

NEWSLETTER

Space Telescope Science Institute

Hubble Heritage: From Inspiration to Realization

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Chances are you've seen some of our images. They are popping up everywhere in textbooks, magazines, and online. Perhaps you've used them in a lecture or maybe pinned one on your bulletin board. You may be one of the 200,000 people who view our web site each month or the millions more who see our monthly images in other venues. You may have even noticed an image credit to NASA/Hubble Heritage and wondered briefly what that signified.

Hubble Heritage is many things. It is an idea—an idea born in a holiday conversation with relatives who wanted to know if I had worked on “that picture from Hubble”—Jeff Hester’s image of the Eagle Nebula, M16. More than any other, that particular image proved to the public that Hubble was back after its shaky, out-of-focus start.

My holiday epiphany crystallized in three facets. I was reminded that beautiful images have a great power to communicate across barriers of educational level and language. This communication is immensely valuable to scientists who rely on public support for the pursuit of their sometimes-esoteric goals. From my experience as an instrument scientist for the Wide Field Planetary Camera (WFPC2), I realized that few other images like the Eagle would come directly from the Hubble science program itself. Hard-nosed Time Allocation Committees and overburdened General Observers (GOs) could be expected to have little sympathy for “pretty pictures”. Most importantly, I saw that I was in a position to change the course of events.

Returning from my holiday, I shared my idea for Hubble Heritage with Anne Kinney and Howard Bond, who were immediately enthusiastic. We went to Bob Williams, then Institute Director, and were happy to receive his

support. More than a year of planning and team-building later, Hubble Heritage unveiled its first four images on October 21, 1998. In the first month thereafter, our new web site recorded 14 million hits from people coming to view our images of the “Fried Egg” Seyfert Galaxy NGC 7742, a colorful field of stars in Sagittarius near the center of the Milky Way, the wisps of the Bubble Nebula, and Saturn’s classic rings. (<http://heritage.stsci.edu>)

Early on in our project, we settled on the pace of producing one new image each month. We have attempted to include as broad and representative a selection of astronomical objects as possible. We use both public, archival data and new images planned by us. We release our images on our web site and have benefited from simultaneous press releases from the Institute’s Office of Public Outreach (OPO). The images reach a wide audience, with many being picked up by other online sites and other forms of traditional media.

Hubble Heritage is a tool for outreach from Hubble to the world. By requiring only that an image be esthetically impressive, we are able to bypass the usual narrow filter for press releases, the requirement that the image contain a “revolutionary discovery”. This doesn’t mean, of course, that the images have little scientific value. Indeed, most of science is the result of the slow accumulation of incremental results that are a necessary prerequisite for the much more rare breakthrough. Also, since we are an inherently visual species, simply seeing a familiar object more clearly can inspire a deeper understanding of the processes and relationships in complex fields. (See article by Nolan Walborn, this issue.) By focusing on the appeal of the

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Faith

Steven Beckwith



In the aftermath of the terrorist attacks, it has been difficult to turn our attention to science. At the time they occurred, we watched helplessly, and our thoughts went to our families, to their safety, and toward ways that we could help the victims. Donating blood, sending contributions, making phone calls in support of friends near the scenes—any response seemed more important than feeding a satellite orbiting serenely 370 miles above the fray.

We knew at the time that our nation would recover quickly, for we are a people of great resilience. I knew that STScI would do its job, too, despite the emotional trauma the staff experienced. Dave Soderblom stayed after we closed on that fateful day to inform me how long we could wait before another schedule build was needed to keep HST running. Pat Fraher assured me that we would continue to process the data even without operators, such was the ability of our automated data pipeline. We heightened security at the Institute. Hubble is also a national symbol. But the next day, we were back to the business of science.

