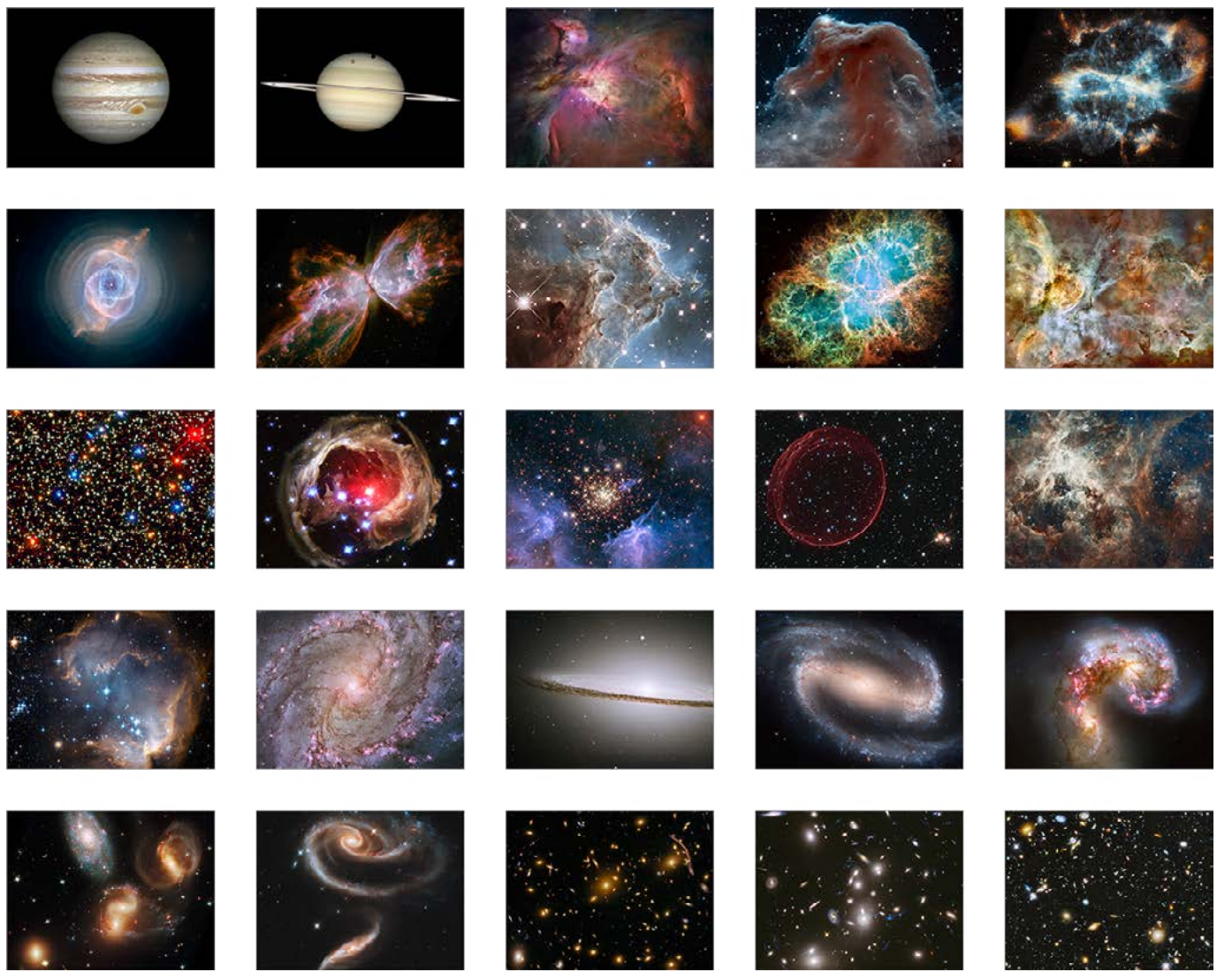
Hubble's work is far from finished, though. Astronomers are continuing to use the orbiting observatory to extend their view and understanding of the cosmos ever farther. In 2009, during Hubble's final servicing mission, astronauts installed new science instruments, batteries, computers, gyroscopes, and other equipment that will keep the observatory hot on the trail of the most pressing celestial mysteries for years to come.

Hubble's Spectacular Images

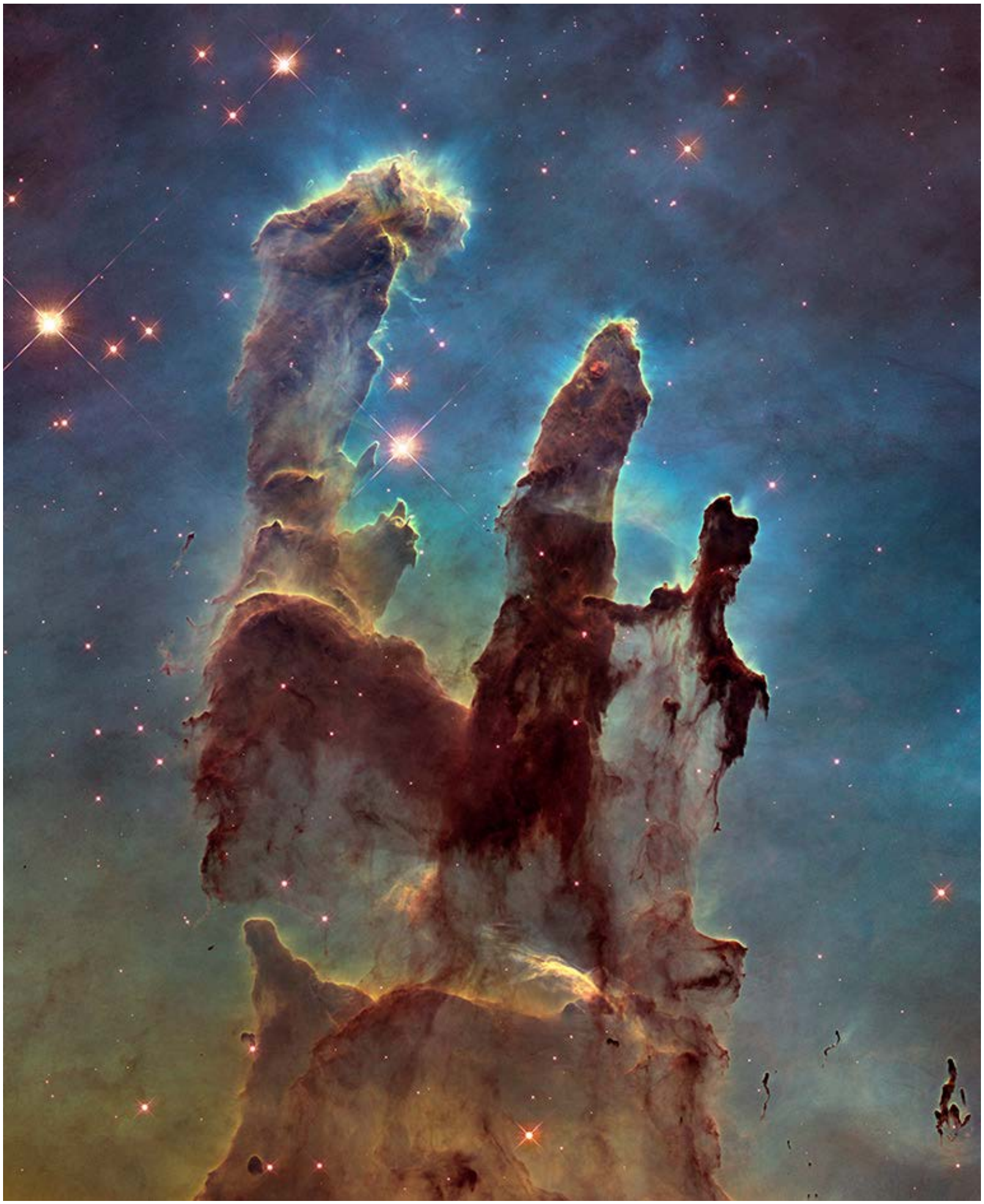
The Hubble Space Telescope is an instrument of science — one of the most productive in history. Thousands of astronomers from around the world have used Hubble to explore nearly every facet of the universe, publishing more than 11,000 scientific papers in the process. Still, the magnificent images Hubble takes have proven time and again their power to capture the hearts and minds of scientists and non-scientists alike. The majestic scenes fire the imagination and inspire awe for the astonishing vastness of the cosmos and all the wonders it contains.

To celebrate Hubble's 25th anniversary, this book presents 25 of the most remarkable images Hubble has acquired so far. They are ordered according to distance from Earth, highlighting Hubble's great range, from observing planets in our own solar system to the stars and galaxies born when the universe was still young.

Each chapter in this book introduces one of Hubble's images and points out some of the features that Hubble's exceptional vision reveals. It also describes a sample of the related scientific research or discoveries achieved with Hubble. Supplemental images and videos provide more context and help bring the subject to life.



Revisiting an Icon



Hubble's newest image of the "Pillars of Creation" in the Eagle Nebula, taken with the Wide Field Camera 3, provides a sharper and wider view of the star-forming structures first imaged by the telescope in 1995.

To kick off Hubble's 25th year in orbit, astronomers used the venerable telescope to revisit one of its most iconic subjects, the so-called "Pillars of Creation" in the Eagle Nebula (M16). Three towers of gas and dust, standing light-years tall, are giving birth to new stars, buried within their dusty spires.

The pillars became famous after Hubble first imaged them in 1995 using the Wide Field Planetary Camera 2. The features were observed again in late 2014 with that instrument's more advanced replacement, the Wide Field Camera 3. With its higher resolution, the new camera provides a sharper view of the pillars and also presents a wider vista, showing the base of the pillars and more of the region surrounding them.

In addition, the new observations captured a portrait of the pillars in infrared light, as well as in visible light. The longer wavelengths of infrared light pass more easily through the dusty environs, allowing us to see more of the wispy details and the stars normally hidden inside or behind the pillars when viewed in visible light.

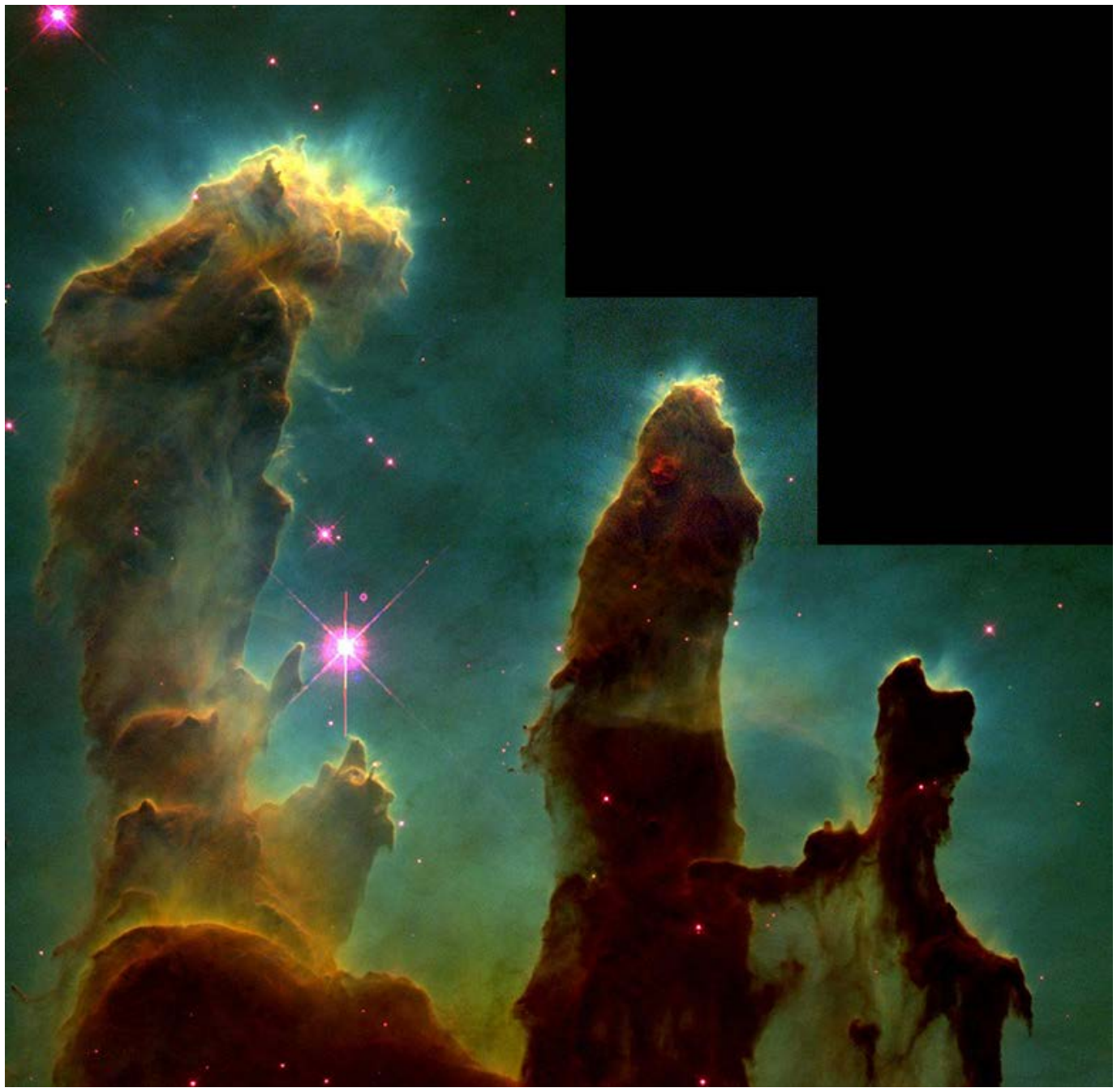
Pillars in the Eagle Nebula, in Visible and Infrared Light

Hubble's infrared view of the "Pillars of Creation" reveals details within the gaseous towers as well as many background stars.

By comparing Hubble's original image of the pillars to the new one, astronomers also noticed changes in a jet-like feature shooting away from one of the newborn stars within the pillars. The jet grew 60 billion miles longer in the time between observations, suggesting material in the jet was traveling at a speed of about 450,000 miles per hour.

Such observations of the details and changes in the pillars of the Eagle Nebula, and of observations near and far throughout the universe, have been made possible by Hubble's viewpoint beyond Earth's atmosphere, by its technical upgrades over the years, and the longevity of its career.

Pillars in the Eagle Nebula, 1995



Hubble's Wide Field Planetary Camera 2 captured this well-known view of the "Pillars of Creation" in 1995.

Image Facts:

Distance from Earth: 6,500 light-years

Description: Emission Nebula

Constellation: Serpens

HubbleSite News Resource: Hubble Goes High Def to Revisit the Iconic 'Pillars of Creation'

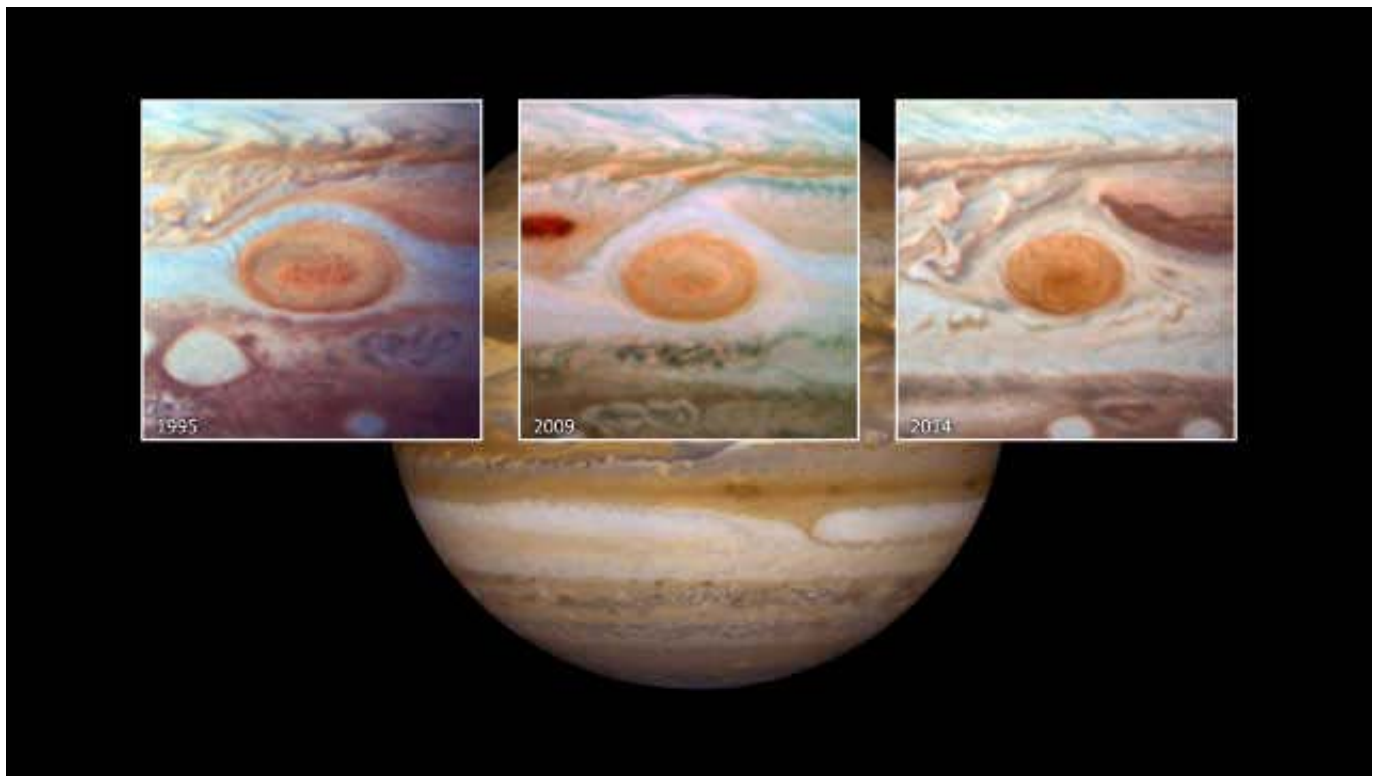
The planet Jupiter is best known for its Great Red Spot, a storm big enough to swallow Earth. Hubble observations over nearly two decades show that this storm is shrinking dramatically.

JUPITER'S GREAT RED SPOT

Located nearly 500 million miles away, the giant planet Jupiter's atmosphere is a roiling cauldron of activity. It includes lightning, oppositely moving cloud belts, and hundreds of rotating storms that appear as large red, white, or brown ovals. The largest of these storms is the legendary anticyclone called the Great Red Spot (GRS). In fact, the GRS is the largest known storm in the solar system.

Located in Jupiter's southern hemisphere, the GRS is larger than Earth, with winds inside it raging at 500 miles per hour. While its longitude drifts relative to surrounding atmospheric bands, the storm's latitude has been stable for as long as records of it have been kept. The GRS may have been seen as early as 1632 by Leander Bandtius, Abbot of Dunisburgh. In 1664, the philosopher, architect, and polymath Robert Hooke reported observing a spot that moved from east to west on the planet. The next year, astronomer, mathematician, and engineer Giovanni Cassini was the first to note a "permanent spot."

Movie 1.1: Jupiter's Great Red Spot Shown Shrinking over Two Decades



The Voyager spacecraft in 1979 measured the long axis of the GRS to be 14,500 miles across; historic observations as far back as the late 1800s gauged the GRS to be 25,500 miles across. Hubble's long life has allowed astronomers to follow Jupiter's atmospheric activity over a period spanning nearly two decades. In a study led by Amy Simon of NASA's Goddard Space Flight Center, Hubble observations show that the GRS is now approximately 8,000 miles from top to bottom and 10,250 miles across: the GRS has now shrunk to the smallest size ever measured, having lost half its size over the past hundred years.

The Hubble observations indicate that the GRS is getting smaller by 580 miles per year along its major axis and its shape is changing from an oval to a circle. At the current rate, the storm is expected to become circular in four years. The vortex could completely disappear or grow larger, since the fate of such storms (even storms on Earth) is difficult to model and predict precisely due to their complexity.

In the new Hubble observations, it is apparent that very small eddies are feeding into the storm. Simon and her team hypothesize that these eddies may be responsible for the sudden change by altering the internal dynamics and energy of the GRS. They plan to study the future motions of the small eddies, along with the internal motions of the GRS, to determine whether such eddies can feed or sap momentum entering the upwelling vortex and contribute to changes in the size and shape of the Great Red Spot.

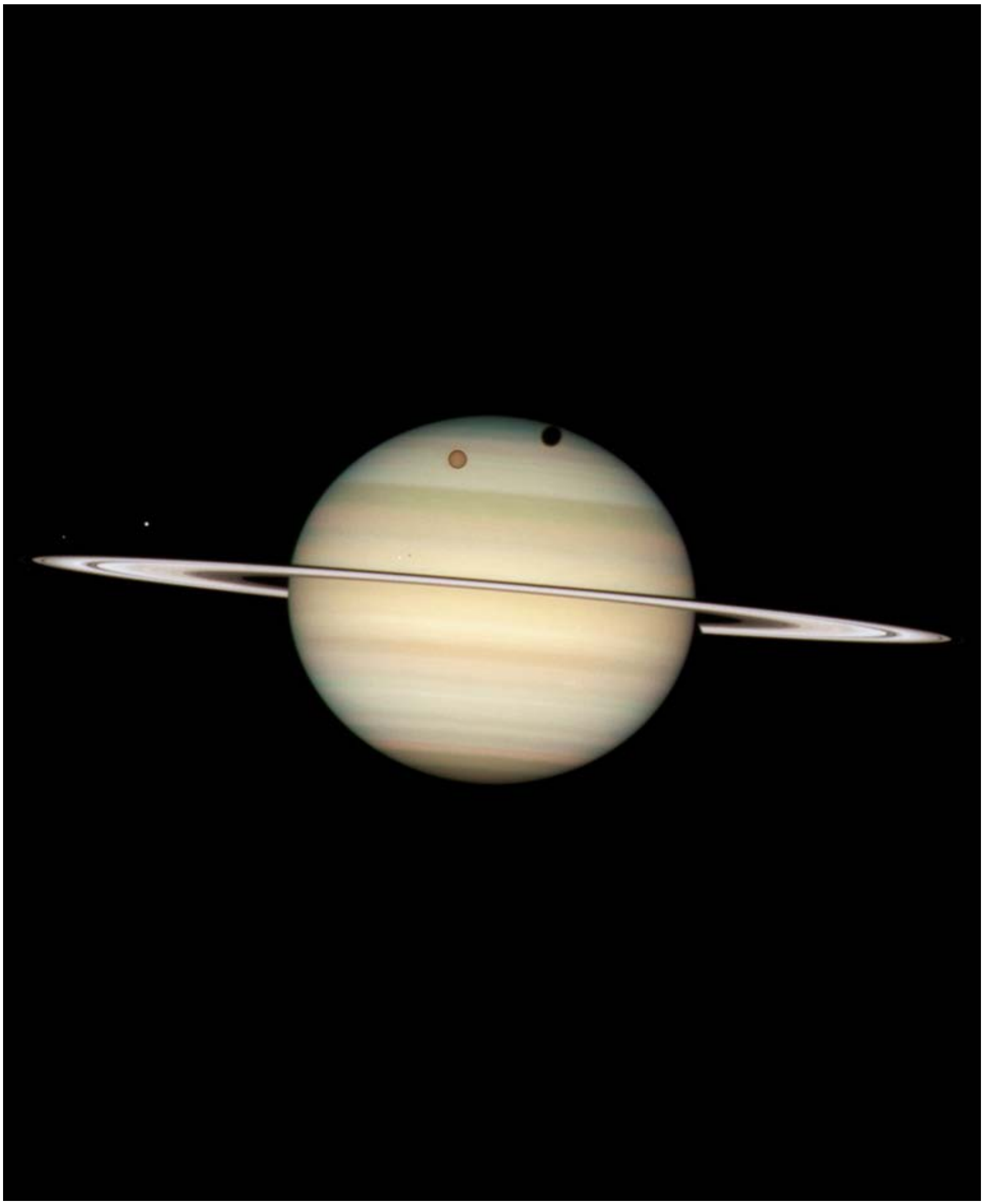
Image Facts:

Location: 5th planet from the Sun

Distance: Average distance from the Sun is 484 million miles (778 million km) or 5.2 astronomical units (AU)

Description: Jovian (Gas Giant) Planet

HubbleSite News Resource: Hubble Shows that Jupiter's Great Red Spot Is Smaller than Ever Seen Before

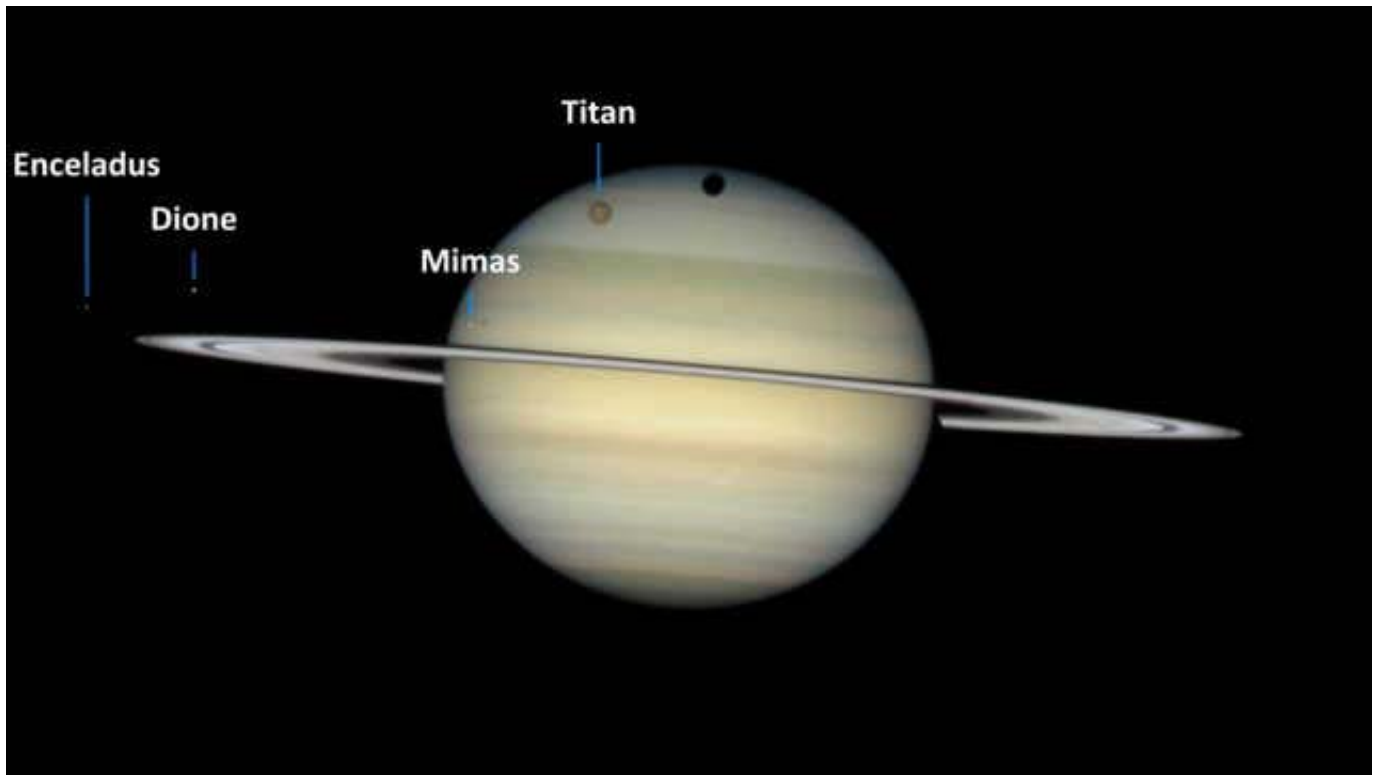


A few moons and their shadows danced in front of Saturn in February 2009, while the planet's famous rings were tilted nearly edge-on. Astronomers used Hubble's Wide Field Planetary Camera 2 to capture the scene from about 775 million miles away.

Saturn is famous for the intriguing rings that encircle it. As Saturn orbits the Sun, though, our view of its rings changes. Roughly every 15 years (halfway through Saturn's almost-30-year orbit), Saturn's rings appear edge-on, sometimes seeming to disappear altogether. Because many of Saturn's moons orbit the planet in the same plane as the rings, they appear to cross in front of the planet during this time.

