

# NEWSLETTER

Space Telescope Science Institute



Interacting Galaxy Pair

Image Credit: NASA, ESA, and the Hubble Heritage Team (STScI/AURA)  
<http://Hubblesite.org/newscenter/archive/releases/2007/36/>

## SKY IN GOOGLE EARTH

C. Christian, [carolc@stsci.edu](mailto:carolc@stsci.edu), and A. Conti, [aconti@stsci.edu](mailto:aconti@stsci.edu)

**A**fter spending hours roaming our home planet via GOOGLE EARTH, it just seemed natural to wonder if we might ramble through the SKY in the same manner. Although we arrived by different paths, we found we shared that same vision. By late 2005, we were collaborating in an experiment to use the technology of GOOGLE EARTH as an interface to the universe of astronomical data and information.

We had an opportunity to give a "Tech Talk" at the Googleplex in Mountain View, California, where we introduced googlers to the treasure trove of *Hubble* data and the standards and protocols of astronomical archives. Members of the GOOGLE EARTH team were intrigued by the possibilities and enthusiastic about our modest experimentation with their technology.

In August 2007, our dream became a reality with the release of SKY IN GOOGLE EARTH, a feature incorporated in GOOGLE EARTH version 4.2, which allows the user to begin roaming the sky with a click of a button (<http://earth.google.com>).

The data in the Digitized Sky Survey and the Sloan Digital Sky Survey forms the foundation of SKY. Colleagues at the University of Pittsburgh and the Google Pittsburgh facility processed and merged this data into

a "basemap." SKY also contains stick figures of constellations, labeling of selected objects from astronomical catalogues, *Hubble* press-release images with explanations, and other features, such as tours.

Each tour is a sequence of locations linked by some theme that you have downloaded into your Places in GOOGLE EARTH/SKY. For example, a tour of some interesting *Hubble* images can be downloaded from the *gSKY* website. Detailed instructions about all aspects of using GOOGLE EARTH and SKY are found at the GOOGLE EARTH website: <http://earth.google.com/userguide/>.

The *Hubble* press-release images were embedded in SKY only after going through a painstaking process of checking and adjusting their alignments on the basemap. To make this process even more complicated, the basemap is constructed from a projection involving the Earth's geometry and coordinate system. The explanations are from the original press releases by the Office of Public Outreach; each is linked to the object's pages at the Astronomical Data System, SIMBAD, and the NASA/IPAC EXTRAGALACTIC DATABASE. All the press-release images are tagged to conform to the Virtual Astronomy Multimedia Project recommendations

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# Possible Multi-Cycle Treasury Program

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If everything goes according to plan, next August the Kennedy Space Center will host a spectacular sight: two space shuttles, poised on adjacent launch pads, ready to go into space. *Atlantis* will be heading to the *Hubble Space Telescope* for the last servicing mission; *Endeavor* will be prepared, if necessary, to rescue the crew of the *Atlantis*. This dramatic display of strategic assets will testify to NASA's commitment to space science.

The primary goal of Servicing Mission 4 (SM4) is to maximize the scientific return from *Hubble* over the following five years.

Here at the Space Telescope Science Institute, we have the responsibility to ensure that the science flowing from the newly refurbished *Hubble* fully justifies the incredible investment the nation, NASA, and the astronaut corps are making in this last servicing mission. Thus, we are inviting input from the community about a possible new class of very large observing programs following SM4.

After SM4, *Hubble* will have new gyros, batteries, and more powerful instrumentation than ever before in its history. The Wide Field Camera 3 (WFC3) and Cosmic Origins Spectrograph (COS) will be installed. If all goes well, we will also have a new Fine Guidance Sensor (FGS) and a repaired Space Telescope Imaging Spectrograph (STIS). NASA is even exploring how to repair the Advanced Camera for Surveys (ACS), which was *Hubble*'s imaging workhorse until it died in late January 2007. Not until *Webb* flies in 2013 will the community have access to so powerful a space observatory as the refurbished *Hubble* will be after SM4.

So how should we allocate time after this last visit to *Hubble*? What programs should we contemplate? Are our current modes of operation sufficient, or are there science questions that demand greater resources?

As one example, *Hubble* has devoted extensive resources to probing the high-redshift universe through deep-imaging surveys on a variety of scales, from the Hubble Deep Field and the Ultra Deep Field through the

Great Observatory Origins Deep Survey and the Cosmic Evolution Survey. There is little question that complementary and supplementary programs using WFC3 will be proposed in Cycle 17.

In another example, the panchromatic capabilities of WFC3 and ACS offer the potential of mapping the star-formation properties in nearby galaxies (such as M33), perhaps coupled with metallicity and kinematic analyses using observations by COS and STIS.


As yet another—STIS, COS, and perhaps even the FGS might feature strongly in concerted investigations of the characteristics of transiting (and non-transiting) extrasolar planets.

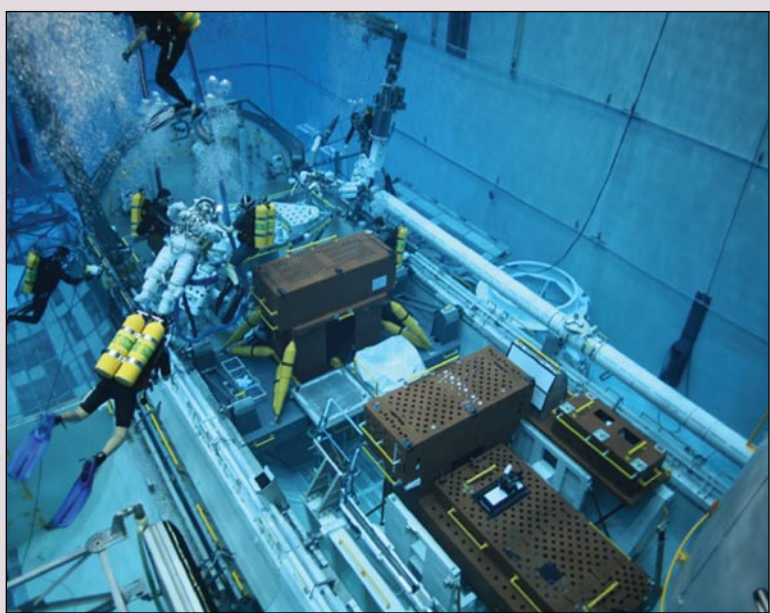
These are just some areas that might profit from very large allocations of *Hubble* time. In order to assess the appetite of the community for such programs, we are soliciting white papers that describe projects in this category. This solicitation in no way pre-selects or restricts the science topics. You may submit ideas for any combination of imaging and spectroscopy.

If you are opposed to the establishment of this type of program, you may also submit a white paper outlining your concerns. For example, you could describe the science that you envision being adversely impacted, or advocate a greater overall allocation to small and medium programs.

If, and only if, we find really compelling ideas for a new Multi-Cycle Treasury (MCT) program, we anticipate allocating 2,000 orbits—distributed over the last few months of Cycle 17 (150 to 200 orbits) and through Cycles 18 and 19—to this category. Up to 600 orbits would be

subsidized from director's discretionary time. The remaining orbits (up to 1200) would be taken from the General Observer allocations in Cycles 18 and 19, drawn predominantly from the time currently set aside for large and Treasury programs. MCT programs should, therefore, have relatively little impact on the number of small and medium programs allocated in those cycles, and there will still be an opportunity to apply for standard large and Treasury programs.

By this time next year, if all goes well, we will be entering a new era of space science capabilities with the post-SM4 *Hubble*. We are looking to the science community to make this a new era of discovery. 



**Figure 1:** Astronauts training to fix The Space Telescope Imaging Spectrograph (STIS) in the Neutral Buoyancy Laboratory (NBL).

