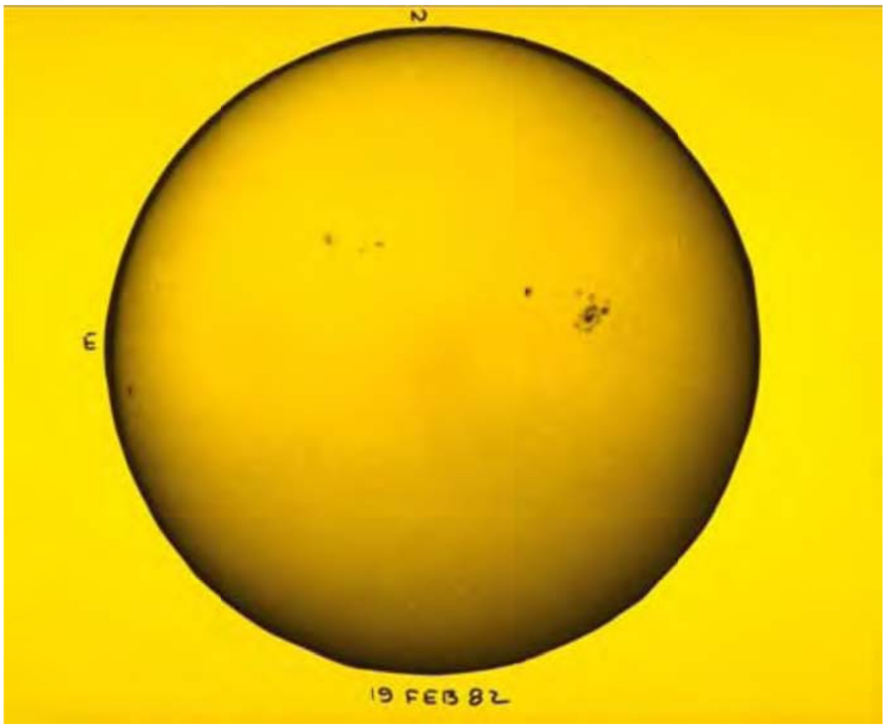
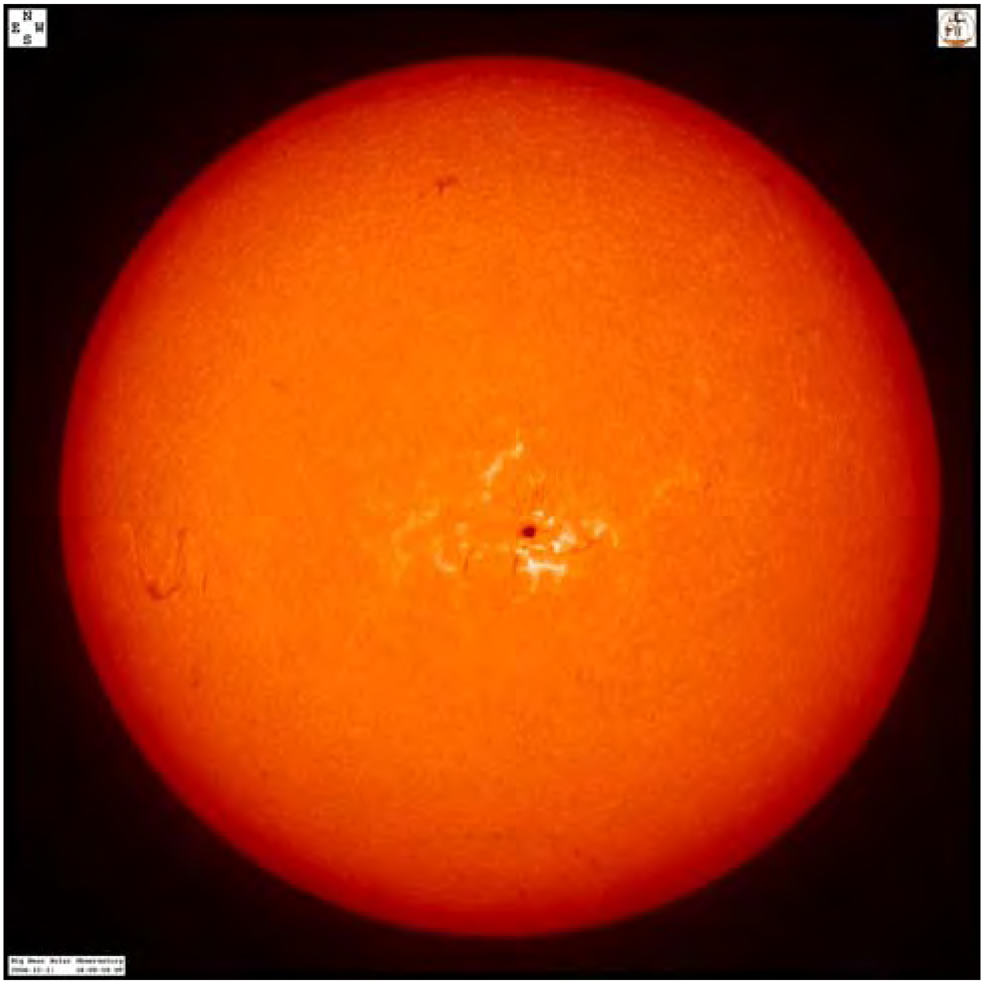
Additional Cosmology Images
Modern Physics 6e



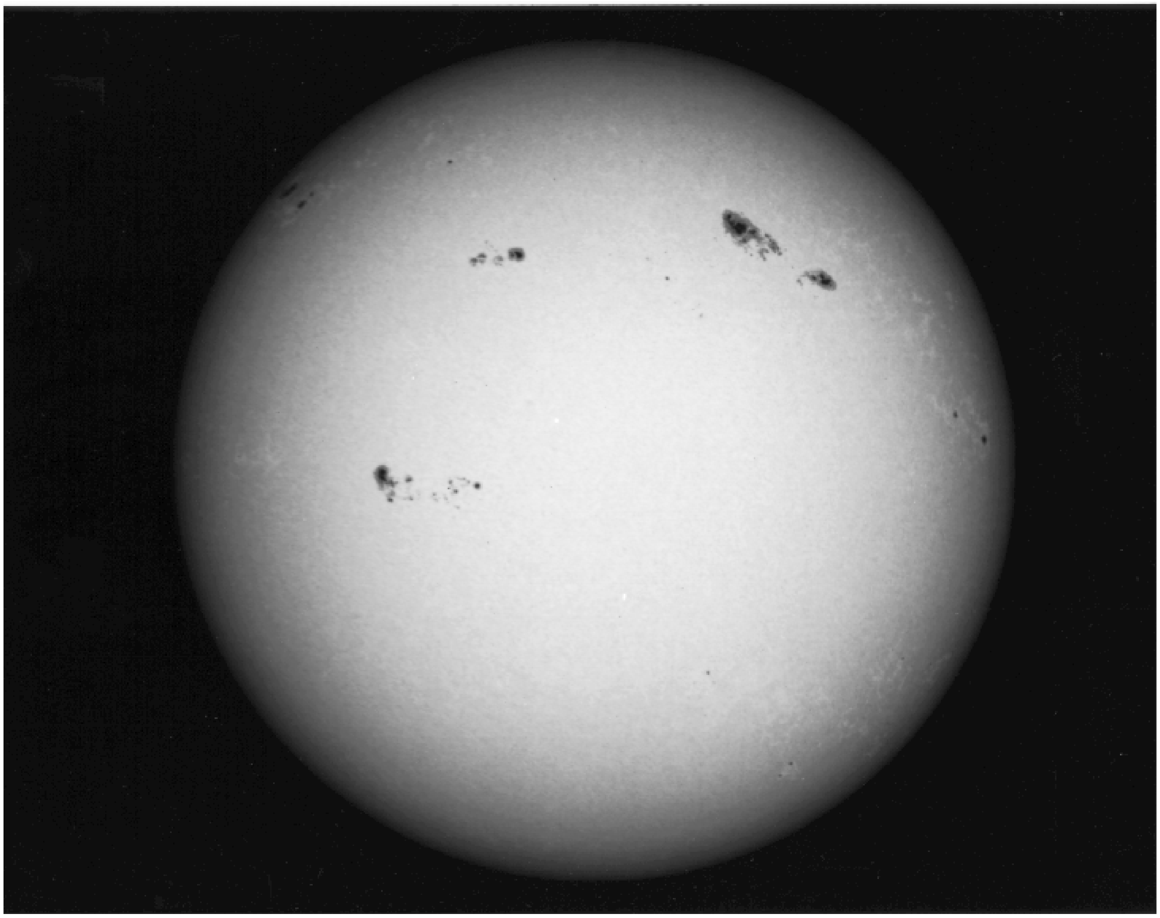
A white light, whole disk image of the Sun, shows a variety of sunspots, including a rare spiral sunspot. The image was made February 19, 1982.

NSO/AURA/NSF



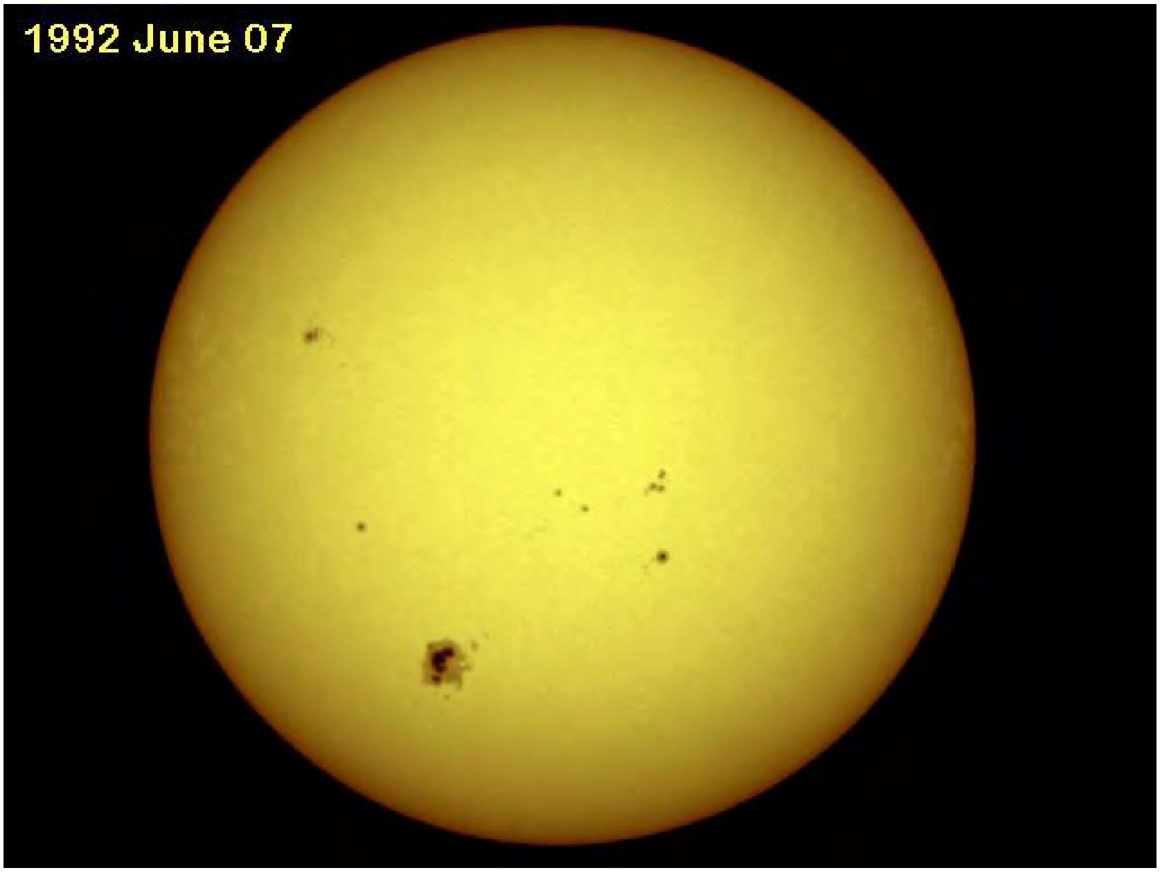
This full-disk image of the Sun was recorded at 18:09:59 (UT) on December 11, 2006, in Hα light. The image was recorded with a 14-bit, 2032 x 2032 pixel Apogee KX4 CCD camera.

BBSO full disk H-alpha image



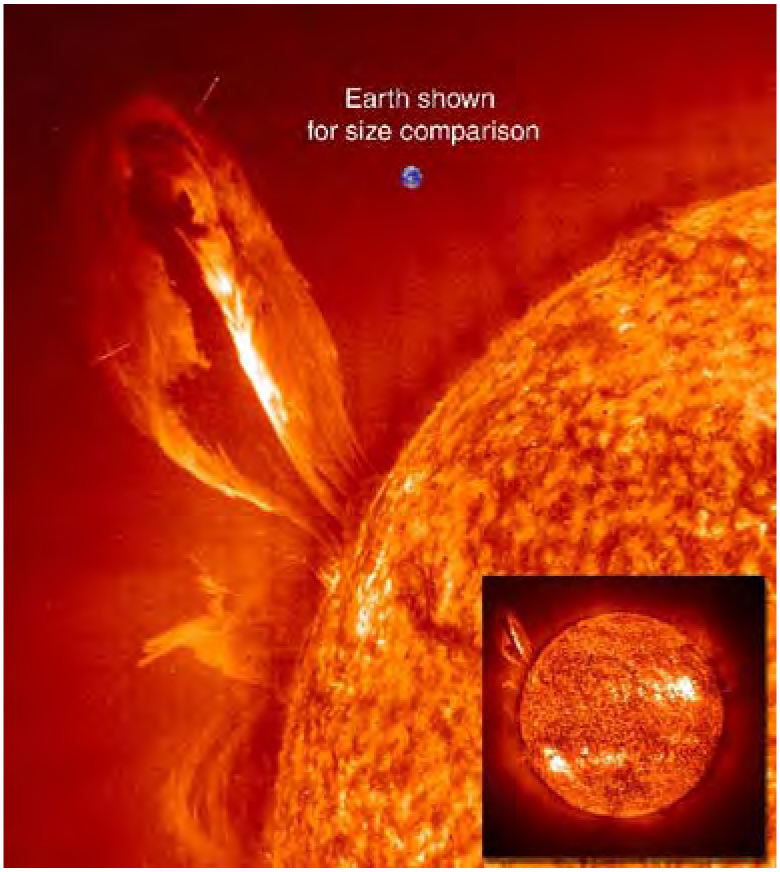
This picture was taken by one of the National Solar Observatory (NSO) patrol cameras. The flare patrol camera takes pictures of the Sun using the light at 656.3 nm emitted by hydrogen atoms, the Hα line of the Balmer series. Pictures are taken at regular intervals over the course of each day. Notice the darkening of the Sun's edge (limb darkening).

National Solar Observatory/AURA/NSF____NSO/ Sacramento Peak Hilltop Dome Facility.



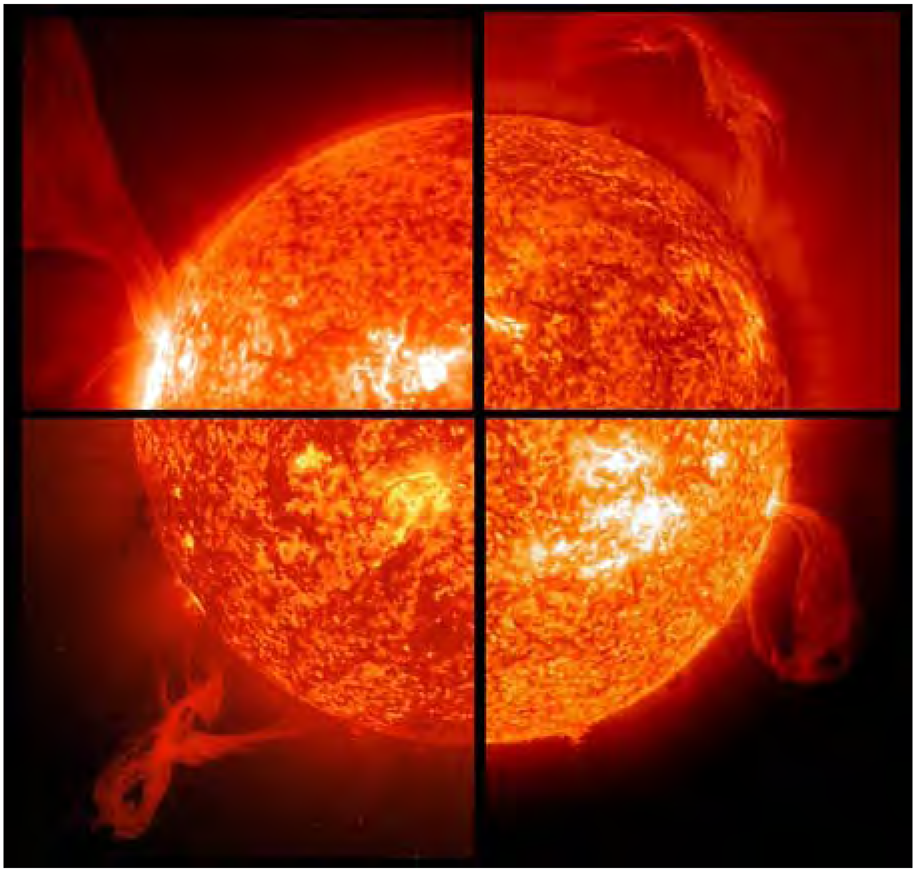
The photosphere is the visible surface of the Sun that we are most familiar with. Since the Sun is a ball of gas, this is not a solid surface but is actually a layer about 100 km thick (very, very, thin compared to the 700,000 km radius of the Sun). When we look at the center of the disk of the Sun we look straight in and see somewhat hotter and brighter regions. When we look at the limb, or edge, of the solar disk we see light that has taken a slanting path through this layer and we only see through the upper, cooler and dimmer regions. This explains the "limb darkening" that appears as a darkening of the solar disk near the edge.

NSO/AURA/NSF



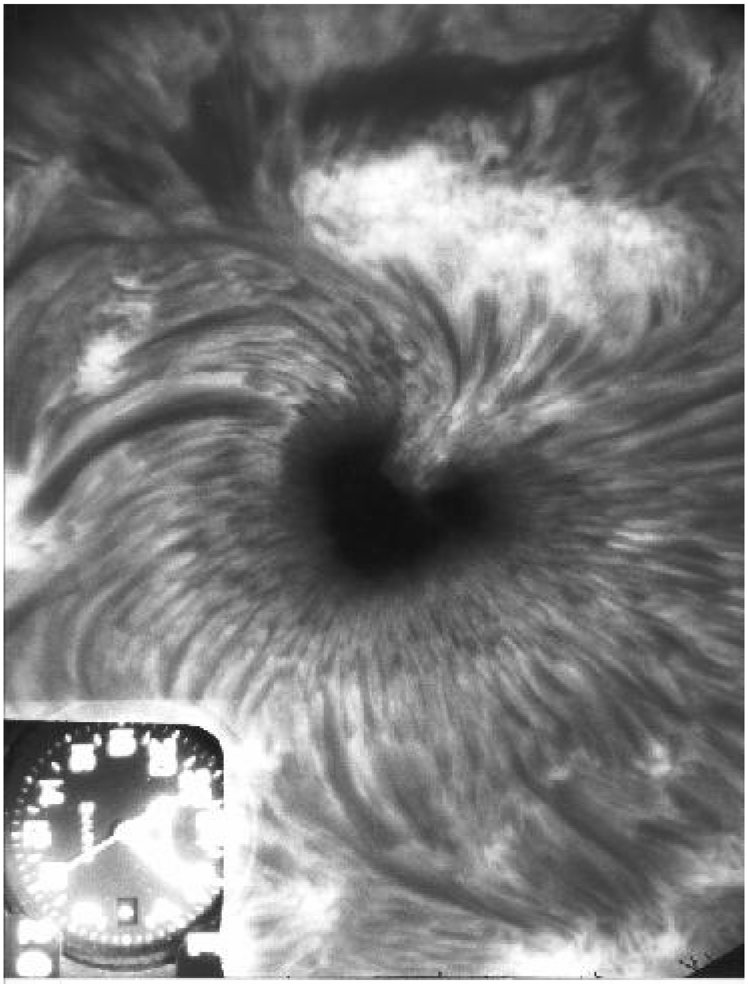
Large, eruptive prominence recorded by the SOHO satellite in He II (singly ionized He) light at 30.4 nm, with an image of the Earth added for size comparison. This prominence from 24 July 1999 is particularly large and looping, extending over 35 Earth diameters out from the Sun. Erupting prominences (when directed toward Earth) can affect communications, navigation systems, even power grids, while also producing auroras visible in the night skies.