On February 24, 2009, when Saturn's rings were nearly edge-on, Hubble tracked four of Saturn's moons as they passed across the face of the giant ringed planet. In this image, captured with Hubble's Wide Field Planetary Camera 2, Saturn's large, orangish moon Titan casts a deep, round shadow near the upper edge of Saturn's disk. The smaller moon Mimas and its shadow appear as white and black dots to the lower left of Titan, just above the long, thin shadow projected onto Saturn by the planet's rings. Bright Dione and the fainter Enceladus hover above the rings on the far left.

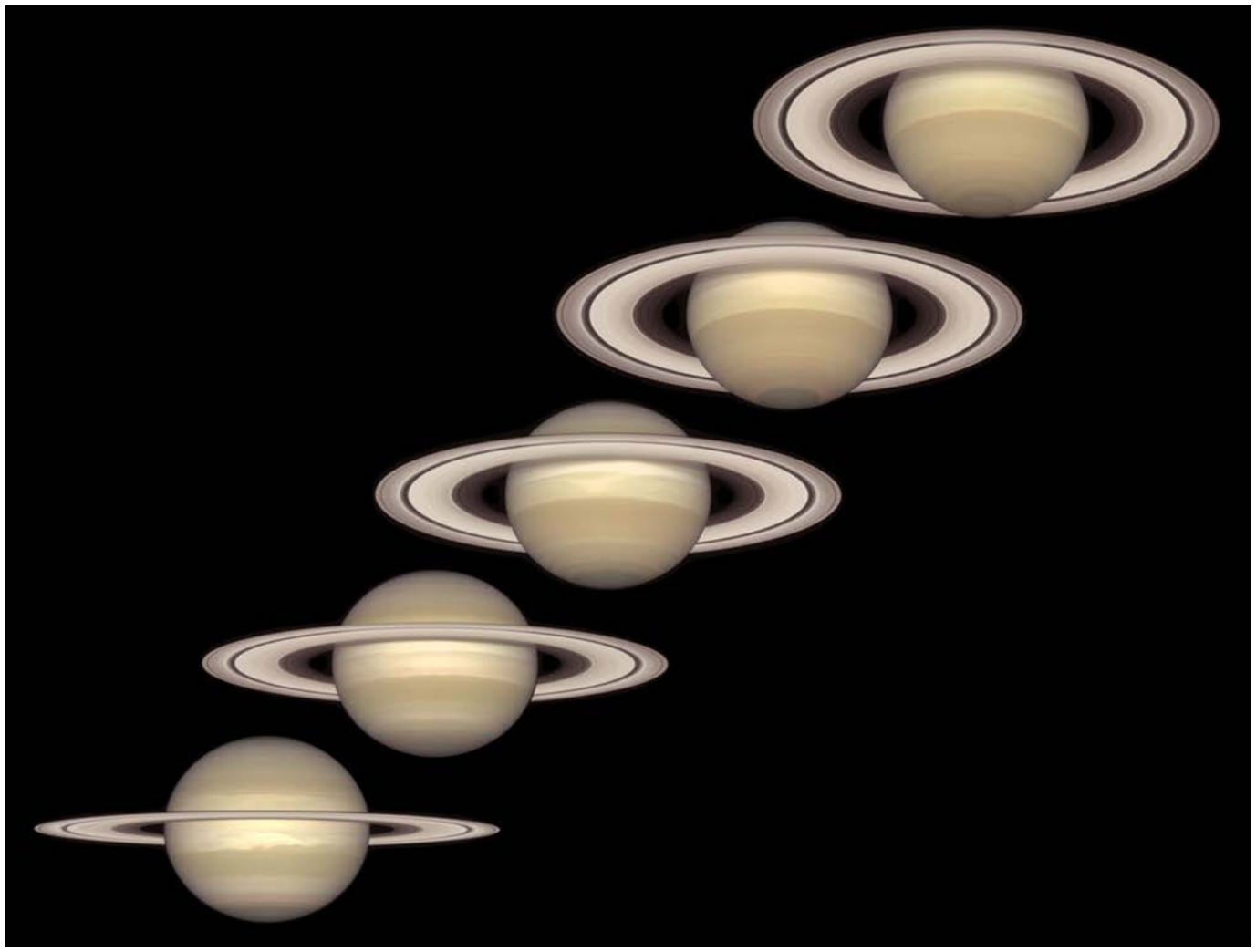
Movie 2.1: Science Visualization of Moons Crossing the Face of Saturn



These rare views of Saturn, when the glare of the bright rings is diminished, give astronomers a chance to find and study fainter rings and moons around Saturn. In fact, astronomers discovered Saturn's hazy E ring and 13 of the planet's moons at times when the rings were edge-on between 1655 and 1980.

When Saturn's rings were turned edge-on in 1995, two teams of astronomers, one led by Amanda Bosh of Lowell Observatory and the other by Philip Nicholson of Cornell University, used Hubble to uncover bright, temporary arcs and clumps within Saturn's narrow F ring that disappeared within weeks. Their Hubble observations also revealed that the orbit of Prometheus, a moon near the F ring, had changed since it was discovered in NASA's Voyager 1 spacecraft images in 1980, suggesting that Prometheus interacts with the F ring or another nearby moon as they orbit Saturn.

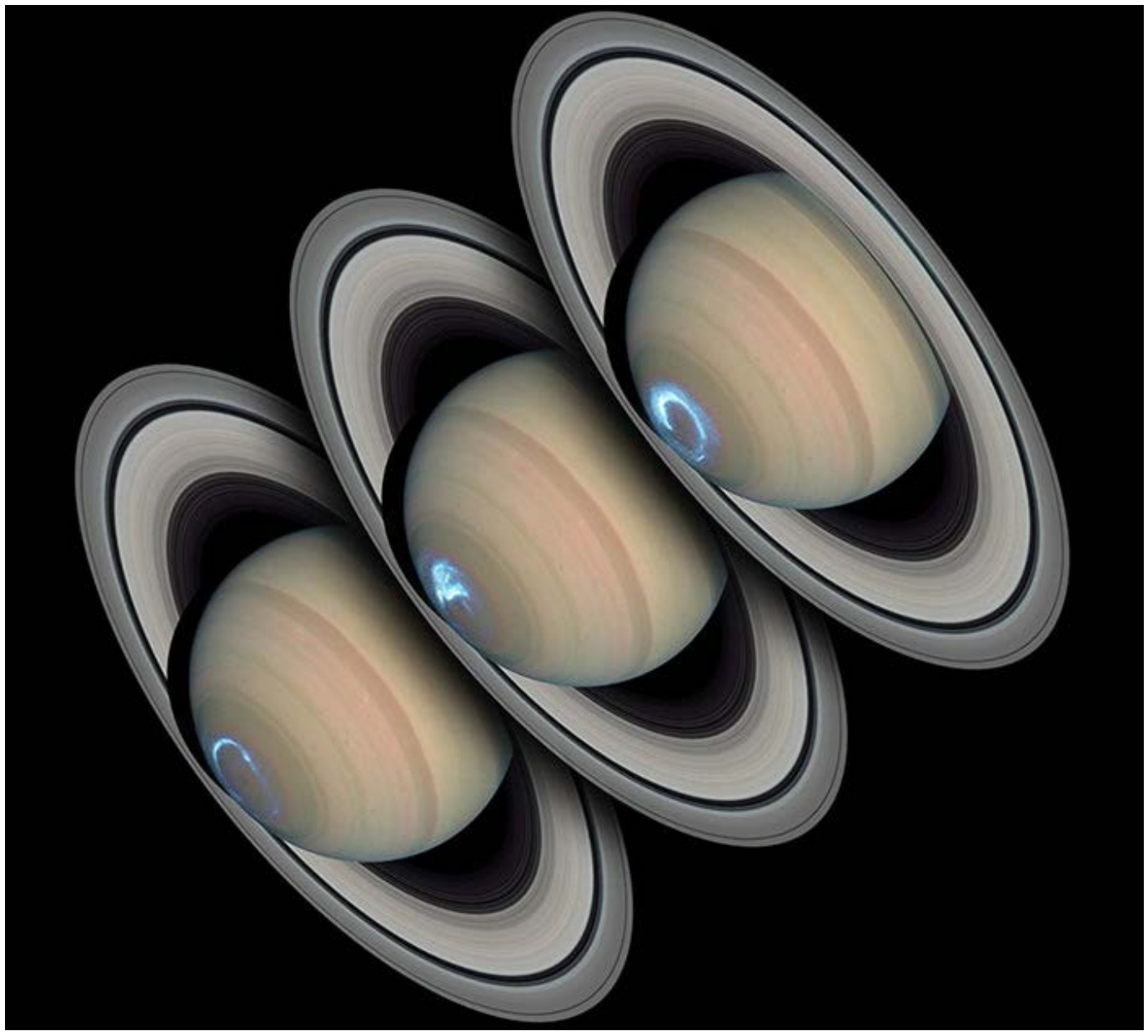
Saturn from 1996 to 2000



Hubble's Wide Field Planetary Camera 2 captured an image of Saturn every year from 1996 (lower left) to 2000 (upper right). Together, these five images show how our view of the planet's rings change over time.

At times when Saturn's rings appear inclined (not edge-on), astronomers can use Hubble's Space Telescope Imaging Spectrograph to study the ultraviolet aurorae glowing around Saturn's south pole. These observations have revealed that Saturn's aurorae change from day to day in response to fluctuations in the stream of solar particles cascading through Saturn's magnetic field.

Saturn's Aurorae



These three composite images display changes in aurorae around Saturn's south pole. The ultraviolet observations, showing the aurorae, were taken by Hubble's Space Telescope Imaging Spectrograph on January 24, 26, and 28, 2004. Hubble's Advanced Camera for Surveys captured the visible-light image of Saturn on March 22, 2004.

Image Facts:

Location: 6th planet from the Sun

Distance: Average distance from the Sun is 886 million miles (1.4 billion km) or 9.5 astronomical units (AU)

Description: Jovian (Gas Giant) Planet

HubbleSite News Resource: Quadruple Saturn Moon Transit Snapped by Hubble

This dramatic Hubble image of the Orion Nebula is the sharpest view ever taken of this region. It offers a glimpse inside a cavern of churning dust and gas where thousands of stars are forming.

ORION NEBULA

The Orion Nebula is a tumultuous region of dust and gas where thousands of stars are being born. Located 1,300 light-years away, it is the nearest area of star formation to Earth. In one of the most detailed astronomical images ever produced, Hubble captured an unprecedented look at this nebula.

The Orion Constellation

The Orion constellation is visible high in the winter sky in the northern hemisphere (summer sky in the southern hemisphere). In the center is Orion's "belt," consisting of three bright blue stars. The Orion Nebula is in the "sword" below the belt, just visible to unaided eyes in clear, dark skies.

More than 3,000 stars of various sizes appear in this image. Some have never before been seen in visible light. These stars reside in a dramatic landscape of plateaus, mountains, and valleys. From the massive, young stars that are shaping the nebula to the pillars of dense gas that may be the homes of budding stars, this image offers a glimpse at the various stages of star formation.

The bright central region is the home of the four most massive stars in the nebula. The stars are called the Trapezium because they are arranged in a trapezoid pattern. Ultraviolet light unleashed by these stars is carving a cavity in the nebula and influencing the growth of hundreds of smaller stars.

Protoplanetary Systems in the Orion Nebula

These Hubble images show six examples of young stars with disks encircling them. The protoplanetary disks, or “proplyds,” contain gas and dust trapped as the stars formed, and left in orbit about the star. They may evolve to form planets.

Located near the Trapezium are stars still young enough to have disks of material encircling them. These disks are called protoplanetary disks or “proplyds” and are too small to see clearly in this image. The disks are the building blocks of planetary systems.

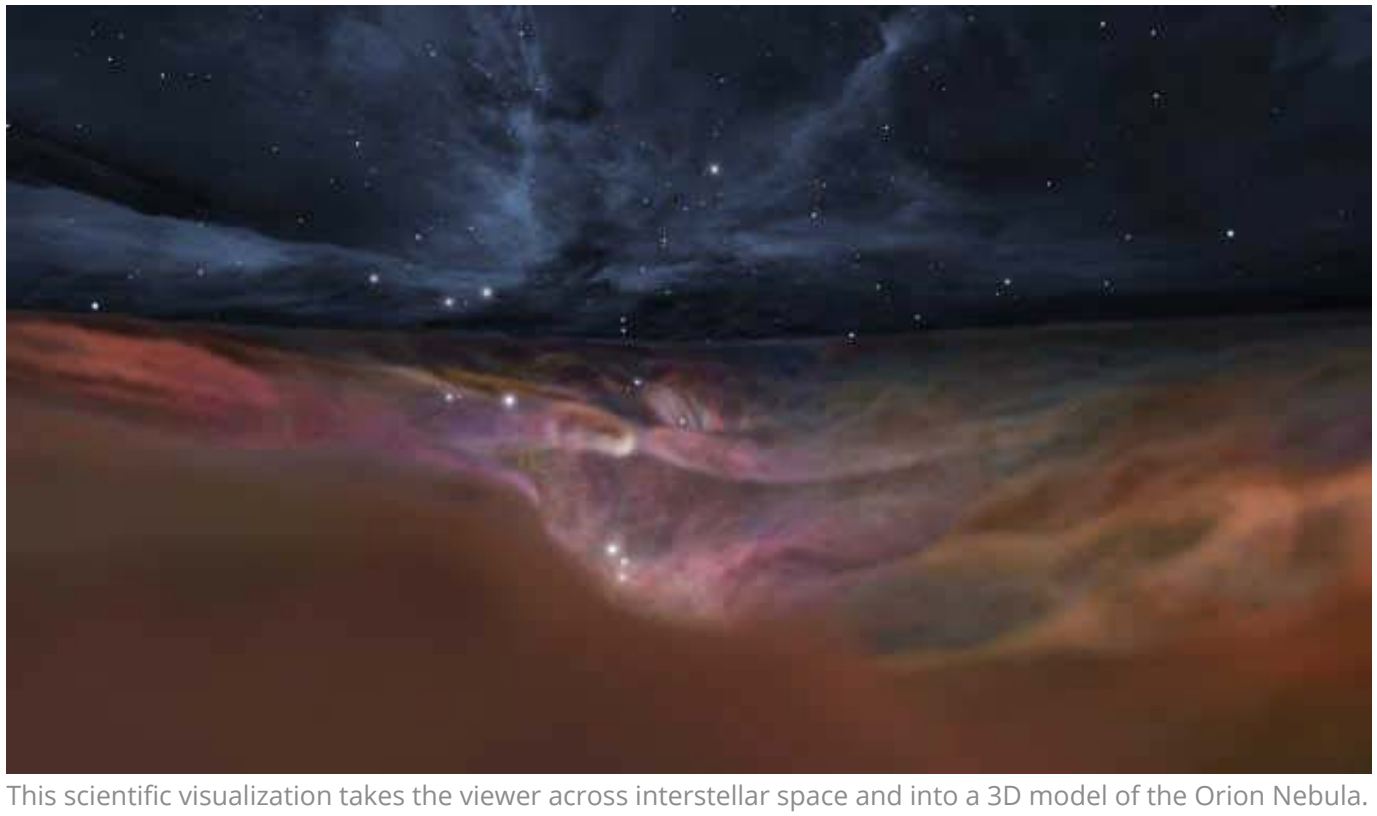
The bright glow at upper left is from M43, a small region being shaped by a massive, young star’s ultraviolet light. Next to M43 are dense, dark pillars of dust and gas that point toward the Trapezium. These pillars, which appear subtle against the dark background, are resisting erosion from the Trapezium’s intense ultraviolet light. The glowing region on the right reveals arcs and bubbles formed when stellar winds — streams of charged particles ejected from the Trapezium stars — collide with material.

The faint red stars near the bottom are the myriad brown dwarfs that Hubble spied for the first time in visible light. Sometimes called “failed stars,” brown dwarfs are cool objects that are too small to be ordinary stars because they cannot sustain nuclear fusion in their cores the way our Sun does. They are much like free-floating, larger versions of the planet Jupiter.

Astronomers used 520 Hubble images, taken in five colors with Hubble’s Advanced Camera for Surveys, to make this picture. They also added ground-based photos to fill out the nebula. The mosaic covers approximately the apparent angular size of the full moon.

A scientific team led by Massimo Robberto of the Space Telescope Science Institute obtained the mosaic observations to study the stellar content of the nebula. In addition to finding stars that formed about 2 million years ago, the specific motions of the stars were measured and an investigation to conduct a census of brown dwarfs and planet-sized objects was initiated.

Movie 3.1: 3D Fly-Through of the Orion Nebula



This scientific visualization takes the viewer across interstellar space and into a 3D model of the Orion Nebula. Seven individual shots of about ten seconds each are cross-faded together to form the sequence. After traversing among the stars, the camera descends through Orion's veil of bluish gas, down the valley carved by winds and high-energy radiation, and past the bright stars of the Trapezium in the core of the nebula. The 3D model combines astronomical knowledge, scientific intuition, and artistic interpretation to create an awe-inspiring journey into the star-forming cloud.

Image Facts:

Distance from Earth: 1,300 light-years

Description: Emission Nebula

Constellation: Orion

HubbleSite News Resource: Hubble's Sharpest View of the Orion Nebula

Hubble's infrared vision shows the iconic Horsehead Nebula in a new light.

HORSEHEAD NEBULA

The iconic Horsehead Nebula has graced astronomy books ever since its discovery more than a century ago in 1888 by Scottish astronomer Williamina Fleming. The nebula is a favorite target for amateur and professional astronomers alike. Hubble's infrared vision shows it in a dramatic new light. The nebula, shadowy in optical light, appears transparent and ethereal when seen at infrared wavelengths, represented here with visible shades.

The Horsehead Nebula in Visible Light

This visible-light image from Hubble, released in 2001, reveals the iconic Horsehead's intricate structure. It stands in sharp contrast to the more recent Hubble image, in which astronomers used the telescope's infrared vision to pierce through the opaque cloud.

The rich tapestry of the Horsehead Nebula pops out against the backdrop of Milky Way stars and distant galaxies that are easily seen in infrared light. The silhouette of a horse's head and neck pokes up mysteriously from what look like whitecaps of interstellar foam.

The nebula is part of the Orion Molecular Cloud, located about 1,500 light-years away in the constellation Orion. The cloud also contains other well-known objects such as the Great Orion Nebula (M42), the Flame Nebula, and Barnard's Loop. It is one of the nearest and most easily photographed regions in which massive stars are being formed.

In this Hubble image, the backlit wisps along the Horsehead's upper ridge are being illuminated by Sigma Orionis, a young five-star system just out of view. Along the nebula's top ridge, two fledgling stars peek out from their now-exposed nurseries.

Movie 4.1: The Horsehead Nebula in Visual and Infrared Light with a Fly-Through Visualization

Scientists know a harsh ultraviolet glare from one of these bright stars is slowly evaporating the nebula. Gas clouds surrounding the Horsehead already have dissipated, but the tip of the jutting pillar contains a slightly higher density of hydrogen and helium, laced with dust. This casts a shadow that protects material behind it from being stripped away by intense stellar radiation evaporating the hydrogen cloud, and a pillar structure forms.

This pillar of tenuous hydrogen gas laced with dust is resisting being eroded away by the radiation from a nearby star. Astronomers estimate the Horsehead will disintegrate in about 5 million to 10 million years.

Image Facts:

Distance from Earth: 1,500 light-years

Description: Dark Nebula

Constellation: Orion

HubbleSite News Resource: Hubble Sees a Horsehead of a Different Color

This Hubble image captures the intricate structure of the nearby planetary nebula NGC 5189. The nebula has a knotty and filamentary structure surrounding bluish lobes. This image was taken with Hubble's Wide Field Camera 3 on July 6, 2012, in filters tuned to the specific colors of fluorescing sulfur, hydrogen, and oxygen atoms. Broad filters in the visible and near-infrared were used to capture the star colors.

PLANETARY NEBULA NGC 5189

Planetary nebulae represent the final, brief stage in the life of a medium-sized star like our Sun. While consuming the last of the fuel in its core, the dying star expels a large portion of its outer envelope. This material is then illuminated by the ultraviolet radiation from the stellar remnant, producing glowing clouds of gas that can show complex structure.

A spectacular example of this beautiful complexity is seen in the bluish lobes of NGC 5189. Most of the nebula is knotty and filamentary in its structure. As a result of the mass-loss process, the planetary nebula has been created with two nested structures, tilted with respect to each other, that expand away from the center in different directions. The bright golden ring that twists and tilts through the nebula is made up of a large collection of radial filaments and cometary knots. These are usually formed by the combined action of photo-ionizing radiation and stellar winds.

The nebula is located 1,800 light-years away in the southern constellation Musca. Hubble's image is the most detailed yet made of this object. Its double bipolar or quadrupolar structure could be explained by the presence of a second star orbiting the central star and influencing the pattern of mass ejection during its nebula-producing death throes. The remnant of the central star, having lost much of its mass, now lives its final days as a white dwarf. However, there is no visual candidate for the possible companion.

Movie 5.1: Zoom into Planetary Nebula NGC 5189

The name "planetary nebulae" originated with astronomers who studied them through early telescopes with little magnification and optics that were far from sharp. The brightly colored nebulae are often roughly spherical, and many appear green or blue like Uranus and Neptune at lower resolution, so their appearance evoked that of the giant planets in the outer solar system. Many do look somewhat planet-like, but not NGC 5189. This nebula forms a dramatic reverse S-shape.

Planetary nebulae tell us about the possible fate of the Sun, which may form such a nebula when it runs out of fuel in a little over 5 billion years. In 2012, Sze-Ning Chong of Japan's Kagoshima University and collaborators used Hubble data to study the three-dimensional shapes of 20 complex planetary nebulae, including NGC 5189, and determined that a multipolar nebula with at least three pairs of lobes could explain many of the features in NGC 5189.

In 2014, Graziela R. Keller of the University of Sao Paulo in Brazil also used Hubble data to study the characteristics of the light and wind emitted from planetary nebulae, including NGC 5189. She studied the chemical composition of NGC 5189's central star and discovered significantly more nitrogen than previously estimated. The larger amount of nitrogen suggests that the star went through an outburst phase that contributed to the formation of the complex structure seen in the image. The different lobes may each come from a separate outburst in the distant past.

Image Facts:

Distance from Earth: 1,800 light-years

Description: Planetary Nebula

Constellation: Musca

HubbleSite News Resource: A Cosmic Holiday Ornament, Hubble-Style

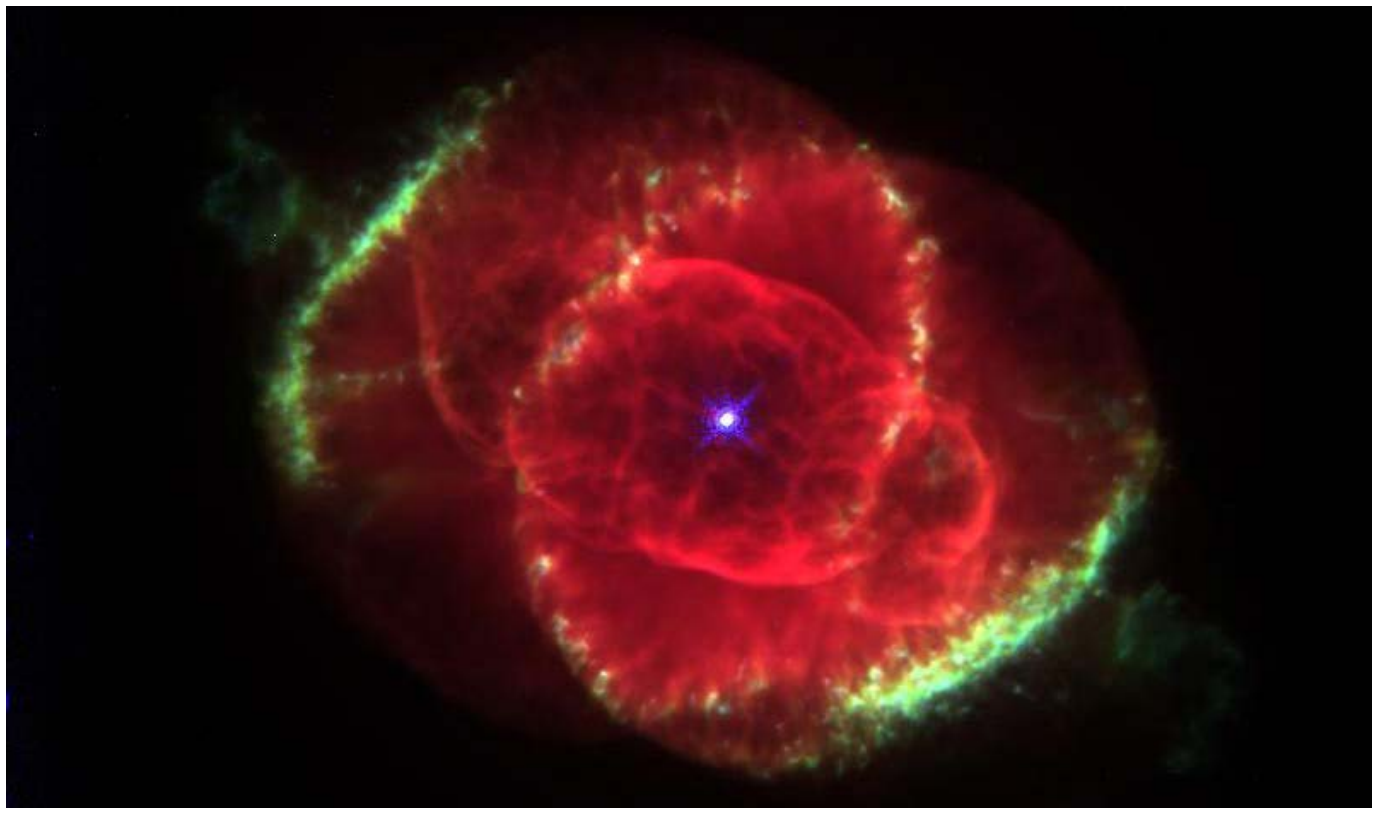
This image, taken with Hubble's Advanced Camera for Surveys in 2002, reveals the full beauty of a bull's-eye pattern of eleven or more concentric rings, or shells, around the Cat's Eye. The observation was made on May 4, 2002.

CAT'S EYE NEBULA

Though the Cat's Eye Nebula was one of the first planetary nebulae to be discovered, it is one of the most complex such nebulae ever seen. Planetary nebulae form when Sun-like stars gently eject their outer gaseous layers, creating amazing and confounding shapes. The Cat's Eye Nebula, also known as NGC 6543, is a visual "fossil record" of the dynamics and late evolution of a dying star. It is estimated to be 1,000 years old.

In 1994, initial Hubble observations revealed the nebula's surprisingly intricate structures, including gas shells, jets of high-speed gas, and unusual shock-induced knots of gas. Subsequent Hubble images showed a bull's-eye pattern of eleven or more concentric rings, or shells, of dust around the Cat's Eye. Each "ring" is actually the edge of a spherical bubble seen projected onto the sky — that's why it appears bright along its outer edge.

Wide Field Planetary Camera 2 Image of the Cat's Eye Nebula



This color picture, taken with Hubble's Wide Field Planetary Camera 2 in 1994, is a composite of three images taken at different wavelengths of the central region of the Cat's Eye Nebula.

Observations suggest the star that created the Cat's Eye Nebula ejected its mass in a series of pulses at 1,500-year intervals. These convulsions created dust shells, each of which contains as much mass as all of the planets in our solar system combined (still only one percent of the Sun's mass). These concentric shells make a layered, onion-skin structure around the dying star. The view from Hubble is like seeing an onion cut in half, where each skin layer is discernible.

Approximately 1,000 years ago the pattern of mass loss suddenly changed, and the Cat's Eye Nebula began forming inside the dusty shells. It has been expanding ever since, as discernible in comparing Hubble images taken in 1994, 1997, 2000, and 2002. But what caused this dramatic change? Many aspects of the process that leads a star to lose its gaseous envelope are still poorly understood, and the study of planetary nebulae is one of the few ways to recover information about these last few thousand years in the life of a Sun-like star.