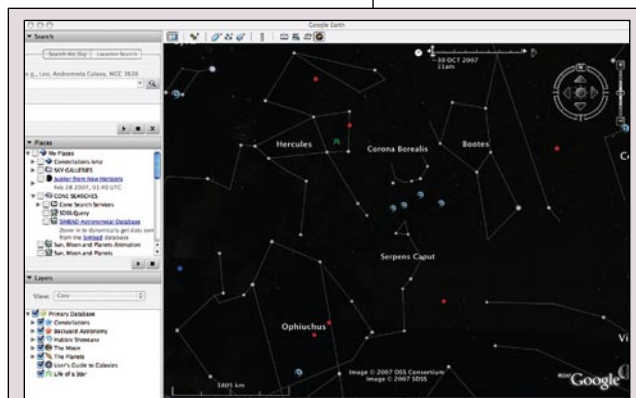
## SKY IN GOOGLE EARTH from page 1

and vetted by the International Virtual Observatory Alliance (<http://www.communicatingastronomy.org/repository>).

Within minutes of the SKY release, a new community blossomed with comments, speculations, and additions. This delighted us, because SKY is intended to be an organic, growing technology for professionals, amateurs, and novices to use—where they all can contribute and collaborate. Many professional astronomers have jumped at the opportunity to share data, including stars with exoplanets from Geoff Marcy, overlays of the constellations from the Naval Observatory and the Institute, and the sky as seen by the *Infrared Astronomical Satellite* contributed by the University of Washington.

We are continuing to work on new features for SKY related to *Hubble* data, such as catalogs, links to the *Hubble* Legacy Archive, the Multimission Archive at Space Telescope, and the National Virtual Observatory. We have already released a layer of *Galaxy Evolution Explorer* images, a tour of the most popular *Hubble* images as described above, and a file that shows the location of *Hubble* and its orbit that can be downloaded from the *gSky* webpage [http://Hubblesite.org/explore\\_astronomy/gSky/](http://Hubblesite.org/explore_astronomy/gSky/). Orbits and positions for other satellites will be available on that site and viewable in both GOOGLE EARTH and SKY.

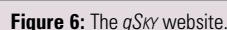
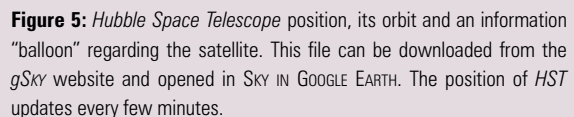
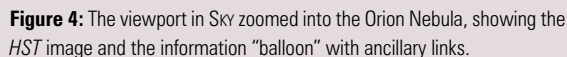
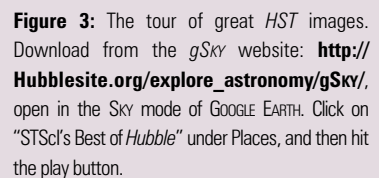
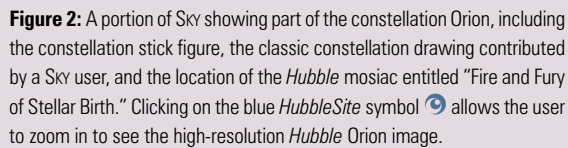
The purpose of the *gSky* page is to make it easier for anyone—public users, educators, students, amateurs, and professional astronomers—to




**Figure 1:** SKY IN GOOGLE EARTH showing constellation stick figures, locations of *Hubble* images (the blue symbols) and the main features of the viewport, including the navigation control in the upper right. The left menus are the search feature, the folders of resources the user has downloaded (middle section) and the resources that are downloaded automatically with SKY (lower left section).

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donate imagery and other data to SKY and to contribute to this interesting interface. The website also is linked to the GOOGLE EARTH community website, where a plethora of add-ons and discussion topics for GOOGLE EARTH/SKY are being contributed daily. 

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**Collaborators:** Office of Public Outreach and B. McLean (Institute), A. Connolly and S. Krughoff (U. Washington), R. Scranton and J. Brewer (Google Pittsburgh), C. Sosin, C. Roat and many others (Google Mt. View).

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## Increasing the Scientific Value of NICMOS Data in Cycle 16

A. Koekemoer, [koekemoer@stsci.edu](mailto:koekemoer@stsci.edu)

**F**ollowing the failure of the Advanced Camera for Surveys (ACS) early in the year, the use of the Near-Infrared Camera and Multi-Object Spectrograph (NICMOS) has increased significantly. During Cycle 16, NICMOS observations accounted for about 40% of the total time available on *Hubble*. To increase the scientific value of these observations, the NICMOS team is working on several aspects of the data. We have expanded and improved calibration observations in Cycle 16, and upgraded software for removing certain detector-related effects from the data.

### Calibration Observations

The NICMOS calibration program now includes 400 parallel orbits to collect detailed information on dark exposures—a tenfold increase over previous cycles. We are obtaining data for all commonly used readout modes for a range of temperatures, which should improve the calibration of dark current and amplifier glow.

We are repeating the extensive flat-field program of Cycle 15 (NICMOS ISR 2007-002), and are now characterizing the time dependence of flat fields for the full filter set.

The combination of the dark- and flat-field programs in Cycle 16 should significantly reduce low-level variations in data, which have affected much of NICMOS' science.

We have implemented new techniques for measuring and adjusting the instrument's focus (NICMOS ISR 2007-003).

The Cycle 16 calibration plan includes new observations of primary and secondary infrared standard stars for grism spectroscopy and direct imaging. The goals include both improving the photometric calibration of NICMOS, and enabling future cross-calibration with the Wide Field Camera 3 and the *James Webb Space Telescope*.

We plan to observe planetary nebulae using the grisms in Camera 3. The goal is to improve the wavelength calibration across the entire detector, and to increase the legacy value of all grism observations in the archive.

Another calibration program will update measurements of the plate scale and geometric distortion in all three NICMOS cameras. Our goal is a distortion model with an accuracy of about 15 milliarcseconds.

### Software

The NICMOS team has released several new software programs to improve the quality of data.

SAACLEAN removes persistence due to charged particles accumulated during *Hubble*'s passages through the South Atlantic Anomaly (NICMOS ISR 2003-010, NICMOS ISR 2007-001). Persistence affects a large fraction of NICMOS data. The new software creates an accurate model of the persistence and subtracts it from affected images (see Figure 1).

RNLINCOR is a software task that removes the count-rate-dependent non-linearity (NICMOS ISR 2006-002, NICMOS ISR 2006-003) on a pixel-by-pixel basis and corrects photometric errors that may be as much as a few percent.

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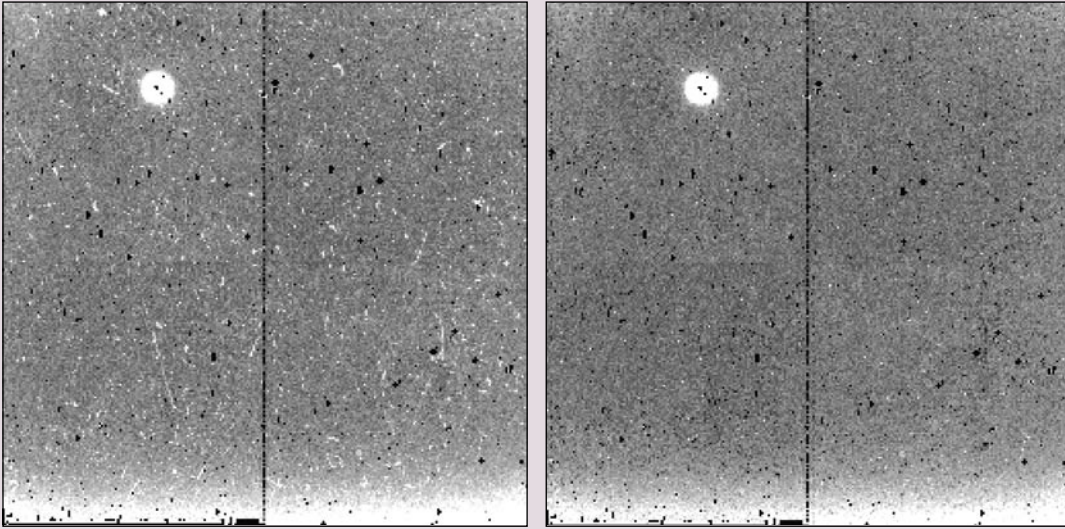
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PUFTCORR is a software task that eliminates electronic cross-talk when a bright source is present in one quadrant of the detector. Cross-talk produces mirror images in the other quadrants, which can masquerade as faint background sources. Removing them increases the scientific robustness of NICMOS images.