SOHO (ESA & NASA)

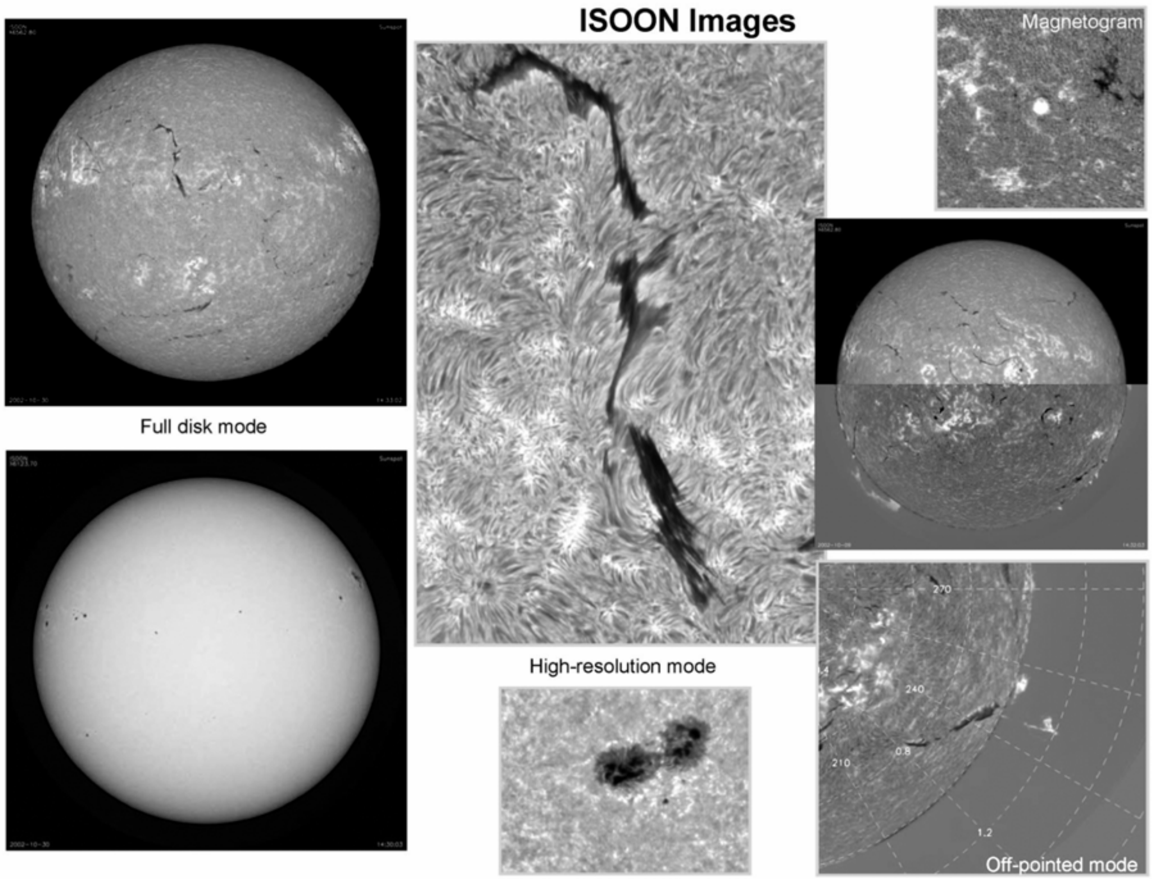


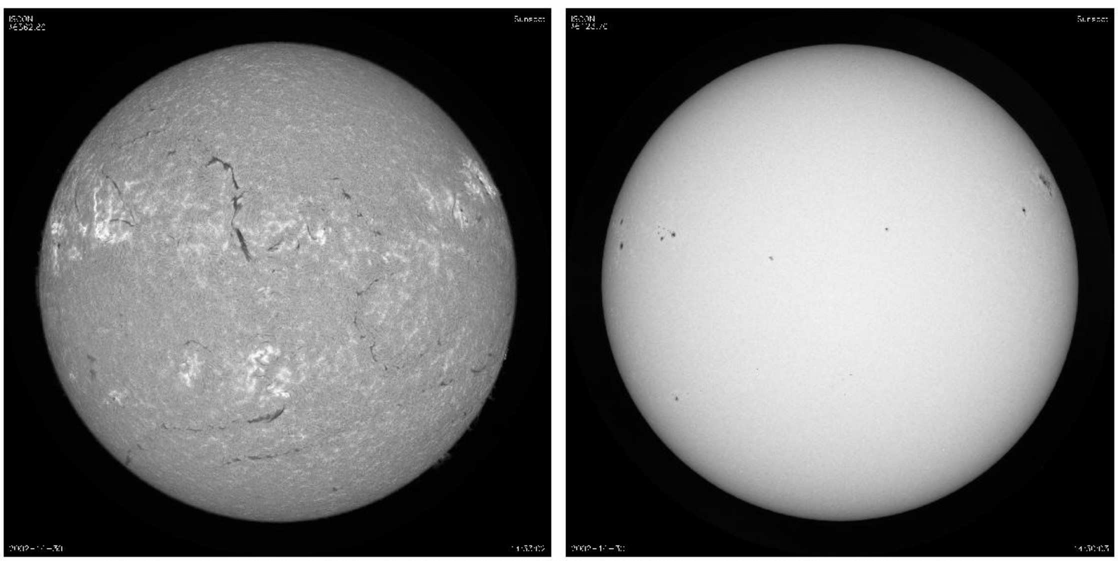
A collage of prominences, which are huge clouds of relatively cool dense plasma suspended in the Sun's hot, thin corona. At times, they can erupt, escaping the Sun's atmosphere. For all four images, emission in this HeII spectral line recorded by the Extreme ultraviolet Imaging Telescope (EIT) at 30.4 nm shows the upper chromosphere at a temperature of about 60,000 K. The hottest areas appear almost white, while the darker red areas indicate cooler temperatures. Going clockwise from the upper left, the images are from: 15 May 2001; 28 March 2000; 18 January 2000, and 2 February 2001.

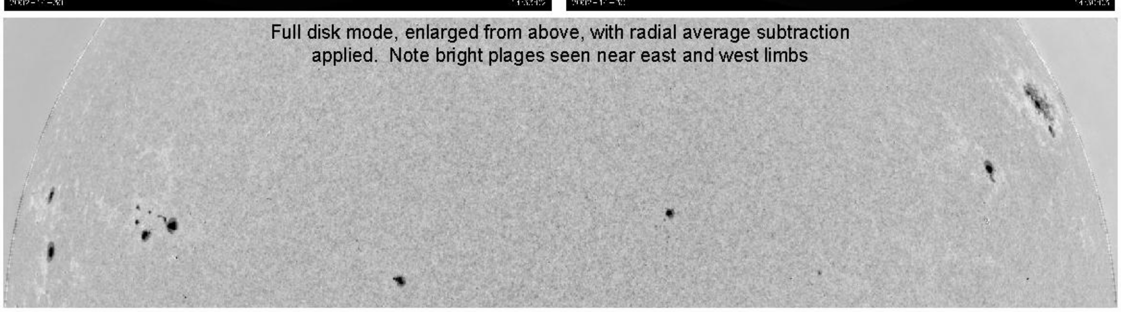
SOHO (ESA & NASA) Extreme ultraviolet Imaging Telescope (EIT) 30.4 nm image of a pair of similarly shaped prominences from 11 January 1998 Joseph B. Gurman Normal Joseph B. Gurman 2 0 2001-12-26T16:53:00Z 2001-12-26T16:53:00Z 1 28 163 NASA GSGC 1 1 200 9.2511 150



A simple sunspot in Hα light: This high resolution image was observed on July 4th, 1974. It is easy to follow the Hα arches from sunspot to the following plage above it. Big Bear Solar Observatory

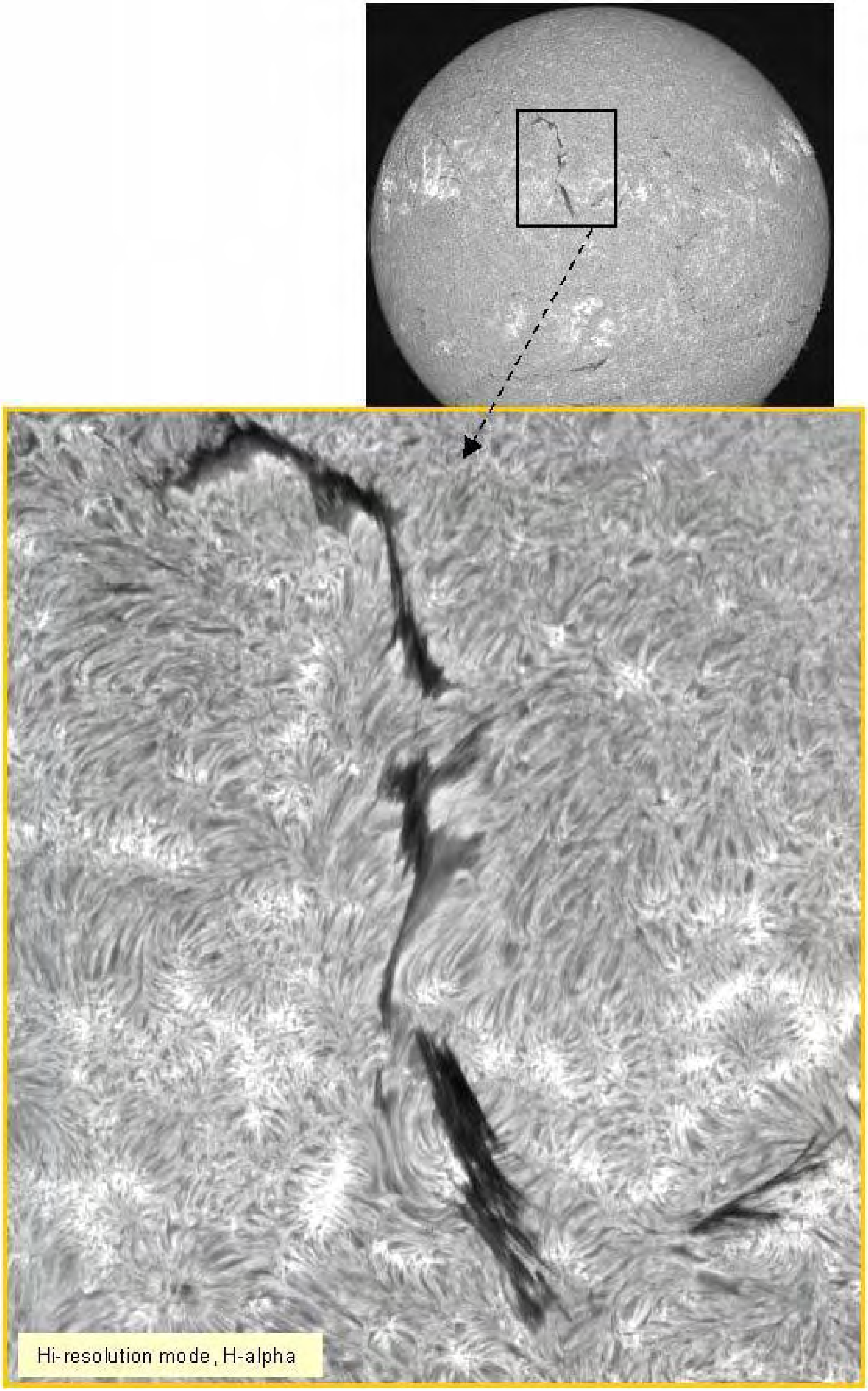




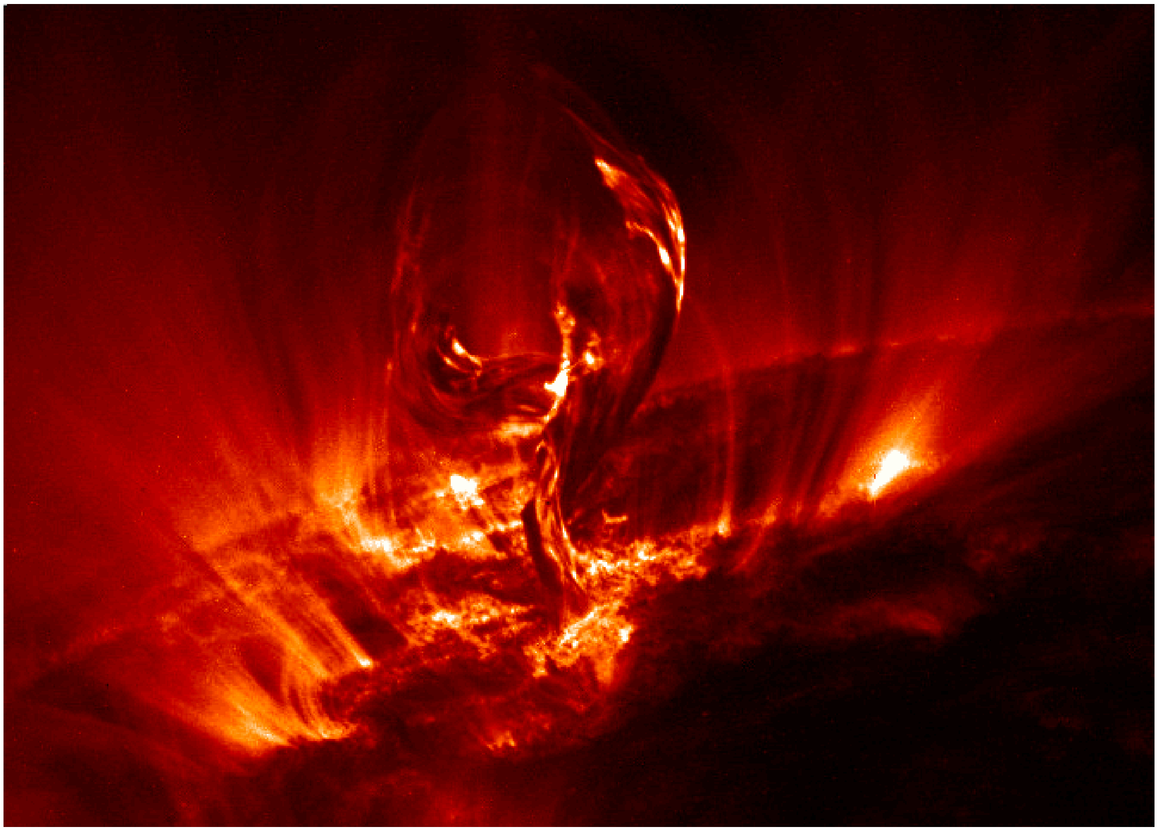


Full disk mode, enlarged from above, with radial average subtraction applied. Note bright plages seen near east and west limbs

The sunspot/plage relationship is illustrated here. Note the bright plages near the east and west limbs just a bit above the equator.

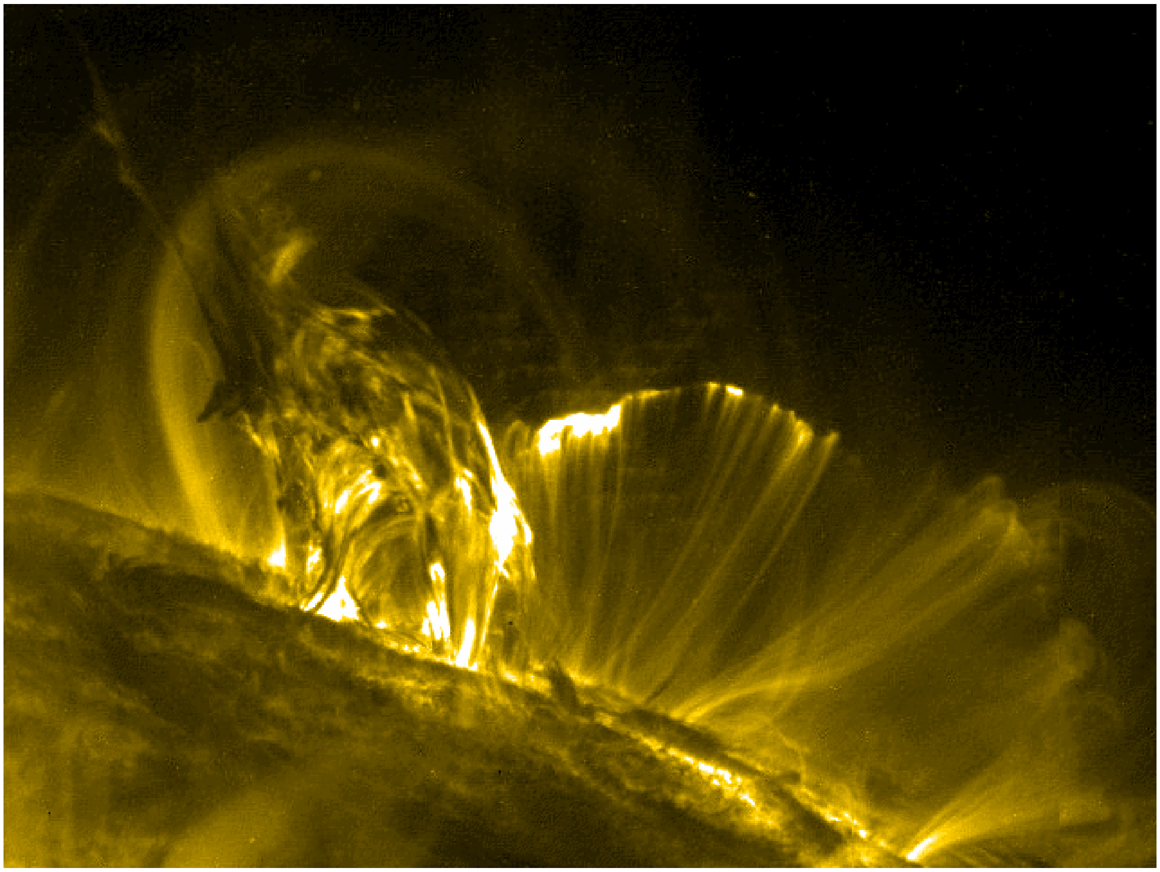


Photographed by the US Air Force Research Laboratory and National Solar Observatory (Sacramento Peak) in Hα light, a filament winds it way across thousands of kilometers of the solar surface.



An image recorded in 17.1 nm ultraviolet light, showing emission from gas at 1 million degrees, of Active Region 9077 on 19 July 2000, at 23:30UT. The image (rotated over 90 degrees, so North is to the left) shows a filament in the process of lifting off from the surface of the Sun. The dark matter is relatively cool, around 20,000 degrees, while hot kernels and threads around it are at a million degrees or more. From footpoint to peak, this rapidly evolving structure measures 75,000 miles.

TRACE/ Stanford-Lockheed Institute for Space Research/ NASA___TRACE

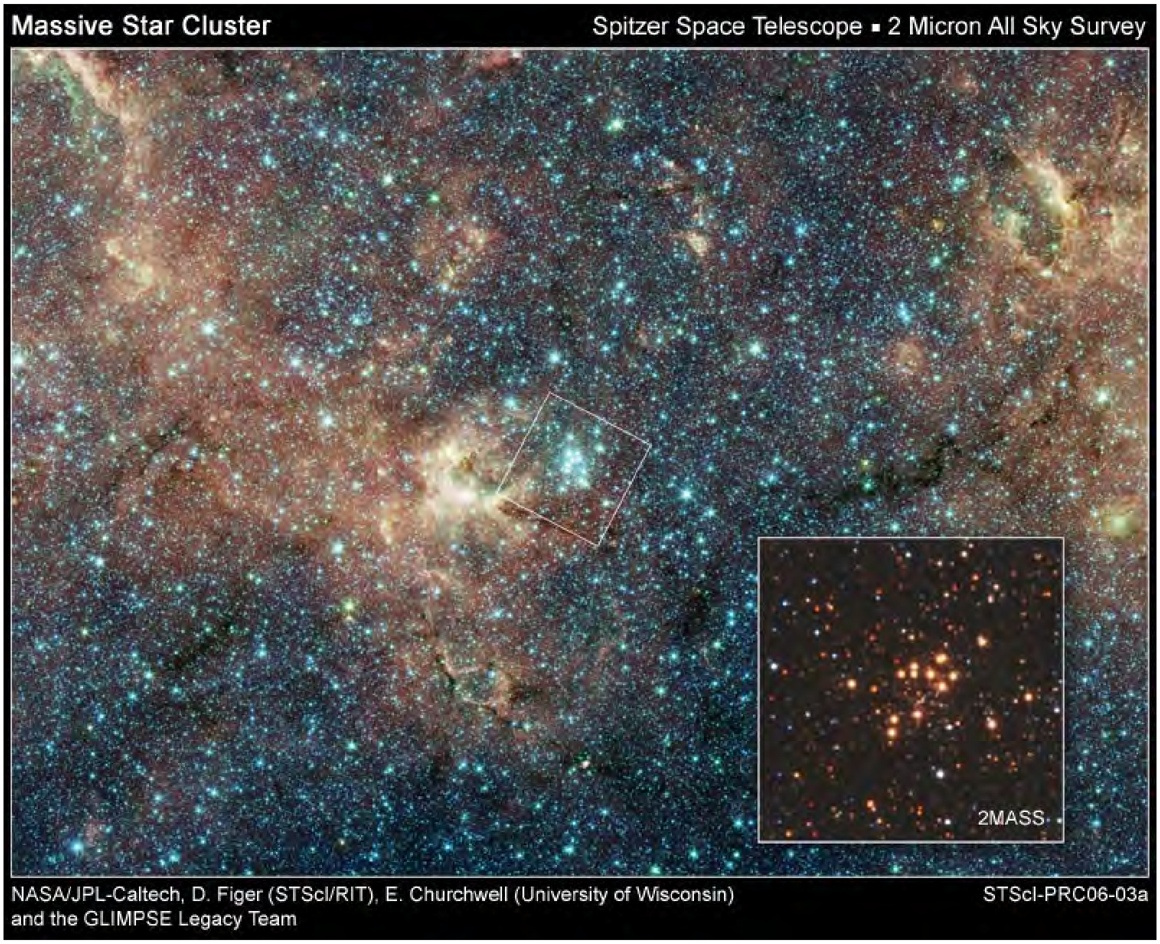


Filament eruption and loop oscillations On 15 April 2001, a relatively small filament in Active Region 9415 began to erupt around 22 UT. Within about 10 minutes, the material (seen here in the 17.1 nm pass band, most sensitive to emission from gas at around 1 million Kelvin) reached up to a height of approximately 80,000 km. The magnetic field within the filament continues to writhe and twist for a while longer, but most of the material begins to fall down again. The filament eruption (not high and strong enough to make it into a true coronal mass ejection) also excites loop oscillations.

credit: TRACE/ Stanford-Lockheed Institute for Space Research/ NASA

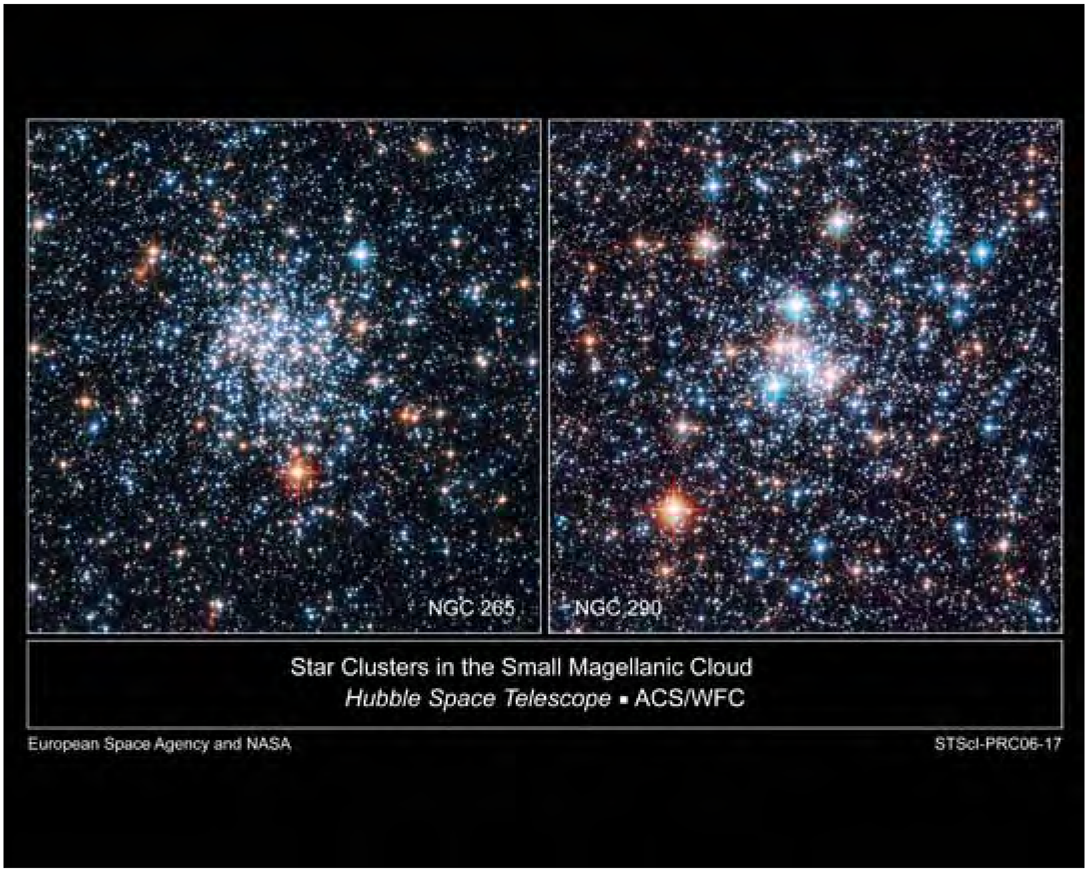
The brilliant stars seen in this image are members of the popular open star cluster known as the Pleiades, or Seven Sisters. The Hubble Space Telescope's Fine Guidance Sensors refined the distance to the Pleiades at about 440 light-years. The Fine Guidance Sensors are at the periphery of Hubble's field-of-view. They trace a circumference that is approximately the angular size of the Moon on the sky. They are overlaid on this image to give a scale to Hubble's very narrow view on the heavens. Hubble Fine Guidance Sensors measured slight changes in the apparent positions of three stars within the cluster when viewed from different sides of Earth's orbit. Astronomers took their measurements six months apart over a 2 1/2-year period. About 1,000 stars comprise the cluster, located in the constellation Taurus. The color-composite image of the Pleiades star cluster was taken by the Palomar 48-inch Schmidt telescope. The image is from the second Palomar Observatory Sky Survey, and is part of the Digitized Sky Survey. The Pleiades photo was made from three separate images taken in red, green, and blue filters. The separate images were taken between Nov. 5, 1986 and Sept. 11, 1996.