Movie 6.1: Zoom into the Cat's Eye Nebula

Until recently, it was thought that shells around planetary nebulae were a rare phenomenon. However, Romano Corradi of the Isaac Newton Group of Telescopes in Spain and his collaborators instead used Hubble to show that the formation of these rings is likely to be the rule rather than the exception. In 2013, Martin A. Guerrero, of the Instituto de Astrofisica de Andalucia in Spain, used Hubble to study the temperature and density of the Cat's Eye Nebula's shells. He found that the shells represent a series of shocks propagating into pre-existing lower density material.

Several explanations have been proposed for the bull's-eye patterns seen around planetary nebulae, including cycles of magnetic activity somewhat similar to our own Sun's sunspot cycle, the action of a companion star orbiting around the dying star, and stellar pulsations. Another school of thought is that the material is ejected smoothly from the star, and the rings are created later on due to the formation of waves in the outflowing material. Further observations and more theoretical studies are needed to decide between these and other possible explanations.

Image Facts:

Distance from Earth: 3,000 light-years

Description: Planetary Nebula

Constellation: Draco

HubbleSite News Resource: The Cat's Eye Nebula: Dying Star Creates Fantasy-like Sculpture of Gas and Dust

NGC 6302 is one of the brightest and most extreme planetary nebulae known. It was imaged on July 27, 2009, with Hubble's Wide Field Camera 3 in ultraviolet and visible light. Filters that isolate emissions from oxygen, helium, hydrogen, nitrogen, and sulfur from the planetary nebula were used to create this composite image.

PLANETARY NEBULA NGC 6302

The spectacular planetary nebula NGC 6302 lies roughly 3,800 light-years away in the constellation Scorpius. More popularly known as the Bug Nebula or the Butterfly Nebula, this celestial object looks like a delicate butterfly. But what resemble dainty wings are actually roiling regions of gas heated to more than 36,000 degrees Fahrenheit. The gas is tearing across space at more than 600,000 miles an hour — fast enough to travel from Earth to the Moon in 24 minutes.

Movie 7.1: A Pan Sequence of the Planetary Nebula NGC 6302

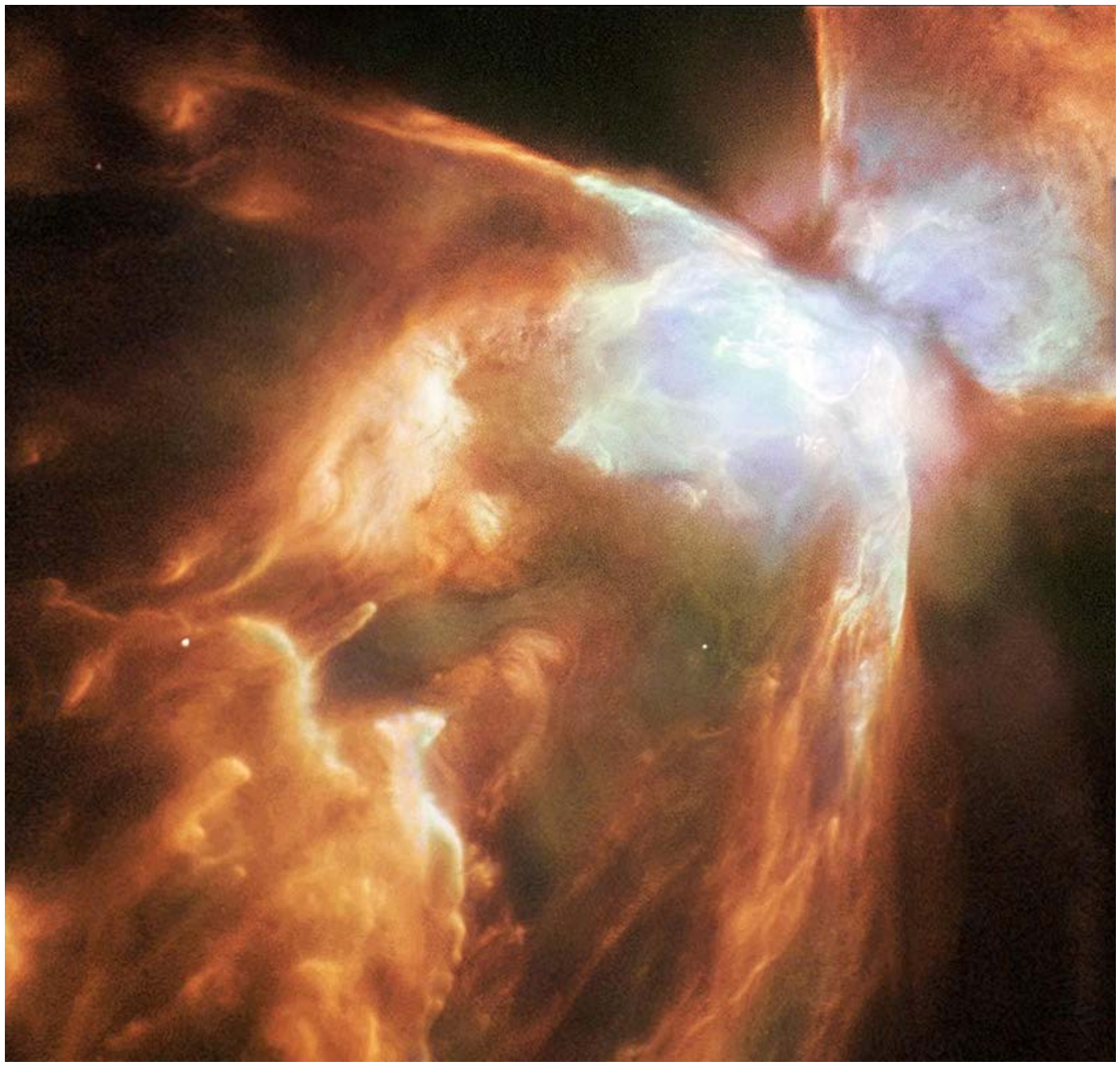
The glowing gas is the star's outer layers, expelled over about 2,200 years. The "butterfly" stretches for more than two light-years, which is about half the distance from the Sun to the nearest star, Alpha Centauri.

A dying star that was once about five times the mass of the Sun is at the center of this fury. It has ejected its envelope of gases and is now unleashing a stream of ultraviolet radiation that is making the cast-off material glow. This object is an example of a planetary nebula, so-named because many of them have a round appearance resembling that of a planet when viewed through a small telescope.

The central star itself cannot be seen, because it is hidden within a doughnut-shaped ring of dust, or torus, which appears as a dark band pinching the nebula in the center. The thick dust belt constricts the star's outflow, creating the classic "bipolar" or hourglass shape displayed by some planetary nebulae.

The star's surface temperature is estimated to be about 400,000 degrees Fahrenheit, making it one of the hottest known stars in our galaxy. Spectroscopic observations made with ground-based telescopes show that the gas is roughly 36,000 degrees Fahrenheit, which is unusually hot compared to a typical planetary nebula.

Wide Field Plantery Camera 2 Image of NGC 6302



Hubble's Wide Field Plantery Camera 2 shows NGC 6302's impressive walls of compressed gas, laced with trailing strands and bubbling outflows. This image was taken on February 21, 2000.

Hubble's Wide Field Camera 3 (WFC3) reveals a complex history of ejections from the star. The star first evolved into a red giant with a diameter of about 1,000 times that of our Sun. It then lost its extended outer layers. Some of this gas was cast off from its equator at a relatively slow speed, perhaps as low as 20,000 miles an hour, creating the torus. Other gas was ejected perpendicular to the ring at higher speeds, producing the elongated lobes or "wings" of the butterfly-shaped structure.

Later, as the central star heated up, a much faster stellar wind (a stream of charged particles traveling at more than 2 million miles an hour) plowed through the existing wing-shaped structure, further modifying its shape. The image also shows numerous finger-like projections pointing back to the star, which may mark denser blobs in the outflow that have resisted the pressure from the stellar wind.

The nebula's reddish outer edges are largely due to light emitted by nitrogen, which marks the coolest gas visible in the Hubble image. WFC3 is equipped with a wide variety of filters that isolate light emitted by various chemical elements, allowing astronomers to infer properties of the nebular gas, such as its temperature, density, and composition.

The white-colored regions are areas where light is emitted by sulfur. These are regions where fast-moving gas overtakes and collides with slow-moving gas that left the star at an earlier time, producing shock waves in the gas (the bright white edges on the sides facing the central star). The white blob with the crisp edge at upper right is an example of one of those shock waves.

Using Hubble data in 2009, Cezary Szyszka of the University of Manchester in the United Kingdom and collaborators directly detected NGC 6302's central star for the first time. In 2011, Szyszka and his team further analyzed Hubble data to determine the motions of two lobes of the ejected material, which appear to have been created rapidly in an event 2,250 years ago. Other parts of the nebula, specifically the dense massive torus of molecular material, was produced more slowly, starting about 5,000 years ago and then terminating about 2,900 years ago, preceding the lobe ejection. This time delay gives clues to how the stellar system was modified through the final stages of the central star.

In 2014, Lucero Uscanga of the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, and collaborators were able to use Hubble data to model both the complex shape and also the movement of the nebula, possibly caused by the interaction of two stellar winds.

Image Facts:

Distance from Earth: 3,800 light-years

Description: Planetary Nebula

Constellation: Scorpius

HubbleSite News Resource: Butterfly Emerges from Stellar Demise in Planetary Nebula NGC 6302

This Hubble mosaic reveals carved knots of gas and dust in a small portion of the Monkey Head Nebula, which is also known as NGC 2174 and Sharpless Sh2-252. The nebula is a star-forming region that hosts dusky dust clouds silhouetted against glowing gas.

PILLARS IN THE MONKEY HEAD NEBULA

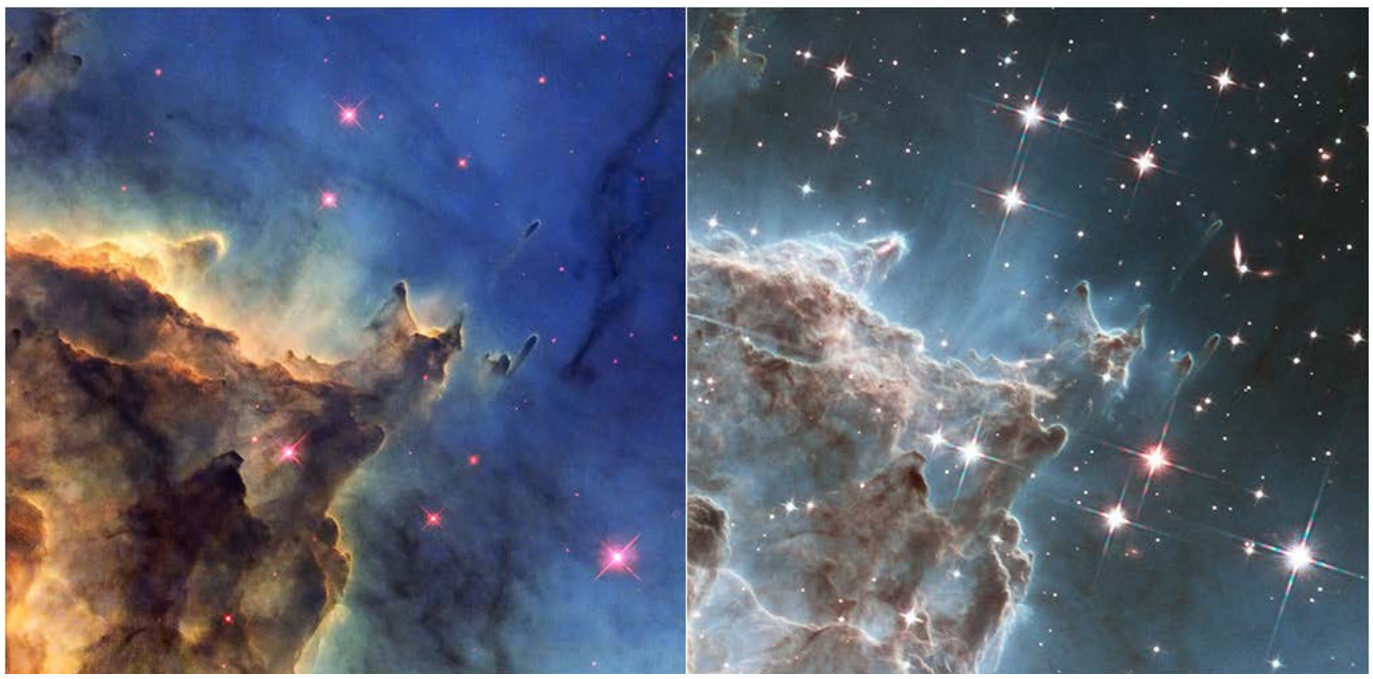
The Monkey Head Nebula is a region of star birth located 6,400 light-years away. It is also known as NGC 2174 and Sharpless Sh2-252. In 2014, astronomers using Hubble's powerful infrared vision imaged a small portion of the nebula in the area of the monkey's "eye."

The nebula is mostly composed of hydrogen gas. The cloud is sculpted by ultraviolet light carving into the cool hydrogen gas and dust. As the interstellar dust particles are warmed from the radiation from the stars in the center of the nebula, they heat up and begin to glow at infrared wavelengths.

This Hubble mosaic unveils a collection of carved knots of gas and dust silhouetted against glowing gas. Massive, newly formed stars near the center of the nebula (and toward the right in this image) are blasting away at dust within the nebula. Ultraviolet light from these bright stars helps sculpt the dust into giant pillars.

The prime source of energy in the nebula is the massive, hot star named HD 42088, which is outside the Hubble image field. This star has a mass 30 times that of the Sun and a surface temperature 6 times greater. Such stars emit extraordinary amounts of ultraviolet radiation. The high-energy particles in these stars' outer atmospheres are being blown away in high-speed "stellar winds."

Visible and Infrared Comparison

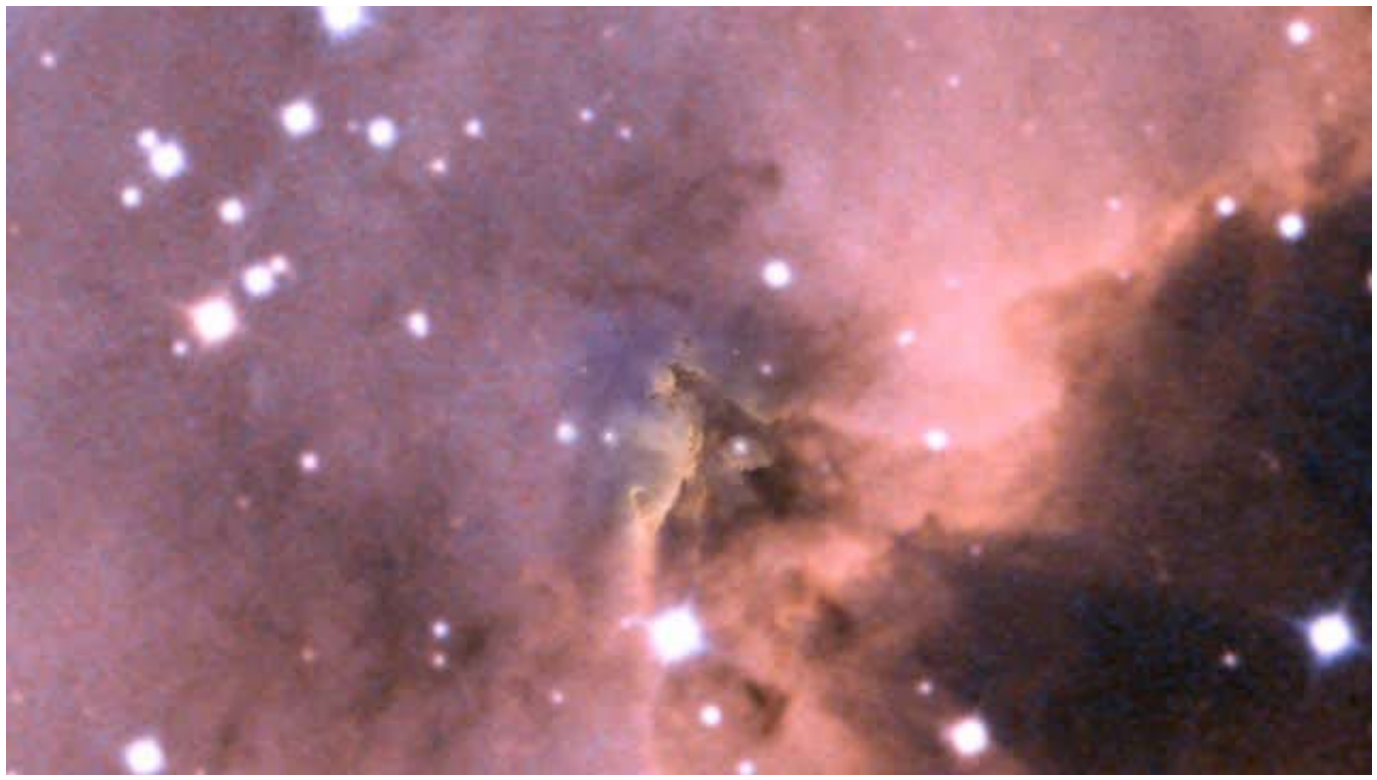


This is a comparison of Hubble's visible-light and infrared views of the same detailed area in the star-forming Monkey Head Nebula. On the left is a visible-light image by the Wide Field Planetary Camera 2 from 2001, and on the right is an image by the Wide Field Camera 3's infrared camera from 2014. Infrared light penetrates more dust and gas than visible light, allowing many details to be seen. A jet of material from a newly forming star is visible in one of the pillars, just above and left of center in the right-hand image. Several distant galaxies also appear in the infrared view.

The ultraviolet radiation causes the nebula to shine. In combination with the stellar wind, this radiation also causes the nebula to expand. Dust and gas are being evaporated and scattered by the energy from the hot star. Where there is a very dense condensation, a pillar is formed pointing toward the star, because the knot shields the material behind it.

If the knot is dense enough, rather than scattering, it may be pushed to collapse into a new star. Such an event is occurring in a pillar above center right of the image. This cannot be seen in visible light, because those wavelengths are blocked by the pillar's dust. The new star will eventually shed its dusty cocoon and emerge to be seen in optical wavelengths.

Movie 8.1: A Tour Through the Monkey Head Nebula



This video showcases visible- and infrared-light views of a collection of pillars along the edge of the star-forming region called the Monkey Head Nebula.

Using a variety of observations including those from Hubble, scientists are studying the whole nebular region to understand the progression of star formation across it. Of particular interest are the embedded contents of the pillars and the generation from which they originated.

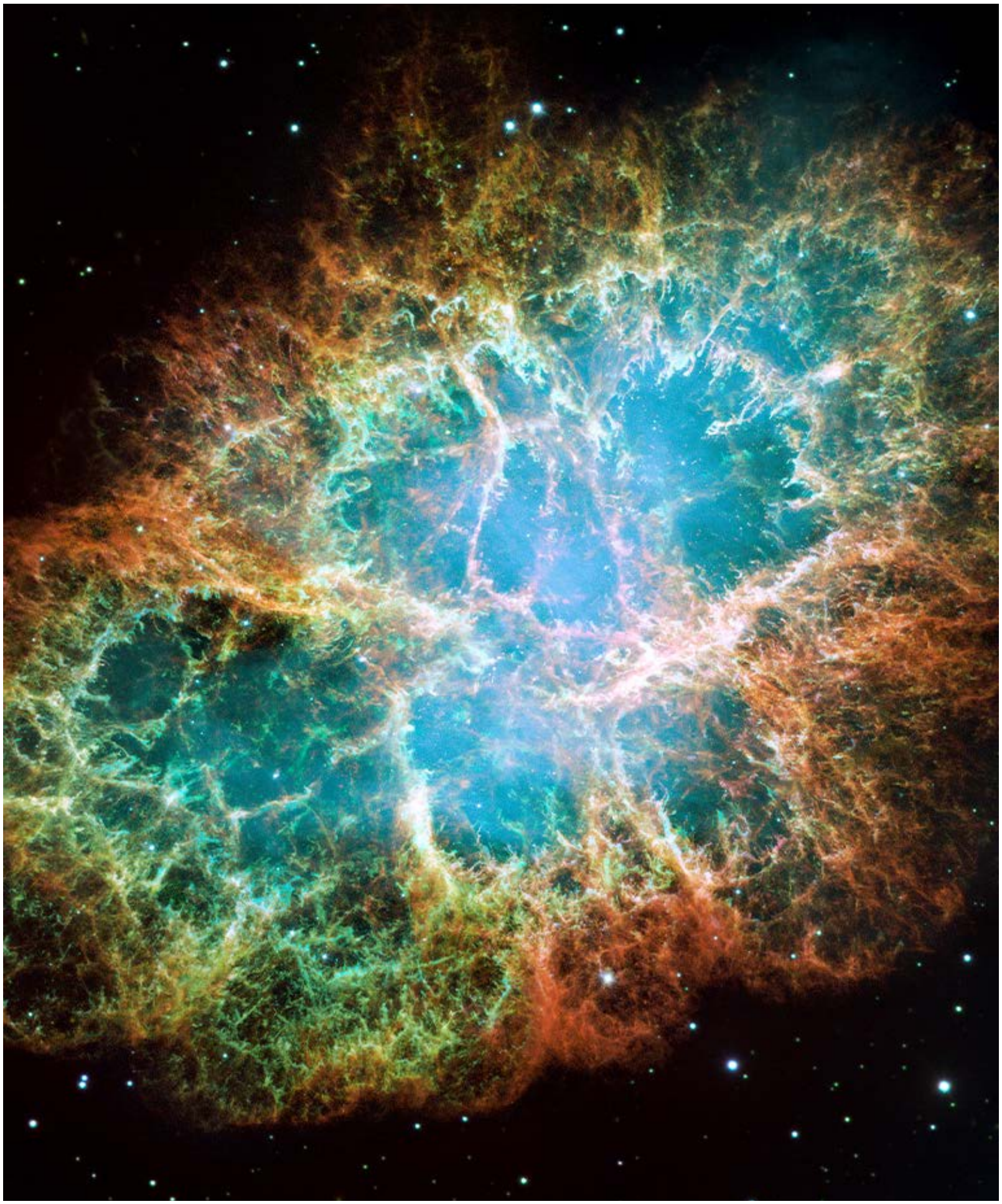
Image Facts:

Distance from Earth: 6,400 light-years

Description: Star-Forming Region

Constellation: Orion

HubbleSite News Resource: An Infrared Look at a Nearby Star Factory



This mosaic Hubble image shows an 11-light-year-wide expanding remnant of a star's supernova explosion. The colors indicate the different elements that were expelled during the explosion. Blue in the filaments in the outer part of the nebula represents neutral oxygen, green is singly ionized sulfur, and red indicates doubly ionized oxygen.

CRAB NEBULA

The Crab Nebula is an expanding remnant of a star's supernova explosion. Japanese and Chinese astronomers recorded this violent event nearly 1,000 years ago in 1054 AD, as did likely the Native Americans. The glowing relic has been expanding since the star exploded, and it is now approximately 11 light-years in width.

This Hubble mosaic is one of the largest images ever taken of a supernova remnant by the space telescope. It is also the highest resolution image ever made of the entire Crab Nebula, which is located 6,500 light-years away. The composite was assembled from 24 individual exposures taken with Hubble's Wide Field Planetary Camera 2 in October 1999, January 2000, and December 2000.

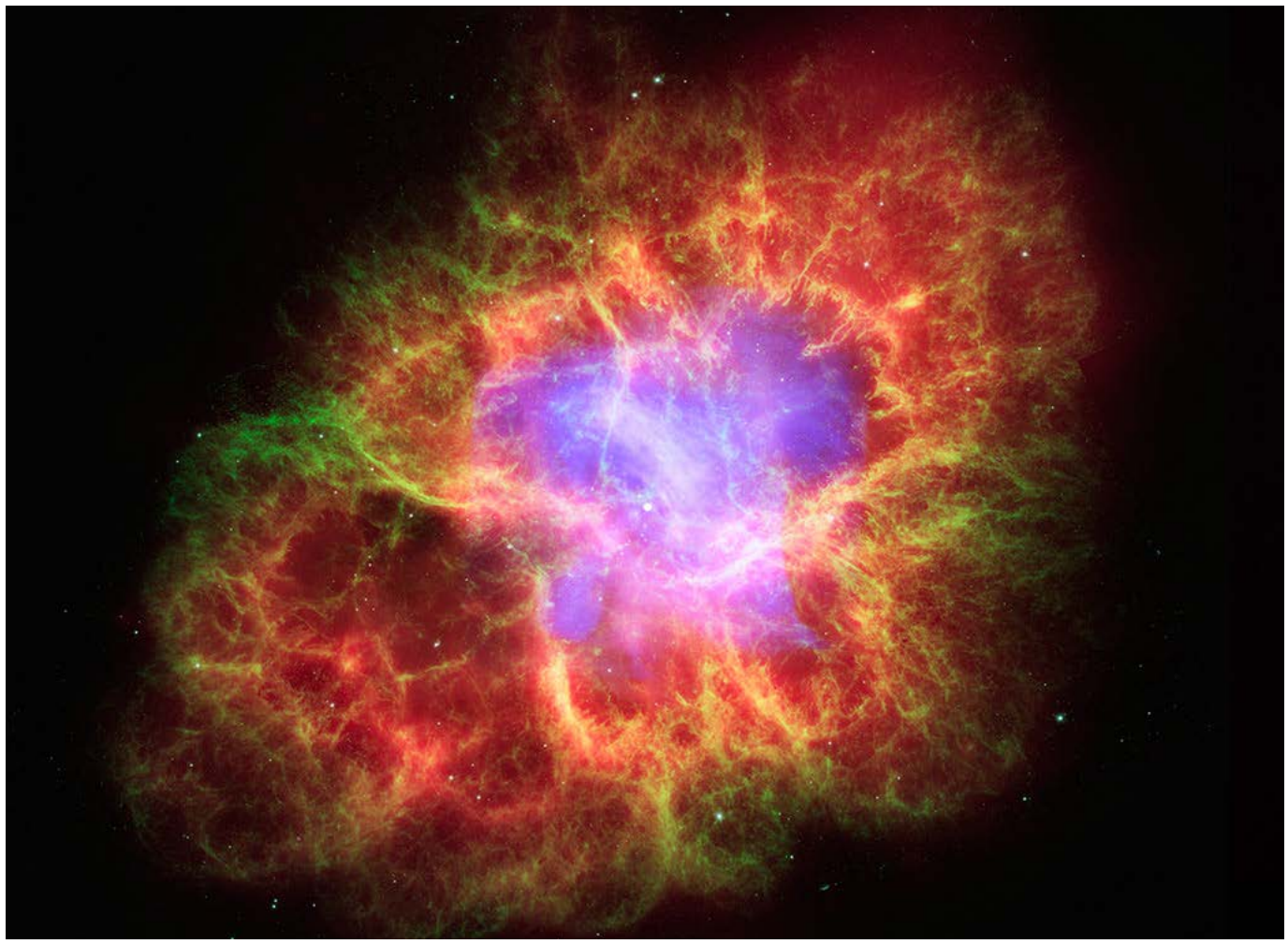
The orange filaments are the tattered remains of the star and consist mostly of hydrogen. The rapidly spinning neutron star embedded in the center of the nebula is the dynamo powering the nebula's eerie interior bluish glow. The blue light comes from electrons whirling at nearly the speed of light around magnetic field lines from the neutron star, which is the crushed, ultra-dense core of the exploded star.

Like a lighthouse, the neutron star produces twin beams of radiation. From Earth, it appears to pulse 30 times a second due to the neutron star's rotation sweeping the beams across our line of sight. It has the mass equivalent to the Sun crammed into a rapidly spinning ball of neutrons 12 miles across.

Movie 9.1: Zoom into the Crab Nebula

The nebula derived its name from its appearance in an 1844 drawing made by Irish astronomer Lord Rosse, who used a 36-inch telescope. When viewed by Hubble, as well as by large, ground-based telescopes, the Crab Nebula takes on a more detailed appearance that yields clues into the spectacular demise of the star.

Composite Image of the Crab Nebula



This composite image shows Chandra X-ray data in light blue, Hubble optical data in green and dark blue, and the Spitzer Space Telescope's infrared data in red. The neutron star is the bright white dot in the center of the image.

In 2002, Emily Schaller and Robert Fesen of Dartmouth College used Hubble to examine the motion and shape of bright knots in the Crab Nebula. They found that the knots lie relatively close to the source of the ionizing radiation, which may lead to higher gas temperatures of the knots than expected. This limits our understanding of the structure of the nebula and what role magnetic fields may play as the material expands outward and eventually combines with other material to form new stars.