We plan to improve the accuracy of measurements of detector temperature. This is essential for improving calibrations and corrections of temperature-dependent affects. It will also improve the ability of the CALNICA software to reject bad pixels, and facilitate the removal of quadrant pedestal offsets and amplifier glow.

The NICMOS team welcomes input and feedback from the community on any other aspects of NICMOS data calibration. We expect the combination of enhanced calibration programs and new



**Figure 1:** Removal of charged-particle persistence by the SAACLEAN software, which creates a model of the decaying signal and subtracts it from the data. Left: original image containing the low-level persistence. Right: the same image after accurate removal of the persistent signal. The benefits are less pixel-to-pixel variation and fainter limiting magnitudes.

software projects will improve the long-term scientific value of NICMOS data, including both the data already in the archive and the results of future observations.

For further information, please visit:

NICMOS web page: <http://www.stsci.edu/hst/nicmos/>

NICMOS bulletin board: <http://forums.stsci.edu/phpbb/viewforum.php?f=13>

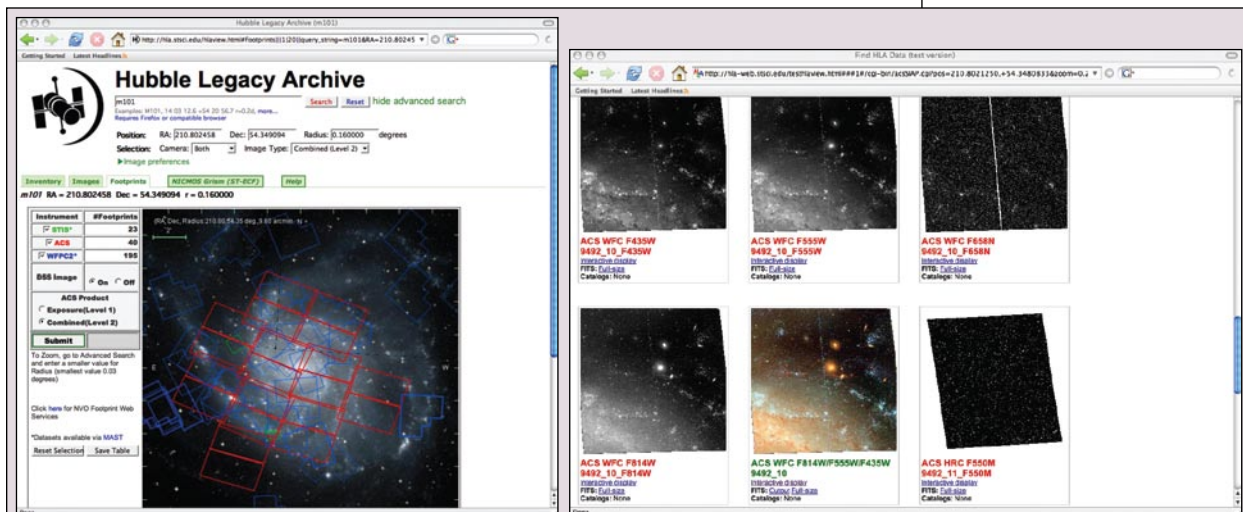
For any questions about NICMOS, please feel free to post a message on the NICMOS bulletin board, or send an email message to [help@stsci.edu](mailto:help@stsci.edu). Ω



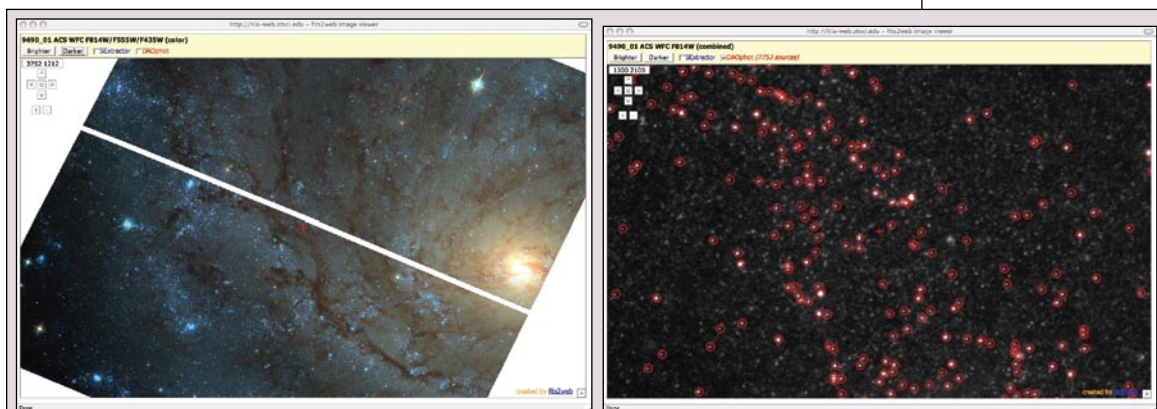
# Enhanced Science with the Hubble Legacy Archive (HLA)

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The Hubble Legacy Archive (HLA) is a new initiative to enhance the scientific value of archival *Hubble* data. It provides instantaneous access to high-quality processed science products through a powerful browsing interface. HLA is a joint project of the Space Telescope Science Institute, the Space Telescope–European Coordinating Facility (ST-ECF), and the Canadian Astronomy Data Centre (CADC).



**Figure 1:** Left: Footprint view of M101 in the HLA interface, showing the locations of several ACS and WFPC2 observations across the target. Right: Examples of single-filter (black and white) and multi-filter (color) preview images available for one of the ACS pointings of M01.



**Figure 2:** Example of a catalog overlay in interactive mode while displaying an image. This mode allows zooming and panning, as well as the ability to overlay catalogs generated using either DAOFIND or SOURCEEXTRACTOR.

The enhanced image products available through the HLA include combined images and individual exposures for all filters employed during an observing sequence. All the images have been calibrated using the latest reference files, and have been geometrically rectified, cleaned and combined using MULTIDRIZZLE. The images are registered onto a common pixel grid, enabling immediate comparison of exposures obtained in different filters. The absolute astrometry of the images has been improved by matching them to the Guide Star Catalog 2, the Sloan Digital Sky Survey, and the Two Micron All-Sky Survey. The processing also generates multi-band catalogs, which are provided with the images. In the future, data from multiple visits will be combined to create larger mosaics.

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The HLA images and associated catalogs can be retrieved through a versatile browsing interface. The interface includes (1) a table format for listing the properties of different images (target names, filters, exposure times, and other useful information), (2) single-filter (black and white) and multi-filter (color) previews of the images, and (3) footprints showing the location of the relevant *Hubble* apertures on the sky.

The scientific advantages of the data products available from the HLA are:

- Absolute astrometric errors reduced by a factor of 10, to about 0.2–0.3 arcsecond;
- Combined, registered images processed using MULTIDRIZZLE, for single and multiple exposures in all filters employed during a given observing sequence;
- Multi-wavelength catalogs for all filters in a given area on the sky;
- Extracted grism spectra (provided by the ST-ECF) for the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) and eventually the Advanced Camera for Surveys (ACS); and
- Eventual inclusion of other spectroscopic data.