Credit: NASA, ESA and AURA/Caltech___



The sky is a jewelry box full of sparkling stars in these infrared images. The crown jewels are 14 massive stars on the verge of exploding as supernovae. These hefty stars reside in one of the most massive star clusters in the Milky Way. The bluish cluster is inside the white box in the large image, which shows the star-studded region around it. A close-up of the cluster can be seen in the inset photo. These large stars are a tip-off to the mass of the young cluster. Astronomers estimate that the cluster is at least 20,000 times as massive as the Sun. Each red supergiant is about 20 times the Sun's mass. The larger color-composite image was taken by the Spitzer Space Telescope for the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) Legacy project. The survey penetrates obscuring dust along the thick disk of our galaxy to reveal never-before-seen stars and star clusters. The false colors in the image correspond to infrared-light emission. The stars in the large color-composite image all appear blue because they emit most of their infrared light at shorter wavelengths. The inset image, a false-color composite, was captured by the Two Micron All Sky Survey (2MASS). The cluster lies 18,900 light-years away in the direction of the constellation Scutum. The Spitzer image was taken April 4, 2004; the 2MASS image on July 4, 1999.

Credit for Spitzer Image: NASA/JPL-Caltech, D. Figer (Space Telescope Science Institute/Rochester Institute of Technology), E. Churchwell (University of Wisconsin, Madison) and the GLIMPSE Legacy Team. Credit for 2MASS Image: NASA/NSF/2MASS/UMass/IPAC-Caltech and D. Figer (Space Telescope Science Institute/Rochester Institute of Technology)



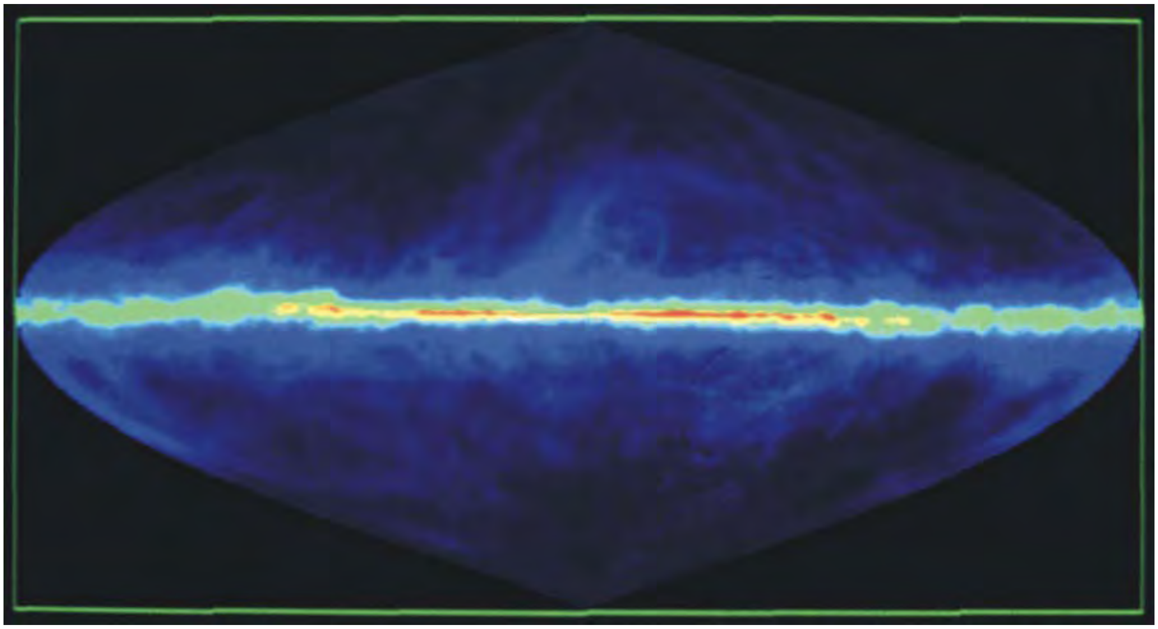
NASA's Hubble Space Telescope has captured the most detailed images to date of the open star clusters NGC 265 and NGC 290 in the Small Magellanic Cloud — two sparkling sets of gemstones in the southern sky. These images, taken with Hubble's Advanced Camera for Surveys, show a myriad of stars in crystal clear detail. The brilliant open star clusters are located about 200,000 light-years away and are roughly 65 light-years across. Star clusters can be held together tightly by gravity, as is the case with densely packed crowds of hundreds of thousands of stars, called globular clusters. Or, they can be more loosely bound, irregularly shaped groupings of up to several thousands of stars, like the open clusters shown in this image. The stars in these open clusters are all relatively young and were born from the same cloud of interstellar gas. The stars in an open cluster will only remain together for a limited time and gradually disperse into space, pulled away by the gravitational tugs of other passing clusters and clouds of gas. Most open clusters dissolve within a few hundred million years, whereas the more tightly bound globular clusters can exist for many billions of years. Open star clusters make excellent astronomical laboratories. The stars may have different masses, but all are at about the same distance, move in the same general direction, and have approximately the same age and chemical composition. They can be studied and compared to find out more about stellar evolution, the ages of such clusters, and much more. The Small Magellanic Cloud, which hosts the two star clusters, is one of the small satellite galaxies of the Milky Way. It can be seen with the unaided eye as a hazy patch in the constellation Tucana (the Toucan) in the Southern Hemisphere. The Small Magellanic Cloud is rich in gas nebulae and star clusters. It is most likely that this irregular galaxy has been disrupted through repeated interactions with the Milky Way, resulting in the vigorous star-forming activity seen throughout the cloud. NGC 265 and NGC 290 may very well owe their existence to these close encounters with the Milky Way. The images were taken in October and November 2004.

Credit: European Space Agency & NASA

All-Sky Panorama

This stunning panorama of the entire sky is a mosaic of 51 wide-angle photographs. Made over a three year period from locations in California (USA), South Africa, and Germany, the individual pictures were digitized and stitched together to create an apparently seamless 360 by 180 degree view. Using a mathematical prescription like one often used to map the whole Earth's surface onto a single flat image, the complete digital mosaic was distorted and projected onto an oval shape. The image is oriented so the plane of the Milky Way runs horizontally through the middle with the Galactic center at image center and Galactic north at the top. Most striking are the "milky" bands of starlight from the multitude of stars in the galactic plane cut by the dark, obscuring dust clouds strewn through the local spiral arms. Two fuzzy patches in the lower right quadrant of the mosaic correspond to external galaxies. Known as the Magellanic Clouds, these are small, nearby satellite galaxies of the Milky Way.

Credit & Copyright: Axel Mellinger axm@rz.uni-potsdam.de



This image shows the distribution of atomic hydrogen at all locations in the sky. All of this hydrogen is in our galaxy. Red indicates directions in which the density of hydrogen is high, blue and black show areas with little hydrogen. The figure is centered on the galactic center and galactic longitude increases to the left. The data came from measurements of the 21cm line of hydrogen by radio telescopes. Some of the hydrogen loops outline old supernova remnants. This image is a composite from many 21cm surveys. It includes data from the NRAO Green Bank, West Virginia, 140- foot and 300-foot telescopes, the 85-foot Hat Creek Telescope of the University of California at Berkeley, the AT&T Bell-Labs Horn-Reflector Telescope at Holmdel, New Jersey and the 60-foot Telescope at the Parkes Radio Observatory in Australia.

Image courtesy of NRAO/AUI.

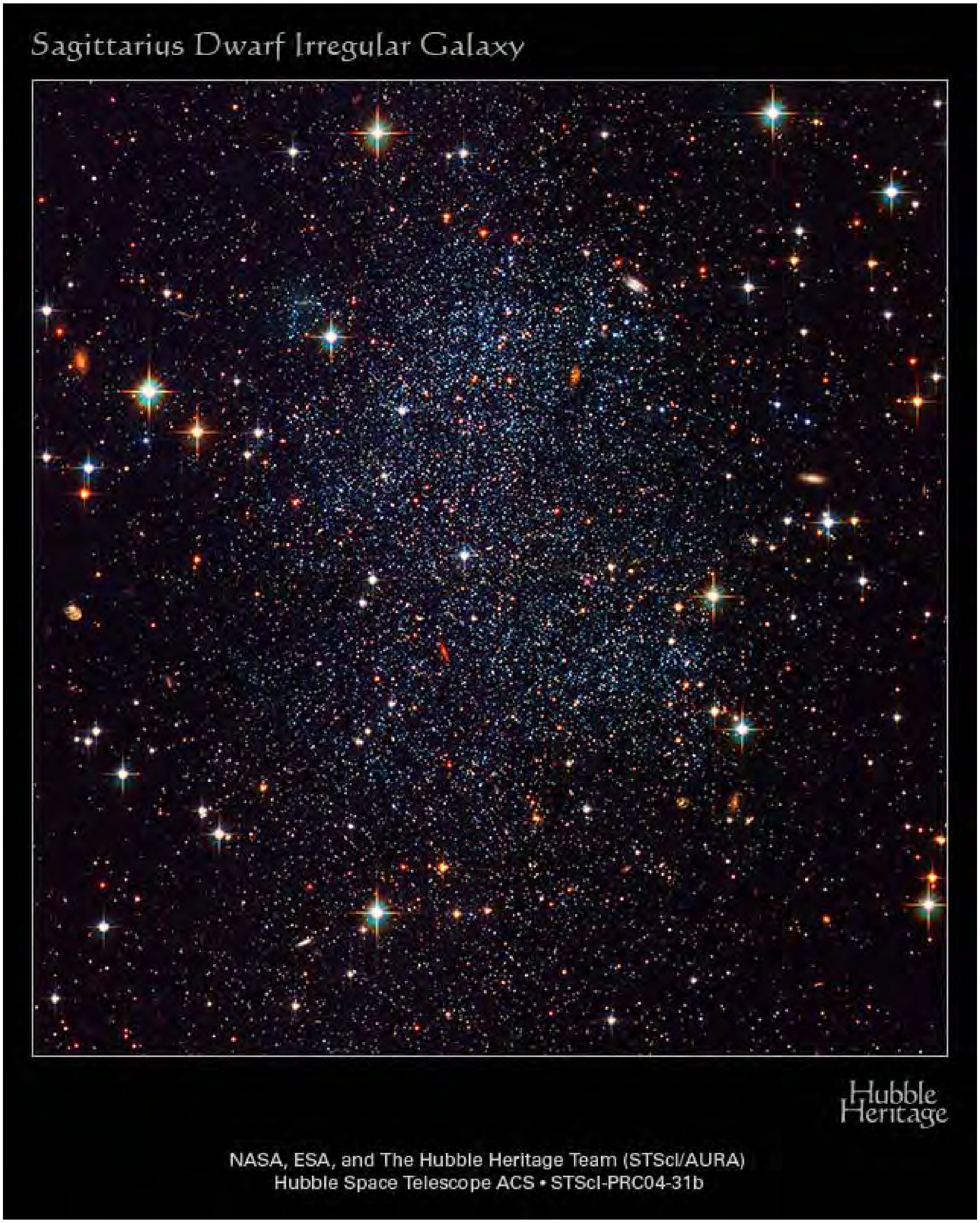
Barred Spiral Milky Way

A recent survey of stars conducted with the Spitzer Space Telescope is convincing astronomers that the Milky Way is not just an ordinary spiral galaxy. Looking out from within the Galaxy's disk, the true structure of the Milky Way is difficult to discern. However, the penetrating infrared census of about 30 million stars indicates that the Galaxy is distinguished by a very large central bar some 27,000 light-years long. From a vantage point that viewed our Galaxy face-on, astronomers in distant galaxies would likely see a striking barred spiral galaxy suggested in this artist's illustration. While previous investigations have identified a small central barred structure, the new results indicate that the Milky Way's large bar would make about a 45 degree angle with a line joining the Sun and the Galaxy's center. Astronomers place the Sun beyond the central bar region, about a third of the way in from the Milky Way's outer edge.

Illustration Credit: R. Hurt (SSC), JPL-Caltech, NASA Survey Credit: GLIMPSE Team

A cauldron of stars at the Galaxy's center. This dazzling infrared image from NASA's Spitzer Space Telescope shows hundreds of thousands of stars crowded into the swirling core of our spiral Milky Way. In visible-light pictures, this region cannot be seen at all because dust lying between Earth and the galactic center blocks our view. In this false-color picture, old and cool stars are blue, while dust features lit up by hot, massive stars are shown in a reddish hue. Both bright and dark filamentary clouds can be seen, many of which harbor stellar nurseries. The plane of the Milky Way's flat disk is apparent as the main, horizontal band of clouds. The brightest white spot in the middle is the very center of the Galaxy, which also marks the site of a supermassive black hole. The region pictured here is immense, with a horizontal span of 890 light-years and a vertical span of 640 light-years. Earth is located 26,000 light-years away, out in one of the Milky Way's spiral arms. Though most of the objects seen in this image are located at the galactic center, the features above and below the galactic plane tend to lie closer to Earth. Scientists are intrigued by the giant lobes of dust extending away from the plane of the Galaxy. They believe the lobes may have been formed by winds from massive stars. This image is a mosaic of thousands of short exposures taken by Spitzer's Infrared Array Camera (IRAC), showing emissions from wavelengths of 3.6 microns (blue), 4.5 microns (green), 5.8 microns (orange), and 8.0 microns (red). The entire region was imaged in less than 16 hours.

Image Credit: NASA/JPL-Caltech/S. Stolovy (Spitzer Science Center/ Caltech) http://gallery.spitzer.caltech.edu/Imagegallery/image.php?image_name=ssc2006-02a



This new image from the Hubble Space Telescope shows a small galaxy called the Sagittarius dwarf irregular galaxy, or "SagDIG" for short. SagDIG is relatively nearby, and Hubble's sharp vision is able to reveal many thousands of individual stars within the galaxy. The brightest stars in the picture (easily distinguished by the spikes radiating from their images, produced by optical effects within the telescope), are foreground stars lying within the Milky Way. Their distances from Earth are typically a few thousand light-years. By contrast, the numerous faint, bluish stars belong to SagDIG, which lies some 3.5 million light-years (1.1 Megaparsecs) from us. Lastly, background galaxies (reddish/brown extended objects with spiral arms and halos) are located even further beyond SagDIG at several tens of millions parsecs away. As their name implies, dwarf irregular galaxies are unlike their spiral and elliptical cousins, because of their much smaller physical size and lack of definite structure. Using Hubble, astronomers are able to resolve dwarf irregular galaxies that are at very large distances from Earth, into individual stars. By examining properties of the galaxy, such as distance, age and chemical composition, the star formation history of the whole galaxy is better understood, and reveals how, where, and when active star formation took place.

M101 (also nicknamed the Pinwheel Galaxy) lies in the northern circumpolar constellation, Ursa Major (The Great Bear), at a distance of 25 million light-years from Earth. Therefore, we are seeing the galaxy as it looked 25 million years ago — when the light we're receiving from it now was emitted by its stars — at the beginning of Earth's Miocene Period, when mammals flourished and the Mastodon first appeared on Earth. The galaxy fills a region in the sky equal to one-fifth the area of the full moon.

Galaxy NGC 474: Cosmic Blender

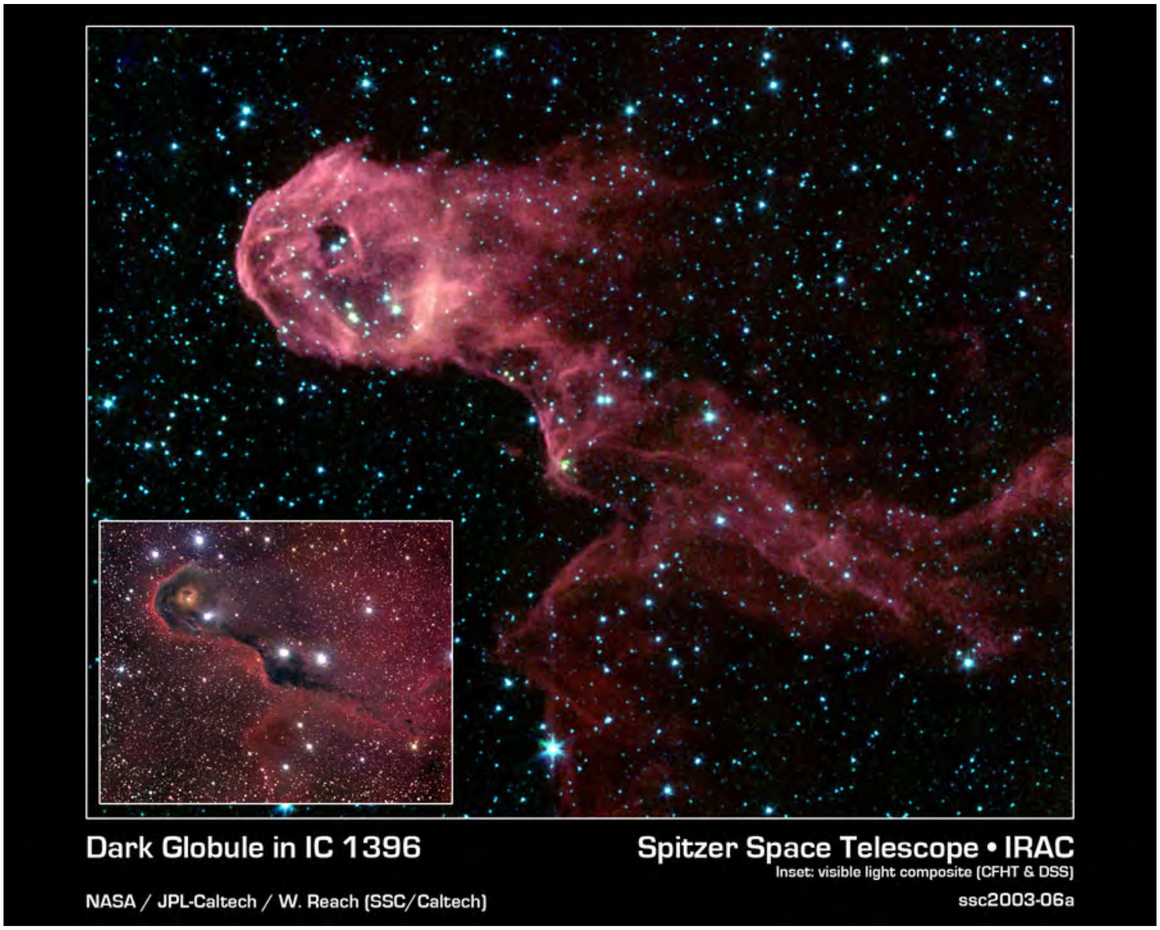
The multiple layers of emission by galaxy NGC 474 appear complex and unexpected given the relatively featureless appearance of the elliptical galaxy in less deep images. The cause of the shells is currently unknown, but possibly tidal tails related to debris left over from absorbing numerous small galaxies in the past billion years. Alternatively the shells may be like ripples in a pond, where the ongoing collision with the spiral galaxy to the right of NGC 474 is causing density waves to ripple though the galactic giant. Regardless of the actual cause, the above image dramatically highlights the increasing consensus that the outer halos of most large galaxies are not really smooth but have complexities induced by frequent interactions with -- and accretions of -- smaller nearby galaxies. The halo of the Milky Way is one example of such unexpected complexity. NGC 474 spans about 250,000 light years and lies about 100 million light years distant toward the constellation of the Fish Pisces.