In 2010 and 2013, Allison Loll of Arizona State University used Hubble to determine several northwest-southeast (upper right to lower left) asymmetries in the nebula's filaments, as well as the development of long "fingers" of gas and dust. She attributes these to the sideways motion of the neutron star in the northwest (upper right) direction. Jeff Hester, also at Arizona State University, studied Hubble observations of the Crab Nebula along with data from other observatories to investigate the expansion and magnetic fields of the nebula remnant from the explosion.

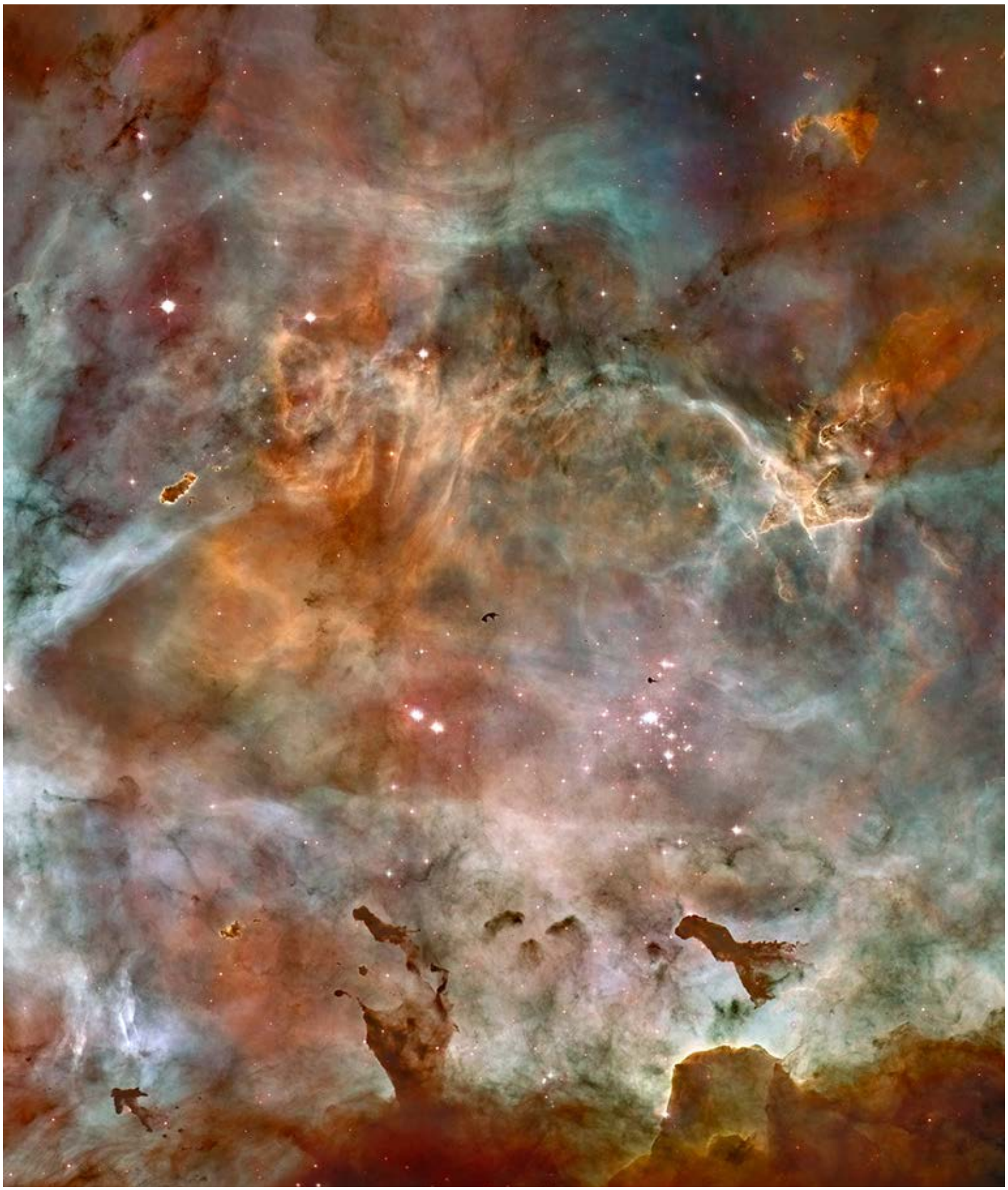
Image Facts:

Distance from Earth: 6,500 light-years

Description: Supernova Remnant

Constellation: Taurus

HubbleSite News Resource: A Giant Hubble Mosaic of the Crab Nebula



Hubble reveals a never-before-seen level of detail in the Carina Nebula, a tumultuous region of star birth and death located about 7,500 light-years away. The Hubble image was taken in the light of neutral hydrogen by the Advanced Camera for Surveys. Color information was added with data from the Cerro Tololo Inter-American Observatory in Chile. Red corresponds to sulfur, green to hydrogen, and blue to oxygen emission.

Panoramic Image of the Carina Nebula

This 50-light-year-wide view of the central region of the nebula is one of the largest panoramic images ever taken with Hubble's cameras.

The Carina Nebula is an immense cloud of gas and dust where a maelstrom of star birth and death is taking place. The nebula is located an estimated 7,500 light-years away in the southern constellation Carina the Keel (part of the older, larger southern constellation Argo Navis, the ship of Jason and the Argonauts).

Hubble's view of the nebula shows star birth in a new level of detail. The nebula's fantastic landscape is sculpted by the action of outflowing winds and scorching ultraviolet radiation from the monster stars that inhabit this inferno. In the process, these stars are shredding the surrounding material that is the last vestige of the giant cloud from which the stars were born. The immense nebula contains at least a dozen brilliant stars that are roughly estimated to be at least 50 to 100 times the mass of our Sun.

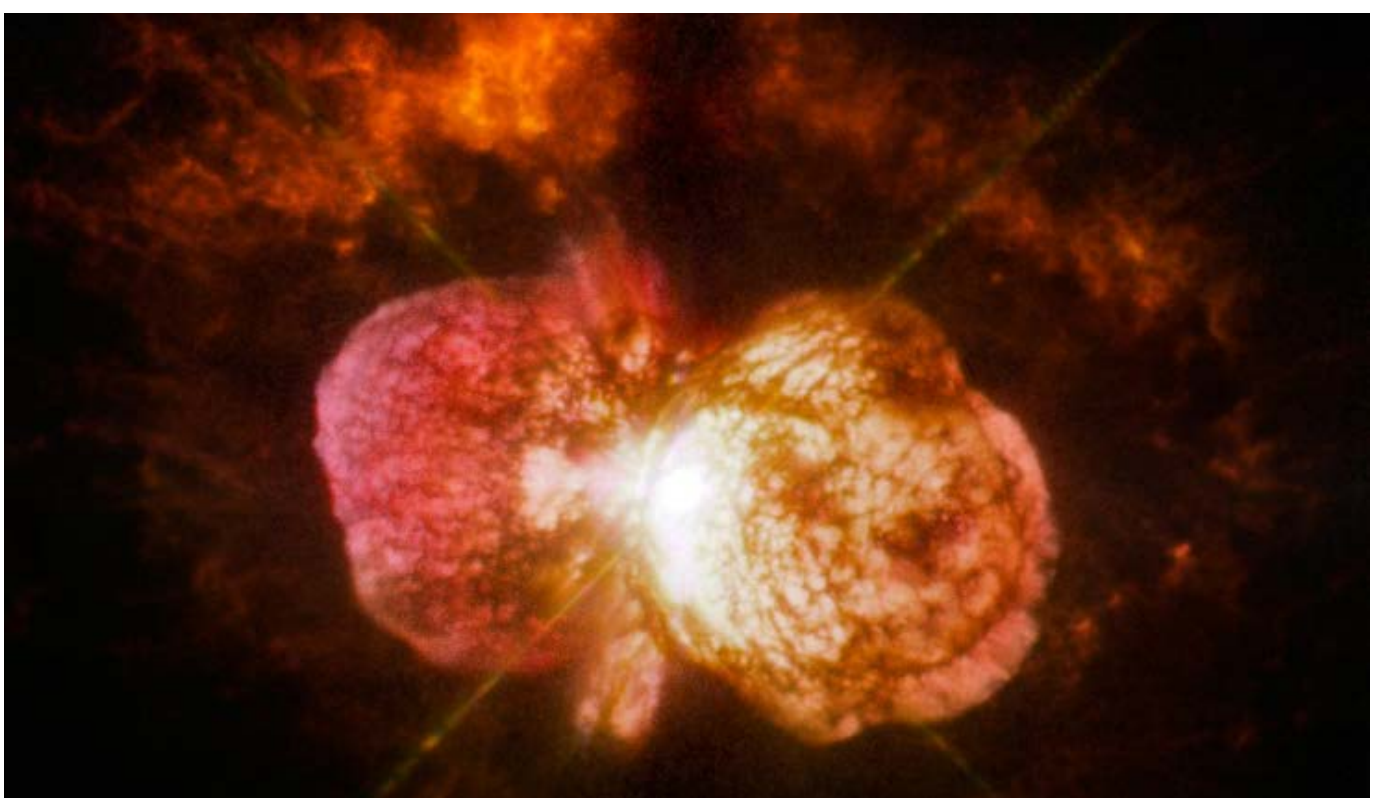
Three million years ago, the nebula's first generation of newborn stars condensed and ignited in the middle of a huge cloud of cold molecular hydrogen. Radiation from these stars carved out an expanding bubble of hot gas. The isolated clumps of dark clouds scattered across the nebula are nodules of dust and gas that are resisting being eaten away by photoionization, the process by which the energy from light removes electrons from atoms.

Movie 10.1: Zoom into the Carina Nebula

The blast of stellar winds and blistering ultraviolet radiation within the cavity is now compressing the surrounding walls of cold hydrogen. This is triggering a second stage of new star formation. Our Sun and our solar system may have been born inside such a cosmic crucible 4.6 billion years ago. The Carina Nebula reveals the genesis of star birth as it commonly occurs along the dense spiral arms of a galaxy such as our Milky Way.

One of the Carina Nebula's most famous denizens is the unstable, behemoth double-star system Eta Carinae. Among the largest and brightest star systems in our Milky Way Galaxy, this stellar duo is known for its spectacular, periodic outbursts. The larger of the pair is an enormous 90 solar masses, while its smaller companion is 30 solar masses. The more massive of these two stars is destined to explode soon as a supernova.

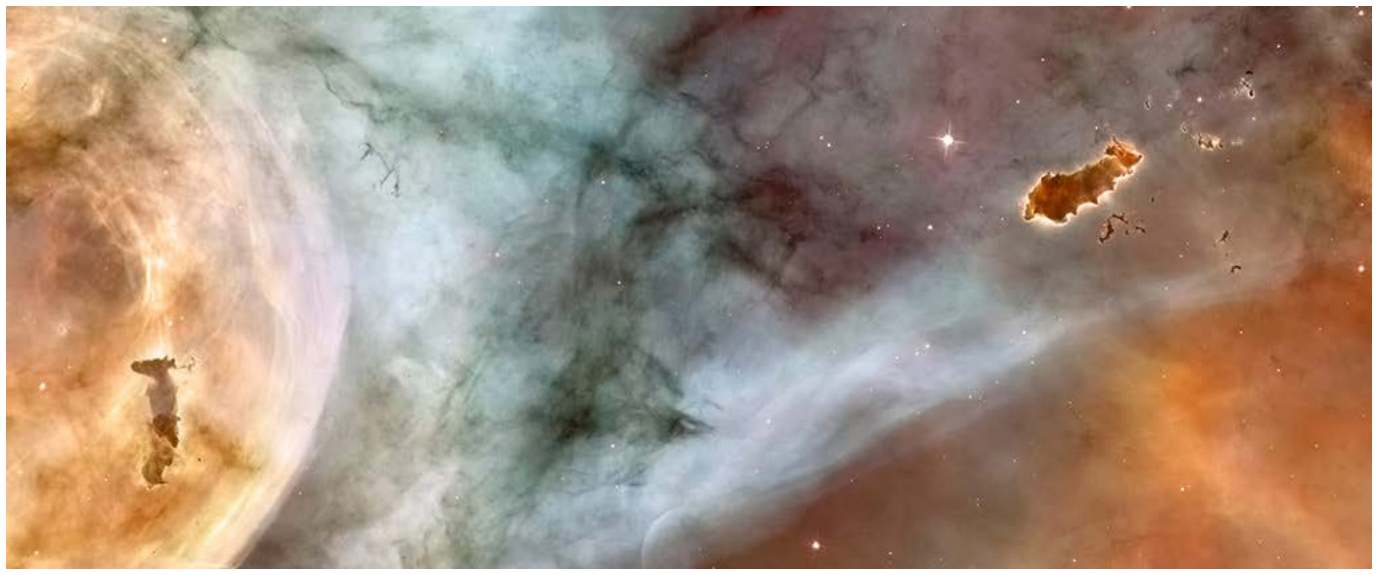
Variable Star Eta Carinae



A huge, billowing pair of clouds made of gas and dust is captured in this stunning Hubble image of the supermassive star Eta Carinae. The unstable, double-star system — one of the largest and brightest star systems in the Milky Way Galaxy — exhibits periodic outbursts.

A science team led by Armin Rest of the Space Telescope Science Institute used Hubble to study a “light echo” from an eruption of Eta Carinae that took place 170 years earlier. Known as “the Great Eruption,” this 20-year event in the mid-1800s caused Eta Carinae to become the second brightest star in the sky. Some of the light from the eruption took an indirect path to Earth and is just arriving now, providing an opportunity to analyze the outburst in detail. The wayward light was heading in a different direction, away from our planet, when it bounced off dust clouds lingering far from the turbulent stars and was rerouted to Earth. The observations of Eta Carinae’s light echo are providing new insight into the behavior of powerful massive stars on the brink of detonation.

Bok Globule Detail



A Bok globule — a dark cloud of dense dust and gas — appears at the right. Its glowing edge indicates that it is being photoionized by the hottest stars in the cluster. Scientists hypothesize that stars may form inside such dusty cocoons. The top of the Keyhole Nebula, the most prominent feature embedded inside Carina, is on the left. Another Bok globule is in the foreground.

Astronomers also have used Hubble’s detailed observations of the Carina Nebula to study small globules within it. For example, a team of astronomers led by Nathan Smith of the University of California, Berkeley, found that even small globules appear to be forming stars, and that some could be analogs to the cloud in which our own Sun and solar system formed. Another team, led by Tia Grenman at the Lulea University of Technology in Sweden, found that some globules are so small they don’t even have enough mass to form a star but could instead form free-floating planets that do not orbit any star.

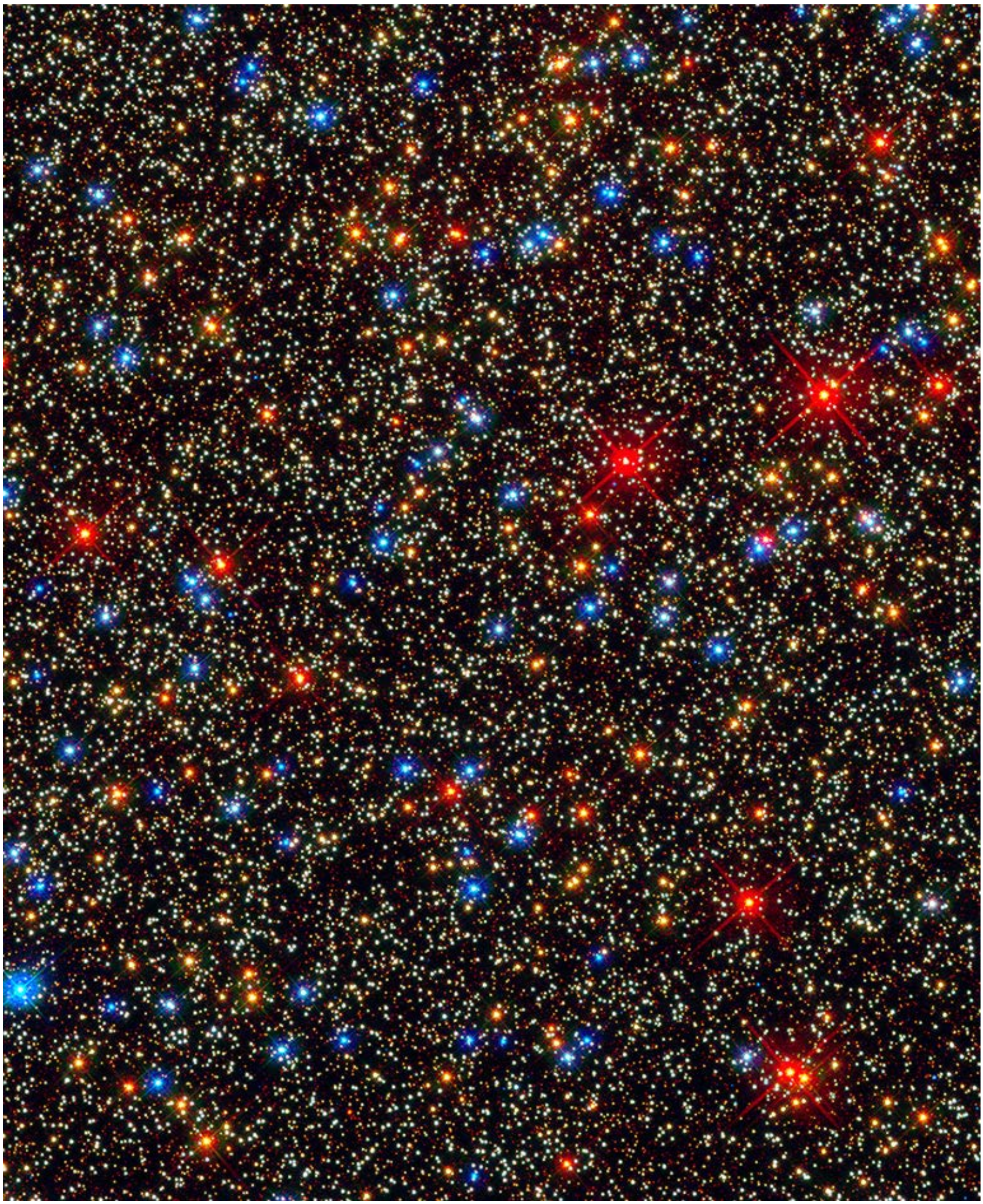
Image Facts:

Distance from Earth: 7,500 light-years

Description: Emission Nebula

Constellation: Carina

HubbleSite News Resource: The Carina Nebula: Star Birth in the Extreme



Lying 17,000 light-years from Earth, Omega Centauri is a huge swarm of stars called a globular cluster. Astronomers used Hubble's Wide Field Camera 3 to construct this image of stars at the heart of Omega Centauri.

CORE OF OMEGA CENTAURI

Resembling a dazzling display of holiday lights, this crowded field of stars lies in the heart of a giant stellar swarm known as Omega Centauri. A collection of nearly 10 million stars in all, Omega Centauri is the largest of about 150 “globular clusters” in the Milky Way. It’s big enough that stargazers can spot it by eye from the southern hemisphere or from low northern latitudes.

The stars’ colors give us information about them. Bright blue stars are old, hot stars that are now burning helium instead of hydrogen in their cores. Bright red stars are cool giants that are heading into old age. Dimmer red stars are cool dwarfs destined to live for a long, long time. White stars are typically middle-aged, average stars.

The stars move around the center of Omega Centauri seemingly at random, like a swarm of bees. But because they are so far away, roughly 17,000 light-years from Earth, it takes years for us to notice any change in their positions. Even then, astronomers need the power of Hubble to see these changes. The center of Omega Centauri is so crowded, telescopes here on the ground have no hope of spotting individual stars there, because Earth’s atmosphere blurs the view.

Movie 11.1: Zoom into the Heart of Omega Centauri

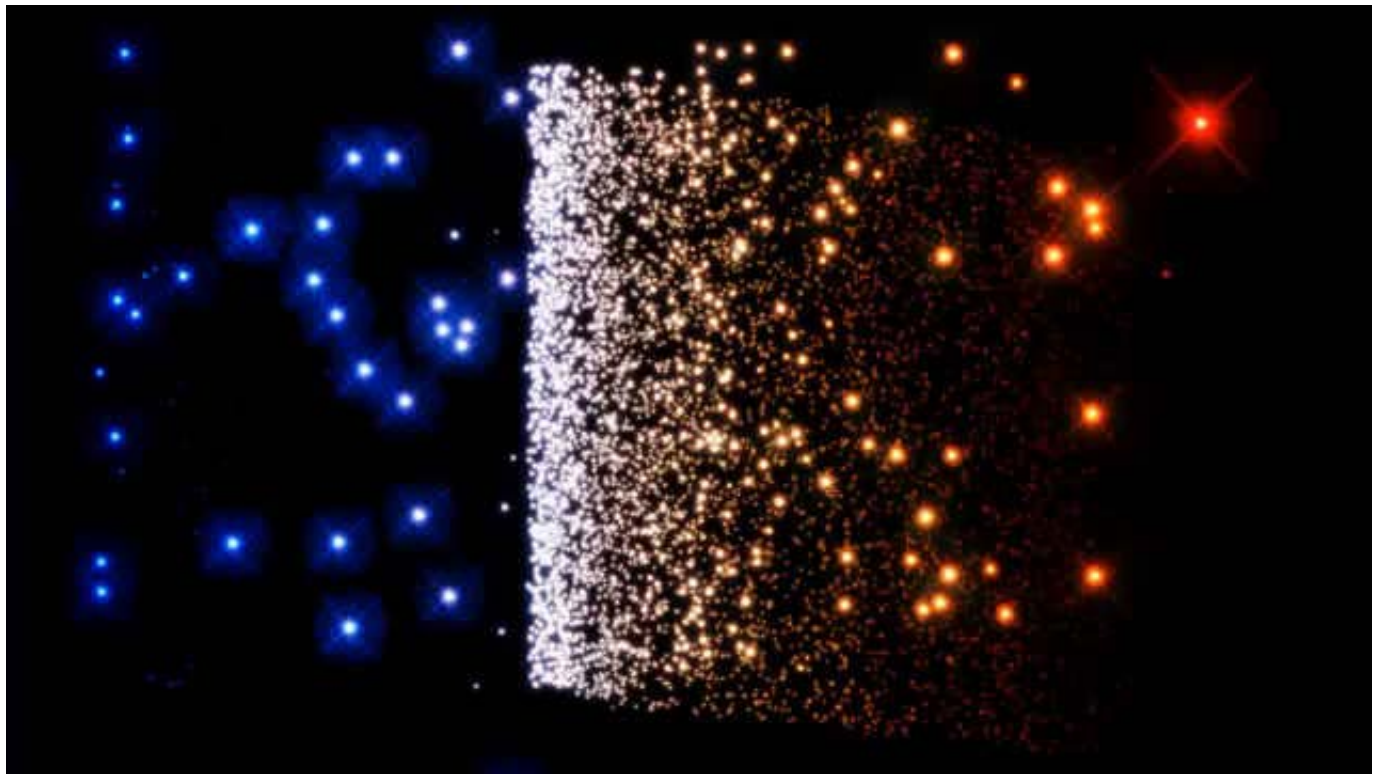
Astronomers Jay Anderson and Roeland van der Marel of the Space Telescope Science Institute analyzed archived Hubble observations of the stars at the center of Omega Centauri taken over four years, from 2002 to 2006, with the Advanced Camera for Surveys. They compared these sets of Hubble observations to measure the motions of more than 100,000 stars in the cluster. They then used the measurements to predict where the stars will go over the next 10,000 years.

Movie 11.2: Future Motions of Omega Centauri Stars

This video shows how the stars at the center of Omega Centauri are predicted to move over the next 10,000 years.

Earlier research had suggested that there might be a black hole at the center of Omega Centauri. This seems unlikely, though, based on Anderson and van der Marel's study of the Hubble observations. The stars at the center of Omega Centauri are not traveling as they would if a massive black hole were gravitationally tugging on them, shepherding their movements.

Movie 11.3: Constructing a Hertzsprung-Russell Diagram for Omega Centauri



This narrated video uses Hubble's color image of the core of Omega Centauri to construct a Hertsprung-Russell (HR) diagram of the stars at the center of the cluster. Such a diagram sorts stars by color and brightness, which astronomers can use to trace stellar evolution.

Image Facts:

Distance from Earth: 17,000 light-years

Description: Globular Star Cluster

Constellation: Centaurus

HubbleSite News Resource: Hubble Data Used to Look 10,000 Years into the Future

This light echo is the result of light from the red supergiant star V838 Monocerotis in the middle of the image illuminating the interstellar dust. Never-before-seen spirals of dust swirl across trillions of miles of interstellar space. This Hubble image was obtained with the Advanced Camera for Surveys on February 8, 2004.

V838 MONOCEROTIS

A halo of light surrounds an unusual, variable star called V838 Monocerotis (V838 Mon). Called a light echo, the expanding illumination of interstellar dust around the star has been revealing remarkable structures in the dusty cloud ever since the star suddenly brightened in January 2002. V838 Mon temporarily became 600,000 times brighter than our Sun, until it faded in April 2002. It was one of the brightest stars in the entire Milky Way. The reason for the eruption is still unclear.

The red supergiant star, seen in the middle of the image, is located about 20,000 light-years away from Earth in the direction of the constellation Monoceros, at the outer edge of our Milky Way Galaxy. The star has some similarities to a class of objects called “novae,” which suddenly increase in brightness due to thermonuclear explosions at their surfaces. However, the detailed behavior of V838 Mon, in particular its extremely red color, has been completely different from any previously known nova.

The light from V838 Mon scatters or “echoes” off the dust and then travels to Earth. Because of the extra distance the scattered light travels, it reaches Earth long after the light from the stellar outburst itself. Therefore, a light echo is an analog of a sound echo produced, for example, when sound from an Alpine yodeler echoes off of the surrounding mountainsides.

Movie 12.1: The Light Echo Around V838 Mon Reveals Dramatic Changes over a Decade

Hubble has observed the V838 Mon light echo several times since 2002. Light from V838 Mon continues propagating outward. Each new observation of the light echo reveals a new and unique “thin-section” through the interstellar dust around the star. Scientists have been studying the structure of V838 Mon to understand the distribution of dust revealed by the echo, and to determine what prompted the progenitor star to create the outburst.

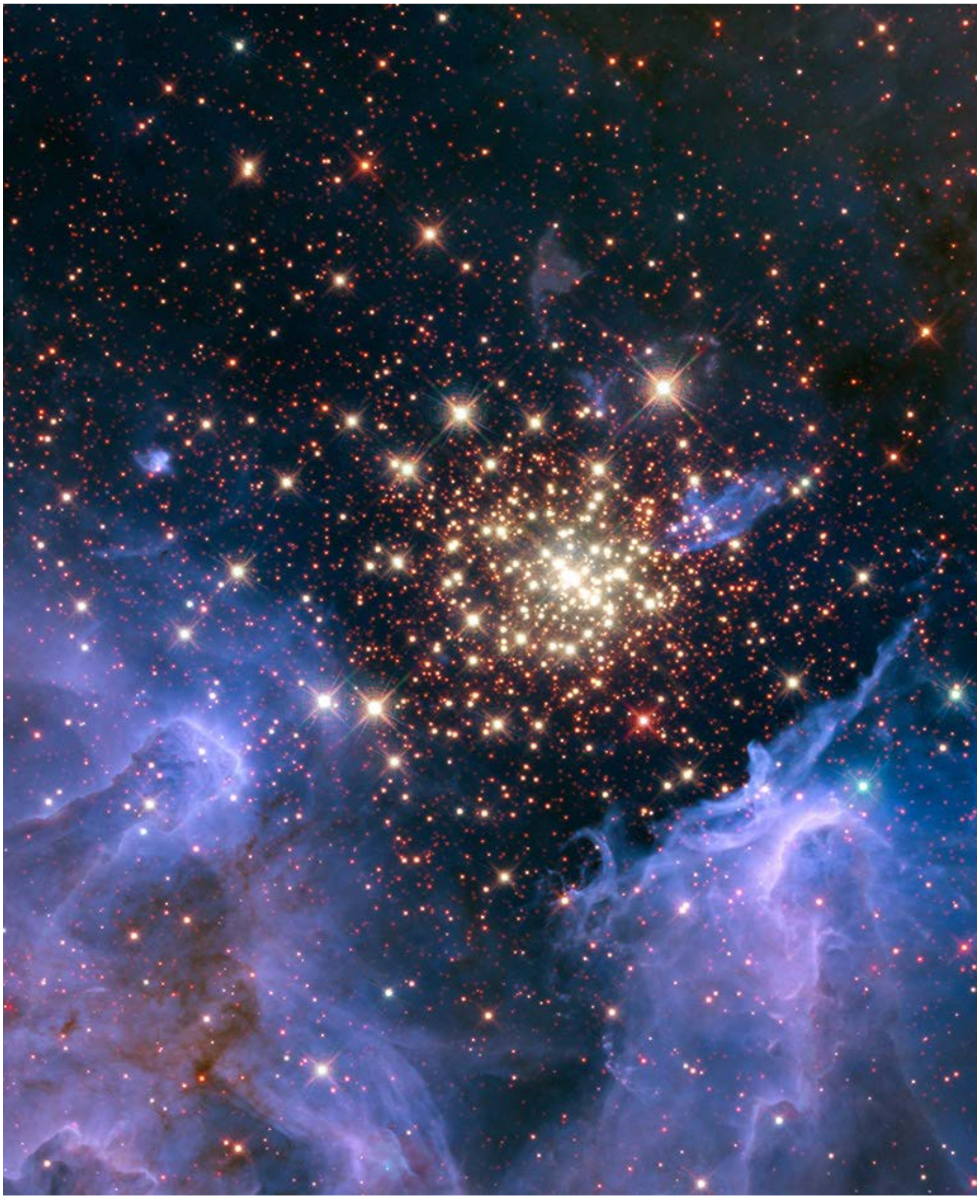
Image Facts:

Distance from Earth: 20,000 light-years

Description: Nova-Like Variable Star and Light Echo

Constellation: Monoceros

HubbleSite News Resource: “Light Echo” Illuminates Dust Around Supergiant Star V838 Monocerotis



Hubble's crisp resolution captures in a single view various stages of the life cycle of stars in the giant nebula NGC 3603.