An early data release for the HLA took place in July 2007, when about 20% of the entire ACS archive was released (2,744 observing visits, consisting of 15,073 separate exposures), along with preliminary NICMOS grism data provided by the ST-ECF.

Data Release 1.0 is planned for January 2008. This will contain the combined, registered data for almost all public ACS observations, along with preliminary combined multi-visit ACS mosaics, as well as combined WFPC2 data, provided by CADC. There will also be significantly more grism data provided by the ST-ECF.  $\Omega$

For more details, please visit the HLA website: <http://hla.stsci.edu/>

## Astrophysics in the Next Decade: JWST and Concurrent Facilities

P. Stockman, [stockman@stsci.edu](mailto:stockman@stsci.edu)

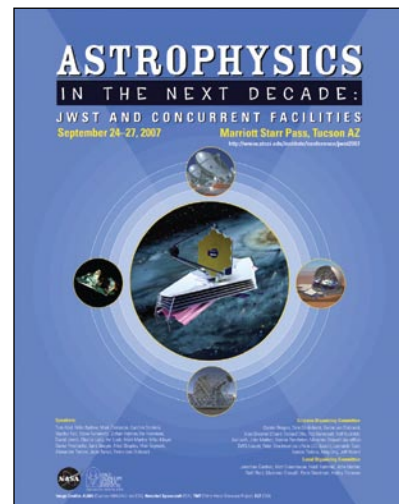
The *Webb* workshop, which was held September 24–27, drew almost 200 participants to Tucson, to hear twenty speakers and moderators discuss the directions of their fields in the next decade, and how future facilities would advance their goals. The subjects ranged from the theory of the very first stars (Tom Abel) to the origins of the outer Solar System (David Jewitt). Over 40 posters expanded on the theme, with many describing new instruments or new mission concepts.

The Institute will publish the conference proceedings in mid-2008. Meantime, as we receive them, we are posting the presentations and posters on the conference web site: <http://www.stsci.edu/institute/conference/jwst2007>.

At the workshop, we also heard from representatives from most of the major funding agencies: Guy Monnet (European Southern Observatory), Eric Smith (NASA), Hiroshi Karoji (National Astronomical Observatory of Japan), and Gillian Wright (informal representative of the European Space Agency).

In addition to thanking the speakers, moderators, and agency representatives (listed on the web site), we particularly acknowledge the work and wisdom of the science organizing committee, led by Alan Dressler. The committee attracted the best and the brightest to the Tucson desert and agreed to the crazy “mash-up” agenda suggested by Heidi Hammel. We encourage other conference organizers to consider this format as a way of juggling the talks such that familiar and new topics are interspersed throughout the meeting. It also emphasized the magnificent range of modern astronomy, including the origins of life.

*Webb* postscript: the project is progressing toward the mission preliminary design review (PDR) in March 2008. All of the science instruments are in construction, with most having passed their critical design reviews. Northrop Grumman continues to refine the design of the sunshield and simplify its deployment. The goal is to freeze the observatory design, except for details of the support structure for the avionics and propulsion system, before PDR.  $\Omega$

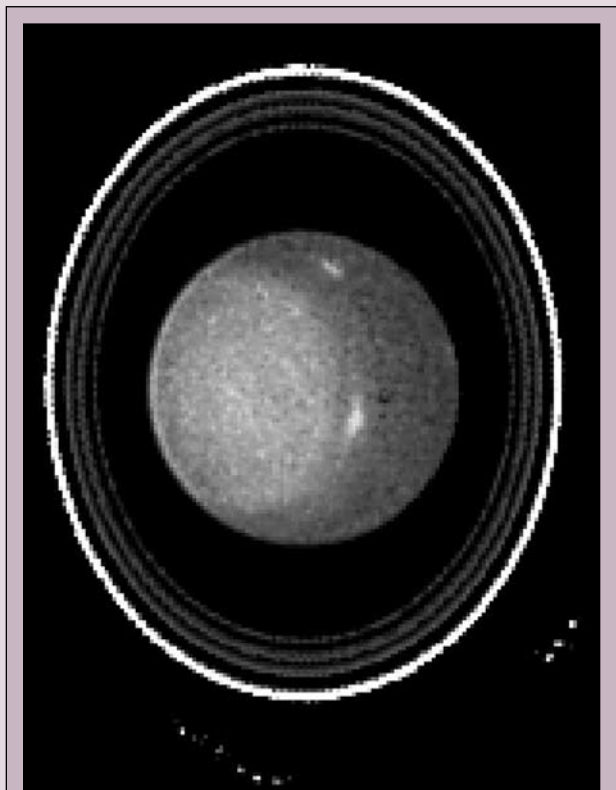




Starting with this edition of the Institute Newsletter, we will regularly reprint science articles from NASA's annual Hubble 200X Science Year in Review. We are pleased to launch this series with "Uranus through the Eyes of Hubble," by Heidi Hammel, and Ted Gull's "Eta Carinae—Materials for Future Worlds," both of which appeared in Hubble 2005.

# Uranus through the Eyes of Hubble

H. B. Hammel, [hbh@alum.mit.edu](mailto:hbh@alum.mit.edu)



**Figure 1:** Hubble's first observations of Uranus in 1994 revealed several bright clouds that contrasted strongly against its atmosphere.

In 1993, three serendipitous *Hubble* images of Uranus created a stir that still reverberates through observatories today. The images showed distinct cloud features on a planet that planetary astronomers had written off as featureless and bland in appearance. The new face of Uranus triggered observing programs across the spectrum, continuing to this day. These investigations pursue the nature and origin of the cloud features and exploit them as tracers of atmospheric evolution.

In 1986, the words that fit *Voyager 2*'s images of Uranus were "dull" and "boring." No storms swirled; no bands waved; no clouds clustered. Many astronomers studying the dynamics of planetary atmospheres turned to more photogenic planets.

Not until three years after its launch did *Hubble* turn toward Uranus. Astronomers were looking *near* Uranus, not *at* it. They were searching for faint moons, and Uranus was in the frame simply to help measure the positions of any new moons discovered. These serendipitous images were startling to anyone familiar with Uranus's atmosphere: bright clouds were clearly visible—and not just one, but several. The new clouds showed astonishingly high contrast against the planet's pale disk.

Uranus is the seventh planet from the Sun, orbiting 19 times further away than

the Earth and traveling at a stately pace that takes 84 years to complete a revolution. Its atmosphere is composed mostly of hydrogen and helium, but a small amount of methane, which preferentially absorbs red light, gives Uranus its distinctive greenish-blue hue.

Sometime in the early history of the Solar System, the young planet Uranus probably experienced a massive collision or some other interaction, which literally knocked the planet on its side. Its rotational spin axis, ring system, and moon orbits are keeled over more than 90 degrees relative to the plane of the Solar System.

The extreme tilt of its rotation axis gives Uranus the most extreme seasons of any planet. During southern summer, the south polar region basks for more than 20 years in unceasing sunlight, while the northern pole faces the cold blackness of space. As the planet progresses in its orbit, the Sun moves toward the equator. At Uranus's equinox, when the Sun lies in the plane of the equator, the days and nights are about 16 hours long. In 1986, *Voyager 2* visited Uranus at the peak of southern summer. Now, two decades—one-quarter Uranus year—later, Uranus approaches equinox again, in 2007. Over the past few pre-equinoctial years, *Hubble* and other telescopes on the ground and in space have shown that the appearance of Uranus is still changing dramatically, apparently responding to the seasons.