Credit & Copyright: Mischa Schirmer http://www.astro.uni-bonn.de/~mischa/

Edge-On Galaxy NGC 5866

Why is this galaxy, NGC 5866, so thin? Many disk galaxies are actually just as thin as NGC 5866, but are not seen edge-on from our vantage point. One galaxy that is situated edge-on is the Milky Way. Classified as a lenticular galaxy, NGC 5866 has numerous and complex dust lanes appearing dark and red, while many of the bright stars in the disk give it a more blue underlying hue. The blue disk of young stars can be seen extending past the dust in the extremely thin galactic plane, while the bulge in the disk center appears tinged more orange from the older and redder stars that likely exist there. Although similar in mass to the Milky Way, light takes about 60,000 years to cross NGC 5866, about 30 percent less than light takes to cross our Galaxy. Galaxy NGC 5866 lies about 44 million light years distant toward the constellation of the Dragon (Draco).

Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA); Acknowledgment: W. Keel (U. Alabama)

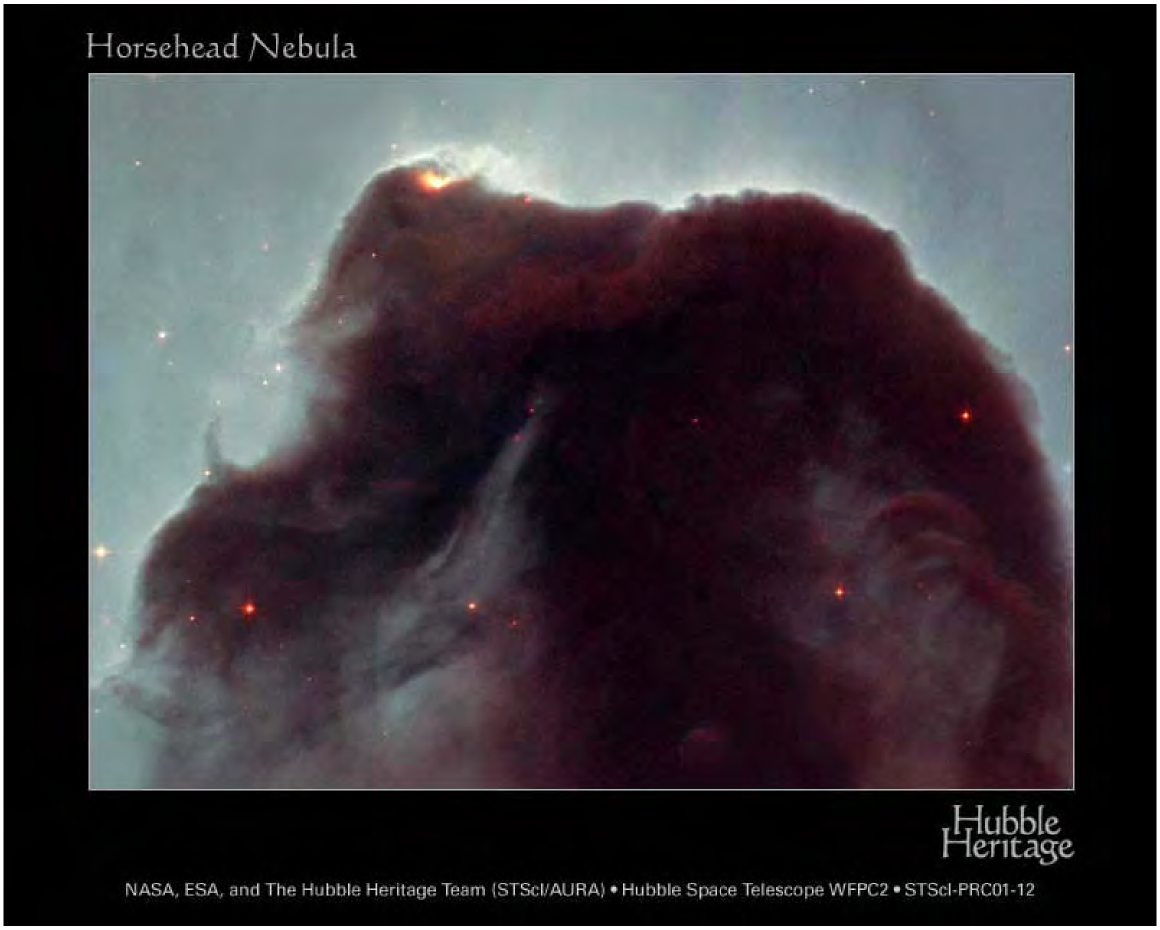


NASA's Spitzer Space Telescope image of a glowing stellar nursery provides a spectacular contrast to the opaque cloud seen in visible light. The Elephant's Trunk Nebula is an elongated dark globule within the emission nebula IC 1396 in the constellation of Cepheus. Located at a distance of 2,450 light-years, the globule is a condensation of dense gas that is barely surviving the strong ionizing radiation from a nearby massive star. The globule is being compressed by the surrounding ionized gas. The dark globule is seen in silhouette at visible-light wavelengths, backlit by the illumination of a bright star located to the left of the field of view. The Spitzer Space Telescope pierces through the obscuration to reveal the birth of new protostars, or embryonic stars, and previously unseen young stars. The infrared image, which transforms the dark cloud into a 'flying dragon,' was obtained by Spitzer's infrared array camera. The image is a four-color composite of invisible light, showing emissions from wavelengths of 3.6 microns (blue), 4.5 microns (green), 5.8 microns (orange) and 8.0 microns (red). The filamentary appearance of the globule results from the sculpting effects of competing physical processes. The winds from a massive star, located to the left of the image, produce a dense circular rim comprising the 'head' of the globule and a swept-back tail of gas. A pair of young stars (LkHa 349 and LkHa 349c) that formed from the dense gas has cleared a spherical cavity within the globule head. While one of these stars is significantly fainter than the other in the visible-light image, they are of comparable brightness in the infrared Spitzer image. This implies the presence of a thick and dusty disc around LkHa 349c. Such circumstellar discs are the precursors of planetary systems. They are much thicker in the early stages of stellar formation when the placental planet-forming material (gas and dust) is still present.

NASA/JPL-Caltech/W. Reach (SSC/Caltech)____Dark Globule in IC 1396

This infrared image from NASA's Spitzer Space Telescope shows the Rosette nebula, a star-forming region more than 5,000 light-years away in the constellation Monoceros. In optical light, the nebula looks like a rosebud, or the "rosette" adornments that date back to antiquity. But lurking inside this delicate cosmic rosebud are so-called planetary "danger zones" (the five spheres). These zones surround super hot stars, called O-stars (blue stars inside the spheres), which give off intense winds and radiation. Young, cooler stars that just happen to reside within one of these zones are in danger of having their dusty planet-forming materials stripped away. Radiation and winds from the super hot stars have collectively blown layers of dust (green) and gas away, revealing the cavity of cooler dust (red). The largest two blue stars in this picture are in the foreground, and not in the nebula itself. While O-star danger zones were known about before, their parameters were not. Astronomers used Spitzer's infrared vision to survey the extent of the five danger zones shown here. The results showed that young stars lying beyond 1.6 light-years, or 10 trillion miles, of any O-stars are safe, while young stars within this zone are likely to have their potential planets blasted into space.

NASA/JPL-Caltech/Z. Balog (Univ. of Ariz./Univ. of Szeged)



The Horsehead, also known as Barnard 33, is a cold, dark cloud of gas and dust, silhouetted against the bright nebula, IC 434. The bright area at the top left edge is a young star still embedded in its nursery of gas and dust, but radiation from this hot star is eroding the stellar nursery. The top of the nebula also is being sculpted by radiation from a massive star located out of Hubble's field of view.

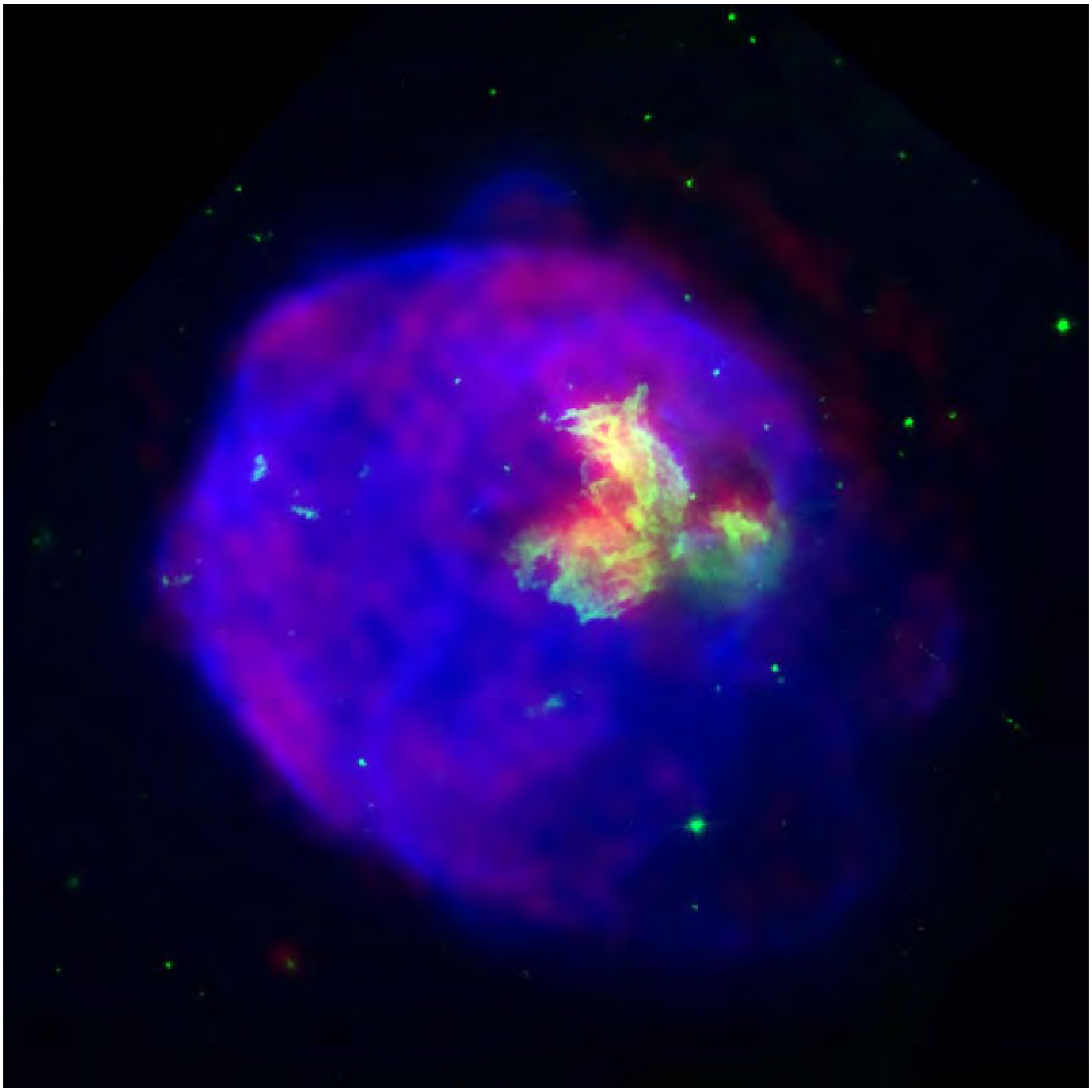
Credit: NASA, NOAO, ESA and The Hubble Heritage Team (STScI/AURA)

Cygnus Loop

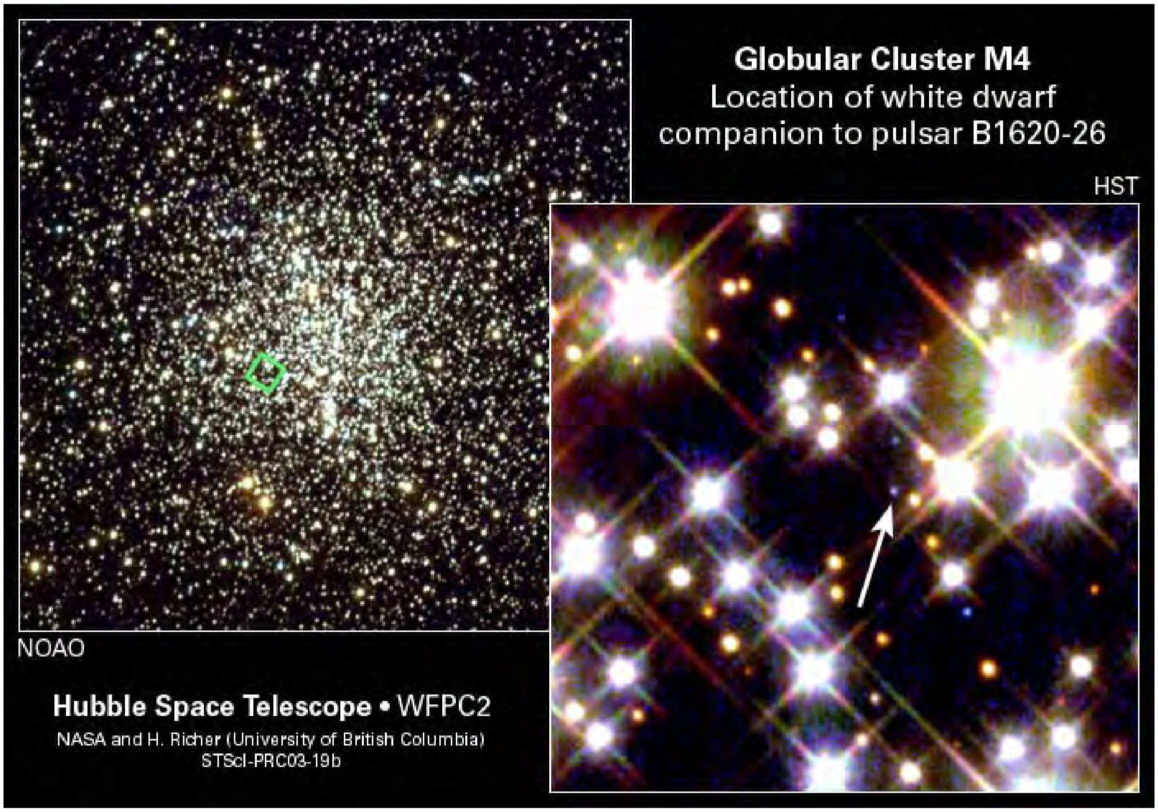
This is an image of a small portion of the Cygnus Loop supernova remnant, taken with the Wide Field and Planetary Camera on NASA's Hubble Space Telescope on April 24, 1991. The Cygnus Loop marks the edge of a bubble-like, expanding blast wave from a colossal stellar explosion which occurred about 15,000 years ago. The HST image shows the structure behind the shock waves in the Cygnus Loop with unprecedented clarity. This is allowing astronomers, for the first time, to compare directly the actual structure of the shock with theoretical model calculations. The supernova blast wave is slamming into tenuous clouds of interstellar gas. This collision heats and compresses the gas, causing it to glow. The shock acts as a searchlight by revealing the structure of the interstellar medium. Hubble's detailed image shows the blast wave overrunning dense clumps of gas. Though HST can reveal details about as small as our Solar System, the clumps are still unresolvable. This means that they must be small enough to fit inside our Solar System, making them relatively small structures by interstellar standards. A bluish ribbon of light stretching left to right across the picture might be a knot of gas ejected by the supernoya. This interstellar "bullet," traveling over three million miles per hour (5 million km/h), is just catching up with the shock front (which has been slowed by plowing into interstellar material). The Cygnus Loop appears as a faint ring of glowing gases about three degrees across (six times the diameter of the Full Moon), located in the northern constellation Cygnus the Swan. The supernova remnant is within the plane of our Milky Way Galaxy and is 2,600 light-years away.

A violent and chaotic-looking mass of gas and dust is seen in this Hubble Space Telescope image of a nearby supernova remnant. Denoted N 63A, the object is the remains of a massive star that exploded, spewing its gaseous layers out into an already turbulent region. The supernova remnant is a member of N 63, a star-forming region in the Large Magellanic Cloud (LMC). Visible from the southern hemisphere, the LMC is an irregular galaxy lying 160,000 light-years from our own Milky Way galaxy. The LMC provides excellent examples of active star formation and supernova remnants to be studied with Hubble. Many of the stars in the immediate vicinity of N 63A are extremely massive. It is estimated that the progenitor of the supernova that produced the remnant seen here was about 50 times more massive than our own Sun. Such a massive star has strong stellar winds that can clear away its ambient medium, forming a wind-blown bubble. The supernova that formed N 63A is thought to have exploded inside the central cavity of such a wind-blown bubble, which was itself embedded in a clumpy portion of the LMC's interstellar medium. Images in the infrared, X-ray, and radio emission of this supernova remnant show the much more expanded bubble that totally encompasses the optical emission seen by Hubble. Odd-shaped mini-clouds or cloudlets that were too dense for the stellar wind to clear away are now engulfed in the bubble interior. The supernova generated a propagating shock wave that continues to move rapidly through the low-density bubble interior, and shocks these cloudlets, shredding them fiercely. Supernova remnants have long been thought to set off episodes of star formation when their expanding shock encounters nearby gas. As the Hubble images have illustrated, N 63A is still young and its ruthless shocks destroy the ambient gas clouds, rather than coercing them to collapse and form stars. Data obtained at various wavelengths from other detectors reveal on-going formation of stars at 10 to 15 light-years from N 63A. In a few million years, the supernova ejecta from N 63A would reach this star-formation site and may be incorporated into the formation of planets around solar-type stars there, much like the early history of the solar system.

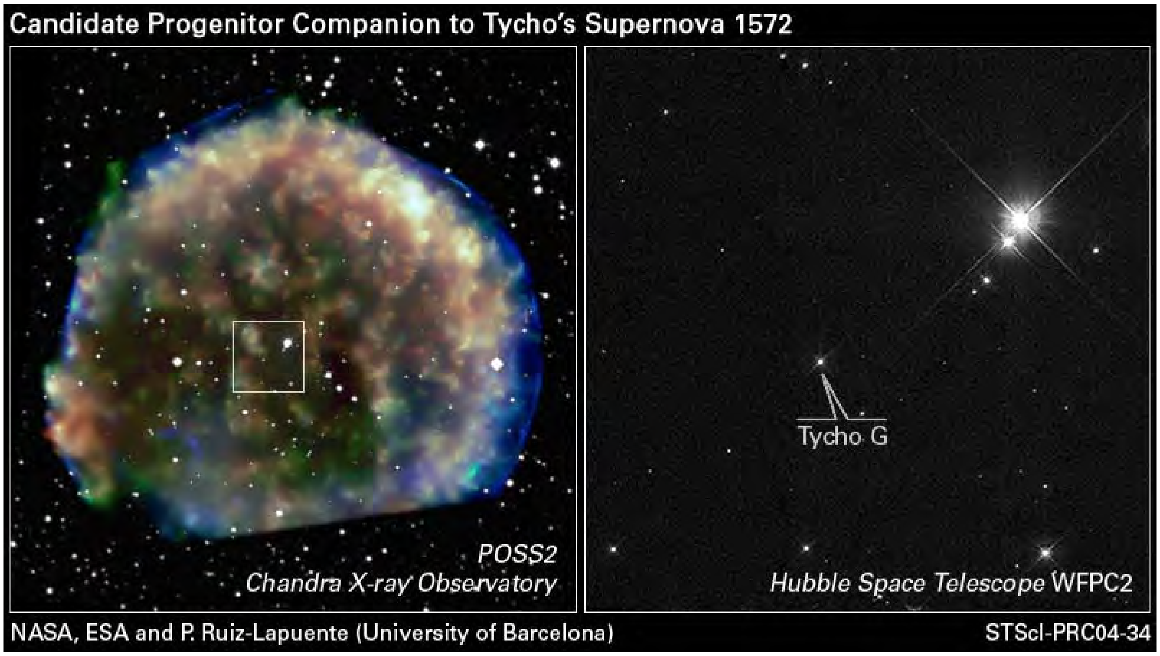
A new image taken with NASA's Hubble Space Telescope provides a detailed look at the tattered remains of a supernova explosion known as Cassiopeia A (Cas A). It is the youngest known remnant from a supernova explosion in the Milky Way. The new Hubble image shows the complex and intricate structure of the star's shattered fragments. The image is a composite made from 18 separate images taken in December 2004 using Hubble's Advanced Camera for Surveys (ACS), and it shows the Cas A remnant as a broken ring of bright filamentary and clumpy stellar ejecta. These huge swirls of debris glow with the heat generated by the passage of a shockwave from the supernova blast. The various colors of the gaseous shards indicate differences in chemical composition. Bright green filaments are rich in oxygen, red and purple are sulfur, and blue are composed mostly of hydrogen and nitrogen. A supernova such as the one that resulted in Cas A is the explosive demise of a massive star that collapses under the weight of its own gravity. The collapsed star then blows its outer layers into space in an explosion that can briefly outshine its entire parent galaxy. Cas A is relatively young, estimated to be only about 340 years old. Hubble has observed it on several occasions to look for changes in the rapidly expanding filaments. In the latest observing campaign, two sets of images were taken, separated by nine months. Even in that short time, Hubble's razor-sharp images can observe the expansion of the remnant. Comparison of the two image sets shows that a faint stream of debris seen along the upper left side of the remnant is moving with high speed - up to 31 million miles per hour (fast enough to travel from Earth to the Moon in 30 seconds!). Cas A is located ten thousand light-years away from Earth in the constellation of Cassiopeia. Supernova explosions are the main source of elements more complex than oxygen, which are forged in the extreme conditions produced in these events.



The Chandra x-ray camera has imaged the glowing shell created by the destruction of a massive star. X-rays from Chandra (blue), combined with optical (green) and radio (red) data, reveal new details in the supernova remnant, LMC N 63A. The x-ray glow is from material heated to about ten million degrees Celsius by a shock wave generated by the supernova explosion. The age of the remnant is estimated to be in the range of 2,000 to 5,000 years.