STAR-FORMING NEBULA NGC 3603

The giant nebula NGC 3603 is a prominent star-forming region in the Carina spiral arm of our galaxy, about 20,000 light-years away. Discovered by Sir John Herschel in 1834, it is the largest nebula seen in visible light in the Milky Way. Within its core is nestled a stellar "jewel box" of thousands of sparkling young stars, one of the most massive young star clusters in the Milky Way Galaxy.

The cluster is surrounded by clouds of interstellar gas and dust — the raw material for new star formation. This environment is not as peaceful as it looks. Powerful ultraviolet radiation and fast winds from the bluest and hottest stars have blown an enormous cavity in the gas and dust enveloping the cluster. This bubble provides an unobstructed view of the cluster and reveals stages in the life cycle of stars.

Most of the stars in the cluster were born around the same time but differ in size, mass, temperature, and color. The course of a star's life is determined by its mass, so a cluster of a given age will contain stars in various stages of their lives, giving an opportunity for detailed analyses of stellar life cycles through these family snapshots in time.

NGC 3603 also contains some of the most massive stars known. These huge stars live fast and die young, burning through their hydrogen fuel quickly and ultimately ending their lives in supernova explosions.

Movie 13.1: Zoom into NGC 3603

The proximity of NGC 3603 makes it an excellent laboratory for understanding the origin of massive star formation in the early, distant universe. For example, Giacomo Beccari, of the European Space Agency, and his colleagues used Hubble to study the central stellar cluster's recent star-formation history. They established for the first time that star formation in and around the cluster has been occurring for at least 10 million to 20 million years, at an apparently increasing rate.

Loredana Spezzi, also of the European Space Agency, and her colleagues subsequently used Hubble to identify unusual objects in NGC 3603 that have the color and temperature of brown dwarfs but the intrinsic brightness of more massive stars. The authors have speculated on a number of causes for the excess brightness, including the possibility that the objects have merged with nearby Jupiter-sized planets.

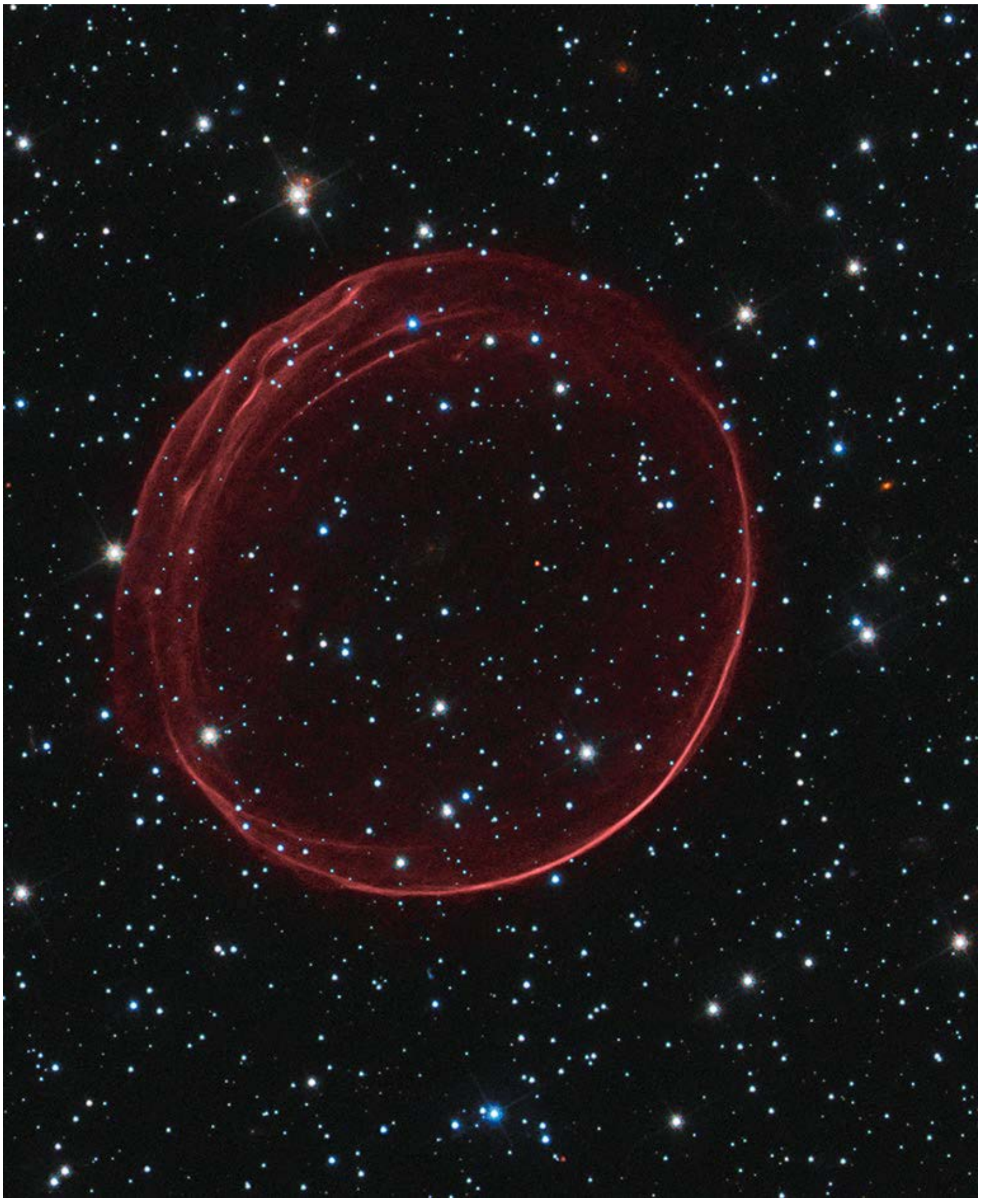
Image Facts:

Distance from Earth: 20,000 light-years

Description: Giant Star-Forming Nebula with Massive Young Stellar Clusters

Constellation: Carina

HubbleSite News Resource: Starburst Cluster Shows Celestial Fireworks



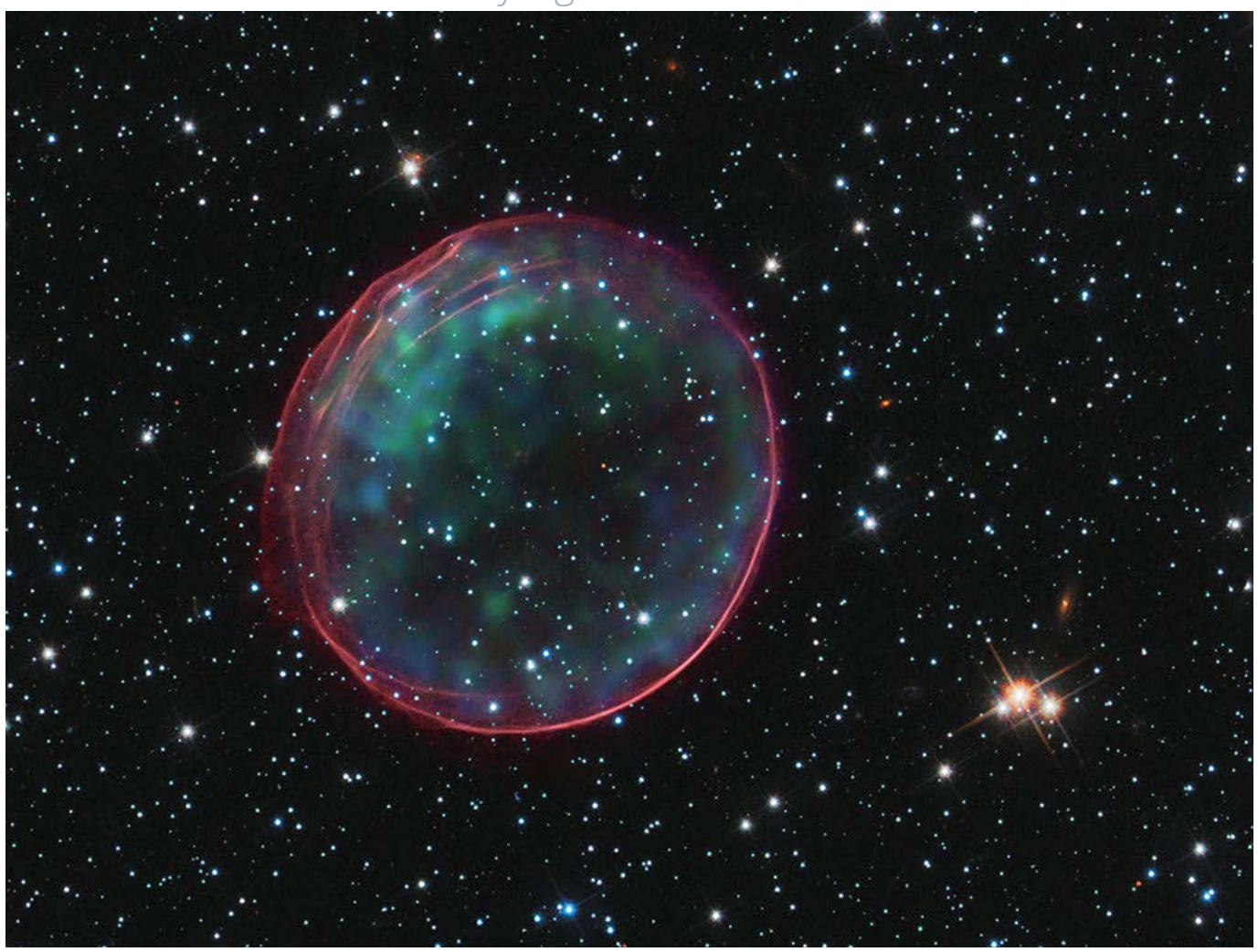
SNR 0509 is a supernova remnant located 160,000 light-years away in the constellation Dorado. This image is a composite of exposures taken with Hubble's Wide Field Camera 3 and Advanced Camera for Surveys.

SUPERNOVA REMNANT 0509-67.5

Floating among the stars, this cosmic bubble might look delicate, but it is the signature of a violent explosion. It is a supernova remnant, the gaseous remains of a star that blew up. Named SNR 0509-67.5 (or SNR 0509 for short), it inhabits a small, nearby galaxy called the Large Magellanic Cloud, roughly 160,000 light-years away. On Earth, stargazers in the southern hemisphere could have seen the explosion about 400 years ago, but so far, no eye-witness accounts have turned up.

This bubble of gas is 23 light-years across and growing. It is expanding at more than 11 million miles per hour (5,000 kilometers per second). Ripples in the edge of the bubble (best seen in the upper left) could be caused by uneven scraps of material ejected by the exploded star, or by clumpiness in the surrounding gas that the supernova material is slamming into as it rushes outward.

SNR 0509 in Visible and X-ray Light



This image of SNR 0509 shows visible light from gas being shocked by the supernova's expanding blast wave, captured by Hubble, in red. X-ray emission from million-degree gas, recorded by NASA's Chandra X-ray Observatory, appears in green and blue.

This celestial sphere was created by a kind of explosion known as a Type Ia supernova. Type Ia supernovae are valuable for measuring distances across the universe, because they are thought to have a standard peak brightness when they explode.

Astronomers believe Type Ia explosions result from the destruction of a white dwarf — the small, compact core of a once-average star that ran out of the nuclear fuel needed to sustain its high-powered life. One explanation is that a white dwarf self-destructs after using its gravity to steal material from a nearby star, causing it to become unstable under the extra bulk and explode. Another idea is that the detonation happens when two white dwarfs collide, destroying both objects.

To investigate the cause of SNR 0509, astronomers Bradley Schaefer and Ashley Pagnotta of Louisiana State University studied archived Hubble data from the Advanced Camera for Surveys and the Wide Field Camera 3 to search for a surviving star that could have fed the doomed white dwarf. However, the Hubble observations turned up none. If a star were there, it should have shown up.

There's only one possible explanation, say Schaefer and Pagnotta. For this supernova, the collision of two white dwarfs is to blame.

Movie 14.1: 3D View of SNR 0509 (Artistic Visualization)

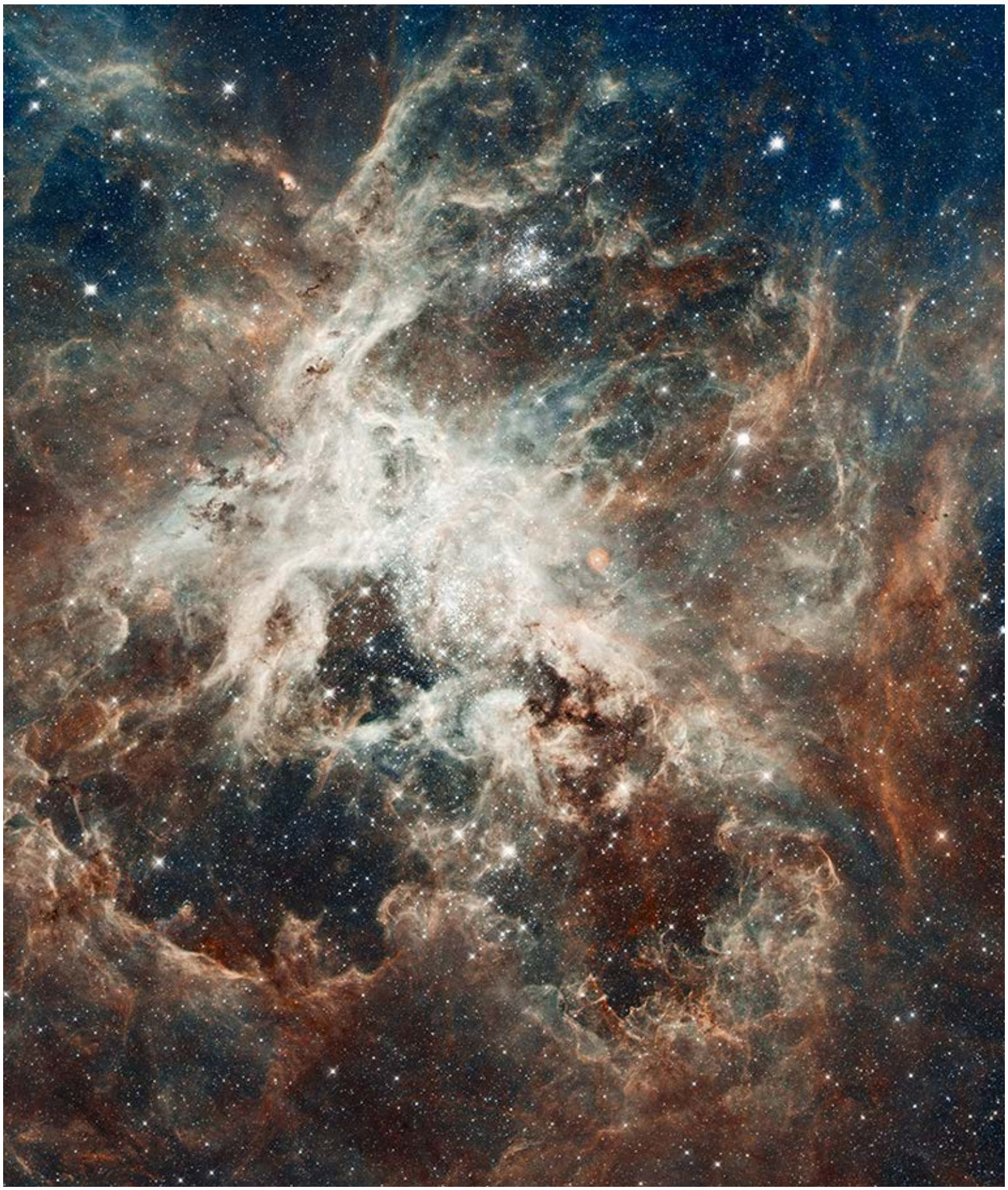
Image Facts:

Distance from Earth: 160,000 light-years

Description: Supernova Remnant

Constellation: Dorado

HubbleSite News Resource: Hubble Supernova Bubble Resembles Holiday Ornament



This is a composite image of the nearby star-forming region 30 Doradus, at the heart of the Tarantula Nebula. It comprises one of the largest mosaics ever assembled from Hubble photos, and includes observations taken by Hubble's Wide Field Camera 3 and Advanced Camera for Surveys in October 2011. The Hubble image is combined with ground-based data from the European Southern Observatory's 2.2-meter telescope in La Silla, Chile.

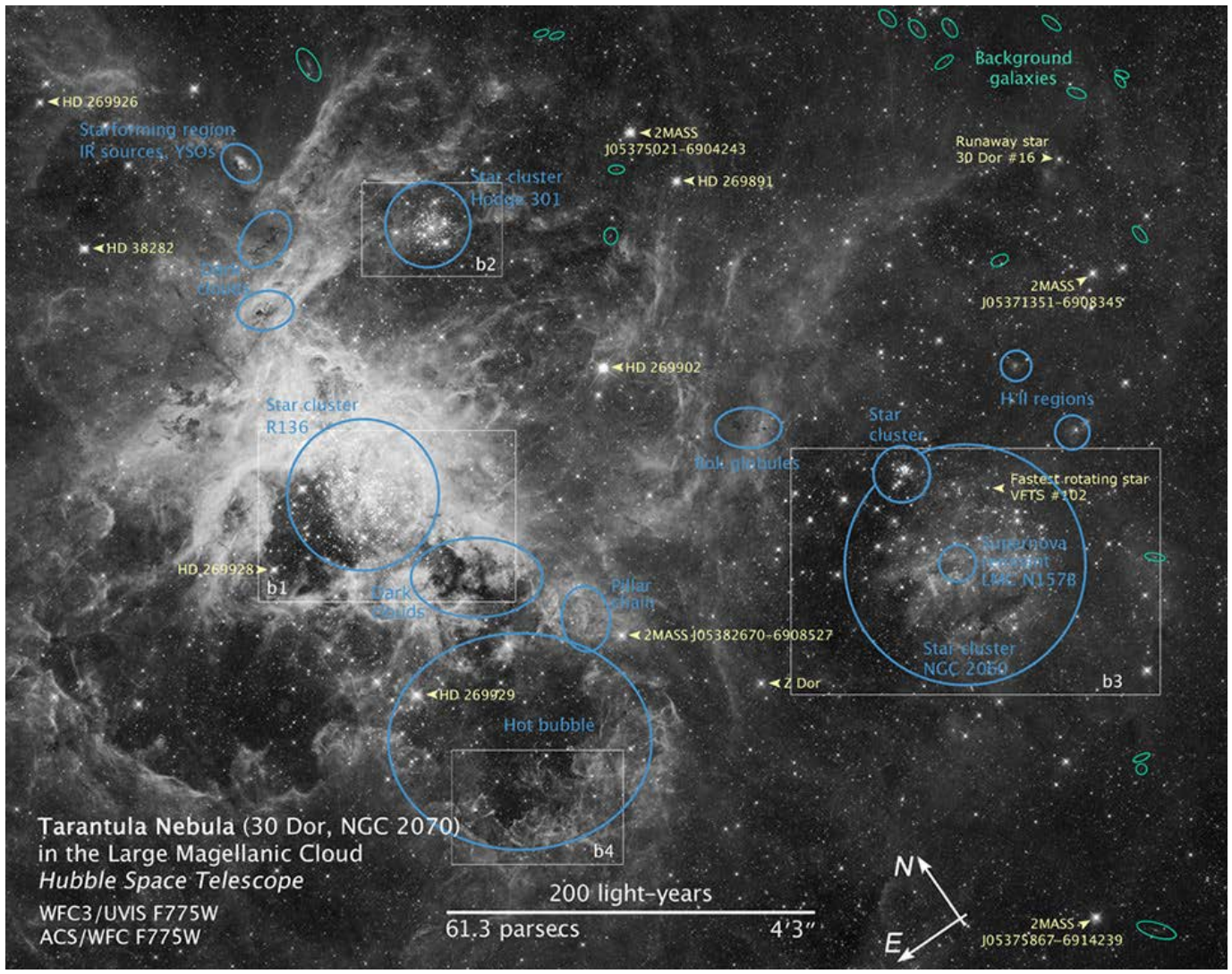
HEART OF THE TARANTULA NEBULA

Several million young stars reside in a nearby region of frenzied star birth known as 30 Doradus. Located 170,000 light-years away in the heart of the Tarantula Nebula, 30 Doradus is part of the Large Magellanic Cloud, a small, satellite galaxy of our Milky Way. It is the brightest star-forming region visible in a neighboring galaxy, and it is home to the most massive stars ever seen. No known star-forming region inside the Milky Way Galaxy is as large or as prolific as 30 Doradus.

The intense star birth in 30 Doradus may be fueled partly by its close proximity to the Small Magellanic Cloud, a companion to its host galaxy. 30 Doradus churns out stars at a furious pace over millions of years. The Hubble image reveals the stages of star birth, from embryonic stars a few thousand years old and still wrapped in cocoons of dark gas, to behemoths that die young in supernova explosions.

Hubble observations show star clusters of various ages, from about 2 million to 25 million years old. Collectively, the stars comprise a bulk material millions of times the mass of the Sun. 30 Doradus contains one of the most rapidly rotating stars and the fastest moving stars ever observed.

Tarantula Nebula Annotated Map



This annotated map identifies several prominent features in an image of the Tarantula Nebula. The image was produced from numerous exposures by Hubble's Wide Field Camera 3 and Advanced Camera for Surveys in red to near-infrared light.

The region's sparkling centerpiece is a giant, young star cluster named NGC 2070, only 2 million to 3 million years old. Its stellar inhabitants number roughly 500,000. The cluster is a hotbed for young, massive stars. Its dense core, known as R136, is packed with several dozen of the most massive stars known, each about 100 times the mass of the Sun and about 10 times as hot. The cluster also harbors many thousands of smaller stars. For many years, it defied analysis from ground-based observations because of the facilities' inadequate resolution. It was once even suggested to be a single "superstar," about 3,000 times the mass of the Sun, until high-resolution images showed that it was actually many smaller stars.

Star Cluster R136 in 30 Doradus

This Hubble image shows the large, young star cluster R136, which is at the center of the Tarantula Nebula. The dense region contains several dozen of the most massive stars known to exist.

The massive stars are carving deep cavities in the surrounding material by unleashing a torrent of ultraviolet light. This light is winnowing away the enveloping hydrogen gas cloud in which the stars were born. The Hubble image reveals a fantastic landscape of pillars, ridges, and valleys. Besides sculpting the gaseous terrain, the brilliant stars may be triggering a successive generation of offspring. When the ultraviolet radiation hits dense walls of gas, it creates shocks, which may generate a new wave of star birth.

30 Doradus is a "Rosetta Stone" for understanding regions of intense star formation. Many small galaxies exhibit more spectacular star birth, but 30 Doradus is near enough to Earth for its stellar contents and nebular structures to be studied in detail. Astronomers using Hubble can resolve individual stars, which provide important information about the stars' birth and evolution.

Movie 15.1: Zoom into the Heart of the Tarantuala Nebula

Elena Sabbi of the Space Telescope Science Institute has studied how star formation propagates across the region. Daniel Lennon of the European Space Astronomy Centre in Spain is calculating the directions of motion of massive runaway stars, searching in particular for the origins of massive stars that have been ejected from R136.

Regions such as 30 Doradus are vital contributors to the evolution of galaxies and even life, because massive stars synthesize many of the heavier chemical elements in their nuclear furnaces and final supernova explosions. The explosions disperse the heavy elements to the surrounding interstellar medium, where new stars and planetary systems form from the enriched material.

Image Facts:

Distance from Earth: 170,000 light-years

Description: Emission Nebula

Constellation: Dorado

HubbleSite News Resource: Hubble's Panoramic View of a Turbulent Star-making Region

Intense radiation from a cluster of hot, young stars called NGC 602 is carving away at the cloud of gas and dust that gave the stars life. Astronomers used Hubble's Advanced Camera for Surveys to capture this view of the star-forming region in the Small Magellanic Cloud, roughly 196,000 light-years away.

STAR CLUSTER NGC 602

In a nearby galaxy called the Small Magellanic Cloud, young stars are spewing radiation that's eating away at the cloud of gas and dust that gave birth to them not too long ago. This Hubble image, taken with the Advanced Camera for Surveys, shows that scene.

The cluster of blue stars, called NGC 602, formed when a large part of the gas cloud collapsed under gravity and became very dense. The fierce radiation now being produced by these hot, young stars is sculpting the inner rim of the gaseous nebula. Parts of the nebula resist this erosion better than others, leaving tall pillars that point toward the source of the radiation — the stars.