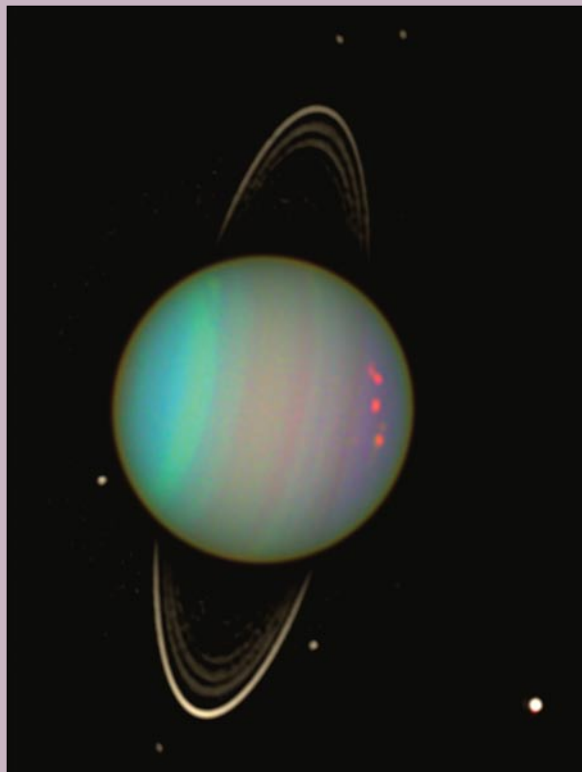
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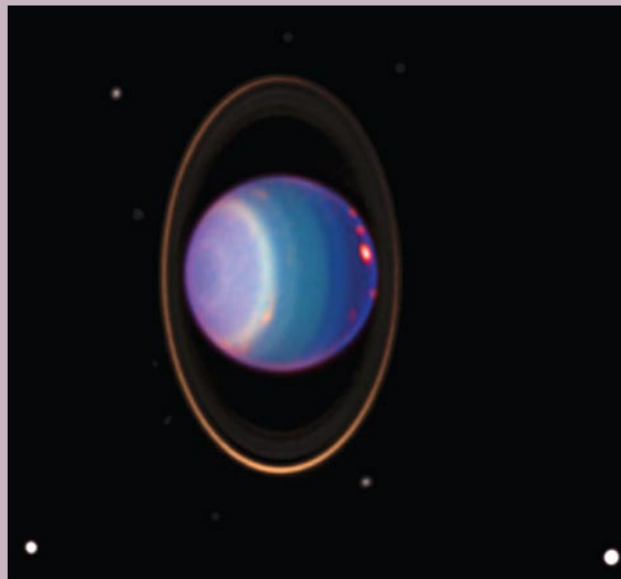
**Heidi B. Hammel** is a planetary astronomer with the Space Science Institute in Boulder, Colorado. She has been studying Uranus and other planets for over 25 years with telescopes on Earth and in space, and led the *Hubble* team that recorded the 1994 impact of Comet Shoemaker-Levy 9 into Jupiter. She is an interdisciplinary scientist for the James Webb Space Telescope.

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Sparked by the 1993 images, astronomers have now used *Hubble* to image the south polar region of Uranus for many years running. This series of images shows that the region darkens as it receives less direct sunlight, due to the Sun moving north. Images taken with the Near Infrared Camera



**Figure 2:** Atmospheric features on Uranus are clearly visible in this enhanced-color image taken with the *Hubble* Advanced Camera for Surveys in August 2003. Also visible are Uranus's rings (enhanced in this rendering) and a few of its moons—clockwise from the top: Desdemona, Belinda, Portia, Cressida, and Puck.



**Figure 3:** *Hubble* images taken with the NICMOS infrared camera in 1998 revealed incredibly bright northern cloud features—one of these clouds had the highest contrast ever recorded for an outer planet. Also visible in this image is the south pole “collar”—the bright ring surrounding the planet’s southern pole.

and Multi-Object Spectrometer in 1998 reveal bright northern cloud features, with one such cloud displaying the highest contrast ever recorded for an outer planet. In the most recent *Hubble* images, which show increasing cloud structure across the planet, we have confirmed the first detection of a planetary-scale dynamical wave wrapping around the equator of Uranus.

If springtime on Earth were anything like on Uranus, we would experience waves of massive storms, each one covering the country from Kansas to New York, with temperatures of 300 degrees below zero and wind speeds of more than 200 miles per hour.

One of the most interesting puzzles about the atmosphere of Uranus is its striking asymmetry. A bright “collar” surrounds the southern pole, but the *Hubble* images show no bright counterpart around the northern pole. Is that due to climate changes as the planet orbits the Sun, or is it a more permanent asymmetry?

To find out, we can use current *Hubble* images to create a computer-generated simulation of Uranus, which we can run backward in time to earlier seasons. We can estimate the brightness of the planet at those earlier times to compare with contemporaneous observations. We can perform this comparison for measurements made as long ago as the 1950s and 1960s, before electronic cameras were in use. Typically, those older measurements provided only a single brightness measurement for the whole planet, but the observations were made with great care and were well calibrated.

Such comparisons tell us without a doubt that Uranus’s overall appearance has changed, and it must have had a northern polar collar in the past.

We do not yet understand why the appearance of Uranus changes. The changing position of the Sun relative to the equator undoubtedly influences circulation patterns in the atmosphere. However, none of the existing computer models shows the polar asymmetry or the kinds of cloud features seen in the *Hubble* images. Changes in color and brightness may be due to methane ice particles evaporating on the warm side of the planet. However, the temperature changes predicted by the atmospheric models do not appear to be sufficient to drive evaporation.

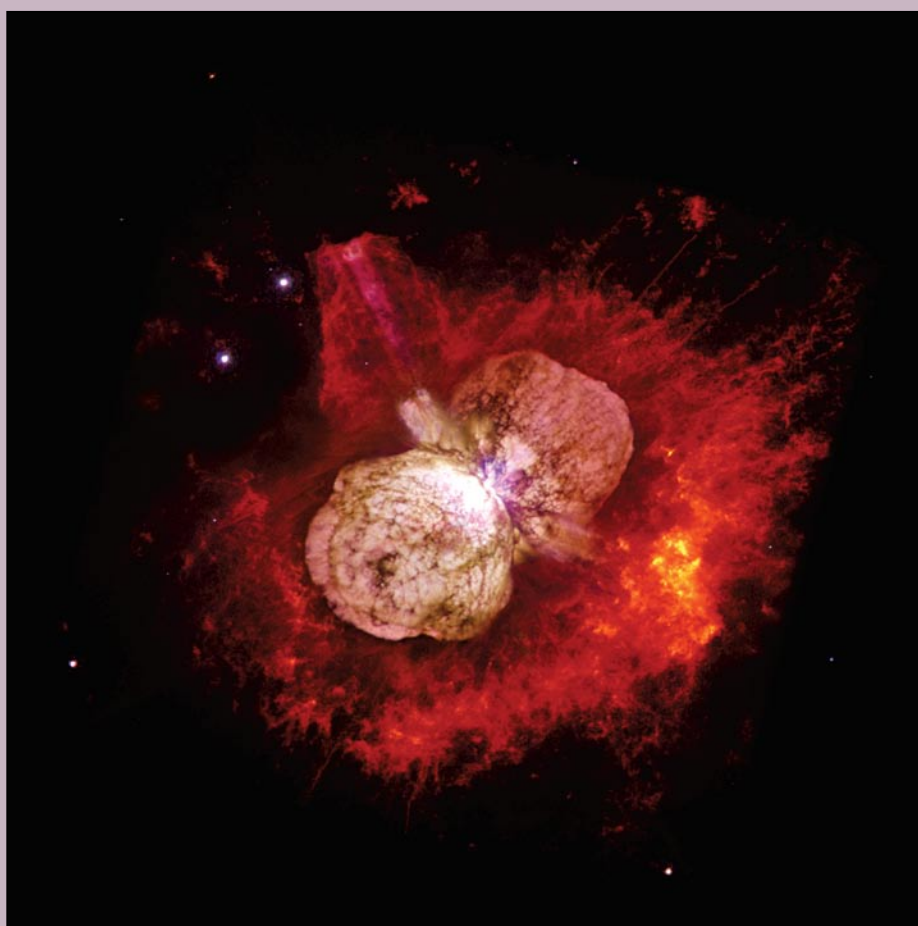
We expect more clues to emerge as Uranus moves through its spring season. When will the southern collar fade and a northern collar appear? What is driving these changes? These are questions that *Hubble* will continue to address in the coming years. The narrative is a new chapter in the history of Uranus, about a planet that is no longer boring, but the dramatic site of atmospheric evolution. ☞

#### Update, 8 November 2007:

Uranus is just weeks away from equinox! The atmospheric asymmetry is fading as expected. New *Hubble* images have revealed the first detection of a Great Dark Spot on Uranus, as well as many new bright features. Investigators using *Hubble* have also discovered an outer ring system—composed of two rings of strikingly different colors—surrounding Uranus. You can find new images of Uranus in the Solar System Collection on *HubbleSite*: [http://hubblesite.org/gallery/album/solar\\_system\\_collection/](http://hubblesite.org/gallery/album/solar_system_collection/).