Three unlikely companions - two burned-out stars and a planet - orbit each other near the crowded core of an ancient globular cluster of more than 100,000 stars. Only one companion, however, is visible in the images. In the image at right, taken by NASA's Hubble Space Telescope, the white arrow points to a burned-out white dwarf star. Radio astronomers discovered the white dwarf and the other burned-out star - a rapidly spinning neutron star, called a pulsar - a decade ago. The third companion's identity was then a mystery. Was it a planet or a brown dwarf? The object was too small and too dim to image. Hubble observations of the dim white dwarf helped astronomers to precisely measure the mass of the mystery object (2.5 times larger than the mass of Jupiter), confirming that it is a planet. In fact, it is the farthest and oldest known planet. Hubble's Wide Field and Planetary Camera 2 resolved individual stars near M4's densely packed core [right] and pinpointed the white dwarf. The image at left, taken by the National Optical Astronomy Observatory, shows the companions' home, a 13-billion-year-old cluster called M4. The green box marks the location of Hubble's close-up view. The Hubble observations of the white dwarf held the key to discovering the identity of the third companion. Astronomers used Hubble to measure the white dwarf's color and temperature. By knowing those physical properties, astronomers then calculated the white dwarf's age and mass. They then compared that information to the amount of wobble in the pulsar signal, which allowed astronomers to calculate the tilt of the white dwarf's orbit as seen from Earth. That critical piece of evidence, when combined with the radio studies of the wobbling pulsar, allowed astronomers to determine the tilt of the planet's orbit and subsequently its mass. The cluster is located 5,600 light-years away in the summer constellation Scorpius. The Hubble image was taken in April 1996.



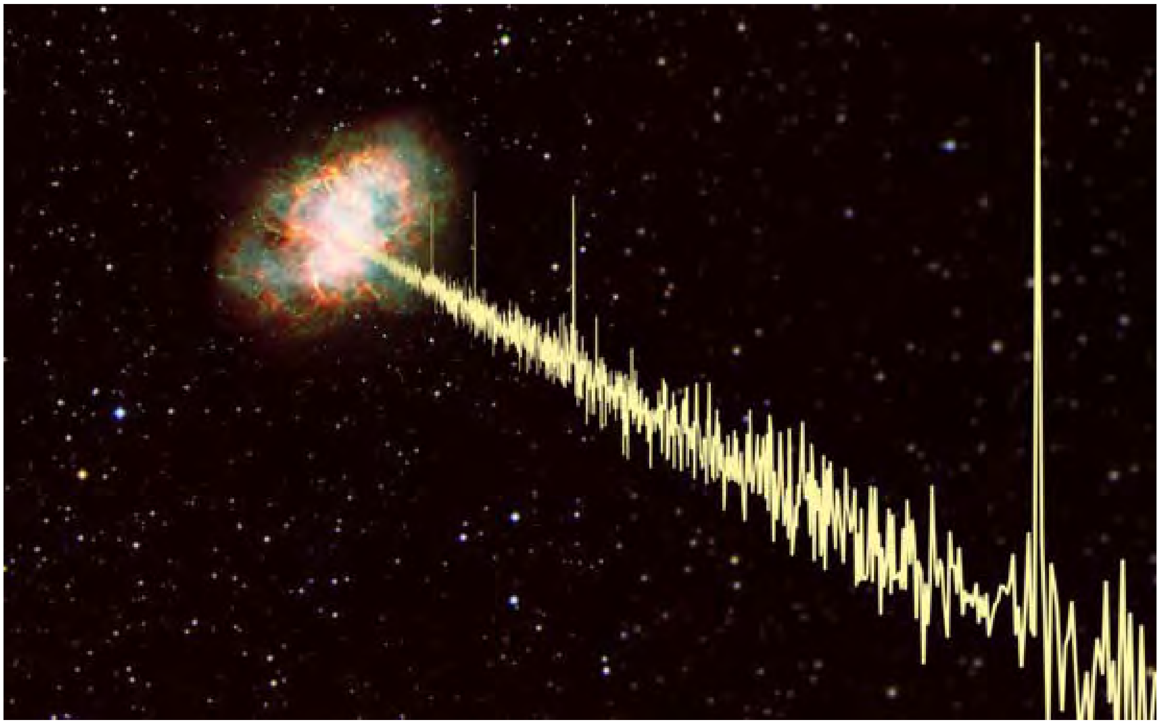
These images show the location of a suspected runaway companion star to a titanic supernova explosion witnessed in the year 1572 by the great Danish astronomer Tycho Brahe and other astronomers of that era. This discovery provides the first direct evidence supporting the long-held belief that Type Ia supernovae come from binary star systems containing a normal star and a burned-out white dwarf star. When the dwarf ultimately explodes by being overfueled by the companion star, the companion is slung away from the demised star. The Hubble Space Telescope played a key role by precisely measuring the surviving star's motion against the sky background.

[Right Image] A Hubble Space Telescope Wide Field Planetary Camera-2 image of a small section of sky containing the candidate star. The star is like our Sun except several billion years older. It is moving through space at three times the speed of the other stars in its neighborhood. Hubble's sharp view allowed for a measurement of the star's motion, based on images taken in 1999 and 2003.

[Left Image] The Hubble view is superimposed on this wide-field view of the region enveloped by the expanding bubble of the supernova explosion; the bubble and candidate star are at approximately the same distance, 10,000 light-years. The star is noticeably offset from the geometric center of the bubble. The colors in the Chandra X-ray image of the hot bubble show different X-ray energies, with red, green, and blue representing low, medium, and high energies, respectively. (The image is cut off at the bottom because the southernmost region of the remnant fell outside the field of view of the Chandra camera.)

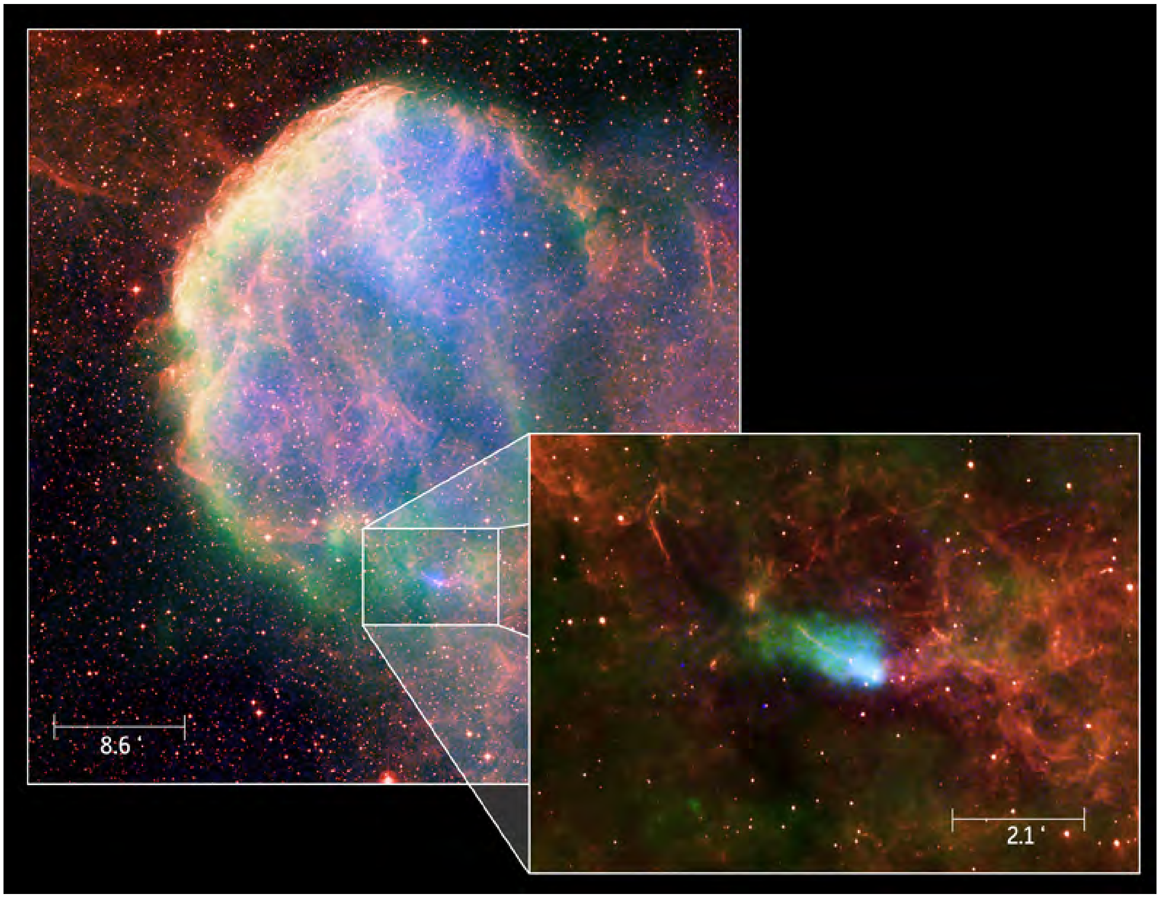
Inset of left image

This picture is an artist's impression showing how the binary star system of Sirius A and its diminutive blue companion, Sirius B, might appear to an interstellar visitor. The large, bluish-white star Sirius A dominates the scene, while Sirius B is the small but very hot and blue white-dwarf star on the right. The two stars revolve around each other every 50 years. White dwarfs are the leftover remnants of stars similar to our Sun. The Sirius system, only 8.6 light-years from Earth, is the fifth closest stellar system known. Sirius B is faint because of its tiny size. Its diameter is only 7,500 miles, slightly smaller than the size of our Earth. The Sirius system is so close to Earth that most of the familiar constellations would have nearly the same appearance as in our own sky. In this rendition, we see in the background the three bright stars that make up the Summer Triangle: Altair, Deneb, and Vega. Altair is the white dot above Sirius A; Deneb is the dot to the upper right; and Vega lies below Sirius B. But there is one unfamiliar addition to the constellations: our own Sun is the second-magnitude star, shown as a small dot just below and to the right of Sirius A. Sirius A is the only star other than the Sun whose surface has been imaged by telescopes.



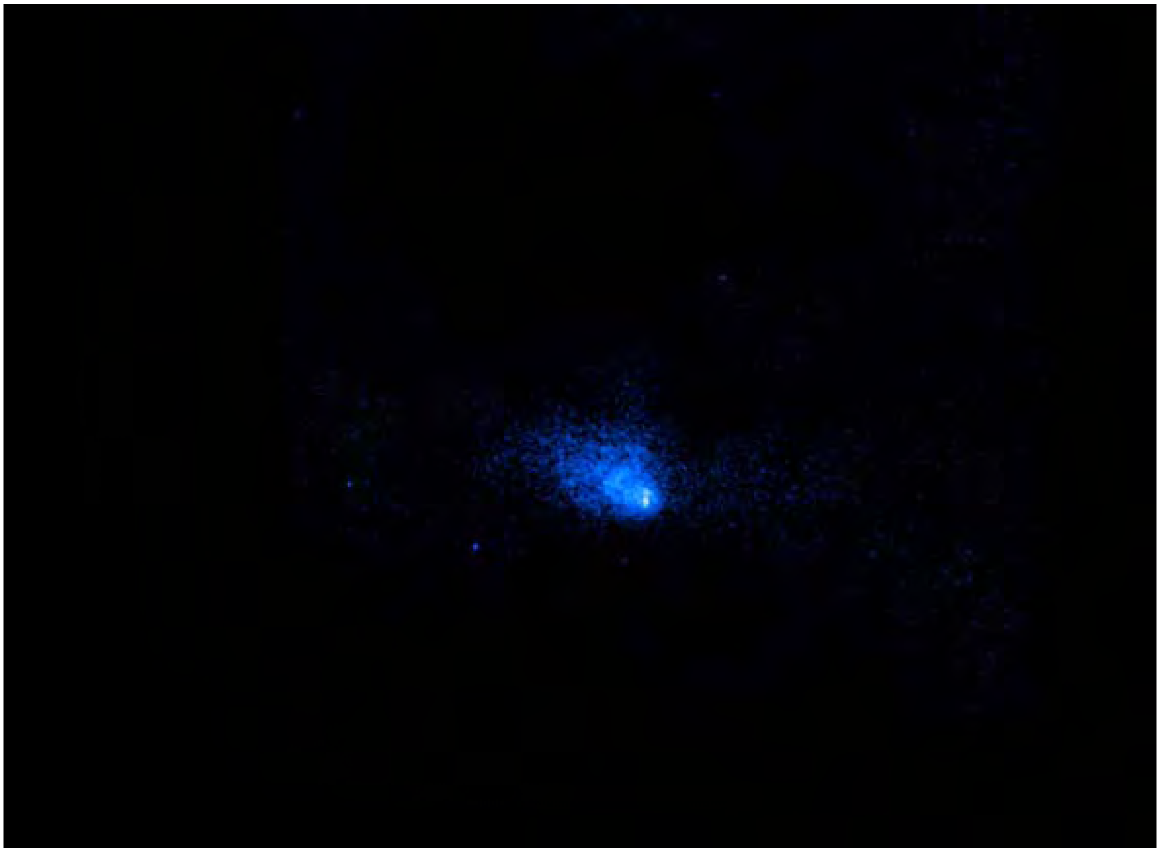
The Crab Pulsar and the Crab Nebula are an impressive pair, especially in this unique image made by a duo of NRAO radio telescopes. The Nebula was formed when the original star exploded: this 'supernova' explosion was so bright that in 1054 A.D it was visible in the daytime for several weeks. In the centuries that followed the remnant has kept expanding. Then, in 1968, another product of the supernova was found, an object that turned out to be the engine powering the bright remnant: the Crab Pulsar. As the outer layers of the original star were ejected in the supernova, the entire core must have collapsed to form a pulsing neutron star or 'pulsar', one of the densest objects in the entire Galaxy. Only 10 miles across but 500.000 times as massive as the Earth, this cosmic lighthouse spins 30 times each second, sweeping around bundles of bright radio waves. In this image we see a 1-second snapshot of these peaked waves as they reach the NRAO Green Bank Telescope after 6000 years of interstellar travel. In the background the still expanding Nebula shines on, with a red glow captured by the NRAO Very Large Array and blue and green light seen by ESO's VLT.

lo Image courtesy of NRAO/AUI and Joeri van Leeuwen (UC Berkeley) / ESO / AURA.



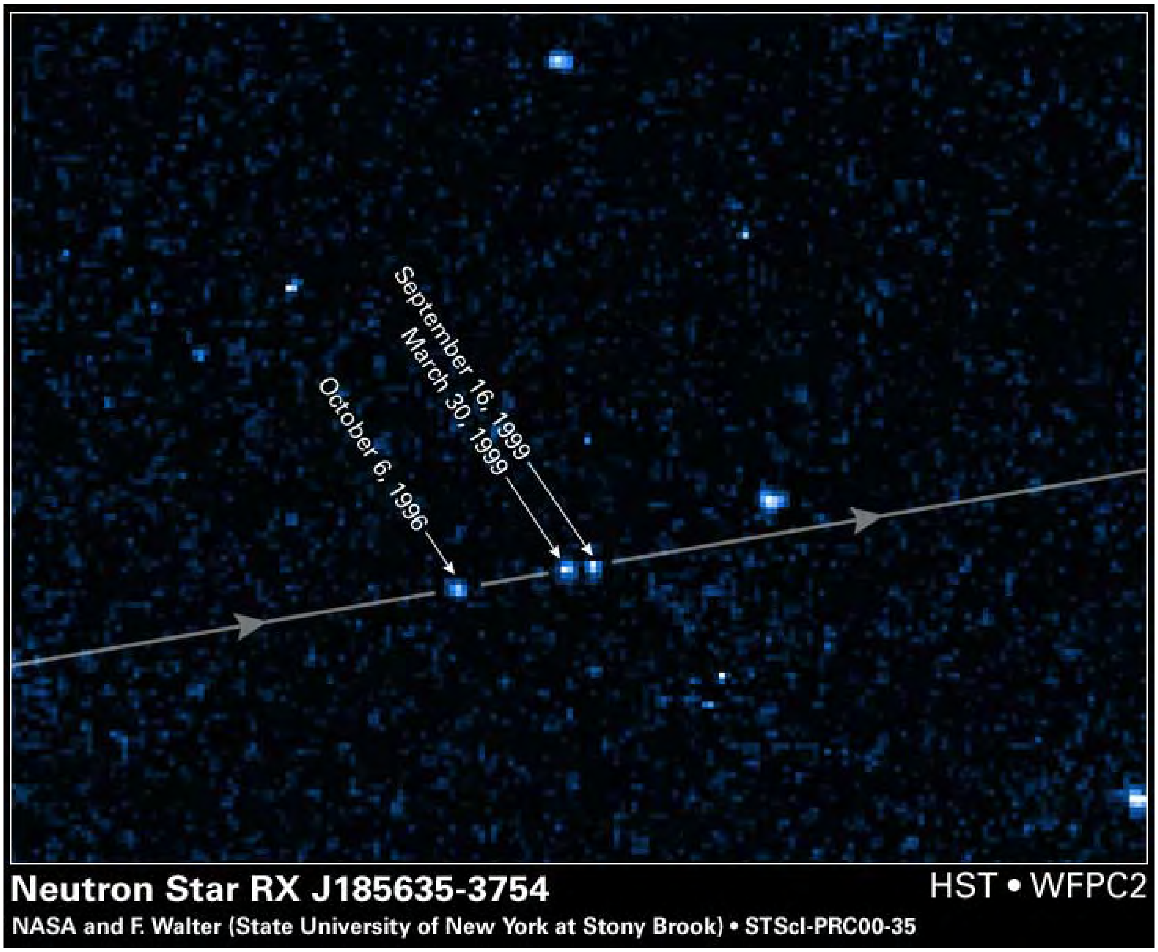
This wide-field composite image was made with x ray (blue/ROSAT & Chandra), radio (green/Very Large Array), and optical (red/Digitized Sky Survey) observations of the supernova remnant, IC 443. The pullout, also a composite with a Chandra X-ray close-up, shows a neutron star that is spewing out a comet-like wake of high-energy particles as it races through space. Based on an analysis of the swept-back shape of the wake, astronomers deduced that the neutron star known as CXOU J061705.3+222127, or J0617 for short, is moving through the multimillion degree Celsius gas in the remnant. However, this conclusion poses a mystery. Although there are other examples where neutron stars have been located far away from the center of the supernova remnant, these neutron stars appear to be moving radially away from the center of the remnant. In contrast, the wake of J0617 seems to indicate it is moving almost perpendicularly to that direction. One possible explanation is that the doomed progenitor star was moving at a high speed before it exploded, so that the explosion site was not at the observed center of the supernova remnant. Fast-moving gusts of gas inside the supernova remnant may have further pushed the pulsar's wake out of alignment. An analogous situation is observed for comets, where a wind of particles from the Sun pushes the comet tail away from the Sun, out of alignment with the comet's motion. If this is what is happening, then observations of the neutron star with Chandra in the next 10 years should show a detectable motion away from the center of the supernova remnant.

Credit: Chandra X-ray: NASA/CXC/B.Gaensler et al; ROSAT X-ray: NASA/ROSAT/Asaoka & Aschenbach; Radio Wide: NRC/DRAO/D.Leahy; Radio Detail: NRAO/VLA; Optical: DSS

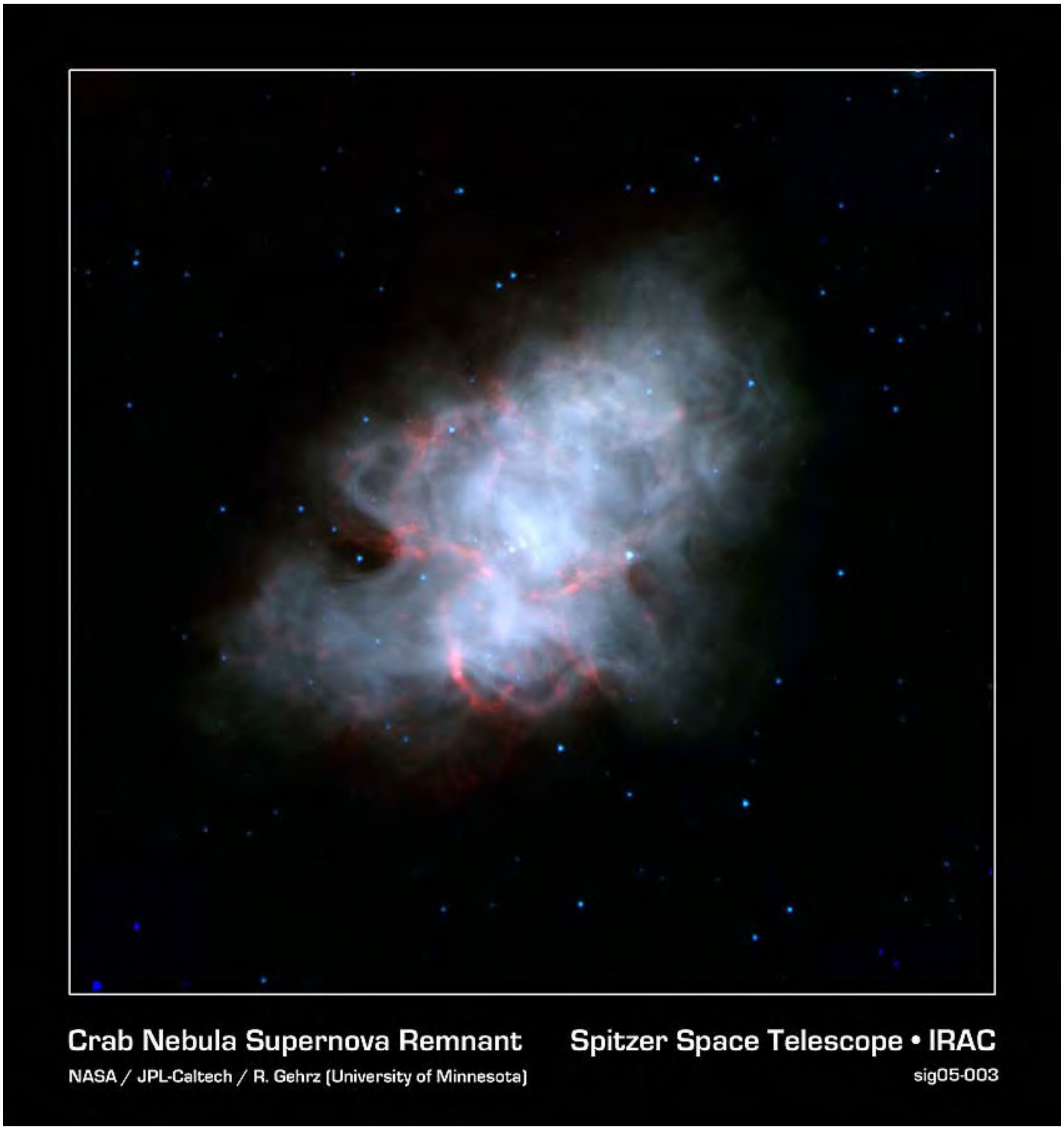


A long observation with NASA's Chandra X-ray Observatory has revealed important new details of a neutron star that is spewing out a wake of high-energy particles as it races through space. The deduced location of the neutron star -- known as J0617 -- on the edge of a supernova remnant and the peculiar orientation of the neutron star's wake pose mysteries that remain unresolved.