It is precisely because of the progress science has brought to our culture that our job remains important. Astronomy may be far removed from the daily struggle required to keep death in abeyance, yet it has a power to transcend this struggle in a way few other endeavors can. Our progress in understanding the universe has been profound and lasting. It gives us insight into nature's workings, and it has been the engine of material progress since its first use several millennia ago.

Progressive enlightenment is our common goal. Our creed is agnosticism, testing each new belief with experiments designed to ferret out the inadequacy of our understanding. We look with skepticism upon those who are too strong in their commitments to theories of the day, knowing that even the greatest scientific ideas are often overturned by new discoveries, and knowing also that our

two greatest physical theories—relativity and quantum mechanics—are contradictory in their basic tenets. Our habit of skepticism breeds a reluctance to act in extreme ways on the basis of theory alone, a reluctance that obviously lacks in persons willing to take the lives of others in the name of their faith or frustration.

Children learn the name of Archimedes but not the name of the soldier who killed him. We all know Galileo, but few of us recall the pope who made him recant his views. Newton, Einstein, Watson and Crick are better known to most people than many important political leaders of their day. We still use scientific discoveries several millennia old. Human politics both noble and evil will come and go, but true understanding builds upon itself.

In the wake of the human tragedy that gripped our nation in September, our job is to do what we do best: to tease nature's secrets from her grasp and give ourselves a basis for understanding the universe based on more than faith alone. It is an important job, one of the pinnacles of modern society. We will not necessarily make society better, but we will help make society worth having in the first place. Our contributions to civilization will stand and will be appreciated in the future.

The Institute will help you with your own contributions to science. You can count on us to keep the flame of scientific inquiry alive and to make the Hubble Space Telescope a symbol for our faith in the future.

NGST Enters Hot Winter Season

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The Next Generation Space Telescope (NGST) project is on the eve of major decisions, including selecting the prime contractor to build the telescope, selecting the team to develop the NIRCam, and appointing the Flight Science Working Group, which will direct the NGST science in the early mission. The imminent Announcement of Opportunity will be posted on the WWW at http://research.hq.nasa.gov/code_s/code_s.cfm

Meanwhile, there is NGST news on procuring the Science & Operations Center, defining the mid-infrared instrument and the near-infrared spectrograph, and deciding the institutional arrangements for developing the NGST instruments.

NGST Science & Operations Center at the Institute

The NGST Project at Goddard Space Flight Center (GSFC) has been authorized by NASA Headquarters to issue a sole-source Request for Proposal (RFP) to AURA/Space Telescope Science Institute for the development of the NGST Science & Operations Center. The approval was based on the Institute's excellent performance in Hubble science operations, the expertise of the staff, and the significant savings that can be realized by inheriting systems developed for Hubble. That is, significant portions of the science operations system will be based on Hubble counterparts, such as the multi-mission archive.

The Institute has reviewed draft versions of the statement of work (SOW) and anticipates receiving the formal RFP in early September. Approximately two months thereafter, AURA will submit a full cost and management proposal to NASA. The contract will run from April 2002 to one year following NGST launch (nominally January 1, 2010).

One of the lessons learned from Hubble is the importance of having the operations center involved early, during the design and implementation phases of the mission. Thus, in the NGST SOW, the Institute will be responsible for developing or procuring the entire NGST ground system and for making some elements available early to test the science instruments and spacecraft. The Institute will also work directly with the instrument teams, the NGST prime contractor, the European Space Agency (ESA), and other NGST contractors during the development and testing phases to ensure a smooth transition from development to science operations.

Mid-infrared Steering Committee Meets in Edinburgh, Scotland

The Mid-infrared Steering Committee (MISC) met at the UK Astronomical Technology Centre in Edinburgh, Scotland, on 16-17 July, 2001. The MISC is chartered to assist NASA, ESA, and the Canadian Space Agency (CSA) in defining the key science capabilities for NGST's mid-infrared instrument (MIRI, formerly MIRSPECT/CAM), developing a preliminary instrument concept, and formulating an international partnership plan. The committee includes representatives from the U.S., Canadian, and European science communities. (See the Summer 2001 Newsletter for membership.)