# Eta Carinae—Materials for Future Worlds

T. R. Gull, *Theodore.R.Gull@nasa.gov*



**Figure 1:** A *Hubble* image of the gas surrounding the giant star Eta Carinae. Most, if not all of the gas appears to have been ejected since the 1840s when the star was, for a decade, nearly the brightest in the sky. Courtesy of Nathan Smith, University of Colorado.

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**Ted Gull** is an astrophysicist affiliated with the NASA Goddard Space Flight Center since 1977. He served as Associate Chief of Goddard's Laboratory for Astronomy and Solar Physics from 1986 to 1996. He has designed and built several instruments for astronomical research, is Deputy Principal Investigator of the Space Telescope Imaging Spectrograph, installed in *Hubble* in 1997, and served as Mission Scientist for the Astro-1 Mission, flown on the Space Shuttle *Columbia* in December 1990. He is a member of a large international consortium of observers and theorists keenly interested in understanding Eta Carinae and the transitory phase this massive stellar system is undergoing.

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One of the biggest, most energetic stars in the Galaxy is barely visible to the naked eye. Eta Carinae lies in the southern sky, about 7000 light-years away. It is over 100 times more massive than the Sun and so large that it would extend out to the orbit of Jupiter if it replaced the Sun. It radiates in one second as much energy as the Sun does in two months. And intriguingly, Eta Carinae seems about to explode!

"Recycling" is a relatively new word, coined for a recent trend on Earth. Nevertheless, recycling has been going on forever in the Galaxy. The high pressures inside stars fuse lighter elements into heavier elements, releasing the energy for stars to shine. Hydrogen and helium are transformed into nitrogen, carbon, and oxygen, plus many even heavier elements, like iron, nickel, and copper. As stars age, stellar winds and explosions spread these atomic products into space, where they mix with the interstellar medium and are swept up into new generations of stars, planets, and—in at least one case—living organisms. Indeed, all the atoms on Earth heavier than hydrogen and helium were created inside earlier, unknown stars. A star like the Sun will recycle about half its mass over its lifetime. A star like Eta Carinae will probably recycle about 90% of its mass, much of it in an expected huge explosion called a "supernova," which occurs when a star exhausts its nuclear fuel and collapses catastrophically.