xray Chandra X-ray Image of J0617 in IC 443



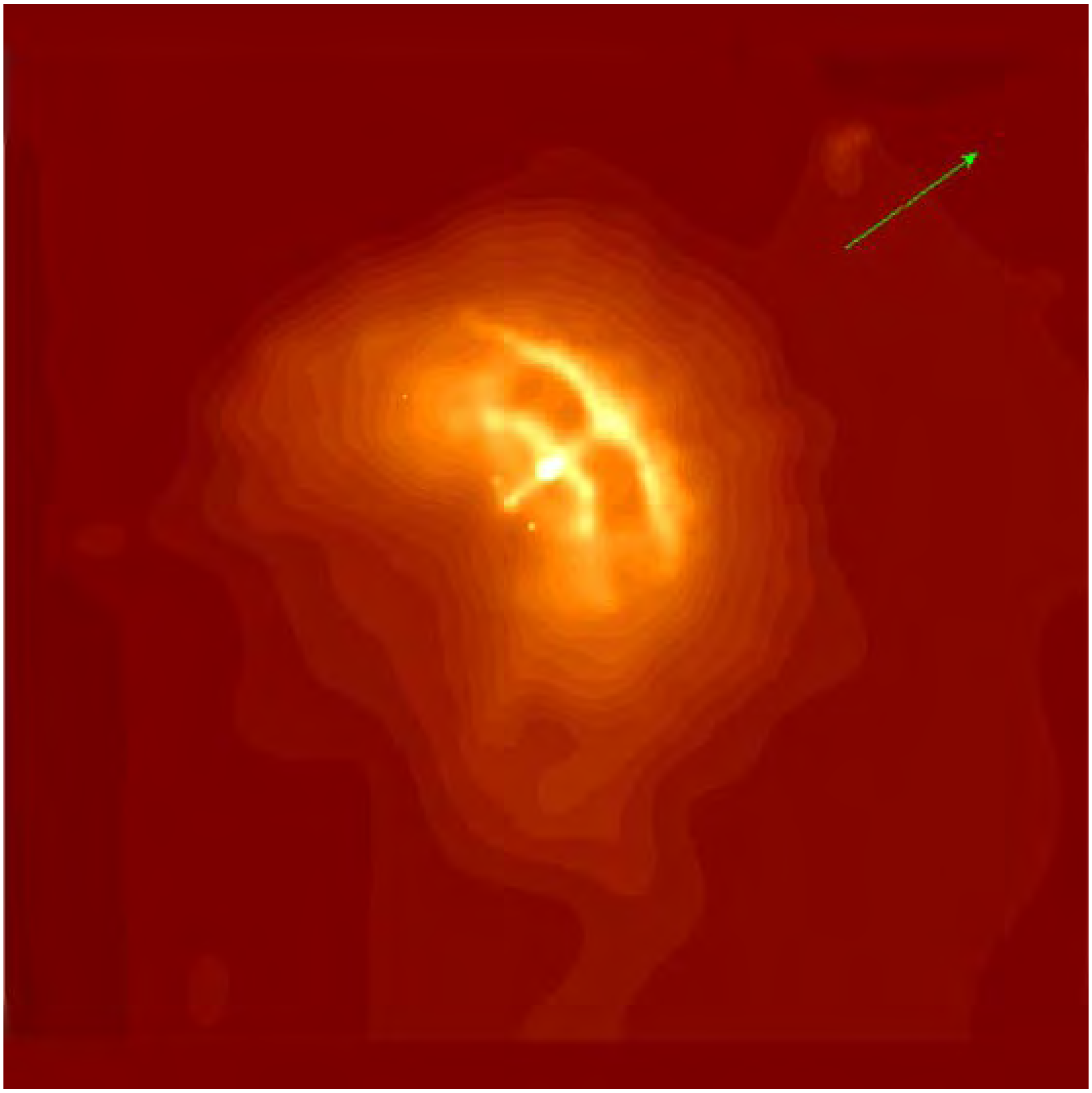
This photograph is the sum of three Hubble Space Telescope images. North is down, east is to the right. The image, taken by the Wide Field and Planetary Camera 2, is 8.8 arc seconds across (west to east), and 6.6 arc seconds top-to-bottom (south to north). (The arc second is a unit of angular measure. There are 3,600 arc seconds in 1 degree and 360 degrees in a full circle.) All stars line up in this composite picture, except the neutron star, which moves across the image in a direction 10 degrees south of east. The three images of the neutron star are labeled by date. The proper motion is 1/3 of an arc second per year. The small wobble caused by parallax (not visible in the image) is 0.016 arc seconds, giving a distance of 200 light-years.



Crab Nebula Supernova Remnant (IRAC Image). The Crab Nebula is the shattered remnant of a massive star that ended its life in a massive supernova explosion. Nearly a thousand years old, the supernova was noted in the constellation of Taurus by Chinese astronomers in the year 1054 AD. This view of the supernova remnant obtained by the Spitzer Space Telescope shows the infrared view of this complex object. The blue-white region traces the cloud of energetic electrons trapped within the star's magnetic field, emitting so-called "synchrotron" radiation. The red features follow the well-known filamentary structures that permeate this nebula. Though they are known to contain hot gasses, their exact nature is still a mystery that astronomers are examining. The energetic cloud of electrons are driven by a rapidly rotating neutron star, or pulsar, at its core. The nebula is about 6,500 light-years away from the Earth, and is 5 light-years across.

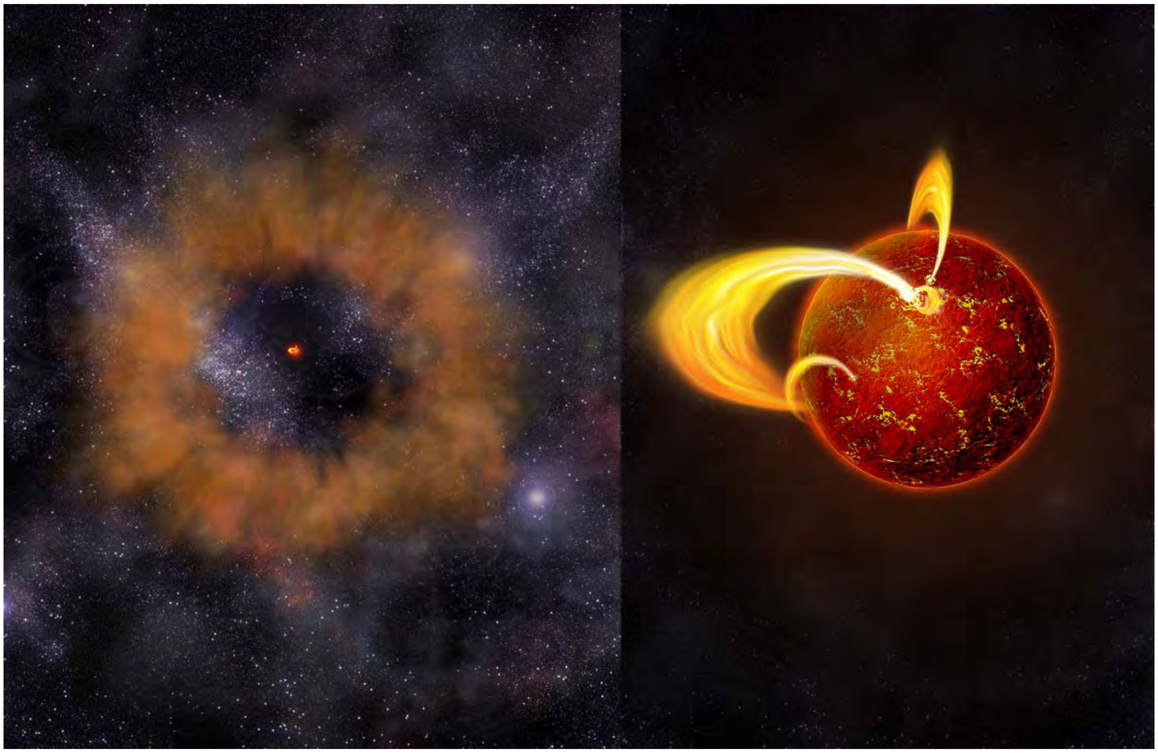
NASA/JPL-Caltech/R. Gehrz (University of Minnesota)

A composite image of the Crab Nebula showing the x ray (blue), and optical (red) images superimposed. The size of the x ray image is smaller because the higher energy x ray emitting electrons radiate away their energy more quickly than the lower energy optically emitting electrons as they move.



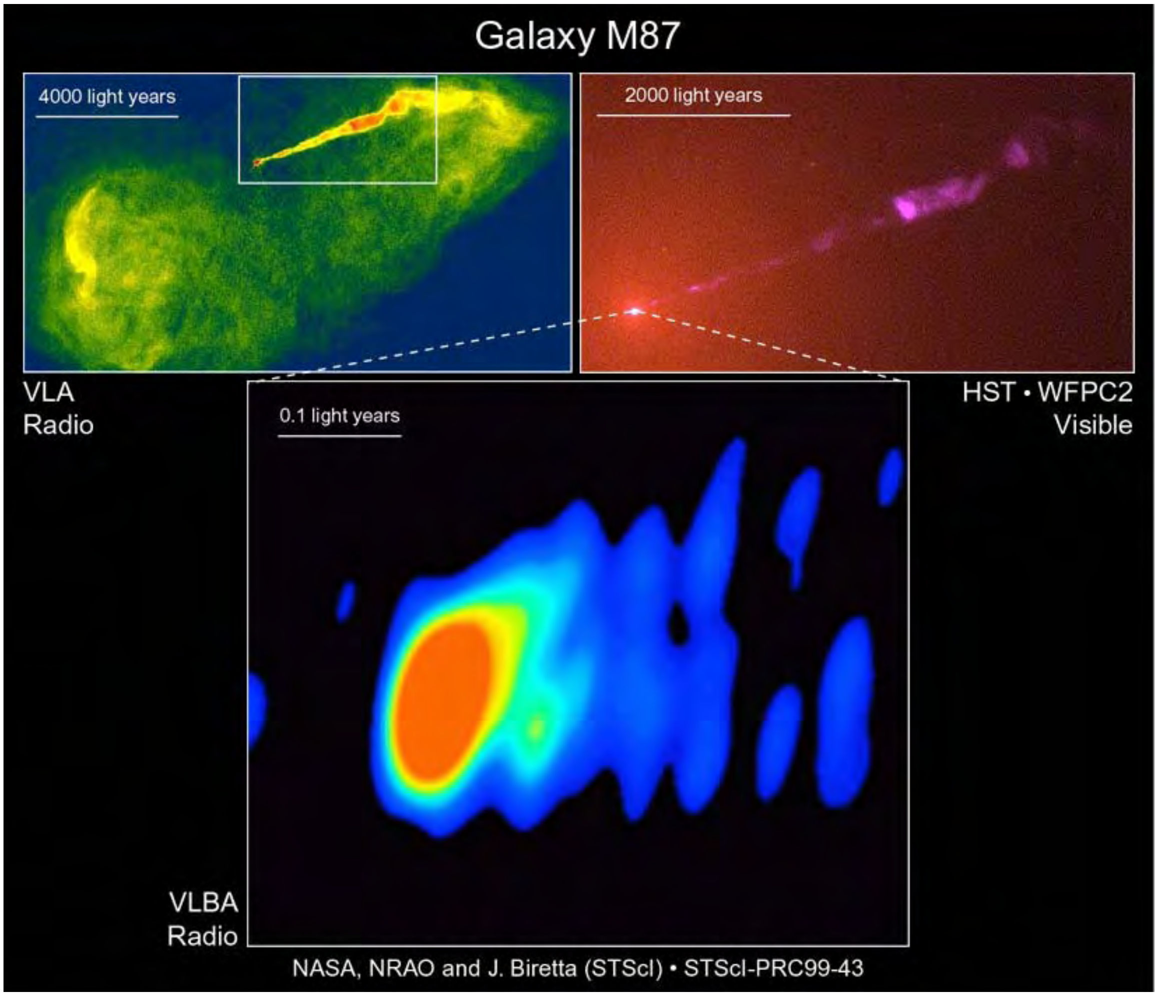
Chandra image of compact nebula around Vela pulsar. The image shows a dramatic bow-like structure at the leading edge of the cloud, or nebula, embedded in the Vela supernova remnant. This bow and the smaller one inside it, are thought to be the near edges of tilted rings of x-ray emission from high-energy particles produced by the central neutron star. Perpendicular to the bows are jets that emanate from the central pulsar, or neutron star. As indicated by the green arrow, the jets point in the same direction as the motion of the pulsar. The swept back appearance of the nebula is due to the motion of the pulsar through the supernova remnant. The rings are thought to represent shock waves due to matter rushing away from the neutron star. More focused flows at the neutron star's polar regions produce the jets. The origin of this activity is thought to be enormous electric fields caused by the combination of the rapid rotation and intense magnetic fields of the neutron star.

xray Credit: NASA/PSU/G.Pavlov et al.



Magnetars are neutron stars with magnetic fields that are about a quadrillion times greater than the magnetic field of Earth. These awesome magnetic fields are thought to be produced when an extremely rapidly rotating neutron star is formed by the collapse of the core of a massive star. When a neutron star forms, it triggers a supernova explosion that expels the outer layers of the star at high speeds. The high rate of the rotation of the neutron star intensifies the already superstrong magnetic field to magnetar levels. When the magnetic forces get strong enough, they may cause starquakes on the surface of the neutron star that produce powerful outbursts of x rays called x-ray flashes. These events may represent an intermediate type of supernova explosion - more energetic than ordinary supernovae, but less so than hypernovae, thought to be responsible for gamma ray bursts. Magnetar outbursts can also occur for hundreds of years after the initial explosion. The strongest steady magnetic field produced on Earth in a lab is about a million times greater than the Earth's magnetic field. Beyond this limit ordinary magnetic material would be blown apart by magnetic forces. Only on a neutron star, where gravity is more than 100 billion times as great as on Earth, can matter withstand the magnetic forces of a magnetar, and even there the neutron star's crust can break apart under the strain.

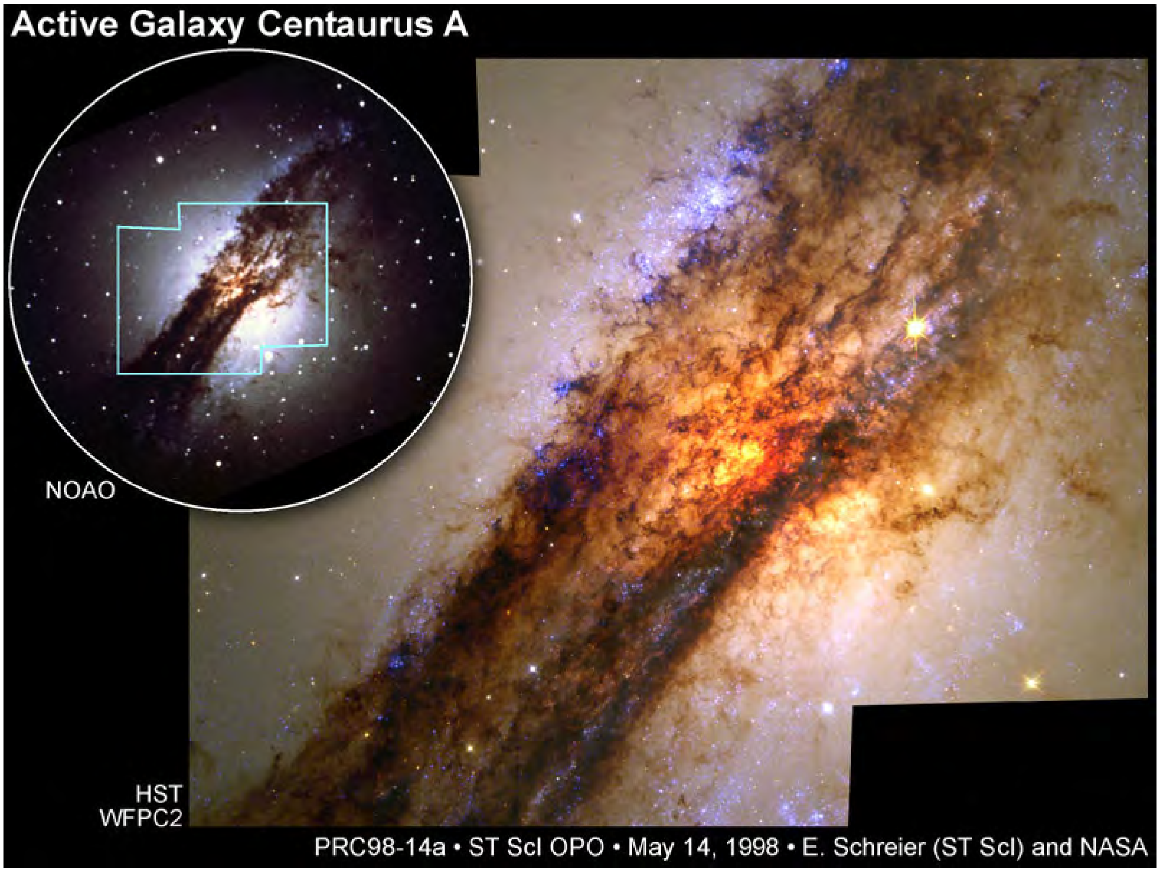
NASA/CXC/M.Weiss)



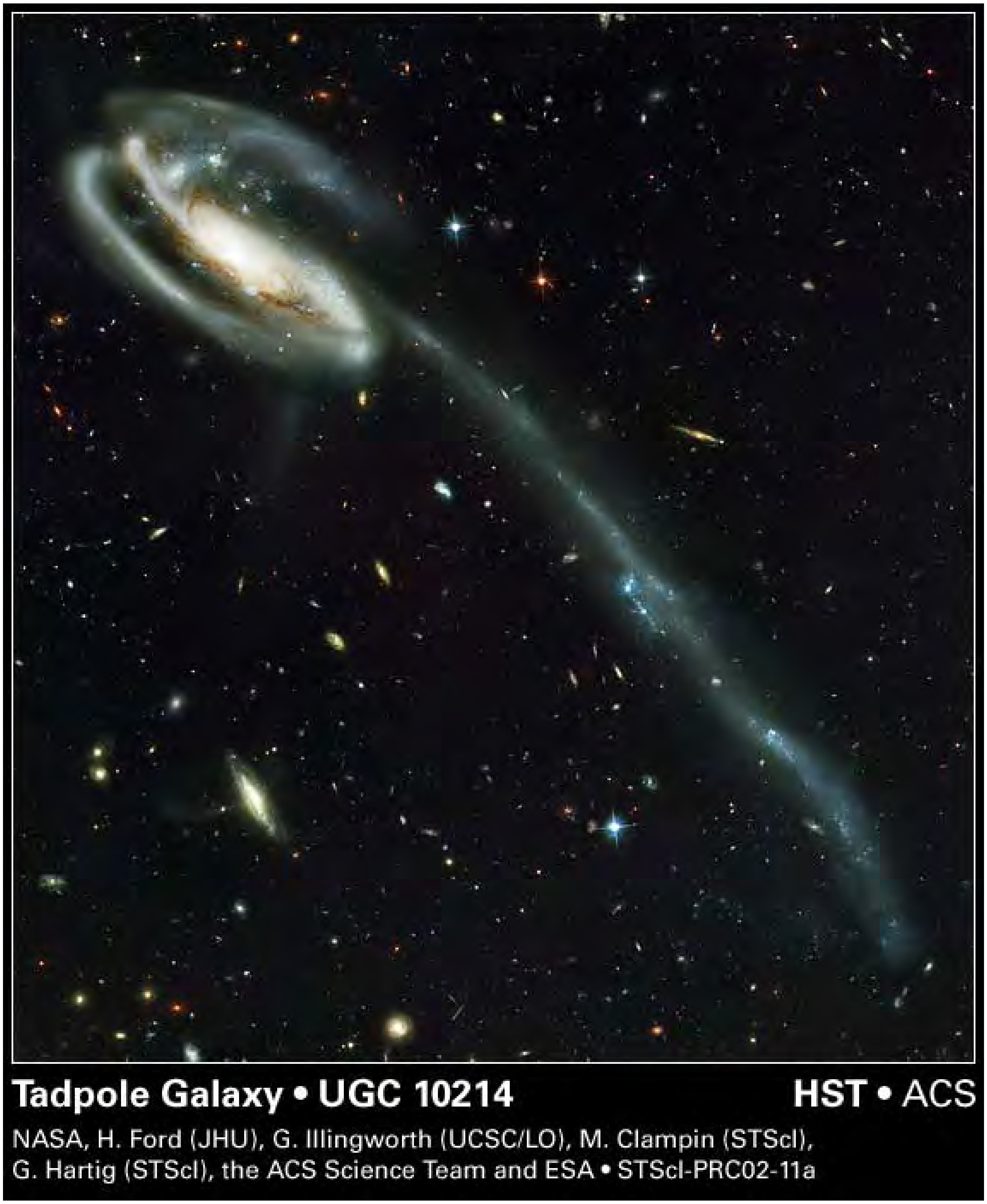
[top left] -This radio image of the galaxy M87, taken with the Very Large Array (VLA) radio telescope in February 1989, shows giant bubble-like structures where radio emission is thought to be powered by the jets of subatomic particles coming from the galaxy's central black hole. The false color corresponds to the intensity of the radio energy being emitted by the jet. M87 is located 50 million light-years away in the constellation Virgo.

[top right] - A visible light image of the giant elliptical galaxy M87, taken with NASA Hubble Space Telescope's Wide Field Planetary Camera 2 in February 1998, reveals a brilliant jet of high-speed electrons emitted from the nucleus (diagonal line across image). The jet is produced by a 3-billion-solar-mass black hole.