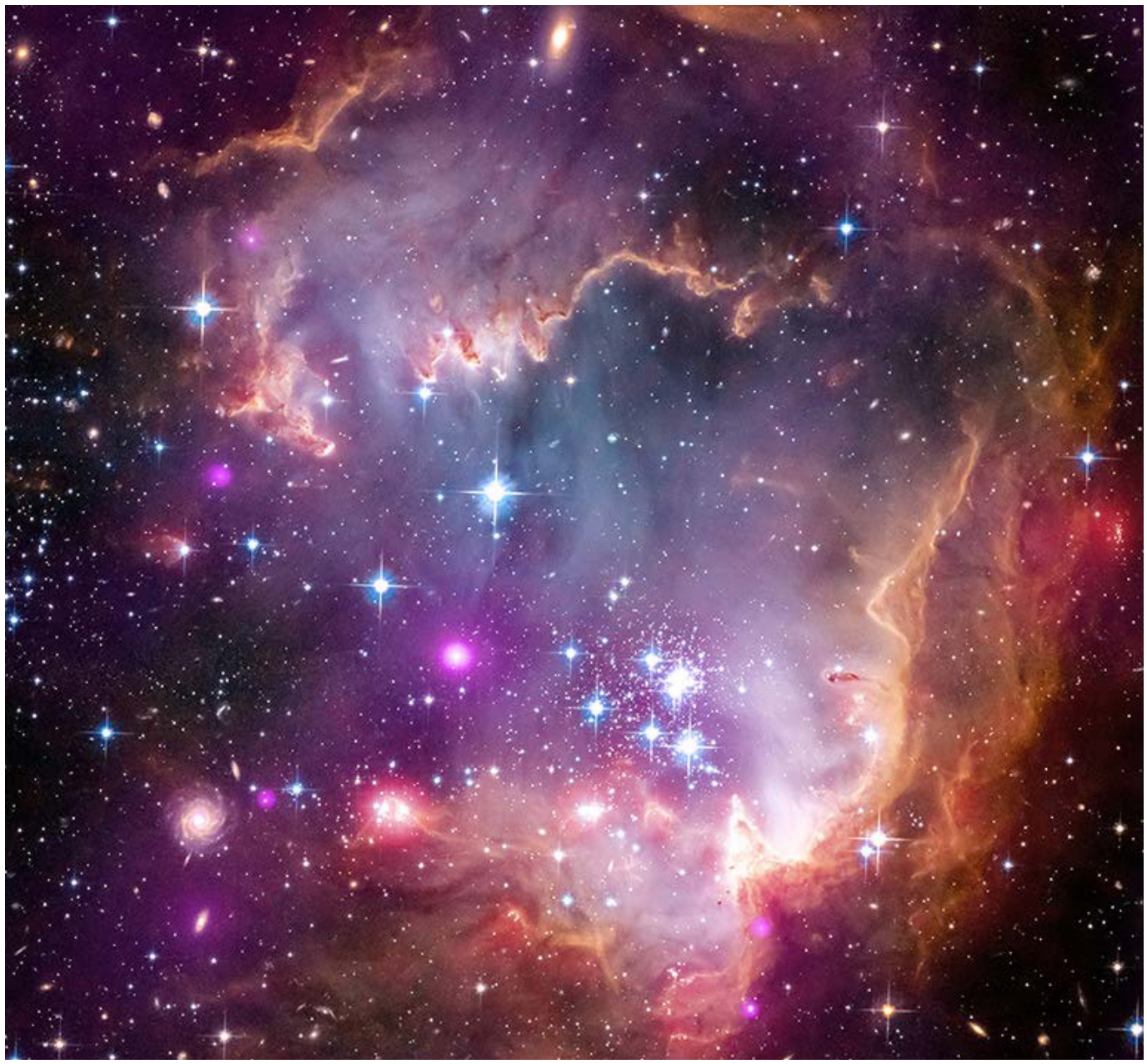
Movie 16.1: Zoom into Star-Forming Region NGC 602

Because the Small Magellanic Cloud is relatively close to us — less than 200,000 light-years away — it gives astronomers a good opportunity to study star formation in a galaxy other than our own, where the conditions are different. It's also a dwarf galaxy, which has fewer stars and lacks the enriched gas that larger galaxies like ours have. So it could provide a glimpse at what star formation might have been like in the early universe, before the first generations of stars created and distributed heavier elements into the cosmic environment.

Using Hubble observations of NGC 602, a team of astronomers led by Lynn Redding Carlson of the Johns Hopkins University determined that the massive stars at the center of the cluster and other, less massive stars formed there about 4 million years ago. When Carlson and her colleagues used NASA's Spitzer Space Telescope to study NGC 602, they uncovered even younger stars, some still cloaked in gas and dust, at the outskirts of the cluster. Some of these stars appeared to have started forming only about a million years ago. The results suggest that star formation began in the center of the cluster and then worked its way outward.

Follow-up studies using Hubble observations, led by Guido De Marchi of the European Space Agency, confirmed that the stars of NGC 602 were not born all at once but at different times, finding that some star formation might have started there as far back as 60 million years ago.

NGC 602 in Visible, Infrared, and X-ray Light



This combined image of NGC 602 shows X-ray emission observed by NASA's Chandra X-ray Observatory in purple, infrared light observed by NASA's Spitzer Space Telescope in red, and visible light observed by Hubble in red, green, and blue.

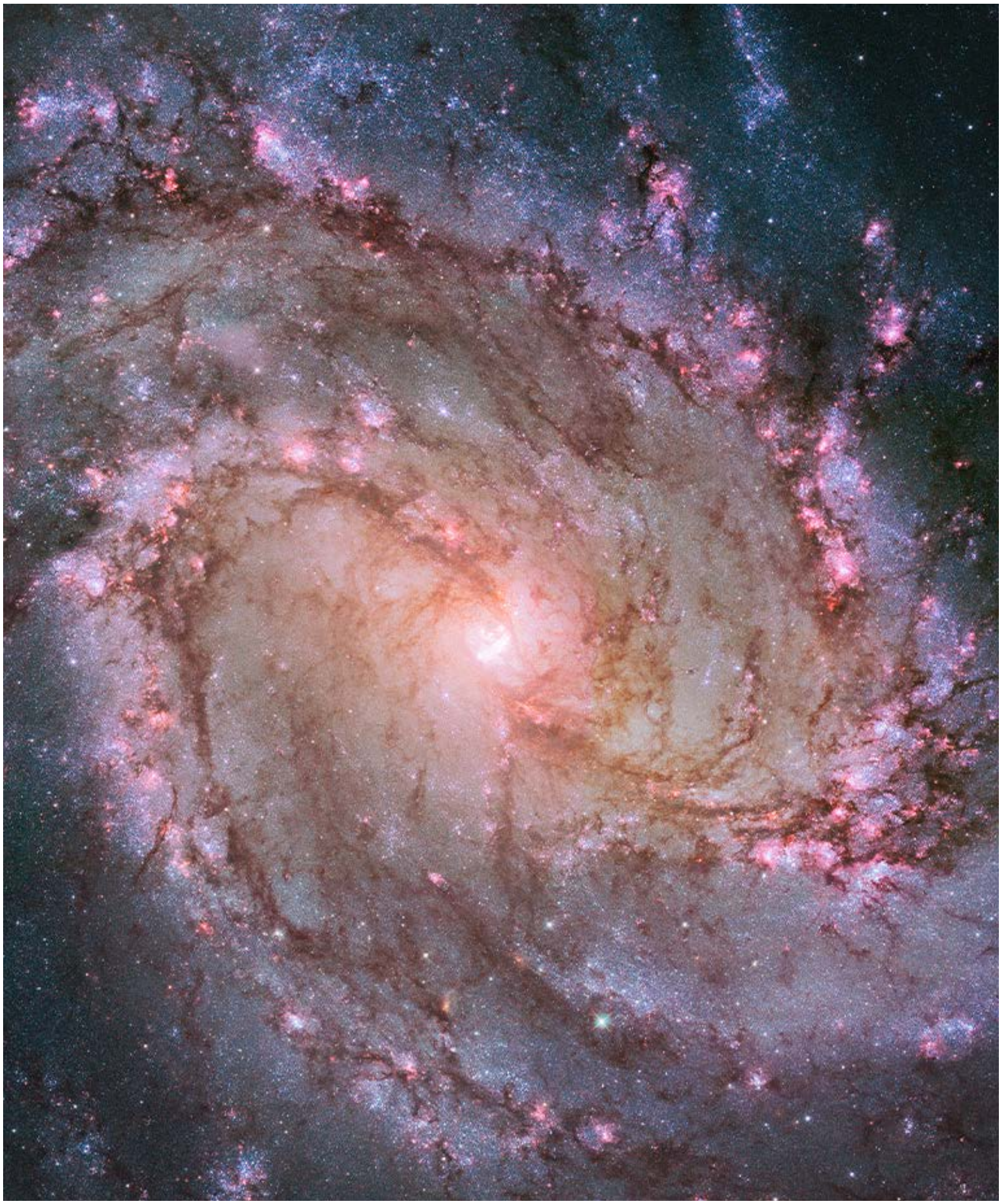
Image Facts:

Distance from Earth: 196,000 light-years

Description: Cluster within a Star-Forming Region

Constellation: Tucana

HubbleSite News Resource: Hubble Observes Infant Stars in Nearby Galaxy



Located in the southern constellation Hydra, spiral galaxy M83 is often called the “Southern Pinwheel,” in comparison to the Pinwheel Galaxy, M101, in northern skies. Observations with Hubble’s Wide Field Camera 3 created this mosaic of the Southern Pinwheel.

GALAXY M83

Located in the constellation Hydra, this colorful, swirling spiral galaxy is known as M83. A “starburst” galaxy, M83 is considerably smaller than our own galaxy but is producing stars at a much faster rate. The pink clouds of hydrogen gas that dot the galaxy’s spiral arms are the nurseries where new stars are being born. The blue, grainy clumps mixed in with these star-forming regions are clusters of hot, young stars that have blown away the surrounding gas with their fierce ultraviolet radiation. Some of these young stars are only about a million years old. The yellow glow closer to the center of the galaxy comes from more mature stars that have lived for 100 million years or more.

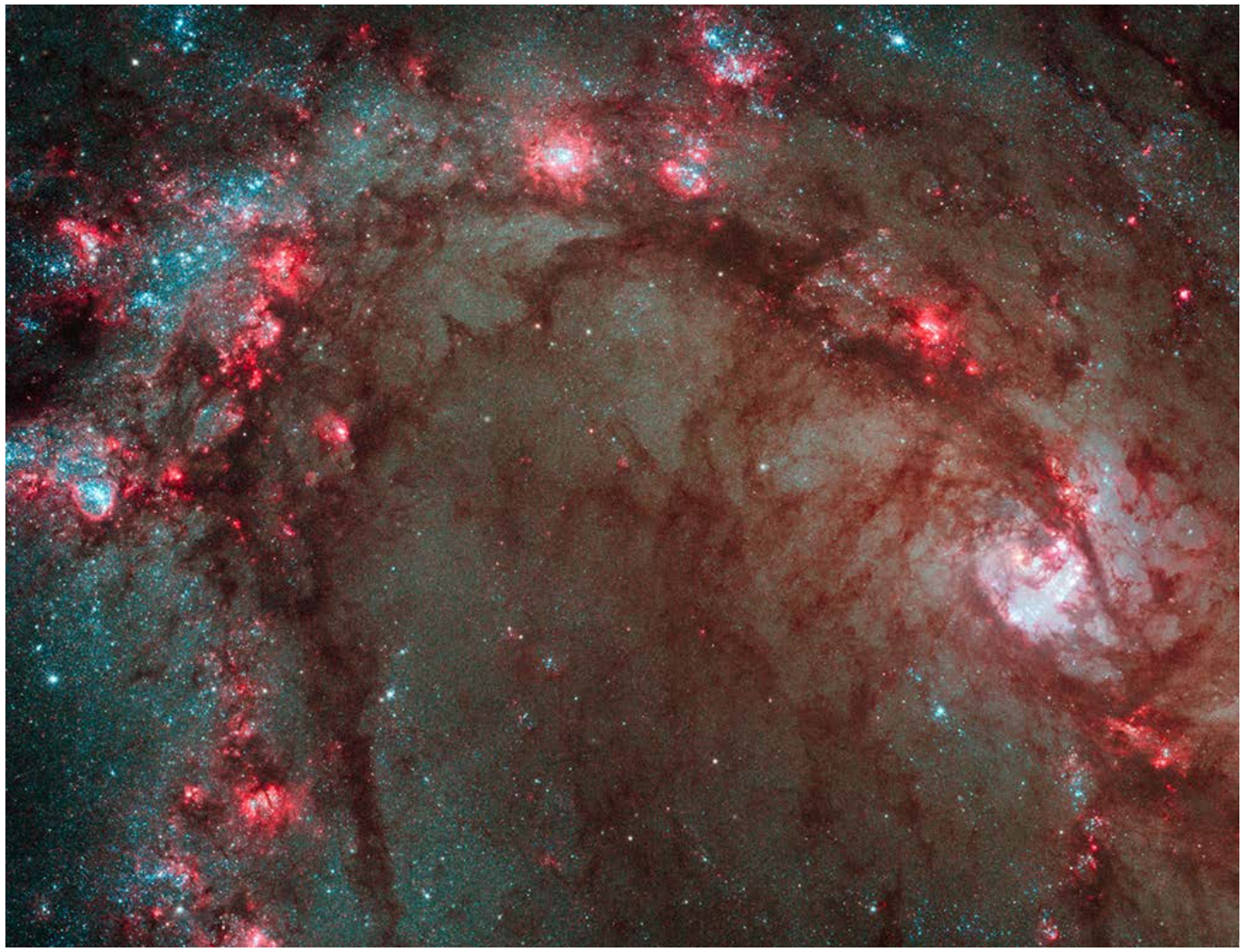
Movie 17.1: Zoom into M83

Astronomers are using Hubble’s detailed examinations of M83 to investigate how stars form in clusters, how those clusters disperse over time, and how the stars eventually die, redistributing their contents into space for future generations of stars to build upon.

For example, astronomers — including Rupali Chandar of the University of Toledo, Brad Whitmore from the Space Telescope Science Institute, and their collaborators — have been scrutinizing Hubble’s high-resolution images in order to estimate the ages of star clusters in M83. This information reveals how many star clusters survive to old age and how many disband while their stars are still young. These studies suggest that star clusters form the same way throughout the galaxy. However, several research teams have found that more clusters are destroyed in the inner regions of M83 than the outer regions, indicating that environment may influence how long a cluster sticks together.

A citizen-science project entitled *Star Date: M83* also enlisted the aid of the general public in analyzing the ages of the galaxy’s star clusters. Volunteers inspected Hubble images of M83 to classify the cluster’s ages based on physical characteristics, providing more accurate age estimates than those generated by an automatic computer algorithm.

Hubble Details Star Birth in M83



This close-up view of one of M83's spiral arms combines Hubble observations in visible, infrared, and ultraviolet light to paint a portrait of stellar evolution. New generations of hot, blue stars are forming, largely in clusters, within pink clouds of gas along the edges of dark dust lanes, which serve as a kind of backbone for the galaxy's spiral arms.

As a consequence of producing lots of new stars, M83 is also rife with stellar death. In the past century, observers have witnessed six stellar explosions, called supernovae, in M83 — more than in almost any other known galaxy. Hubble has helped identify the remnants of these supernovae and hundreds of others in M83, including one from what appears to be a recent supernova not observed by anyone on Earth. Analyzing Hubble's observations, a team led by William Blair of the Johns Hopkins University has found evidence that environment also affects how these catastrophic stellar deaths disperse the raw materials for new star formation into the galaxy.

Image Facts:

Distance from Earth: 15 million light-years

Description: Barred Spiral Galaxy

Constellation: Hydra

HubbleSite News Resource: Hubble Views Stellar Genesis in the Southern Pinwheel

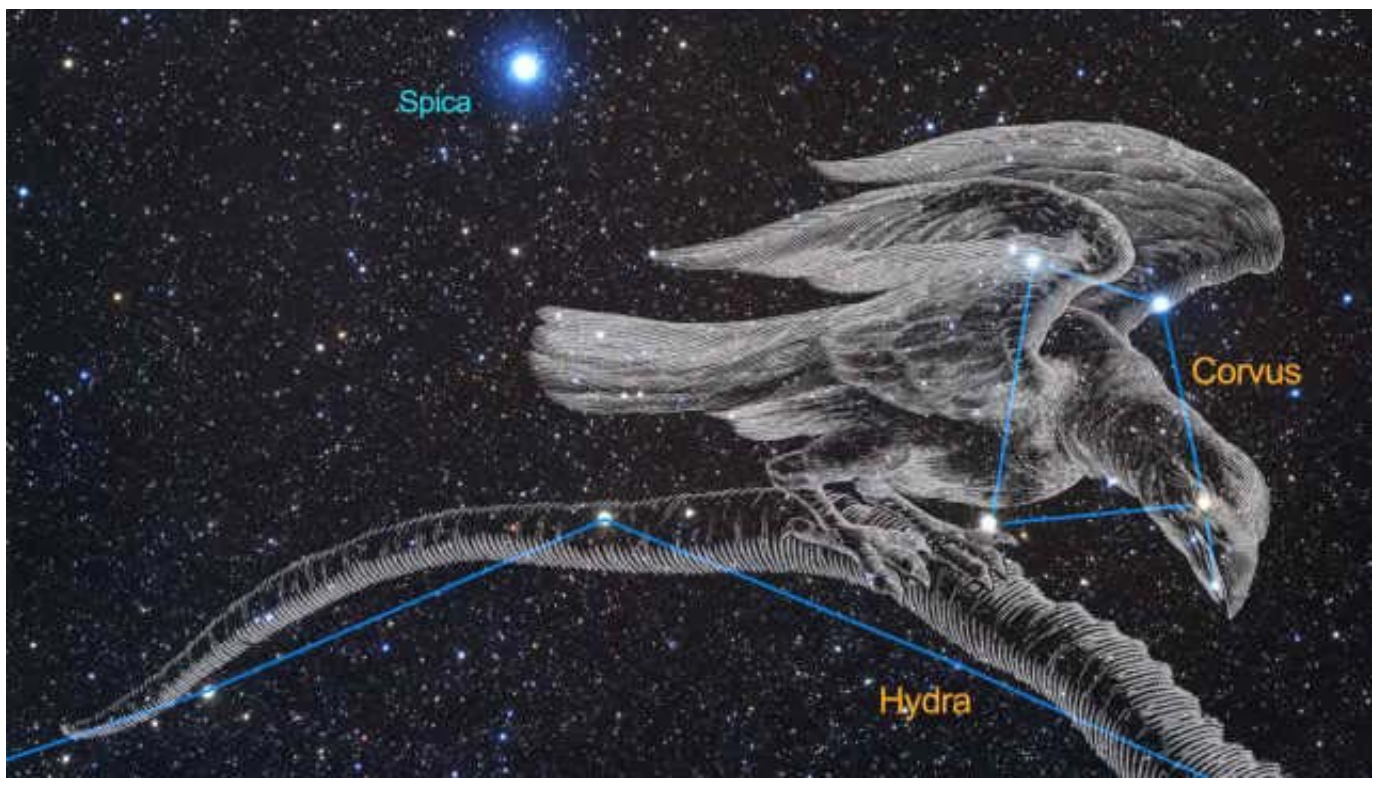
Hubble's image of the Sombrero Galaxy, taken with the Advanced Camera for Surveys, shows off details in the galaxy's dust-laden disk and unusually large bulge of stars and star clusters.

Panoramic View of the Sombrero Galaxy

Located in the constellation Virgo, galaxy M104 has a wide, edge-on disk and a large bulge of stars, leading observers to nickname it the Sombrero Galaxy.

Resembling a wide-brimmed hat with a tall bulge at the center, galaxy M104 is nicknamed the Sombrero Galaxy. Far larger than any hat on Earth, this Sombrero is 50,000 light-years wide. We see the galaxy nearly edge-on, so the dark dust in its pancake-like disk appears to bisect a large, white, rounded core of stars. Roughly 29 million light-years away, the Sombrero can be spotted with a modest telescope in the constellation Virgo.

Movie 18.1: Zoom into and Pan of the Sombrero Galaxy



Using Hubble, a team of astronomers led by John Kormendy of the University of Hawaii found evidence of a supermassive black hole at the center of the Sombrero Galaxy. Estimated to be as massive as a billion Suns, it's one of the heftiest black holes in the neighboring universe.

Hubble observations also reveal that the Sombrero Galaxy includes nearly 2,000 globular clusters — 10 times more than in our galaxy. Globular clusters are giant, spherical-shaped groups of stars that are sometimes older than the galaxy in which they reside. The Sombrero's globular clusters range from 10 billion to 13 billion years old, similar to those in the Milky Way.

The Sombrero Galaxy in Infrared and Visible Light

Infrared light from dust in the Sombrero Galaxy's disk (colored red) shines through in this image combining visible-light observations from Hubble with infrared observations made with NASA's Spitzer Space Telescope. The infrared light from stars appears in blue.

Several teams of astronomers have used Hubble and telescopes on the ground to study the Sombrero's globular clusters. They've found that some clusters are rich in elements heavier than helium (which astronomers call "metals") and some are poor. Among other findings, the observations reveal that the "metal-rich" clusters are concentrated in the galaxy's bulge and that they are typically smaller than the "metal-poor" ones. Such studies are helping astronomers figure out how ancient globular clusters developed early in the universe's history.

Image Facts:

Distance from Earth: 29 million light-years

Description: Edge-on Spiral Galaxy

Constellation: Virgo

HubbleSite News Resource: The Majestic Sombrero Galaxy (M104)

NGC 1300 is a barred spiral galaxy located 61 million light-years away in the constellation Eridanus. Hubble's Advanced Camera for Surveys reveals details in the galaxy never seen before.

SPIRAL GALAXY NGC 1300

Full View of NGC 1300

NGC 1300 features a prominent bar of stars and many blue clusters of stars.

Bold and beautiful, NGC 1300 is a marvelous example of a barred spiral galaxy. Unlike in other spiral galaxies where the starry arms curl outward from the center of the galaxy, NGC 1300's arms twist away from the ends of a straight bar of stars that stretches across the galaxy's core. Observational evidence suggests that our own galaxy, the Milky Way, is a barred spiral as well.

NGC 1300's spiral arms include blue clusters of young stars, pink clouds that are forming new stars, and dark lanes of dust. Two prominent dust lanes also cut through the galaxy's bar, which contains mostly older, orangish stars. These dust lanes disappear into a tight spiral feature at the center of the bar. Interestingly, only galaxies with large bars appear to have such a "spiral within a spiral." Hubble's image of NGC 1300, taken with the Advanced Camera for Surveys, reveals finer details in these features than ever seen before.

Using Hubble to study more than 2,000 spiral galaxies both near and far, astronomers have learned that barred spiral galaxies are more common today than they were in the past. Led by Kartik Sheth of the Spitzer Science Center at the California Institute of Technology, the team found that 65 percent of present-day spiral galaxies have bars, but 7 billion years ago, only 20 percent of spirals had them. The researchers also noticed that the percentage of massive spiral galaxies that have bars was about the same in the past as it is today, but for low-mass spirals, more present-day galaxies have bars than the earlier ones do.

Movie 19.1: Zoom into NGC 1300

Galaxies take time to mature, so today's galaxies are typically more developed than those from billions of years ago. Astronomers also know that larger, more massive galaxies tend to develop faster — and thus earlier — than smaller, less massive galaxies do. The findings, therefore, imply that bars are a sign of maturity among spiral galaxies.

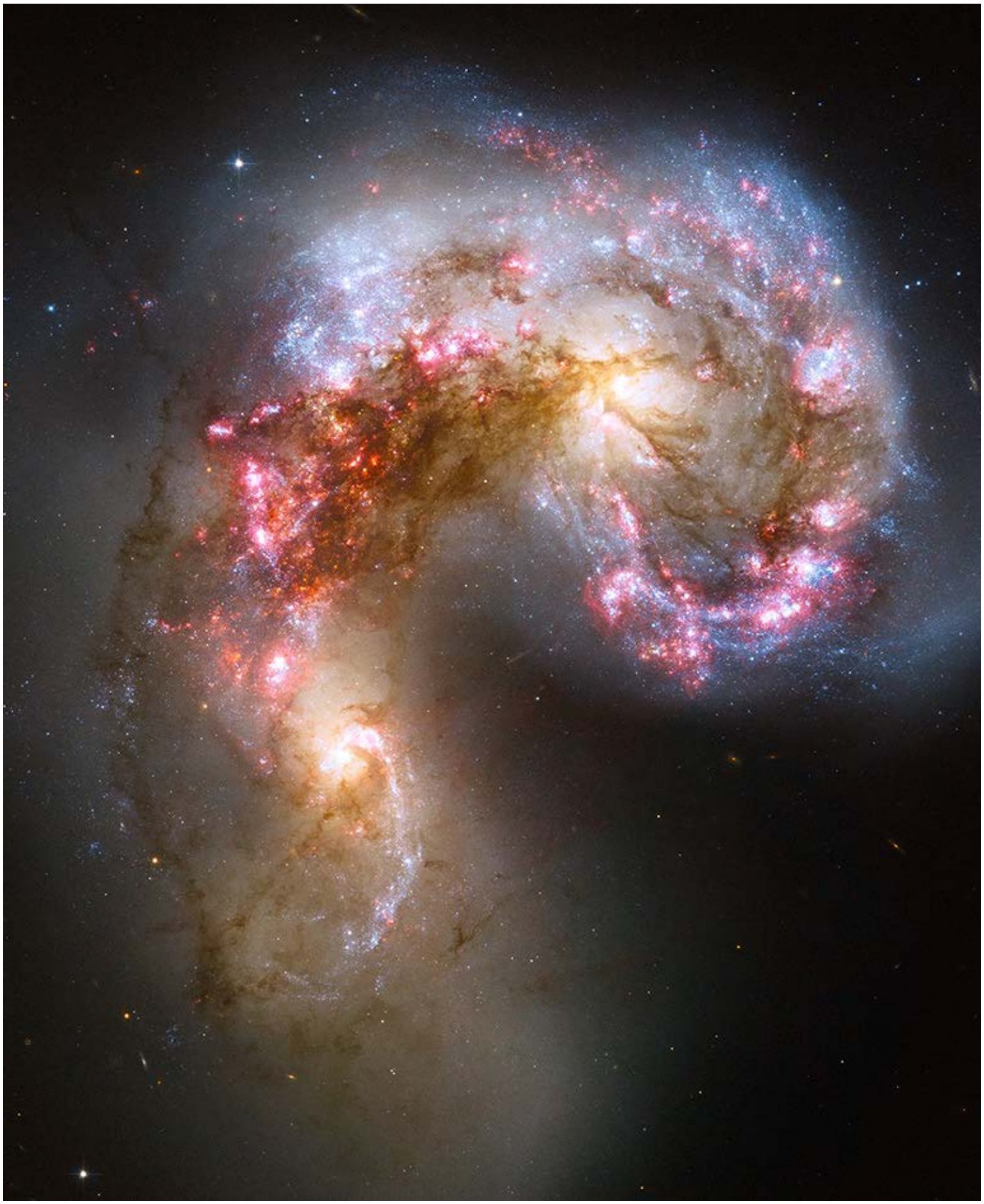
Image Facts:

Distance from Earth: 61 million light-years

Description: Barred Spiral Galaxy

Constellation: Eridanus

HubbleSite News Resource: Barred Spiral Galaxy NGC 1300



Roughly 65 million light-years away in the constellation Corvus, two spiral galaxies known as the Antennae Galaxies have crashed together, creating this spectacular light show.

ANTENNAE GALAXIES

This celestial firestorm is the blazing wreckage of a collision between two spiral galaxies. The two galaxies, whose bright yellow cores appear to the lower left and upper right of center, began their fateful confrontation a few hundred million years ago. Formally known as NGC 4038 and NGC 4039, the pair is nicknamed the Antennae Galaxies because of two long streamers of stars, gas, and dust that extend from the crash site. Wide-field images reveal the elongated "antennae" formed during the initial impact, but this Hubble image concentrates on the heart of the galactic collision.

Wide-Field View of the Antennae Galaxies

The Antennae Galaxies got their name from the long, antenna-like tails of stars, gas, and dust streaming from the galaxies, seen in wide-field images like this one taken at Kitt Peak National Observatory in Arizona.

The cosmic smashup has pulled dark dust into long strands stretching from one galaxy to the other. It has also compressed huge clouds of gas and dust, igniting a rash of new star formation within the galaxies. Clusters of young stars sparkle in blue, while pinkish star-forming nebulae are churning out even more stars. Astronomers estimate that billions of new stars will form as the two galaxies complete their collision and eventually merge into one galaxy.

Hubble's view of the Antennae is the sharpest taken to date, allowing astronomers to study these galaxies and their newly forming star clusters in unprecedented detail. Using Hubble to investigate the Antennae, Brad Whitmore of the Space Telescope Science Institute and his colleagues found that the merging galaxies contain more than a thousand young "super star clusters." They believe many of these clusters will eventually disperse, but the largest ones will survive to become giant, spherical-shaped stellar groupings called globular clusters, like those that reside in the outskirts of our own galaxy. Most globular clusters contain ancient stars and were thought to be relics of a galaxy's earliest days, but Hubble's observations suggest that globular clusters can also be born more recently from galactic mergers.

About 65 million light-years away, the Antennae Galaxies make up one of the closest pairs of colliding galaxies to us. Because many (if not all) present-day, large galaxies are thought to have grown from smaller galaxies that collided and merged, studying nearby collisions such as the Antennae Galaxies helps astronomers understand how galaxies evolved over the universe's history. It might even provide insight into our own spiral galaxy's future collision with the large, spiral Andromeda Galaxy.