In Edinburgh, the MISC reviewed a suite of potential NGST mid-infrared science programs and their required instrumental capabilities. The scientific themes included searching for the origins of galaxies, studying the birth of stars and planets, and understanding the evolution of planetary systems.

Based on these science programs, the MISC recommended the following MIRI capabilities:

For imaging:

- Wavelength range: 5 – 27 microns
- Diffraction limited imaging: Nyquist sampled at no longer than 8 microns wavelength
- Minimum field of view: 1.5 arcminutes
- Larger imaging field of view is a goal
- Filters: at least 8 spectral bands, 4-5 for spectral energy distribution (SED) definition and others to isolate polyaromatic hydrocarbons (PAH) and identify brown dwarf atmospheric colors.
- Simple coronagraph



NGST

For spectroscopy:

- Single object
- Wavelength range: 5 – 27 microns
- Extension to 28.3 microns is a goal
- Resolution: $R \sim 100$ from 5 to 10 microns wavelength
- Resolution $R \sim 1000$ to 3000 from 5 to 28.3 microns wavelength
- Resolution close to 3000 (or slightly higher) is a goal

The European consortium presented a baseline instrument concept for MIRI that might satisfy these functional requirements. It is a 2-channel system with common fore-optics feeding separate modules for imaging and integral field spectroscopy, each of which has an individual focal-plane detector array.

Based on this concept, the MISC made recommendations to guide the follow-on MIRI design studies:

Imaging:

- Pixel size of 0.1 arcsecond with a 1024x1024 array
- Bright-object limit at least 4 mJy at 10 microns to provide overlap with imaging from the ground
- At least 12 bandpass filters
- Imager should include low-resolution spectroscopic capability
- Coronagraph should be included in the instrument study

Spectroscopy:

- The spectrograph should use an integral field unit with a field of view of at least 2 arcsecond and a goal of at least 3 arcsecond.
- The pixel size in the spectrograph should be 0.2 arcsecond, with one or two 1024x1024 arrays.

The MISC also recommended that the MIRI instrument study should address the tradeoff between using one and two arrays, which could eliminate a grating-exchange mechanism and reduce the number of filter wheel positions required to obtain a full spectrum.

Third Meeting of the Interim Science Working Group

The Interim Science Working Group (ISWG; see the summer 2001 Newsletter for membership) met at NASA-HQ on August 21-22, 2001, to review the development plans for NGST instruments.

The ISWG discussed the science requirements and performance characteristics of the near-infrared spectrograph, NIRSPEC. To study high-*z* galaxies, massive stars, star formation, properties of low-mass stars, and the interstellar medium, they recommended that NIRSPEC offer multi-object spectroscopy with

resolving power $R \sim 1000$ over the wavelength range 1 to 5 microns. To enable observations of the Gunn-Peterson effect at all interesting redshifts, the ISWG recommended a lower-resolution, compound-prism capability with $R \sim 100$ and wavelength range extending to shorter wavelengths (0.6 microns).

The ISWG was brought up to date on institutional arrangements for developing NIRSpec. ESA will procure and oversee development of NIRSPEC, guided by an ESA-selected science team. NASA will provide the micro-mirror/micro-shutter aperture mechanism and near-infrared detectors. (In return for the NASA contributions, ESA will provide the cryostat for the MIRI.) Since the development of the MEMS addressable aperture technologies will be funded until 2003, ESA is funding alternative spectrograph designs, including micro-mirrors, micro-shutters, multi-slit, and integral field designs. As



Group photo taken at the ISWG meeting on August 22, 2001.