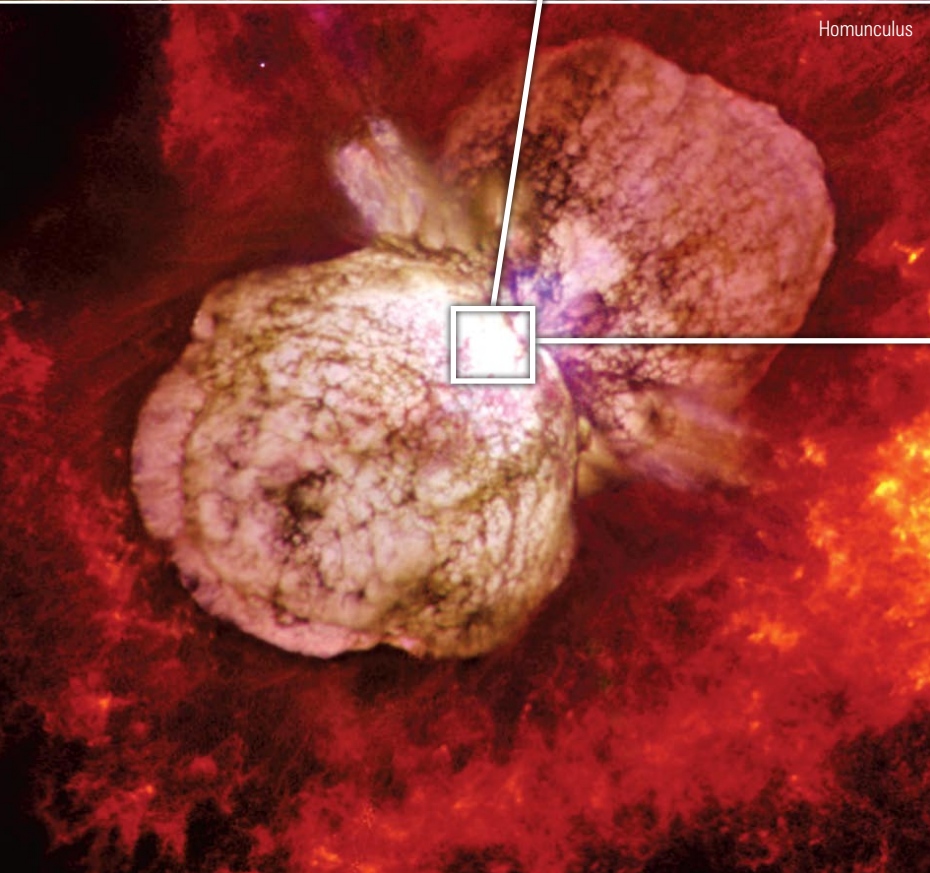
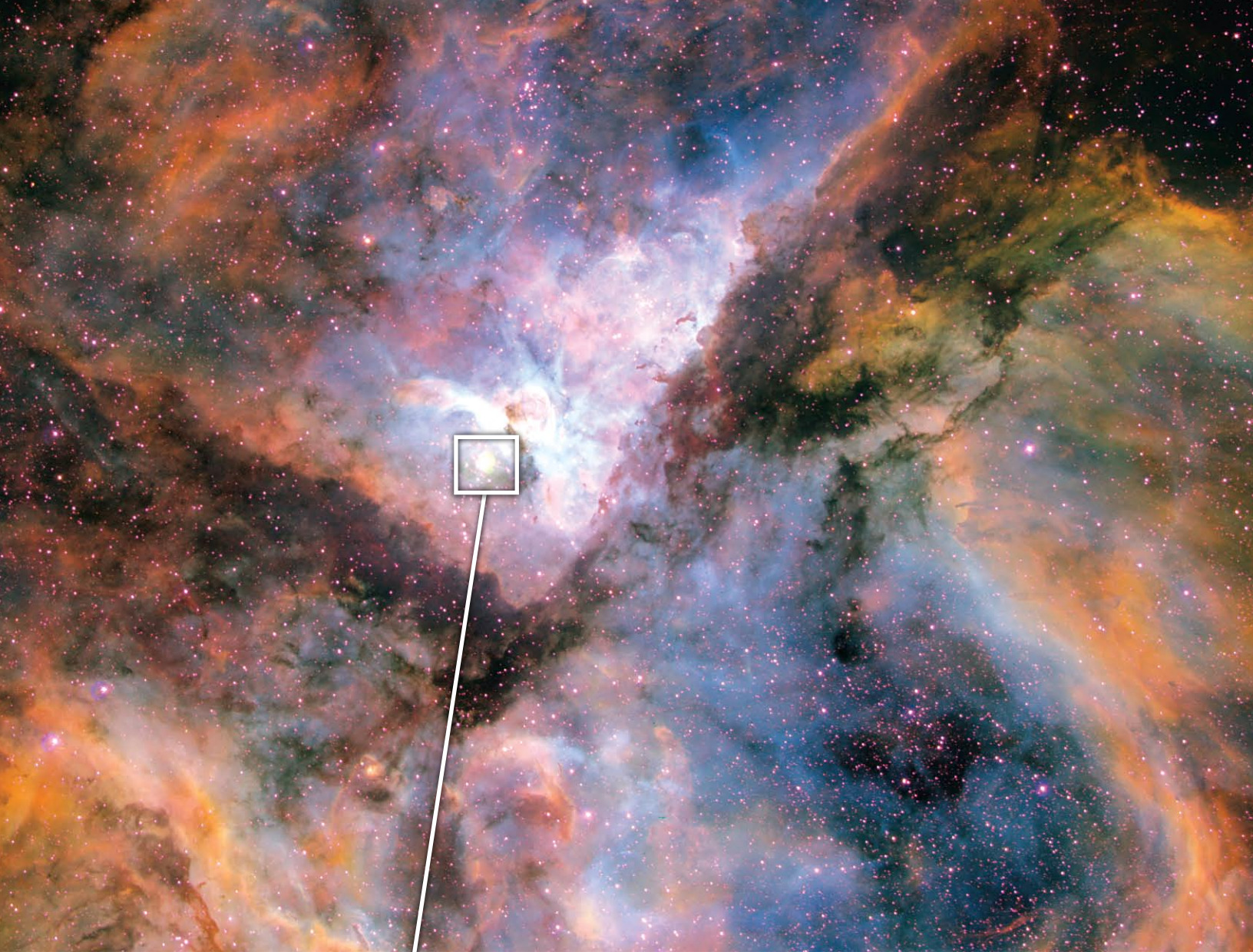
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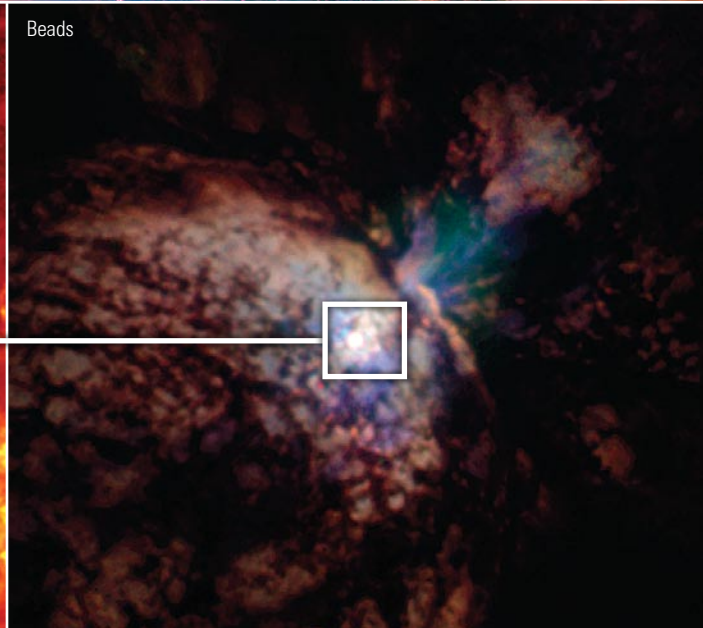
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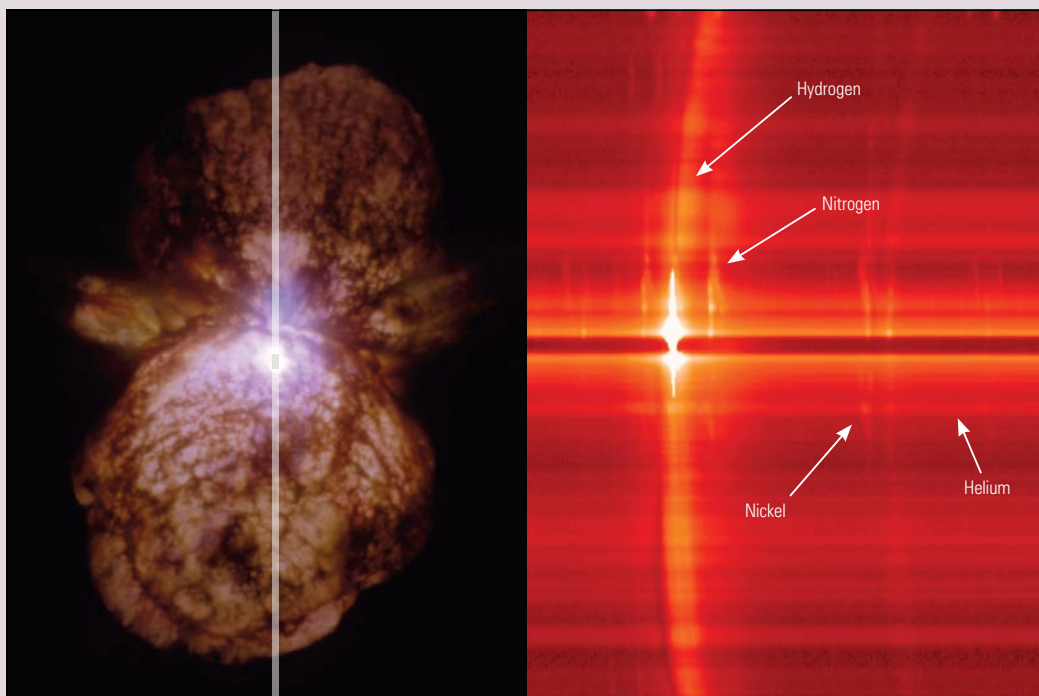
Homunculus



Beads

**Figure 1:** The Carina nebula at different scales. On the largest scales, Eta Carina is embedded in an enormous star-forming cloud. A bipolar nebula, known as the Homunculus, surrounds Eta Carina itself, and consists of material that was ejected from the star in the mid 1800s. Immediately surrounding Eta Carina itself, a ring of knots glows like bright beads on a necklace. Courtesy: Nathan Smith, *University of Minnesota/NOAO/AURA/NSF*.





#### SPECTROSCOPY IS AN ESSENTIAL TOOL FOR PROBING THE ETA CARINAE NEBULA.

By breaking light from the nebula into its component colors, a spectrum provides information on the chemical makeup, temperature, and motion of the gas. To measure the spectrum, astronomers used the Space Telescope Imaging Spectrograph (STIS), and placed the entrance aperture, a long, narrow slit, across the face of the Homunculus (as traced on the image). A small tab at the center of the aperture blocked most of the light from the star and allowed astronomers to study the light scattered by dust in the Homunculus and specific emission lines. A small portion of the spectrum is shown to the right of the image. The light within the slit has been stretched out in wavelengths, running from 6490 Ångstroms at the left of the spectrum to 6770 Ångstroms at the right. The faint red glow across the whole spectrum is starlight that is scattered by dust in the nebula. The bright, broad emission feature is light from hydrogen atoms in Eta Carinae that has been scattered by the expanding shell of dust. By measuring the shape of this feature, astronomers can determine the velocities within the expanding shell. Faint emission from hydrogen in the gas outside the Homunculus can be seen above and below the broad features. A narrow darker feature, an absorption line, can be traced against the broad stellar hydrogen emission and is due to a thin disk of cooler hydrogen that lies between two lobes, shaped much like an hourglass. Still closer to the center are narrow emission lines that shift with position. These originate from the Little Homunculus, the smaller nebula nested like a Russian doll within the Homunculus. Fainter narrow lines of helium, nickel and other elements can be traced against the dust-scattered background.