Movie 20.1: Zoom into the Antennae Galaxies

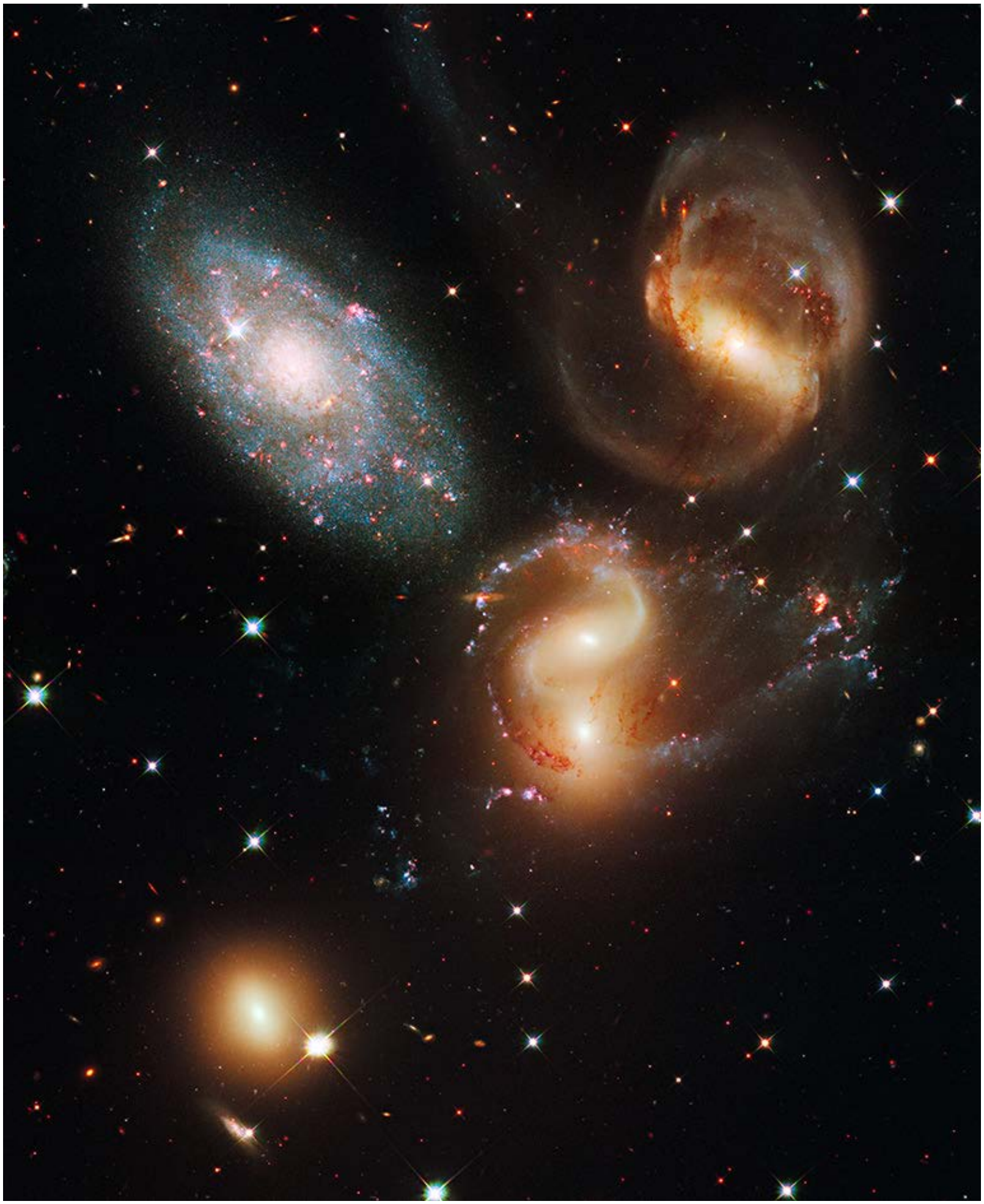
Image Facts:

Distance from Earth: 65 million light-years

Description: Interacting Galaxies

Constellation: Corvus

HubbleSite News Resource: Super Star Clusters in the Antennae Galaxies



The five galaxies of Stephan's Quintet appear together in the sky, but one member of the quintet is actually much closer to us than the others.

STEPHAN'S QUINTET

In 1877, French astronomer Édouard Stephan turned a telescope to a spot in the constellation Pegasus and discovered this cozy collection of five large galaxies. Stephan's Quintet, as the group is now known, includes four distant galaxies that are connected to each other through gravity and one galaxy that is much closer to us but just happens to lie in the same direction in the sky. The imposter is easy to pick out in this Hubble image, because it looks different than the other galaxies. The bluer galaxy, called NGC 7320, is only about 40 million light-years from Earth, while the other, redder galaxies are about 290 million light-years away.

The four allied galaxies are involved in a gravitational relationship that's transforming some of their shapes and sparking new waves of star birth both inside and outside of the galaxies. In the twisted galaxy at top right, called NGC 7319, each blue fleck in the upper spiral arm and red blotch to the right of the galaxy's core is a cluster of many thousands of stars. Near the center of the image, two galaxies, NGC 7318A and NGC 7318B, are so close together they at first seem to be one. Wrapped around the pair are sparkling garlands of bright blue star clusters and pinkish gas clouds where new stars and star clusters are developing. The smooth, sedate galaxy in the lower left, NGC 7317, seems strangely unaffected by the gravitational commotion happening nearby but claims some orange-colored star clusters of its own.

Movie 21.1: Zoom into Stephan's Quintet

Hubble was the first telescope to distinguish individual star clusters in the galaxies of Stephan's Quintet. Astronomers used Hubble, first in the late 1990s with the Wide Field Planetary Camera 2 and then again in 2009 with the Wide Field Camera 3, to examine those star clusters. Both studies used Hubble to analyze the clusters' colors, which indicate the clusters' ages. As a star cluster matures, its hot, blue stars die off, leaving the longer-lived red stars behind. So, the redder a cluster, the older it is.

The most recent Hubble study of Stephan's Quintet, led by Konstantin Fedotov of the University of Western Ontario, identified hundreds of star clusters with varying ages, some within the galaxies themselves and others in long streamers of material stretching away from the galaxies. Because gravitational encounters between galaxies can trigger star formation, Fedotov's team was able to use the ages of the star clusters to reconstruct a history of the galaxies' interactions.

Image Facts:

Distance from Earth: 290 million light-years

Description: Galaxy Group

Constellation: Pegasus

HubbleSite News Resource: Stephan's Quintet

Two interacting galaxies, known as Arp 273, form the stem and petals of a cosmic rose 350 million light-years from Earth in the constellation Andromeda.

INTERACTING GALAXIES ARP 273

Two misshapen spiral galaxies combine to form a beautiful celestial flower in this Hubble image taken with the Wide Field Camera 3. Known as Arp 273, the pair is among hundreds of "peculiar" galaxies catalogued by astronomer Halton Arp in the 1960s. The gravitational attraction between these two galaxies has created their physical distortions.

The outermost arm of the larger spiral appears to have been pulled into a wide ring around the galaxy — a characteristic astronomers often see in galaxy pairs where one galaxy has passed through the other. The ring around this galaxy is off-center, though. This suggests the smaller galaxy plunged through the larger one, but that its kamikaze dive was not a direct hit.

The encounter seems to have also tipped the large galaxy's inner arms relative to the rest of the galaxy, while the smaller galaxy has become somewhat stretched out, with two sprawling tails on either end.

The interactions between the galaxies appear to have set off a stellar baby boom. In the larger galaxy, a flurry of new star birth recently erupted along the outer spiral arms, where bright, blue clusters of young stars now sparkle. The smaller galaxy's star formation, on the other hand, seems concentrated in its bright core.

Movie 22.1: 3D Zoom into Arp 273

Like the galaxies of Arp 273, most galaxies do not live in isolation. Their encounters with each other are an influential part of the growing-up process for galaxies. By observing how galaxies are affected by their gravitational exchanges, astronomers can better understand how galaxies developed and how the universe evolved.

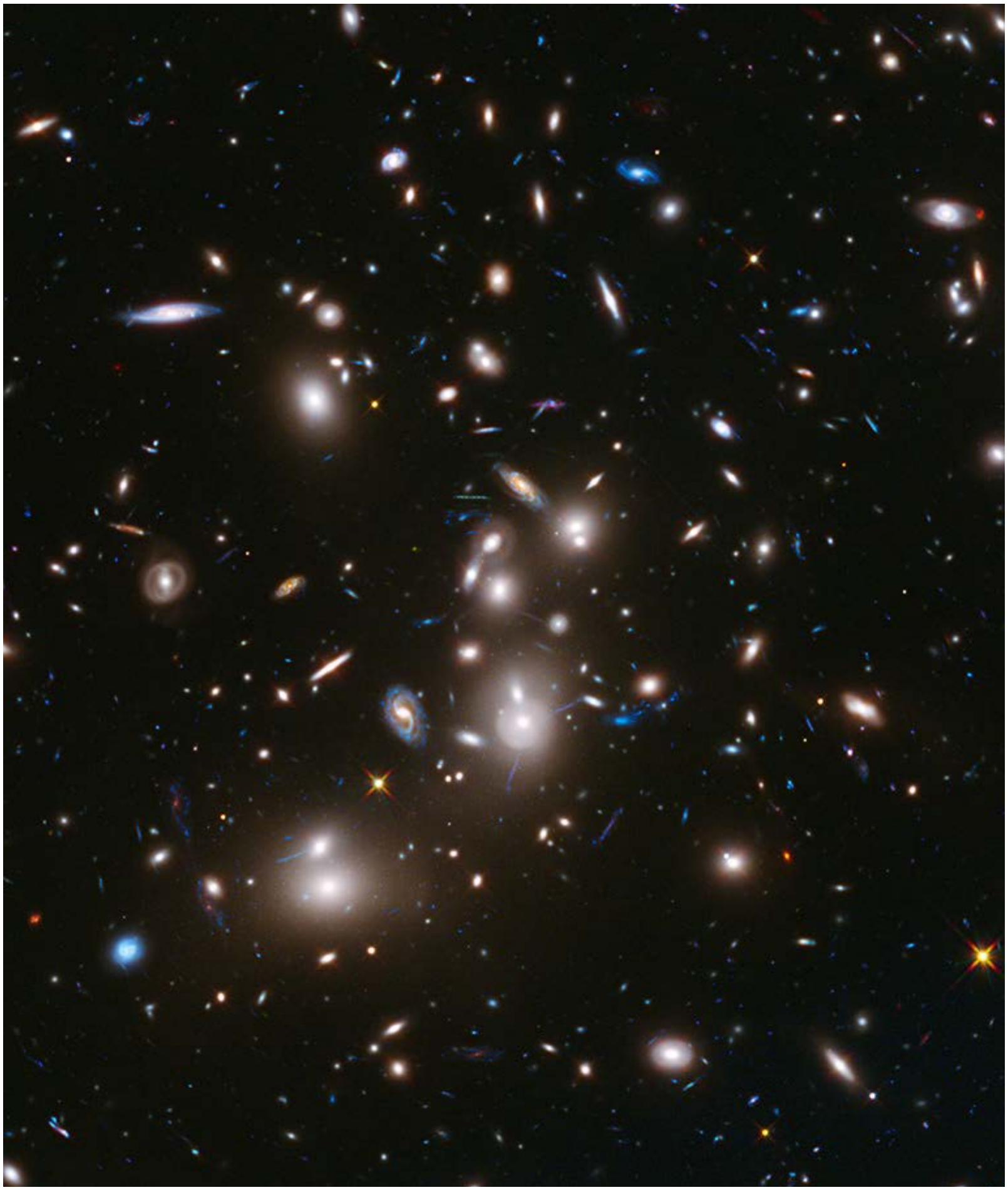
Image Facts:

Distance from Earth: 350 million light-years

Description: Interacting Galaxies

Constellation: Andromeda

HubbleSite News Resource: NASA's Hubble Celebrates 21st Anniversary with "Rose" of Galaxies



This long-exposure Hubble image of massive galaxy cluster Abell 2744 shows some of the faintest and youngest galaxies ever detected. The immense gravity in Abell 2744 acts as a lens to warp space and brighten and magnify the images of nearly 3,000 distant background galaxies. The more distant galaxies appear as they did more than 12 billion years ago, not long after the Big Bang. This visible-light and near-infrared composite image was taken with the Wide Field Camera 3.

ABELL 2744 FRONTIER FIELD

The Frontier Fields program is an ambitious, three-year effort that combines the power of space telescopes with nature's own lenses to peer deeper into the universe than ever before. Hubble, in conjunction with the Spitzer and Chandra space telescopes, is harnessing the phenomenon known as gravitational lensing, by which the gravity of massive clusters of galaxies acts as a natural "zoom lens" in space.

Galaxy clusters are so massive that their gravity deflects light passing through them, magnifying, brightening, and distorting light. Frontier Fields astronomers are exploiting this gravitational lensing by using six separate clusters to magnify the light of very distant galaxies that otherwise would be too faint to see.

Astronomers hope to learn not only what is inside the clusters but also what is beyond them. By unleashing the telescopes' full potential, they are uncovering galaxies that are as much as 100 times fainter than what the three Great Observatories typically can detect. Astronomers anticipate these observations will reveal populations of galaxies that existed when the universe was only a few hundred million years old, and many that have not been seen before.

Hubble's Frontier Fields team uses both the Wide Field Camera 3 (WFC3) and Advanced Camera for Surveys (ACS) in parallel. While one of the telescope's cameras looks at a massive cluster of galaxies, another camera will simultaneously view an adjacent patch of sky. This second region is called a "parallel field" — a seemingly sparse portion of sky that will provide a deep look into the early universe. These parallel fields are nearly as deep as the Hubble Ultra Deep Field. They will show how similar the distant universe looks in different directions.

Hubble will observe each cluster with both the WFC3 and the ACS to obtain both optical and infrared measurements. To get additional deep fields, the telescope will be rotated so that a parallel field is observed by the other instrument. For example, ACS would observe the target galaxy cluster while WFC3 observes the parallel field. This is to allow for complete wavelength coverage in both infrared and visible light for the galaxy cluster and the parallel field.

Movie 23.1: Zoom into the Massive Galaxy Cluster Abell 2744

The first cluster to be completed was Abell 2744, also known as Pandora's Cluster. Located in the constellation Sculptor, the giant galaxy cluster is about 4 million light-years across and has the mass of 4 trillion suns. It appears to be the result of a simultaneous pile-up of at least four separate, smaller galaxy clusters that took place over a span of 350 million years.

If you look carefully at the Hubble image of Abell 2744, you will see a few galaxies that look like duplicates of each other, in a smooth arc. These are actually the same galaxy, revealed in multiple, bent-light paths by the gravitational lens.

Among the first science to come from the Abell 2744 observations involves the faint, ghostly glow of stars ejected from ancient galaxies that were gravitationally ripped apart several billion years ago. Mireia Montes and Ignacio Trujillo of the Instituto de Astrofísica de Canarias (IAC) in Spain made the observation of the scattered stars, which are no longer bound to any one galaxy and drift freely between galaxies in the cluster. The team estimates that the combined light of about 200 billion outcast stars contributes approximately 10 percent of the cluster's brightness.

Another team of international astronomers, led by Adi Zitrin of the California Institute of Technology used the gravitational lensing of Abell 2744 to view one of the farthest, faintest, and smallest galaxies ever seen. The diminutive object is estimated to be more than 13 billion light-years away. This new detection is considered one of the most reliable distance measurements of a galaxy that existed in the early universe.

More data on the remaining clusters is currently being taken, and more fascinating science results are certain to follow. By peering deeper into the universe than ever, the revolutionary Frontier Fields observing program will provide a first glimpse of the universe to be unveiled by the James Webb Space Telescope.

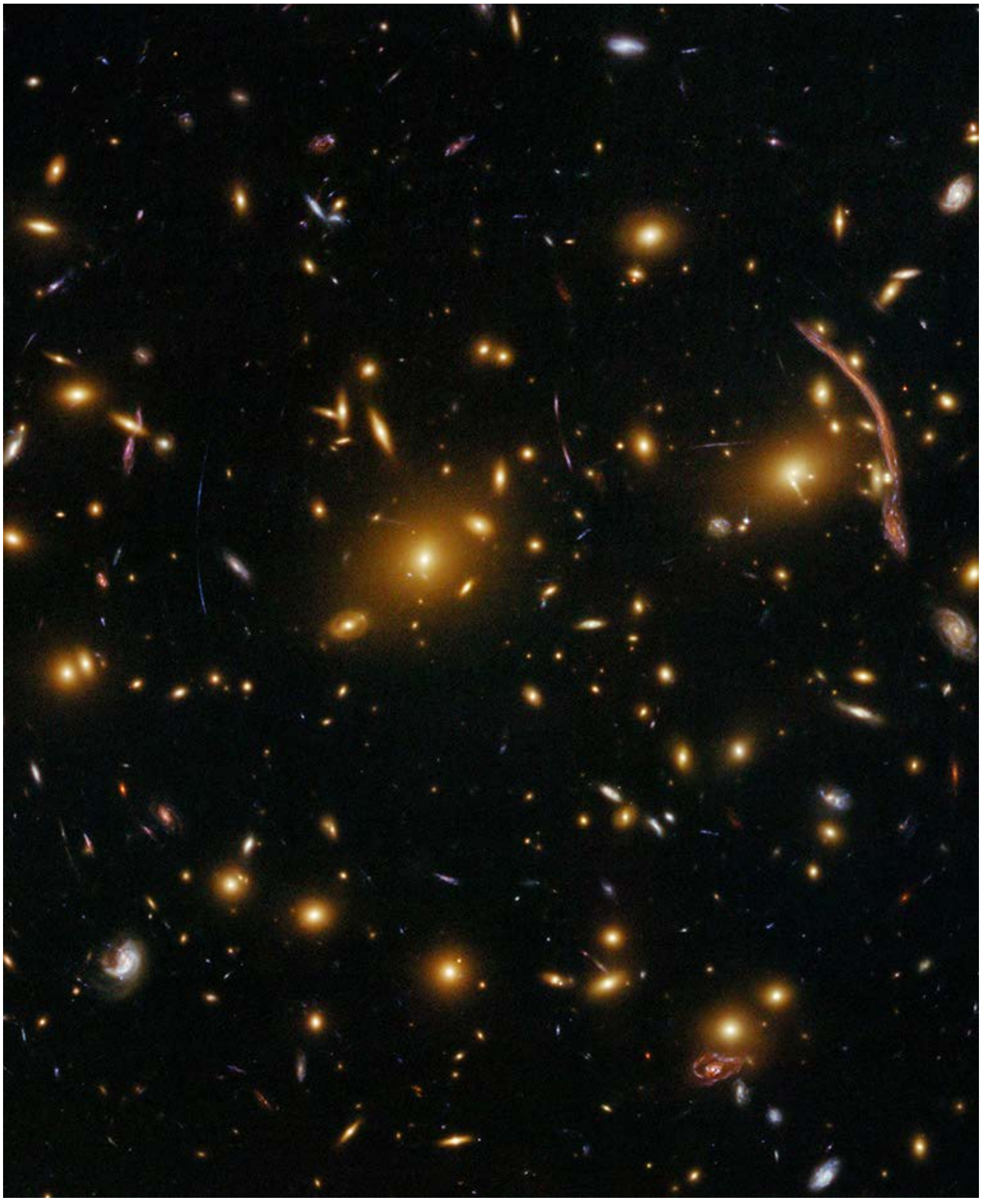
Image Facts:

Distance from Earth: 3.5 billion light-years

Description: Galaxy Cluster

Constellation: Sculptor

HubbleSite News Resource: Hubble Finds Extremely Distant Galaxy through Cosmic Magnifying Glass



Astronomers used Hubble's Advanced Camera for Surveys to detail the distorted shapes of distant galaxies whose appearances are warped and magnified by the gravity of a massive galaxy cluster nearly 6 billion light-years away called Abell 370.

GALAXY CLUSTER ABELL 370

Smears and streaks of light punctuate this Hubble image of an enormous cluster of galaxies called Abell 370. These weird shapes are the warped appearances of galaxies that are not part of the cluster but lie far beyond it. The immense gravity of the galaxy cluster causes these far-off galaxies to look distorted.

Albert Einstein's general theory of relativity tells us that gravity can change the course of not just physical objects but light as well. As light from a distant galaxy travels toward us, through the Abell 370 galaxy cluster, the cluster's gravitational force bends and magnifies the distant galaxy's light like a lens. This quirk of nature is called gravitational lensing. Abell 370 is one of the first galaxy clusters in which astronomers saw the effects of gravitational lensing.

This view from Hubble, captured with the Advanced Camera for Surveys, uncovers far more detail in the numerous streaks and arcs scattered throughout Abell 370 than telescopes on the ground could provide. For example, Hubble's fine resolution reveals that the source of the large, bright streak in the upper right is a faraway spiral galaxy with a red central bulge, blue spiral arms, and clumps of active star formation.

Movie 24.1: Zoom into Galaxy Cluster Abell 370

Johan Richard of Durham University in the United Kingdom and his colleagues studied Hubble's images of Abell 370 and identified ten distant galaxies lensed by the cluster, including six that hadn't been spotted before. How these background galaxies appear to us depends on the amount and location of mass in the cluster. So Richard and his team analyzed Hubble's observations of the lensed galaxies to improve estimates of Abell 370's total mass, including what we can see (galaxies and gas) and what we cannot (mysterious stuff known as dark matter). They found that Abell 370 contains two large, separate clumps of dark matter. This, along with other evidence, suggests that Abell 370 is the product of two smaller galaxy clusters that are merging together.

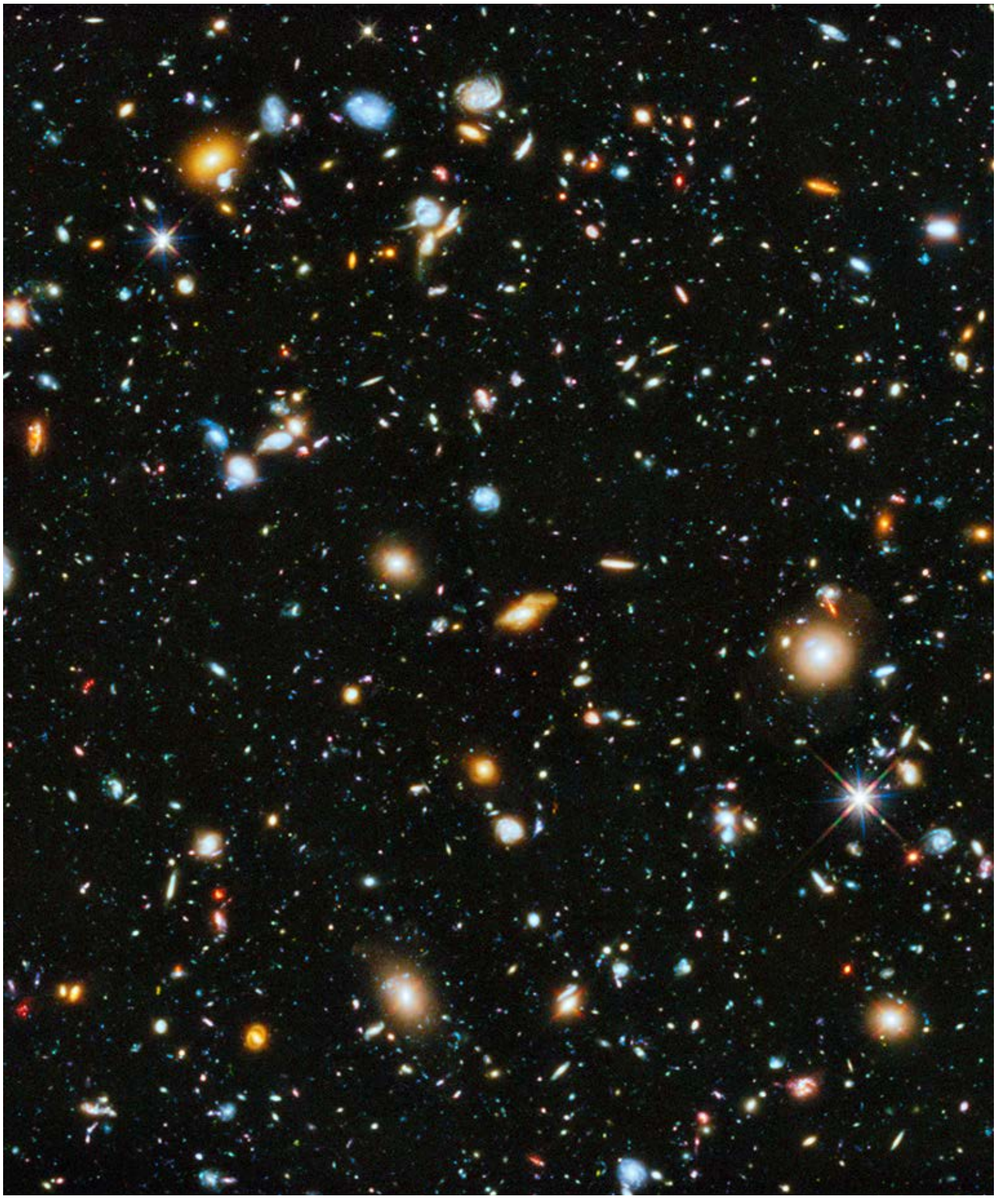
Image Facts:

Distance from Earth: 5 billion to 6 billion light-years

Description: Galaxy Cluster

Constellation: Cetus

HubbleSite News Resource: Gravitational Lensing in Galaxy Cluster Abell 370



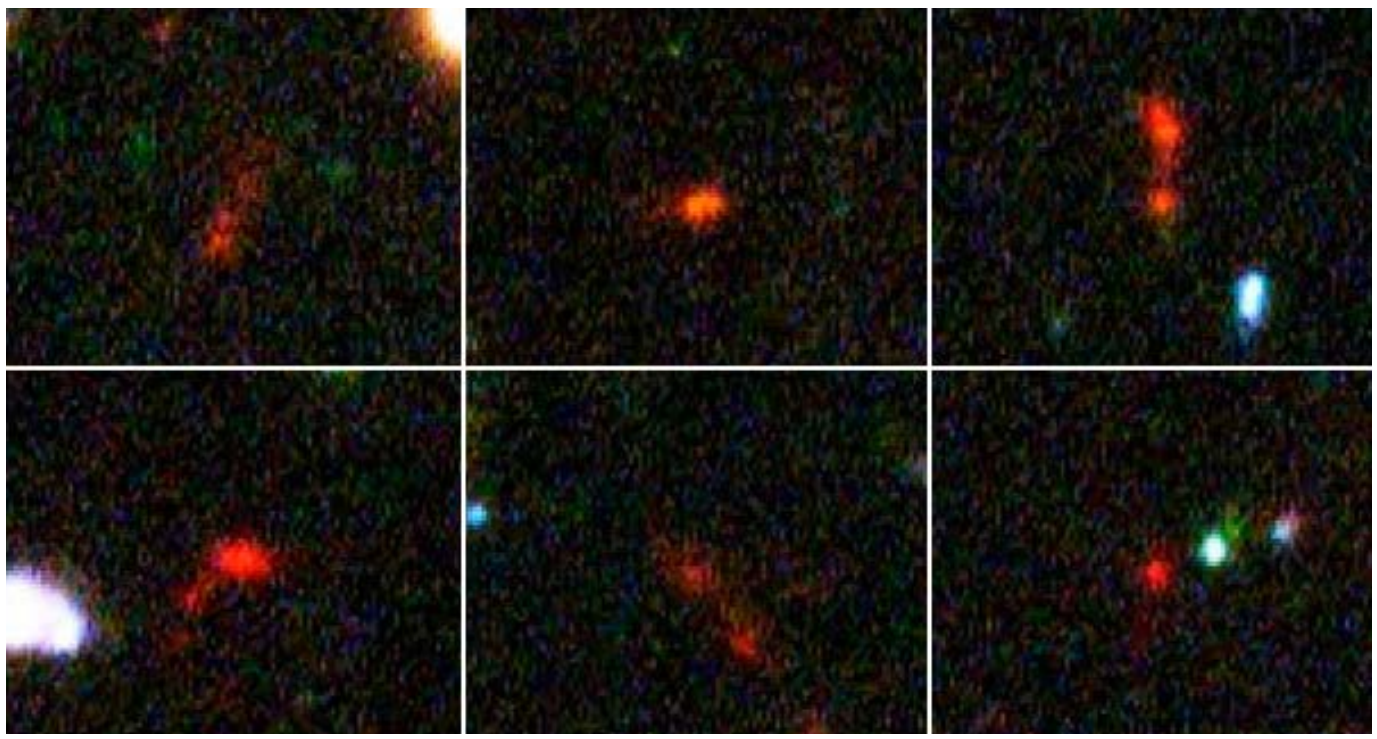
This view of the Hubble Ultra Deep Field includes thousands of galaxies glowing in visible, infrared, and ultraviolet light, some more than 13 billion light-years away. The image, released in 2014, combines hundreds of hours of observations made from 2002 to 2012 with Hubble's Advanced Camera for Surveys and Wide Field Camera 3.