[bottom] - A Very Long Baseline Array (VLBA) radio image of the region close to the black hole, where an extragalactic jet is formed into a narrow beam by magnetic fields. The false color corresponds to the intensity of the radio energy being emitted by the jet. The red region is about 1/10 light-year across. The image was taken in March 1999.



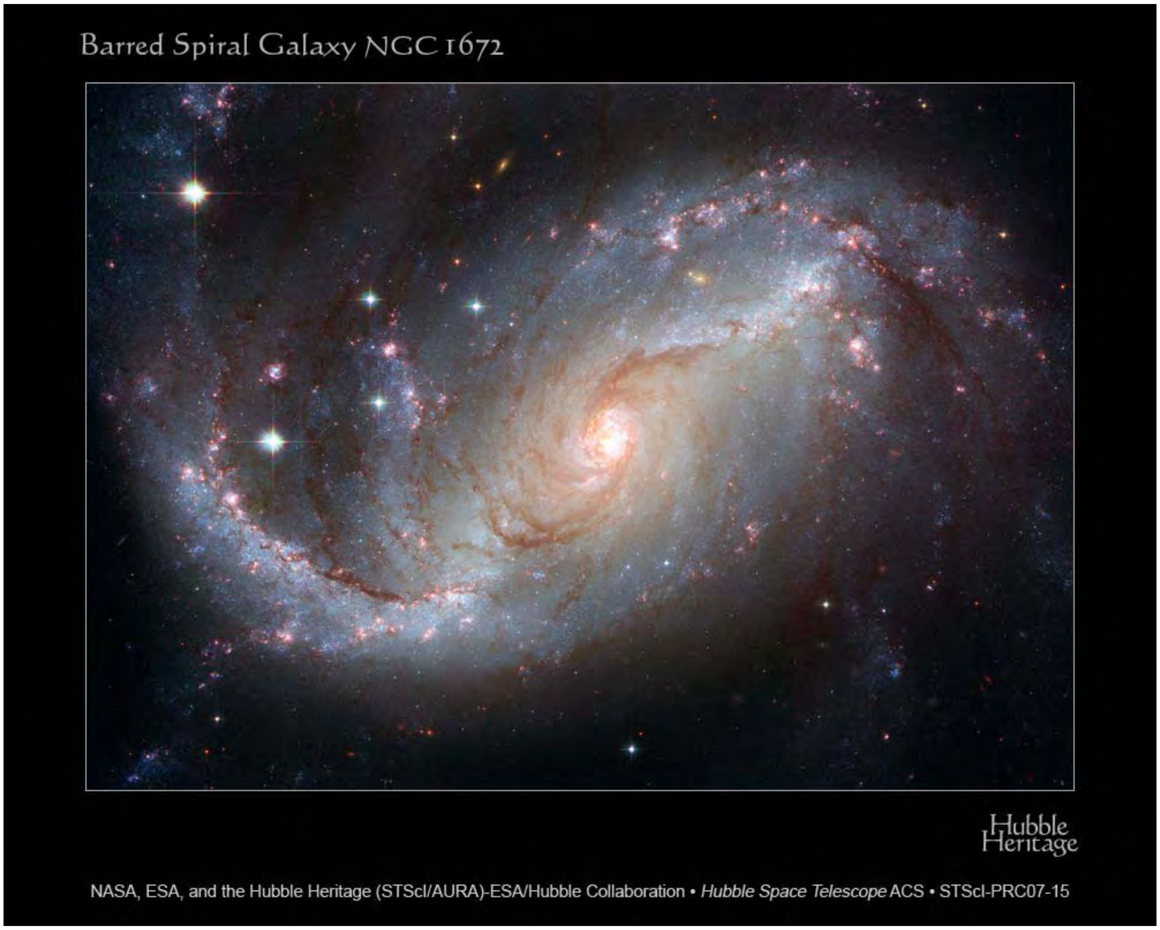
NASA's Hubble Space Telescope offers a stunning unprecedented close-up view of a turbulent firestorm of starbirth along a nearly edge-on dust disk girdling Centaurus A, the nearest active galaxy to Earth. A ground-based telescopic view (upper left insert) shows that the dust lane girdles the entire elliptical galaxy. This lane has long been considered the dust remnant of a smaller spiral galaxy that merged with the large elliptical galaxy. The spiral galaxy deposited its gas and dust into the elliptical galaxy, and the shock of the collision compressed interstellar gas, precipitating a flurry of star formation. Resembling looming storm clouds, dark filaments of dust mixed with cold hydrogen gas are silhouetted against the incandescent yellow-orange glow from hot gas and stars behind it. Brilliant clusters of young blue stars lie along the edge of the dark dust rift. Outside the rift the sky is filled with the soft hazy glow of the galaxy's much older resident population of red giant and red dwarf stars. The dusty disk is tilted nearly edge-on, its inclination estimated to be only 10 or 20 degrees from our line-of-sight. The dust lane has not yet had enough time since the recent merger to settle down into a flat disk. At this oblique angle, bends and warps in the dust lane cause us to see a rippled "washboard" structure. The picture is a mosaic of two Hubble Space Telescope images taken with the Wide Field Planetary Camera 2, on Aug. 1, 1997 and Jan. 10, 1998. The approximately natural color is assembled from images taken in blue, green and red light. Details as small as seven light-years across can be resolved. The blue color is due to the light from extremely hot, newborn stars. The reddish-yellow color is due in part to hot gas, in part to older stars in the elliptical galaxy and in part to scattering of blue light by dust — the same effect that produces brilliant orange sunsets on Earth.



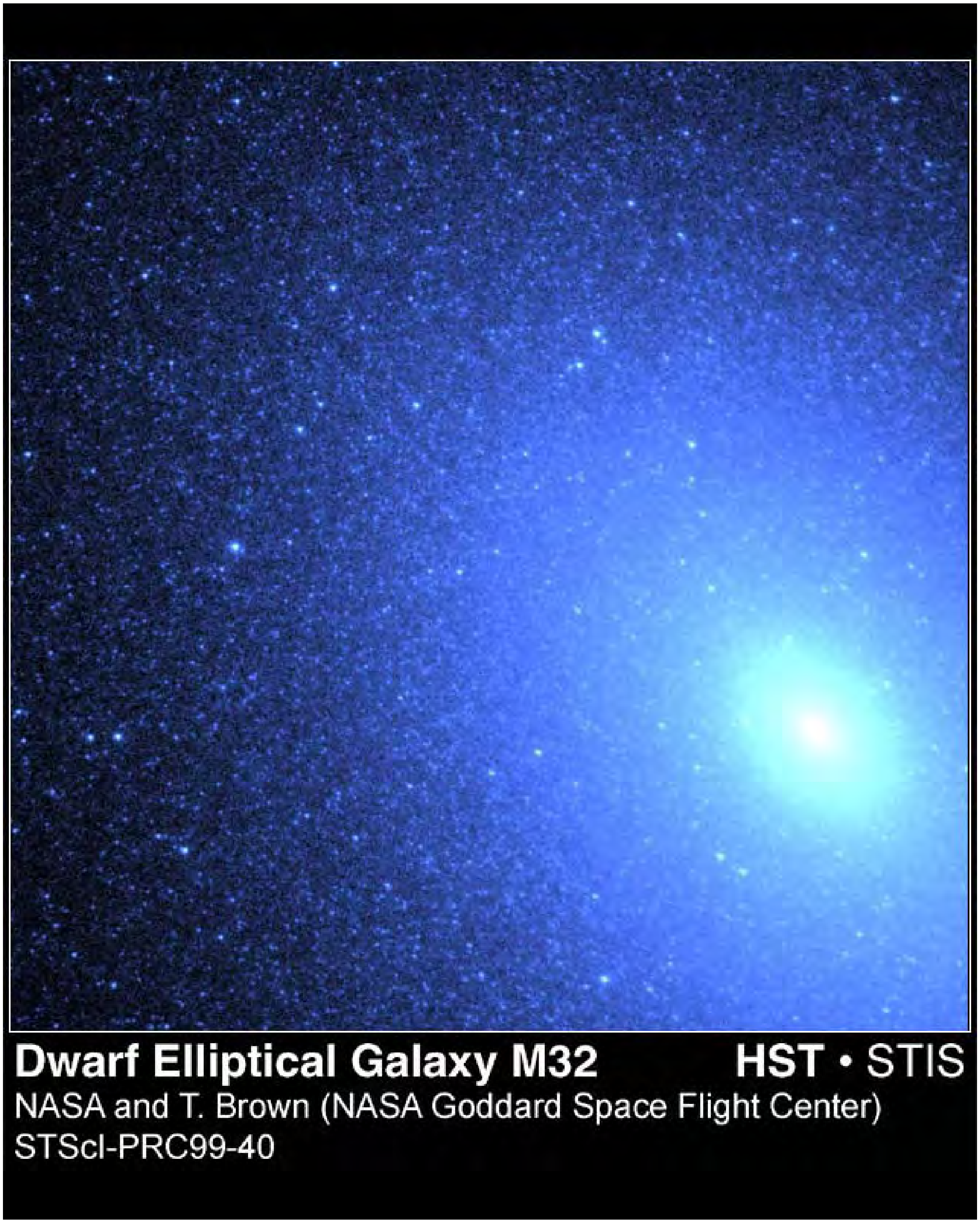
Against a stunning backdrop of thousands of galaxies, this odd-looking galaxy with the long streamer of stars appears to be racing through space, like a runaway pinwheel firework. This picture of the galaxy UGC 10214 was taken by the Advanced Camera for Surveys (ACS) aboard NASA's Hubble Space Telescope. Dubbed the "Tadpole," this spiral galaxy is unlike the textbook images of stately galaxies. Its distorted shape was caused by a small interloper, a very blue, compact galaxy visible in the upper left corner of the more massive Tadpole. The Tadpole resides about 420 million light-years away in the constellation Draco. Seen shining through the Tadpole's disk, the tiny intruder is likely a hit-and-run galaxy that is now leaving the scene of the accident. Strong gravitational forces from the interaction created the long tail of debris, consisting of stars and gas that stretch out more than 280,000 light-years. The image is so sharp that astronomers can identify distant colliding galaxies, the "building blocks" of galaxies, an exquisite "Whitman's Sampler" of galaxies, and many extremely faraway galaxies. ACS made this observation on April 1 and 9, 2002. The color image is constructed from three separate images taken in near-infrared, orange, and blue filters.

Resembling a diamond-encrusted bracelet, a ring of brilliant blue star clusters wraps around the yellowish nucleus of what was once a normal spiral galaxy in this image from NASA's Hubble Space Telescope (HST). The sparkling blue ring is 150,000 light-years in diameter, making it larger than our entire galaxy, the Milky Way. The galaxy, cataloged as AM 0644-741, is a member of the class of so-called "ring galaxies." It lies 300 million light-years away in the direction of the southern constellation Volans. Ring galaxies are an especially striking example of how collisions between galaxies can dramatically change their structure, while also triggering the formation of new stars. They arise from a particular type of collision, in which one galaxy (the "intruder") plunges directly through the disk of another one (the "target"). In the case of AM 0644-741, the galaxy that pierced through the ring galaxy is out of the image but visible in larger-field images. The soft spiral galaxy that is visible to the left of the ring galaxy in the image is a coincidental background galaxy that is not interacting with the ring. The resulting gravitational shock imparted due to the collision drastically changes the orbits of stars and gas in the target galaxy's disk, causing them to rush outward, somewhat like ripples in a pond after a large rock has been thrown in. As the ring plows outward into its surroundings, gas clouds collide and are compressed. The clouds can then contract under their own gravity, collapse, and form an abundance of new stars. The rampant star formation explains why the ring is so blue: It is continuously forming massive, young, hot stars, which are blue in color. Another sign of robust star formation is the pink regions along the ring. These are rarefied clouds of glowing hydrogen gas, fluorescing because of the strong ultraviolet light from the newly formed massive stars. Anyone who lives on planets embedded in the ring would be treated to a view of a brilliant band of blue stars arching across the heavens. The view would be relatively short-lived because theoretical studies indicate that the blue ring will not continue to expand forever. After about 300 million years, it will reach a maximum radius, and then begin to disintegrate.

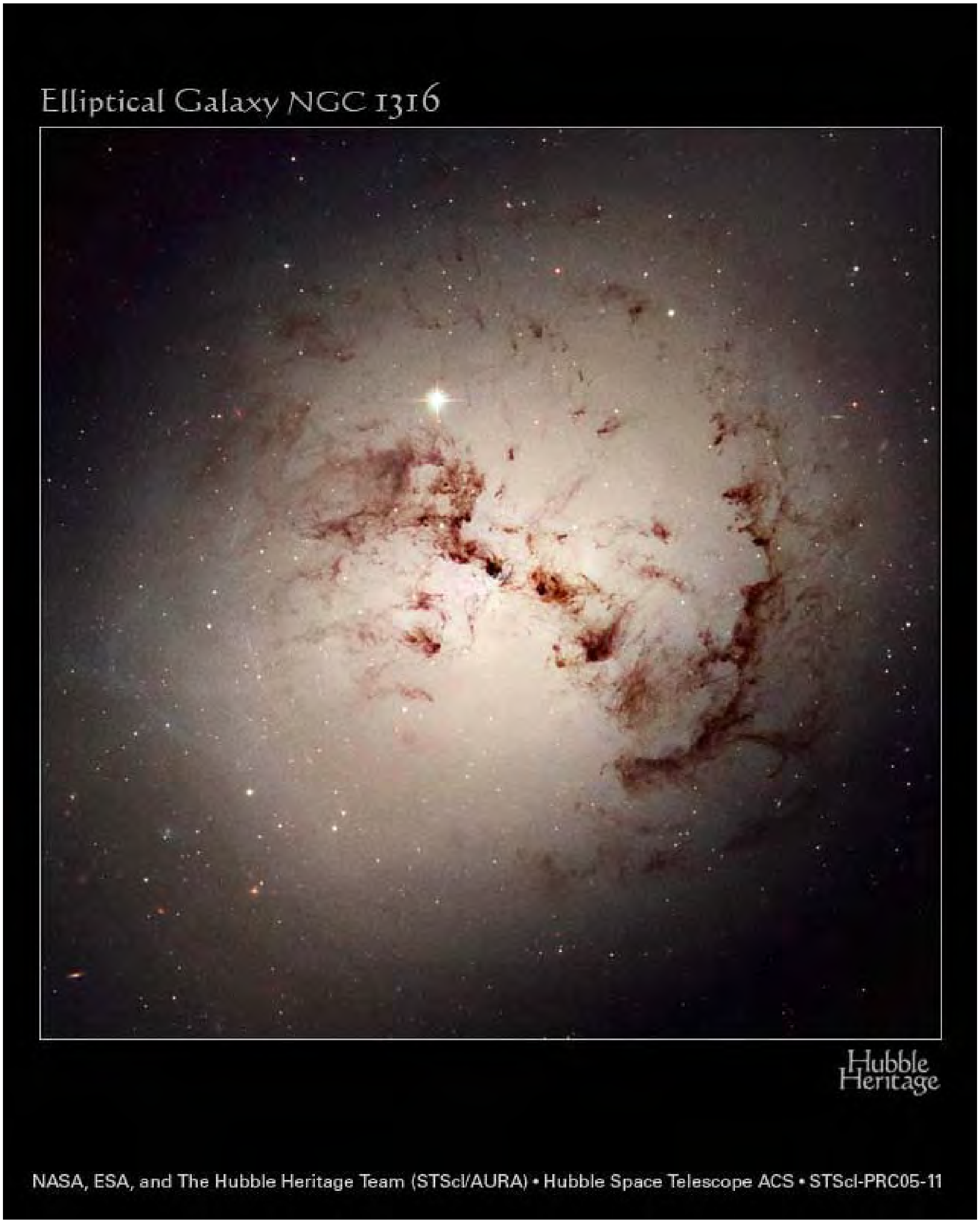
Two galaxies perform an intricate dance in this Hubble Space Telescope image. The galaxies, containing a vast number of stars, swing past each other in a graceful performance choreographed by gravity. The pair, known collectively as Arp 87, is one of hundreds of interacting and merging galaxies known in our nearby universe. The resolution in the Hubble image shows exquisite detail and fine structure that was not observable when Arp 87 was first cataloged in the 1960s. The two main players comprising Arp 87 are NGC 3808 on the right (the larger of the two galaxies) and its companion NGC 3808A on the left. NGC 3808 is a nearly face-on spiral galaxy with a bright ring of star formation and several prominent dust arms. Stars, gas, and dust flow from NGC 3808, forming an enveloping arm around its companion. NGC 3808A is a spiral galaxy seen edge-on and is surrounded by a rotating ring that contains stars and interstellar gas clouds. The ring is situated perpendicular to the plane of the host galaxy disk and is called a "polar ring." Arp 87 is in the constellation Leo, the Lion, approximately 300 million light-years away from Earth. These observations were taken in February 2007 with the Wide Field Planetary Camera 2. Light from isolated blue, green, red, and infrared ranges was composited together to form this color image.



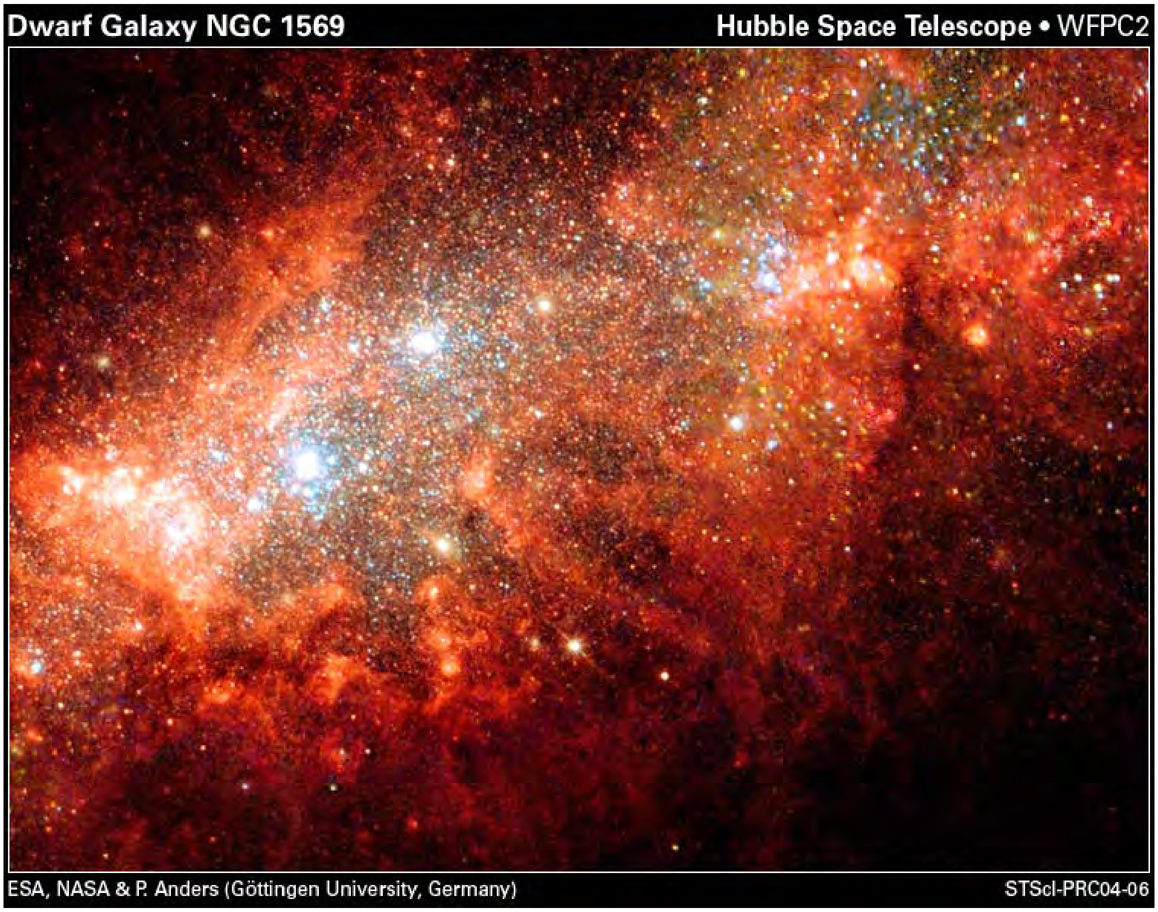
This NASA Hubble Space Telescope view of the nearby barred spiral galaxy NGC 1672 unveils details in the galaxy's star-forming clouds and dark bands of interstellar dust. One of the most striking features is the dust lanes that extend away from the nucleus and follow the inner edges of the galaxy's spiral arms. Clusters of hot young blue stars form along the spiral arms and ionize surrounding clouds of hydrogen gas that glow red. Delicate curtains of dust partially obscure and redden the light of the stars behind them by scattering blue light. Galaxies lying behind NGC 1672 give the illusion they are embedded in the foreground galaxy, even though they are really much farther away. They also appear reddened as they shine through NGC 1672's dust. A few bright foreground stars inside the Milky Way appear in the image as bright and diamond-like objects. As a prototypical barred spiral galaxy, NGC 1672 differs from normal spiral galaxies, in that the arms do not twist all the way into the center. Instead, they are attached to the two ends of a straight bar of stars enclosing the nucleus. Viewed nearly face on, NGC 1672 shows intense star formation regions especially off in the ends of its central bar. Astronomers believe that barred spirals have a unique mechanism that channels gas from the disk inward towards the nucleus. This allows the bar portion of the galaxy to serve as an area of new star generation. NGC 1672 is also classified as a Seyfert galaxy. Seyferts are a subset of galaxies with active nuclei. The energy output of these nuclei can sometimes outshine their host galaxies. This activity is powered by accretion onto supermassive black holes. NGC 1672 is more than 60 million light-years away in the direction of the southern constellation Dorado. These observations of NGC 1672 were taken with Hubble's Advanced Camera for Surveys in August of 2005. The composite image was made by using filters that isolate light from the blue, green, and infrared portions of the spectrum, as well as emission from ionized hydrogen.