As the closest example of a massive star near the end its life, Eta Carinae provides our best object for studying the events leading up to a supernova and the violent outflows from a dying star, which enrich its surroundings.

Eta Carinae already exploded at least once, but somehow survived the blast. In the 1840s, the star suddenly became the second brightest in the sky. Sir John Herschel, working from South Africa, studied it intensively. By the mid 1870s, the star had faded and become invisible to the unaided eye. It underwent a smaller outburst in the 1890s.

Today, the images from *Hubble*'s cameras allow us to see fine detail on a spectacular expanding shell from the 1840s outburst, which is called the Homunculus—Latin for “little man”—because of its appearance to the eye through a small telescope. The shell is expanding at a rate of about 1.5 million miles per hour, which is so rapid that, despite the distance, *Hubble* images change noticeably year to year. Indeed, astronomers can map the expansion with repeated images. The Space Telescope Imaging Spectrograph (STIS) has measured the velocity of the out-flowing gas by the Doppler effect, and mapped variations across the face of the nebula. The STIS observations have found a second shell, “Little Homunculus,” from the 1890 outburst, nestled like a Russian doll within the 1840s shell.

In the mid 1990s, astronomers discovered that the spectrum of Eta Carinae changes in a regular, predictable manner. For several months every 5.5 years, many emission lines of the star and the surrounding nebulosity disappear, then reappear. The most probable explanation is that Eta Carinae is not just one star, but is a binary. Observations with the *Chandra X-Ray Observatory* suggest that the massive primary star,

*Continued  
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**Update, 8 November 2007:**

Observations with the *HST*/STIS, with ESO's Very Large Telescope Interferometer, and with *Chandra* have led to demonstrated proof that the periodic variability is caused by interacting winds of a massive binary system. Further observations, possibly with the repaired STIS, are planned to test supercomputer-generated three-dimensional models of these highly-clumped massive winds.

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with its prodigious wind, is interacting with a smaller, but still very massive, companion star. At visible and ultraviolet wavelengths, *Hubble* revealed that the surrounding nebulosity consists of bright beads in a ring of gas about 20 times the size to our Solar System (see page 45). Some of the beads glow brightly due to the huge amount of ultraviolet light they receive, especially from the less massive companion. Revolving in a highly elliptical orbit, the companion spends most of its time at a distance from the primary star that is about 20 times the distance from the Sun to the Earth. For a few months every 5.5 years, it zips in to within a few Sun-Earth distances. At these times, the massive winds of the two stars interact and disrupt the ultraviolet radiation for a few months. When this occurs, several beads dim, and then brighten again over a period of a few months.

*Hubble*'s spectroscopy detects the changes in these beads as the ultraviolet radiation turns off and on. Moreover, it finds that the Little Homunculus and the Homunculus respond to these changes. STIS detects signatures of iron, nickel, chromium, titanium—and even strontium and scandium—originating in the bipolar shells and a disk-like region between the shells. Curiously, STIS sees nitrogen, but little or no oxygen, nor carbon. It appears that as soon as nitrogen is formed in Eta Carinae, circulating currents conduct the nitrogen into the stellar atmosphere, but move the carbon and oxygen down into the stellar core.

The lack of oxygen and carbon has an interesting effect on the nebula. Astronomers measure huge quantities of titanium, vanadium, and strontium in the nebular gas. This is very unusual. The gas in most interstellar clouds contains only trace amounts of these heavy elements, because they combine with oxygen as a molecule and contribute to the formation of dust grains. In the Homunculus, it appears that the lack of oxygen and carbon inhibits dust formation. There is nevertheless some dust within the Homunculus, and it is unusual in that it scatters, but it does not easily absorb light. The spectroscopy from *Hubble* provides strong evidence that lack of oxygen is the cause.

Astronomers estimate that Eta Carinae ejected at least twelve times the mass of the Sun to form the Homunculus and the Little Homunculus. Nevertheless, they are not sure which star threw out the gas. Computer modeling should answer this question as efforts are made to reproduce the shape, velocity distribution, and chemistry of the nebula.

Eta Carinae provides an important test of our understanding of stellar evolution. Most other massive stars exhibit carbon- and oxygen-rich debris around them. But we have caught Eta Carinae at a very critical point of time: just as the hydrogen fuel is close to exhaustion. At this phase in the evolution of massive stars, theorists predict that nitrogen will be transported into the outer layers of the massive star before the nuclear furnace can turn it into oxygen. They expect the outer layers of the star to become rich in nitrogen and have much less carbon and oxygen. Hence, Eta Carinae, by exhibiting this nitrogen over-abundance and carbon and oxygen under-abundance, is reinforcing the predictions of stellar modelers.

Astronomers do not yet fully understand what led to the great eruption of Eta Carinae 150 years ago. Nevertheless, the existence of heavy elements in the debris of that eruption—as well as the continued instability of the star—lead some to speculate that a supernova explosion is imminent. This could mean anytime between today and 50,000 years from now. If Eta Carinae does explode as a supernova, it will become the brightest star in the sky for a several weeks, after which it will slowly fade to invisibility. The burnt-out core of the star will be propelled inwards by the force of the explosion and will probably end up as a black hole. The sudden loss of mass from the binary system will send the companion star flying away at about 2 million miles per hour. In the meantime, studies of Eta Carina with *Hubble* and other telescopes are teaching us much about the fate of massive stars. Ω



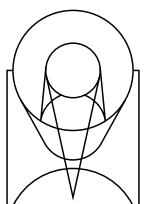


## Star Cluster Bursts into Life

**T**housands of sparkling young stars are nestled within the giant nebula NGC 3603. This stellar "jewel box" is one of the most massive young star clusters in the Milky Way Galaxy. NGC 3603 is a prominent star-forming region in the Carina spiral arm of the Milky Way, about 20,000 light-years away. This latest image from NASA's *Hubble Space Telescope* shows a young star cluster surrounded by a vast region of dust and gas. The image reveals stages in the life cycle of stars.

<http://hubblesite.org/newscenter/archive/releases/2007/34>

**Image Credit:** NASA, ESA, and the Hubble Heritage (STScI/AURA)-ESA/Hubble Collaboration



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International callers can use 1-410-338-1082.

For current *Hubble* users, program information is available at:  
[http://www.stsci.edu/hst/scheduling/program\\_information](http://www.stsci.edu/hst/scheduling/program_information).

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## ST-ECF Newsletter

**T**he Space Telescope–European Coordinating Facility publishes a newsletter which, although aimed principally at European Space Telescope users, contains articles of general interest to the *HST* community. If you wish to be included in the mailing list, please contact the editor and state your affiliation and specific involvement in the Space Telescope Project.

**Richard Hook (Editor)**

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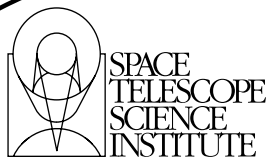
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## Calendar

### Cycle 16

Release of Cycle 17 Call for Proposals .....	early December 2007
AAS meeting (Austin) .....	8–11 January 2008
AAS Special Session at 10:00 a.m. "Going Deep: Results and Future Prospects with <i>HST</i> " .....	8 January 2008
JWST Technology Town Hall, AAS (Austin) .....	10 January 2008
Science with the new <i>Hubble Space Telescope</i> after Servicing Mission 4 Website: <a href="http://www.iasfbo.inaf.it/bawhst/">http://www.iasfbo.inaf.it/bawhst/</a> .....	29–31 January 2008
JWST SWG (STScI) .....	5–6 February 2008
STIC .....	11–12 February 2008
HST Cycle 17 Phase I deadline .....	7 March 2008
Hubble Fellows Symposium .....	10–12 March 2008
MAST Senior Review Proposal Deadline .....	15 March 2008



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