HUBBLE ULTRA DEEP FIELD

This tiny slice of the universe, speckled with galaxies near and far, tells the story of galaxy evolution over cosmic time. Among the 10,000 or so galaxies pictured here are newborns, adolescents, adults, and retirees. Like looking through a vast collection of family photos, astronomers are poring over this comprehensive image to see how galaxies grew up, matured, and aged.

This portrait of our universe's history is called the Hubble Ultra Deep Field (or HUDF). It is a minuscule patch of sky first targeted by the Hubble Space Telescope in 2002 and revisited over and over again since then. This version of the HUDF is extra special, though. It combines observations of the field taken with Hubble's Advanced Camera for Surveys and the Wide Field Camera 3 from 2002 to 2012, providing one of the farthest views into the universe we've ever seen. Plus, it includes light not just from the visible part of the spectrum but from the (invisible) infrared and ultraviolet ranges, too, giving us different details of the story of how galaxies came to be.

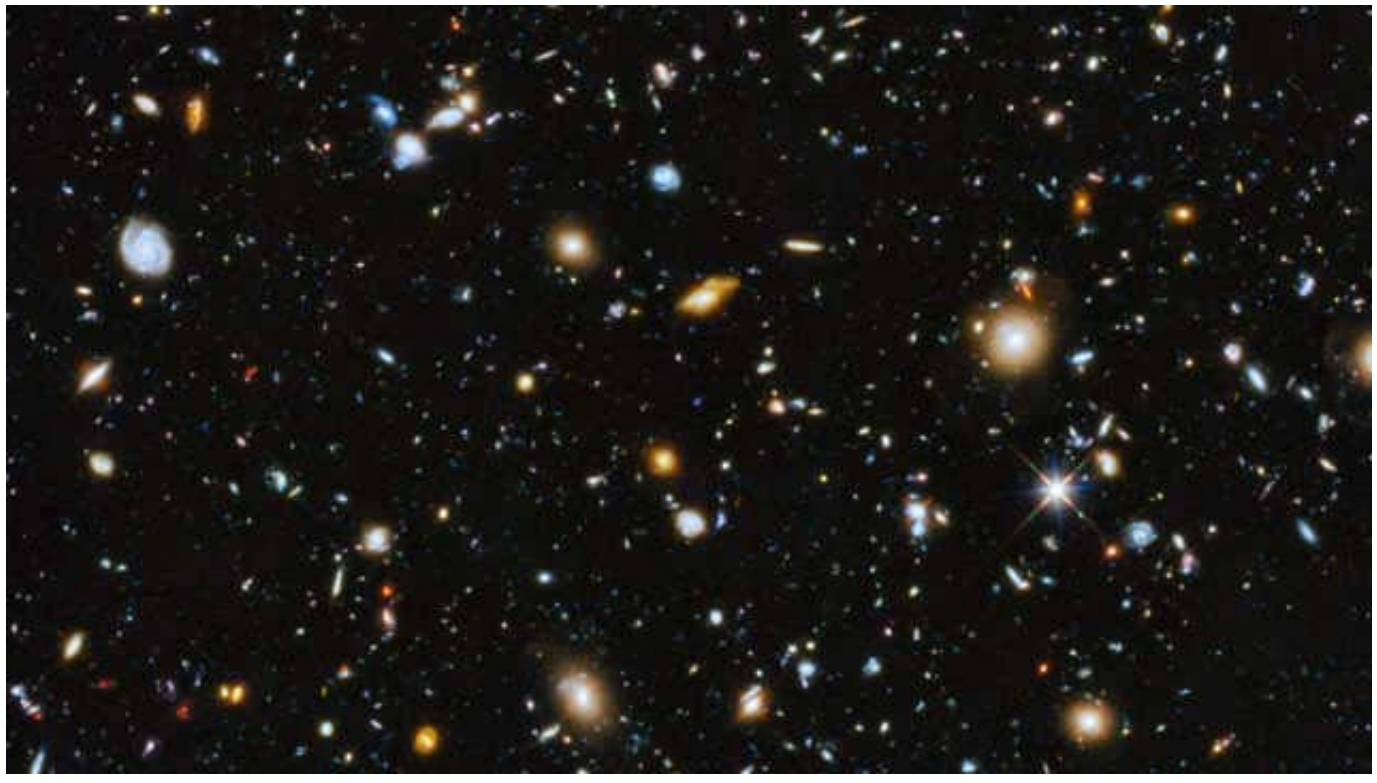
Very Distant Galaxies in the Hubble Ultra Deep Field



These six images, taken with the Advanced Camera for Surveys, show some of the most distant, and therefore youngest, galaxies in the Hubble Ultra Deep Field. We see the galaxies as they existed when the universe was only about one billion years old.

Infrared light lets us see the universe's youngest galaxies. These galaxies lie far, far away from us, and as their light travels across the universe, it gets stretched by the expansion of space. Wavelengths of visible light grow longer, becoming infrared light by the time it reaches us. Combining Hubble's observations of the HUDF in visible and infrared light, a team of astronomers led by Garth Illingworth of the University of California identified more than 5,500 galaxies in a central portion of the field, some so faint that they are just one ten-billionth the brightness of what the human eye can see. Another team, headed by Richard Ellis of the California Institute of Technology (Caltech), used Hubble's infrared observations to find galaxies more than 13 billion light-years away, when the universe was only about 400 million years old — or about three percent of its present age.

Movie 25.1: Ultraviolet Hubble Ultra Deep Field (UVHUDF) Zoom and Pan



Alternatively, to understand slightly older, growing galaxies that are not so far away, observing in ultraviolet light is best. The hottest and youngest stars give off huge amounts of ultraviolet light, making them easy to spot at those wavelengths of light. Most recently, a team of astronomers led by Harry Teplitz of Caltech used the ultraviolet-sensing abilities of Hubble's Wide Field Camera 3 to add the ultraviolet piece to this view of the HUDF. With this part of the galaxy evolution picture in hand, astronomers are investigating how galaxies grew through bursts of star formation and exactly where, when, and how many stars formed over time.

Because our atmosphere blocks or absorbs most infrared and ultraviolet light that reaches Earth, only a telescope in space, like Hubble, can provide such insights into the history of galaxies. Without both infrared and ultraviolet light, the tale is incomplete.

Image Facts:

Distance from Earth: 13.2 billion light-years

Description: Ultraviolet, Optical, and Infrared Survey

Constellation: Fornax

HubbleSite News Resource: Hubble Team Unveils Most Colorful View of Universe Captured by Space Telescope

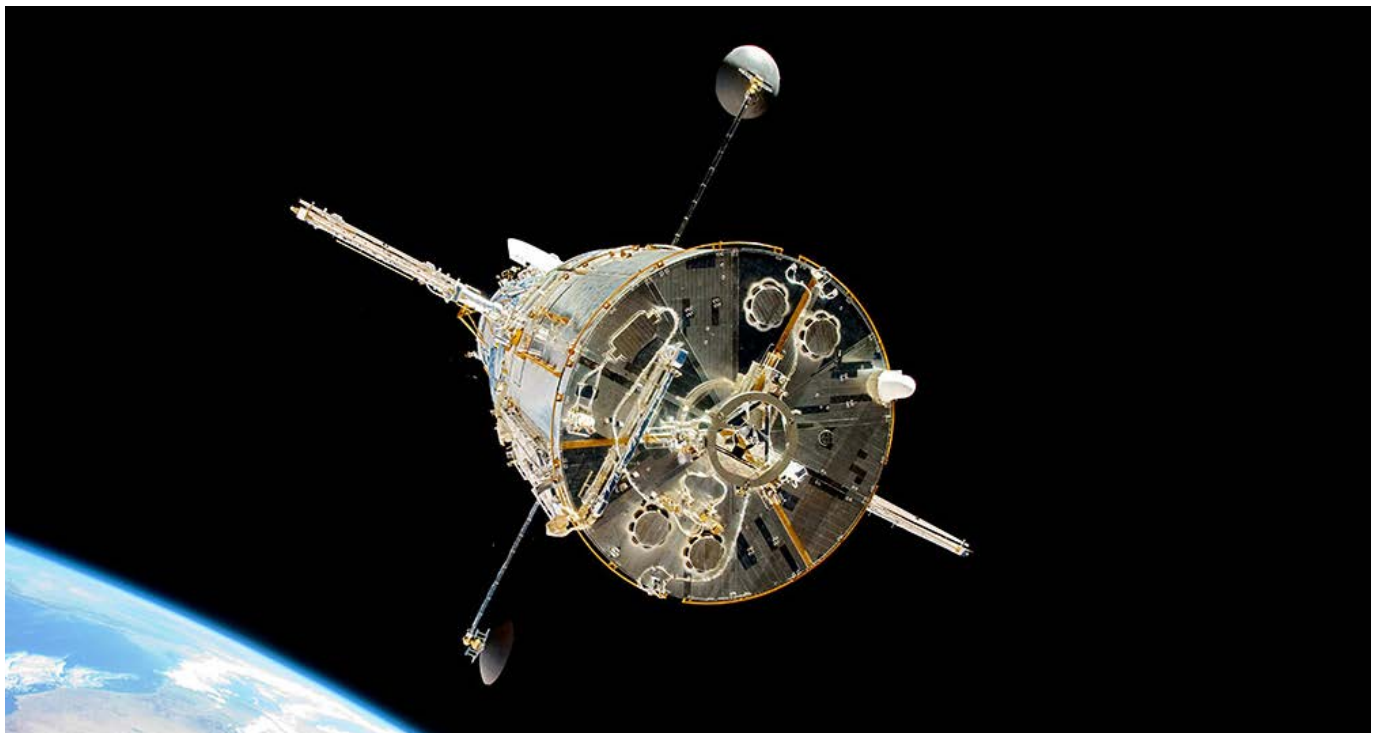
CONCLUSION

Over 25 years of discovery, the Hubble Space Telescope has reinvigorated and reshaped the public's perception of our universe. Successful beyond all expectations, the space telescope easily accomplished its primary scientific goals and then proved to be flexible and powerful enough to tackle unexpected frontiers such as extrasolar planets and dark energy.

Hubble's scientific contributions are unprecedented. Its observations have dramatically impacted most fields of astronomical research. The telescope has also supported interplanetary missions on a dynamic basis.

Hubble's astronomical images revealed properties of the cosmos that could previously only be probed in the imagination. Hubble's large section of filters provides an opportunity to bring out scientific, as well as aesthetic, detail in astronomical targets. The ever-growing portfolio of evocative and colorful space imagery is easily accessible to all space enthusiasts. These views make the universe more accessible, relevant, and intimate to the public than ever before in human history.

Hubble After the Telescope's Release on May 19, 2009



Thanks to the maintenance and upgrades provided by five NASA space shuttle servicing missions, the telescope is now more technologically advanced and capable than when it was launched in 1990. Hubble is expected to operate beyond 2020 and work in synergy with the next generation of space telescopes, including the James Webb Space Telescope, as well as the major ground-based observatories to address the top scientific questions of the next decade.

Perhaps the best is yet to come.

STAY CONNECTED

Websites

Hubble25th.org (http://hubble25th.org)

HubbleSite.org (http://hubblesite.org)

Hubble at NASA (http://www.nasa.gov/hubble)

Hubble at ESA (http://www.spacetelescope.org)

Social Channels

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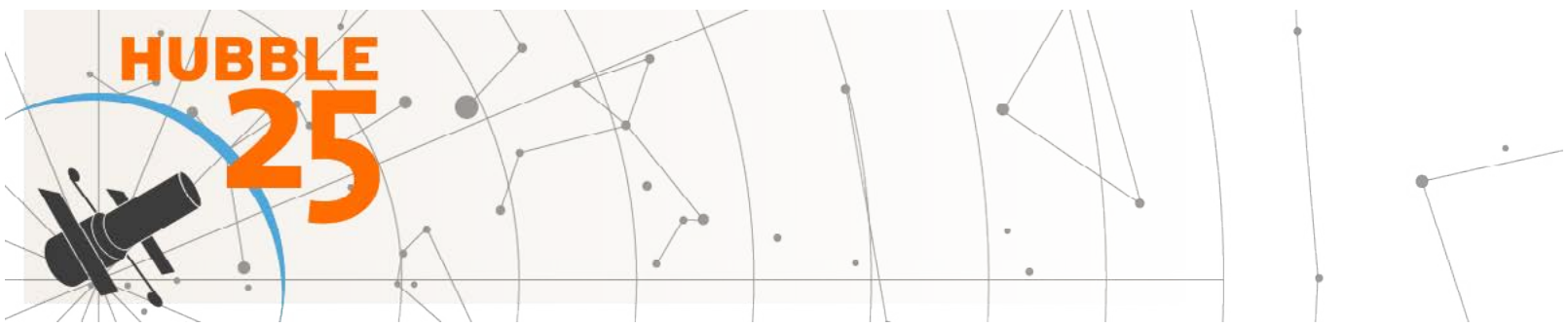

CREDITS

The Hubble Space Telescope is a cooperative project between the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA). The Hubble Space Telescope is part of NASA's Great Observatories Program, a series of four space-based observatories designed to conduct astronomical studies over many different wavelengths, which also includes the Chandra X-ray Observatory, the Spitzer Space Telescope, and the Compton Gamma Ray Observatory.

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Contributors

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Introduction

Hubble over Earth, 2009
Credit: NASA, STS-125 Space Shuttle Atlantis crew

The Eagle Nebula (Visible), 2015
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Pillars in the Eagle Nebula, in Visible and Infrared Light
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Pillars in the Eagle Nebula, 1995
Credit: NASA, ESA, STScI, and J. Hester and P. Scowen (Arizona State University)

Chapter 1: Jupiter's Great Red Spot

Jupiter's Great Red Spot
Credit: NASA, ESA, and A. Simon (Goddard Space Flight Center);
Acknowledgment: C. Go, H. Hammel (Space Science Institute, Boulder, and AURA), and R. Beebe (New Mexico State University)

Movie 1.1: Jupiter's Great Red Spot Shown Shrinking over Two Decades
Credit: NASA, ESA, and G. Bacon and M. Estacion (STScI);
Acknowledgment: C. Go, H. Hammel (Space Science Institute and AURA), and R. Beebe (New Mexico State University). Science Credit: A. Simon (Goddard Space Flight Center), G. Orton (Jet Propulsion Laboratory), J. Rogers (University of Cambridge, UK), and M. Wong and I. de Pater (University of California, Berkeley).

Chapter 2: Saturn

Saturn
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Movie 2.1: Science Visualization of Moons Crossing the Face of Saturn
Credit: NASA, ESA, and G. Bacon (STScI)

Saturn from 1996 to 2000
Credit: NASA and the Hubble Heritage Team (STScI/AURA)

Saturn's Aurorae
Credit: NASA, ESA, J. Clarke (Boston University), and Z. Levay (STScI)

Chapter 3: Orion Nebula

Orion Nebula
Credit: NASA, ESA, M. Robberto (Space Telescope Science Institute/ESA) and the Hubble Space Telescope Orion Treasury Project Team

The Orion Constellation
Credit: Akira Fujii

Protoplanetary Systems in the Orion Nebula
Credit: Mark McCaughrean (Max-Planck-Institute for Astronomy), C. Robert O'Dell (Rice University), and NASA

Movie 3.1: 3D Fly-Through of the Orion Nebula
Credit: NASA, ESA, F. Summers, G. Bacon, L. Frattare, Z. Levay, and K. Litaker (STScI);
Acknowledgment: A. Mellinger, R. Gendler, and R. Andreo

Chapter 4: Horsehead Nebula

Horsehead Nebula
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

The Horsehead Nebula in Visible Light
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Movie 4.1: The Horsehead Nebula in Visual and Infrared Light with a Fly-Through Visualization
Video Credit: NASA, ESA, and G. Bacon, T. Borders, L. Frattare, Z. Levay, and F. Summers (Viz 3D Team, STScI);
Image Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA), J. Emerson (ESO, VISTA), and Cambridge Astronomical Survey Unit

Chapter 5: Planetary Nebula NGC 5189

Planetary Nebula NGC 5189
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Movie 5.1: Zoom into Planetary Nebula NGC 5189
Credit:NASA, ESA, and G. Bacon (STScI);
Acknowledgment: A. Fujii, Digitized Sky Survey (DSS), STScI/AURA, Palomar/Caltech, and UKSTU/AAO, Gemini Observatory, AURA, T. Rector (U. Alaska) and the Hubble Heritage Team (STScI/AURA)

Chapter 6: Cat's Eye Nebula

Cat's Eye Nebula
Credit: NASA, ESA, HEIC, and the Hubble Heritage Team (STScI/AURA);
Acknowledgment: R. Corradi (Isaac Newton Group of Telescopes, Spain) and Z. Tsvetanov (NASA)

Wide Field Planetary Camera 2 Image of the Cat's Eye Nebula
Credit: J.P. Harrington and K.J. Borkowski (University of Maryland), and NASA

Movie 6.1: Zoom into the Cat's Eye Nebula
Credit: NASA, ESA, and G. Bacon (STScI);
Acknowledgment: NASA, ESA, HEIC, NOT, Digitized Sky Survey 2 (DSS2), STScI/AURA, Palomar/Caltech, and UKSTU/AAO, the Hubble Heritage Team (STScI/AURA), and R. Corradi (Isaac Newton Group of Telescopes, Spain)

Chapter 7: Planetary Nebula NGC 6302

Planetary Nebula NGC 6302
Credit: NASA, ESA, and the Hubble SM4 ERO Team

Movie 7.1: A Pan Sequence of the Planetary Nebula NGC 6302
Credit: NASA, ESA, and G. Bacon (STScI)

Wide Field Plantery Camera 2 Image of NGC 6302
Credit: NASA, ESA and A. Zijlstra (UMIST, Manchester, UK)

Chapter 8: Pillars in the Monkey Head Nebula

Pillars in the Monkey Head Nebula
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Visible and Infrared Comparison
Credit: NASA and ESA;
Acknowledgment: The Hubble Heritage Team (STScI/AURA) and J. Hester

Movie 8.1: A Tour Through the Monkey Head Nebula
Credit: NASA, ESA, and G. Bacon, L. Frattare, Z. Levay, and F. Summers (Viz3D Team, STScI);
Acknowledgment: A. Fujii, the Digitized Sky Survey 2, and the Hubble Heritage Team (STScI/AURA)

Chapter 9: Crab Nebula

Crab Nebula
Credit: NASA, ESA, J. Hester and A. Loll (Arizona State University)

Movie 9.1: Zoom into the Crab Nebula
Credit: NASA, ESA, and G. Bacon (STScI);
Acknowledgment: A. Fujii, Digitized Sky Survey (DSS), STScI/AURA, Palomar/Caltech, and UKSTU/AAO, and J. Hester and A. Loll (Arizona State University)

Composite Image of the Crab Nebula
Credit: NASA, ESA, CXC, JPL-Caltech, J. Hester and A. Loll (Arizona State Univ.), R. Gehrz (Univ. Minn.), and STScI

Chapter 10: Carina Nebula

Carina Nebula
Credit (Hubble Image): NASA, ESA, N. Smith (University of California, Berkeley), and the Hubble Heritage Team (STScI/AURA);
Credit (CTIO Image): N. Smith (University of California, Berkeley) and NOAO/AURA/NSF

Panoramic Image of the Carina Nebula
Credit (Hubble Image): NASA, ESA, N. Smith (University of California, Berkeley), and the Hubble Heritage Team (STScI/AURA);
Credit (CTIO Image): N. Smith (University of California, Berkeley) and NOAO/AURA/NSF

Movie 10.1: Zoom into the Carina Nebula
Credit: NASA, ESA, and G. Bacon (STScI)

Variable Star Eta Carinae
Credit: NASA, ESA, and the Hubble SM4 ERO Team

Bok Globule Detail
Credit (Hubble Image): NASA, ESA, N. Smith (University of California, Berkeley), and the Hubble Heritage Team (STScI/AURA);
Credit (CTIO Image): N. Smith (University of California, Berkeley) and NOAO/AURA/NSF

Chapter 11: Core of Omega Centauri

Core of Omega Centauri
Credit: NASA, ESA, and J. Anderson and R. van der Marel (STScI)

Movie 11.1: Zoom into the Heart of Omega Centauri
Credit: NASA, ESA, and J. Anderson, R. van der Marel, and G. Bacon (STScI)

Movie 11.2: Future Motions of Omega Centauri Stars
Credit: NASA, ESA, and J. Anderson (STScI)

Movie 11.3: Constructing a Hertzsprung-Russell Diagram for Omega Centauri
Credit: NASA, ESA, and J. Anderson, R. van der Marel, G. Bacon, and M. Estacion (STScI)

Chapter 12: V838 Monocerotis

V838 Monocerotis
Credit: NASA and the Hubble Heritage Team (AURA/STScI)

Movie 12.1: The Light Echo Around V838 Mon Reveals Dramatic Changes over a Decade
Credit: NASA, ESA, and G. Bacon

Chapter 13: Star-Forming Nebula NGC 3603

Star-Forming Nebula NGC 3603
Credit: NASA, ESA, R. O'Connell (University of Virginia), F. Paresce (National Institute for Astrophysics, Bologna, Italy), E. Young (Universities Space Research Association/Ames Research Center), the WFC3 Science Oversight Committee, and the Hubble Heritage Team (STScI/AURA)

Movie 13.1: Zoom into NGC 3603
Credit: NASA, ESA, and G. Bacon (STSCI)

Chapter 14: Supernova Remnant 0509-67.5

Supernova Remnant 0509-67.5
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

SNR 0509 in Visible and X-ray Light
Credit: NASA, ESA, CXC, SAO, the Hubble Heritage Team (STScI/AURA), and J. Hughes (Rutgers University)

Movie 14.1: 3D View of SNR 0509 (Artistic Visualization)
Credit: NASA, ESA, and G. Bacon, T. Borders, L. Frattare, Z. Levay, and F. Summers (STScI)

Chapter 15: Heart of the Tarantula Nebula

Heart of the Tarantula Nebula
Credit: NASA, ESA, D. Lennon and E. Sabbi (ESA/STScI), J. Anderson, S. E. de Mink, R. van der Marel, T. Sohn, and N. Walborn (STScI), N. Bastian (Excellence Cluster, Munich), L. Bedin (INAF, Padua), E. Bressert (ESO), P. Crowther (University of Sheffield), A. de Koter (University of Amsterdam), C. Evans (UKATC/STFC, Edinburgh), A. Herrero (IAC, Tenerife), N. Langer (AifA, Bonn), I. Platais (JHU), and H. Sana (University of Amsterdam)

Tarantula Nebula Annotated Map
Illustration Credit: NASA, ESA, and Z. Levay (STScI);
Image Credit: NASA, ESA, and D. Lennon (ESA/Hubble)

Star Cluster R136 in 30 Doradus
Credit: NASA, ESA, and E. Sabbi (ESA/STScI);
Acknowledgment: R. O'Connell (University of Virginia) and the Wide Field Camera 3 Science Oversight Committee

Movie 15.1: Zoom into the Heart of the Tarantuala Nebula
Video Credit: NASA, ESA, and G. Bacon (STScI);
Science Credit: NASA, ESA, D. Lennon and E. Sabbi (ESA/STScI), J. Anderson, S. E. de Mink, R. van der Marel, T. Sohn, and N. Walborn (STScI), N. Bastian (Excellence Cluster, Munich), L. Bedin (INAF, Padua), E. Bressert (ESO), P. Crowther (University of Sheffield), A. de Koter (University of Amsterdam), C. Evans (UKATC/STFC, Edinburgh), A. Herrero (IAC, Tenerife), N. Langer (AifA, Bonn), I. Platais (JHU), and H. Sana (University of Amsterdam)

Chapter 16: Star Cluster NGC 602

Star Cluster NGC 602
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA) - ESA/Hubble Collaboration

Movie 16.1: Zoom into Star-Forming Region NGC 602
Credit: NASA, ESA, and G. Bacon (STScI)

NGC 602 in Visible, Infrared, and X-ray Light
Credit: NASA, ESA, CXC and the University of Potsdam, JPL-Caltech, and STScI

Chapter 17: Galaxy M83

Galaxy M83
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA);
Acknowledgment: W. Blair (STScI/Johns Hopkins University) and R. O'Connell (University of Virginia)

Movie 17.1: Zoom into M83
Credit: NASA, ESA, and G. Bacon (STScI)

Hubble Details Star Birth in M83
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA);
Acknowledgment: R. O'Connell (University of Virginia) and the Wide Field Camera 3 Science Oversight Committee

Chapter 18: Sombrero Galaxy

Sombrero Galaxy
Credit: NASA and the Hubble Heritage Team (STScI/AURA)

Panoramic View of the Sombrero Galaxy
Credit: NASA and the Hubble Heritage Team (STScI/AURA)

Movie 18.1: Zoom into and Pan of the Sombrero Galaxy
Credit: NASA and G. Bacon (STScI)

The Sombrero Galaxy in Infrared and Visible Light
Credit: NASA/JPL-Caltech and the Hubble Heritage Team (STScI/AURA)

Chapter 19: Spiral Galaxy NGC 1300

Spiral Galaxy NGC 1300
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA);
Acknowledgment: P. Knezek (WIYN)

Full View of NGC 1300
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA);
Acknowledgment: P. Knezek (WIYN)

Movie 19.1: Zoom into NGC 1300
Credit: NASA, ESA, and G. Bacon (STScI)

Chapter 20: Antennae Galaxies

Antennae Galaxies
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA) - ESA/Hubble Collaboration;
Acknowledgment: B. Whitmore (STScI)

Wide-Field View of the Antennae Galaxies
Credit: Bob and Bill Twardy/Adam Block/NOAO/AURA/NSF

Movie 20.1: Zoom into the Antennae Galaxies
Credit: NASA, ESA, and G. Bacon (STScI)

Chapter 21: Stephan's Quintet

Stephan's Quintet
Credit: NASA, ESA, and the Hubble SM4 ERO Team

Movie 21.1: Zoom into Stephan's Quintet
Credit: NASA, ESA, and the Hubble SM4 ERO Team

Chapter 22: Interacting Galaxies Arp 273

Interacting Galaxies Arp 273
Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)

Movie 22.1: 3D Zoom into Arp 273
Credit: NASA, ESA, and G. Bacon, T. Borders, L. Frattare, Z. Levay, and F. Summers (Viz 3D team, STScI);
Image Credits: A. Block, Mount Lemmon SkyCenter, University of Arizona, and the Hubble Heritage Team (STScI/AURA)

Chapter 23: Abell 2744 Frontier Field

Abell 2744 Frontier Field
Credit: NASA, ESA, and J. Lotz, M. Mountain, A. Koekemoer, and the HFF Team (STScI)

Movie 23.1: Zoom into the Massive Galaxy Cluster Abell 2744

Credit: NASA, ESA, and G. Bacon (STScI);
Acknowledgment: NASA, ESA, A. Fujii, Digitized Sky Survey (DSS), STScI/AURA, Palomar/Caltech, and UKSTU/AAO, and J. Lotz, M. Mountain, A. Koekemoer, and the HFF Team (STScI)

Chapter 24: Galaxy Cluster Abell 370

Galaxy Cluster Abell 370

Credit: NASA, ESA, the Hubble SM4 ERO Team, and ST-ECF

Movie 24.1: Zoom into Galaxy Cluster Abell 370

Credit: NASA, ESA, and the SM4 ERO Team

Chapter 25: Hubble Ultra Deep Field

Hubble Ultra Deep Field

Credit: NASA, ESA, H. Teplitz and M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst (Arizona State University), and Z. Levay (STScI)

Very Distant Galaxies in the Hubble Ultra Deep Field

Credit: NASA and Grism ACS Program for Extragalactic Science (STScI)

Movie 25.1: Ultraviolet Hubble Ultra Deep Field (UVHUDF) Zoom and Pan

Credit: NASA, ESA, H. Teplitz and M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst (Arizona State University), and Z. Levay and G. Bacon (STScI). The deepest data in this field are from programs led by S. Beckwith, R. Ellis, G. Illingworth, H. Teplitz, and R. Thompson, and include data from many other programs.

Conclusion

Hubble After the Telescope's Release on May 19, 2009

Credit: NASA/STS-125 Space Shuttle Atlantis crew