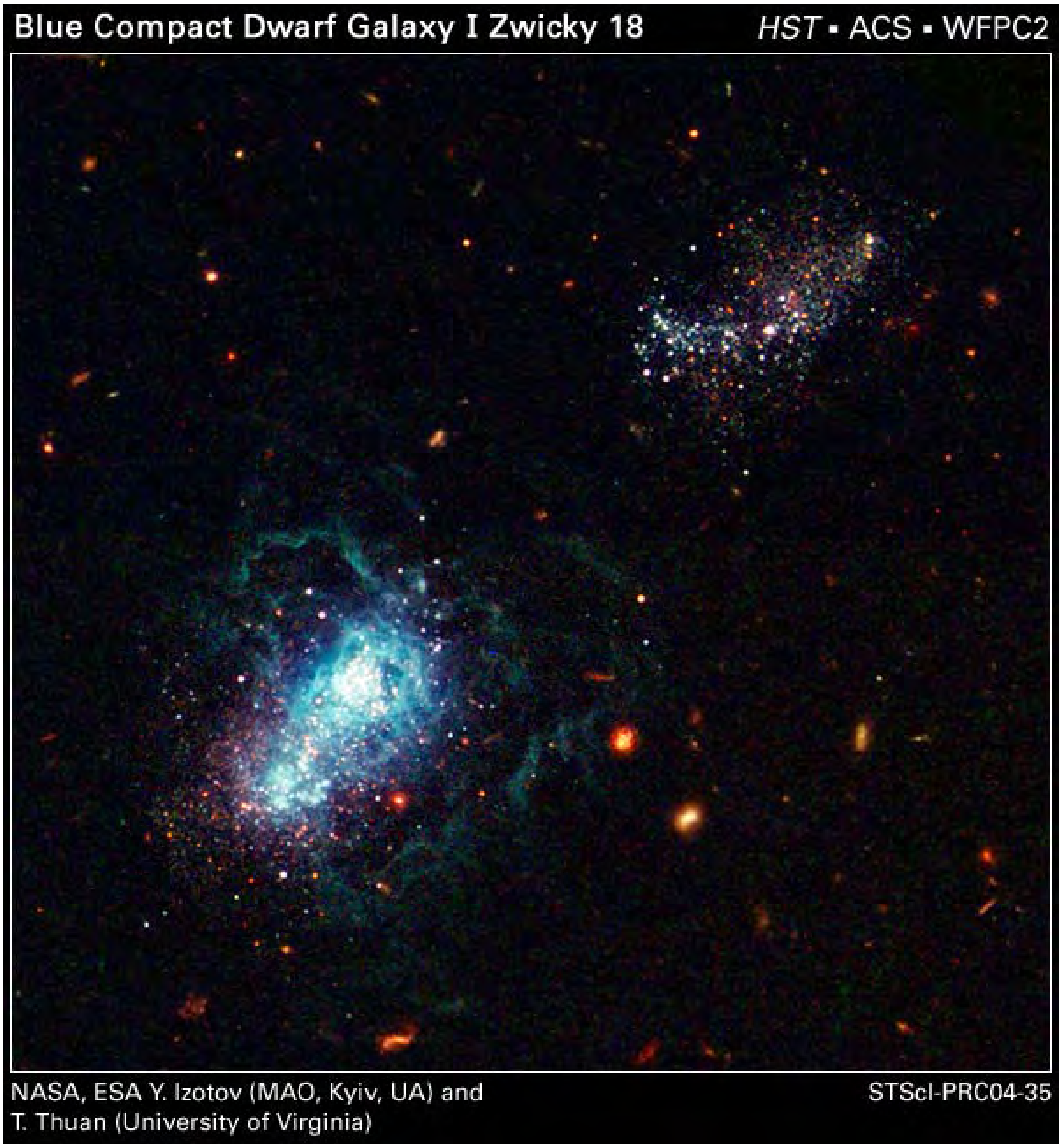
Hubble Space Telescope's high resolution has allowed astronomers to resolve hot blue stars deep inside an elliptical galaxy. The swarm of nearly 8,000 blue stars resembles a blizzard of snowflakes near the core (lower right) of the neighboring galaxy M32, located 2.5 million light-years away in the constellation Andromeda. Hubble confirms that the ultraviolet light comes from a population of extremely hot helium-burning stars at a late stage in their lives. Unlike the Sun, which burns hydrogen into helium, these old stars exhausted their central hydrogen long ago, and now burn helium into heavier elements. Thirty years ago, the first ultraviolet observations of elliptical galaxies showed that they were surprisingly bright when viewed in ultraviolet light. Before those pioneering UV observations, old groups of stars were assumed to be relatively cool and thus extremely faint in the ultraviolet. Over the years since the initial discovery of this unexpected ultraviolet light, indirect evidence has accumulated that it originates in a population of old, but hot, helium-burning stars. Now Hubble provides the first direct visual evidence.



Complex loops and blobs of cosmic dust lie hidden in the giant elliptical galaxy NGC 1316. This image made from data obtained with the NASA Hubble Space Telescope reveals the dust lanes and star clusters of this giant galaxy that give evidence that it was formed from a past merger of two gas-rich galaxies. The combination of Hubble's spatial resolution and the sensitivity of the Advanced Camera for Surveys (ACS) enabled accurate measurements of a class of red star clusters in NGC 1316. Astronomers conclude that these star clusters constitute clear evidence of the occurrence of a major collision of two spiral galaxies that merged together a few billion years ago to shape NGC 1316 as it appears today. NGC 1316 is on the outskirts of a nearby cluster of galaxies in the southern constellation of Fornax, at a distance of about 75 million light-years. It is one of the brightest ellipticals in the Fornax galaxy cluster. NGC 1316, also known as Fornax A, is one of the strongest and largest radio sources in the sky, with radio lobes extending over several degrees of sky (well off the Hubble image).



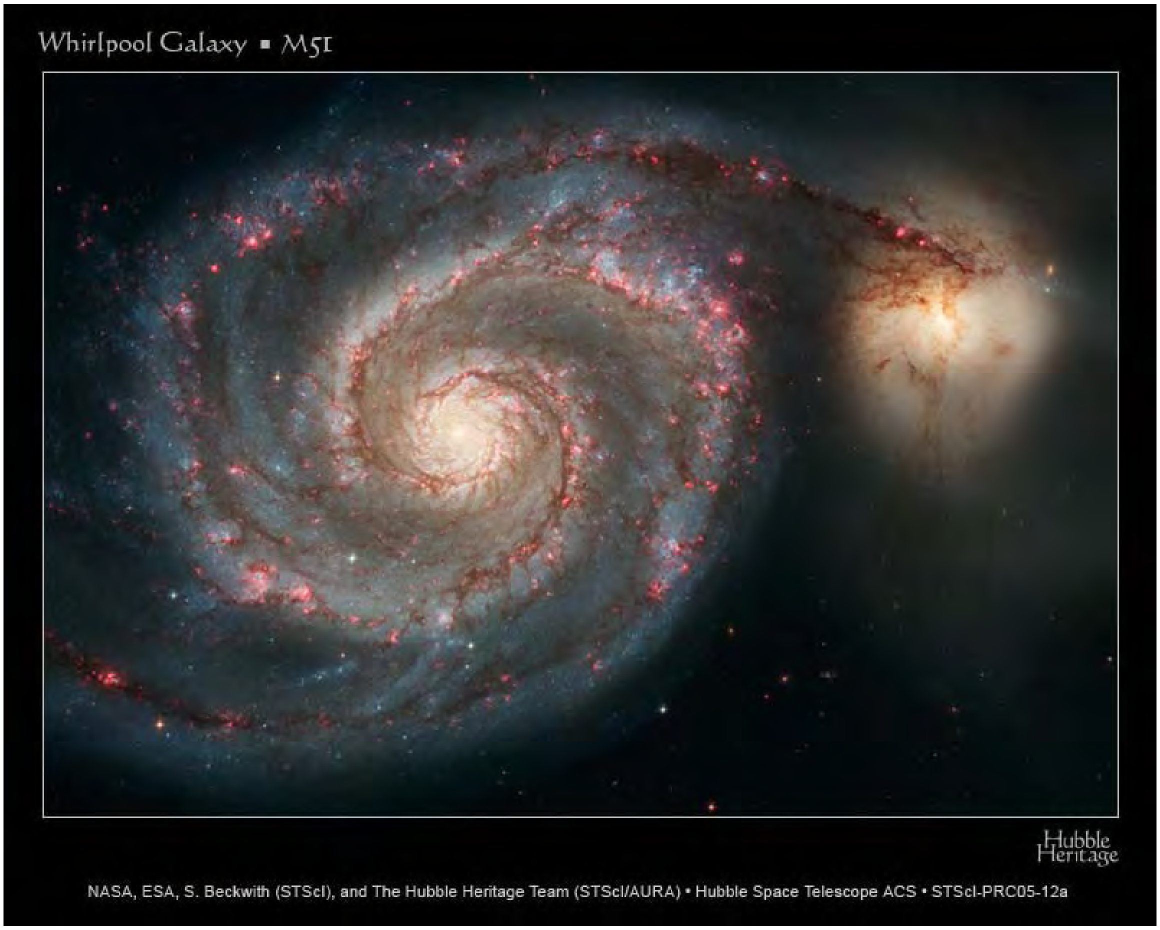
The nearby dwarf galaxy NGC 1569 is a hotbed of vigorous star birth activity which blows huge bubbles that riddle the main body of the galaxy. The galaxy's "star factories" are also manufacturing brilliant blue star clusters. This galaxy had a sudden onset of star birth about 25 million years ago, which subsided about the time the very earliest human ancestors appeared on Earth. In this image, taken with NASA's Hubble Space Telescope, the bubble structure is sculpted by the galactic super-winds and outflows caused by a colossal input of energy from collective supernova explosions that are linked with a massive episode of star birth. NGC 1569 is one of the closest starburst galaxies. It harbors two very prominent young, massive clusters plus a large number of smaller star clusters. The two young massive clusters match the globular star clusters we find in our own Milky Way galaxy, while the smaller ones are comparable with the less massive open clusters around us. The bubble-like structures seen in this image are made of hydrogen gas that glows when hit by the fierce winds and radiation from hot young stars and is racked by supernovae shocks. The first supernovae blew up when the most massive stars reached the end of their lifetimes roughly 20-25 million years ago. The environment in NGC 1569 is still turbulent and the supernovae may not only deliver the gaseous raw material needed for the formation of further stars and star clusters, but also actually trigger their birth in the tortured swirls of gas.



NASA's Hubble Space Telescope snapped a view of what may be the youngest galaxy ever seen. This "late bloomer" may not have begun active star formation until about 13 billion years after the Big Bang. Called I Zwicky 18 [below, left], the galaxy may be as young as 500 million years old. This youngster has gone though several sudden bursts of star formation — the first only some 500 million years ago and the latest only 4 million years ago. This galaxy is typical of the kinds of galaxies that inhabited the early universe. The galaxy is classified as a dwarf irregular galaxy and is much smaller than the Milky Way. The two major starburst regions are the concentrated bluish-white knots embedded in the heart of the galaxy. The wispy blue filaments surrounding the central starburst region are bubbles of gas that have been heated by stellar winds and intense ultraviolet radiation unleashed by hot, young stars. The redder stars are slightly older stars and star clusters, but they are still less than 1 billion years old. A companion galaxy lies just above and to the right of the dwarf galaxy. The companion may be interacting with the dwarf galaxy and may have triggered that galaxy's recent star formation. The red blobs surrounding the dwarf galaxy are the dim glow from ancient fully formed galaxies. This image was taken with Hubble's Advanced Camera for Surveys in 2003.

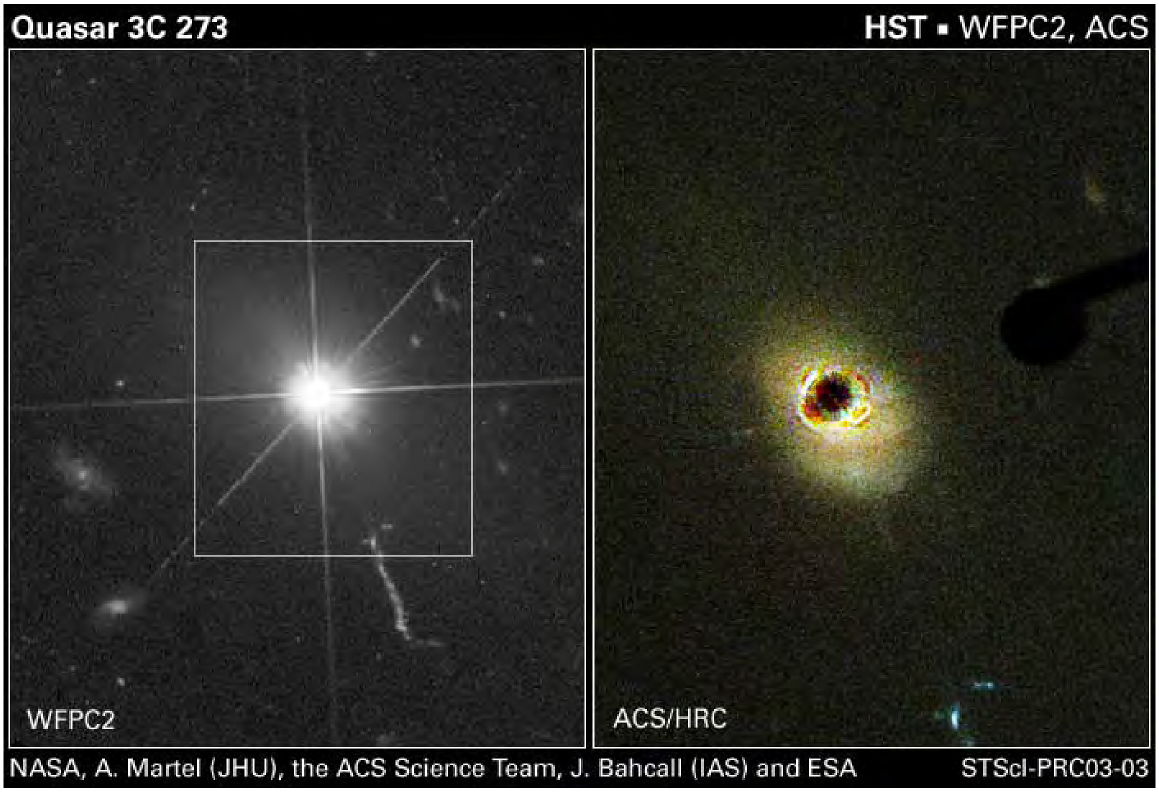
This beautiful galaxy is tilted at an oblique angle on to our line of sight, giving a "birds-eye view" of the spiral structure. The galaxy is similar to the Milky Way, but our favorable view provides a better picture of the typical architecture of spiral galaxies. M81 may be undergoing a surge of star formation along the spiral arms due to a close encounter it may have had with its nearby spiral galaxy NGC 3077 and a nearby starburst galaxy (M82) about 300 million years ago. M81 is one of the brightest galaxies that can be seen from the Earth. It is high in the northern sky in the circumpolar constellation Ursa Major, the Great Bear. At an apparent magnitude of 6.8 it is just at the limit of naked-eye visibility. The galaxy's angular size is about the same as that of the Full Moon.

Hubble data: NASA, ESA, and A. Zezas (Harvard-Smithsonian Center for Astrophysics); GALEX data: NASA, JPL-Caltech, GALEX Team, J. Huchra et al. (Harvard-Smithsonian Center for Astrophysics); Spitzer data: NASA/JPL/Caltech/S. Willner (Harvard-Smithsonian Center for Astrophysics)



The graceful, winding arms of the majestic spiral galaxy M51 (NGC 5194) appear like a grand spiral staircase sweeping through space. They are actually long lanes of stars and gas laced with dust. This sharpest-ever image of the Whirlpool Galaxy, taken in January 2005 with the Advanced Camera for Surveys aboard NASA's Hubble Space Telescope, illustrates a spiral galaxy's grand design, from its curving spiral arms, where young stars reside, to its yellowish central core, a home of older stars. The galaxy is nicknamed the Whirlpool because of its swirling structure. The Whirlpool's most striking feature is its two curving arms, a hallmark of so-called grand-design spiral galaxies. Many spiral galaxies possess numerous, loosely shaped arms which make their spiral structure less pronounced. These arms serve an important purpose in spiral galaxies. They are star-formation factories, compressing hydrogen gas and creating clusters of new stars. In the Whirlpool, the assembly line begins with the dark clouds of gas on the inner edge, then moves to bright pink star-forming regions, and ends with the brilliant blue star clusters along the outer edge. Some astronomers believe that the Whirlpool's arms are so prominent because of the effects of a close encounter with NGC 5195, the small, yellowish galaxy at the outermost tip of one of the Whirlpool's arms. At first glance, the compact galaxy appears to be tugging on the arm. Hubble's clear view, however, shows that NGC 5195 is passing behind the Whirlpool. The small galaxy has been gliding past the Whirlpool for hundreds of millions of years. As NGC 5195 drifts by, its gravitational muscle pumps up waves within the Whirlpool's pancake-shaped disk. The waves are like ripples in a pond generated when a rock is thrown in the water. When the waves pass through orbiting gas clouds within the disk, they squeeze the gaseous material along each arm's inner edge. The dark dusty material looks like gathering storm clouds. These dense clouds collapse, creating a wake of star birth, as seen in the bright pink star-forming regions. The largest stars eventually sweep away the dusty cocoons with a torrent of radiation, hurricane-like stellar winds, and shock waves from supernova blasts. Bright blue star clusters emerge from the mayhem, illuminating the Whirlpool's arms like city streetlights.

NASA's Hubble Space Telescope has trained its razor-sharp eye on one of the universe's most stately and photogenic galaxies, the Sombrero galaxy, Messier 104 (M104). The galaxy's hallmark is a brilliant white, bulbous core encircled by the thick dust lanes comprising the spiral structure of the galaxy. As seen from Earth, the galaxy is tilted nearly edge-on. We view it from just six degrees north of its equatorial plane. This brilliant galaxy was named the Sombrero because of its resemblance to the broad rim and high-topped Mexican hat. At a relatively bright magnitude of +8, M104 is just beyond the limit of naked-eye visibility and is easily seen through small telescopes. The Sombrero lies at the southern edge of the rich Virgo cluster of galaxies and is one of the most massive objects in that group, equivalent to 800 billion suns. The galaxy is 50,000 light-years across and is located 28 million light-years from Earth. Hubble easily resolves M104's rich system of globular clusters, estimated to be nearly 2,000 in number — 10 times as many as orbit the Milky Way. The ages of the clusters are similar to the clusters in the Milky Way, ranging from 10-13 billion years old. Embedded in the bright core of M104 is a smaller disk, which is tilted relative to the large disk. X-ray emission suggests that there is material falling into the compact core, where a 1-billion-solar-mass black hole resides.



NASA Hubble Space Telescope's new Advanced Camera for Surveys (ACS) has provided the clearest visible-light view yet of the nearby quasar 3C 273. The ACS' coronagraph was used to block the light from the brilliant central quasar, revealing that the quasar's host galaxy is significantly more complex than had been suggested in previous observations. Features in the surrounding galaxy normally drowned out by the quasar's glow now show up clearly. The ACS reveals a spiral plume wound around the quasar, a red dust lane, and a blue arc and clump in the path of the jet blasted from the quasar. These details had never been seen before. Previously known clumps of hot gas and the inner blue optical jet are now resolved more clearly. Quasars (also known as QSOs — short for quasi-stellar objects) were discovered in the early 1960s, but at least two decades passed before astronomers had observational evidence that they reside in galaxies. They now are commonly accepted to be supermassive black holes accreting infalling gas and dust. Using the ACS, astronomers want to learn what activities in a quasar's host galaxy feed the black hole, allowing it to "turn on" as a quasar.

In the direction of the constellation Canis Major, two spiral galaxies pass by each other like majestic ships in the night. The near-collision has been caught in images taken by NASA's Hubble Space Telescope and its Wide Field Planetary Camera 2. The larger and more massive galaxy is NGC 2207 (on the left in the image), and the smaller one on the right is IC 2163. Strong tidal forces from NGC 2207 have distorted the shape of IC 2163, flinging out stars and gas into long streamers stretching out a hundred thousand light-years toward the right-hand edge of the image. Calculations based on computer simulations indicate that IC 2163 is swinging past NGC 2207 in a counterclockwise direction, having made its closest approach 40 million years ago. However, IC 2163 does not have sufficient energy to escape from the gravitational pull of NGC 2207, and is destined to be pulled back and swing past the larger galaxy again in the future. The high resolution of the Hubble telescope image reveals dust lanes in the spiral arms of NGC 2207, clearly silhouetted against IC 2163, which is in the background. Hubble also reveals a series of parallel dust filaments extending like fine brush strokes along the tidally stretched material on the right-hand side. The large concentrations of gas and dust in both galaxies may well erupt into regions of active star formation in the near future. Trapped in their mutual orbit around each other, these two galaxies will continue to distort and disrupt each other. Eventually, billions of years from now, they will merge into a single, more massive galaxy. It is believed that many present-day galaxies, including the Milky Way, were assembled from a similar process of coalescence of smaller galaxies occurring over billions of years.

The Advanced Camera for Surveys (ACS) on NASA's Hubble Space Telescope has captured a spectacular pair of galaxies engaged in a celestial dance of cat and mouse or, in this case, mouse and mouse. Located 300 million light-years away in the constellation Coma Berenices, the colliding galaxies have been nicknamed "The Mice" because of the long tails of stars and gas emanating from each galaxy. Otherwise known as NGC 4676, the pair will eventually merge into a single giant galaxy. The image shows the most detail and the most stars that have ever been seen in these galaxies. In the galaxy at left, the bright blue patch is resolved into a vigorous cascade of clusters and associations of young, hot blue stars, whose formation has been triggered by the tidal forces of the gravitational interaction. Streams of material can also be seen flowing between the two galaxies. The clumps of young stars in the long, straight tidal tail [upper right] are separated by fainter regions of material. These dim regions suggest that the clumps of stars have formed from the gravitational collapse of the gas and dust that once occupied those areas. Some of the clumps have luminous masses comparable to dwarf galaxies that orbit in the halo of the Milky Way. Computer simulations show that we are seeing two nearly identical spiral galaxies approximately 160 million years after their closest encounter. The long, straight arm is actually curved, but appears straight because we see it edge-on. The simulations also show that the pair will eventually merge, forming a large, nearly spherical galaxy (an elliptical galaxy). The stars, gas, and luminous clumps of stars in the tidal tails will either fall back into the merged galaxies or orbit in the halo of the newly formed elliptical galaxy. The Mice presage what may happen to our own Milky Way several billion years from now when it collides with our nearest large neighbor, the Andromeda Galaxy (M31).