From left to right (seated) Hashima Hasan, George Helou, Marcia Rieke, Bob Kirshner, Marc McCaughrean, Peter Jakobsen; **(standing)** Bob Fosbury, Ewine van Dishoeck, Mike Werner, Rolf Kudritzki, Nino Panagia, Massimo Stiavelli, Duccio Macchetto, Bruce Margon, John Mather, Rob Kennicutt, John Hutchings, Peter Stockman. (Courtesy of Marcia and George Rieke.)

image itself, we are able to reach a broad audience and perhaps interest some people to delve deeper into the wealth of astronomy.

Hubble Heritage provides an opportunity for members of the Hubble community to take advantage of the skills of our team in producing images and web releases. We don't have any real secrets to producing our color images. We invest lots of time in cleaning and color balancing. We judiciously apply limited image enhancement techniques, for example, a logarithmic intensity stretch to show the large dynamic range present in many celestial objects. We are, however, always conscious of the need to avoid even the impression that we are altering or "colorizing" our data. To enable viewers to judge the fidelity of our work for themselves, we have begun posting the unprocessed images as well as the final product on our web site.

Because our color images are intended for visual appeal rather than rigorous scientific analysis, we eliminate image artifacts that would otherwise mar the final image. The next time you look at the famous Eagle Nebula image, try to find a small pink ring just above the bright star in the lower left of the image. That ring is a well-known artifact, a "filter ghost", caused by doubly reflected light, off the detector surface and off the surface of the slightly tilted filter, back to the detector. Heritage would have removed it.

Approximately half of our images are produced from archival data originally obtained by GOs. Typically, we identify candidate images by searching the archive and then contacting the GOs, though we are happy when a GO brings an interesting picture to our attention. We ask the original observers to write descriptive material for the press release, more detailed descriptions for our web pages, and to respond to inquiries from the press. We will link to personal home pages, preprints, and published papers, if the GO desires.

Hubble Heritage is aimed at the future as well as the present. While we are happy when a Heritage image appears on the front page of the New York Times—as happened with the image of interacting galaxies NGC 2207 and IC 2163—headlines are not really our goal. Our long-term vision is the astronomy textbooks of 2015. If, as we already know, the science in those texts will have been greatly expanded by the work of the Hubble community, shouldn't they also be illustrated with Hubble images?

There is a tremendous appetite for images that emphasize the awe-inspiring beauty of our universe. In May 2000 I had the privilege of accepting the International Center of Photography's Infinity Award for Applied Photography for our team. Time and again at the award ceremony I heard members of the exclusively non-scientific audience remark on the *beauty* of the Heritage images, even when the admirer did not know the difference between a planet and a planetary nebula.

Finally, Hubble Heritage is a team. All of our images bear a credit to the Hubble Heritage Project. The anonymity inherent in this name is intentional. It can safely be said that no image from Hubble, certainly none from Hubble Heritage, is the product of a single individual. For sure, in some cases one individual has made major contributions to an image. However, in every case, the proposal, image selection, color balance, cropping, orientation, caption, and supplementary educational materials have multiple creators. Besides our permanent team members, we have often benefited from the gracious assistance of members of the wider Hubble community lending their time and expertise.

One of the best additions to our web site, added in 1999, is the collection of short biographies of the scientists who collected the data used in an image or who helped us in some other way. These include interesting and unique descriptions of their motivations and aspirations. Many of the biographies cite childhood experiences of the night sky or space missions in their decision to later become astronomers. Personally, I've found these biographies a fascinating way to learn a little more about colleagues that I would ordinarily know only professionally. Our team hopes these personal descriptions will lend Hubble a human face and inspire young people about science. Perhaps today's children, living in a world where dark skies are becoming increasingly rare, are gazing at our images from Hubble and dreaming the dreams that will power their future. [Ω](#)

The Hubble Heritage Team

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A Glimpse at Hubble Heritage



Ring Around a Galaxy

Space Telescope Science Institute astronomers are giving the public chances to decide where to aim NASA's Hubble Space Telescope. Guided by 8,000 Internet voters, Hubble has already been used to take a close-up, multi-color picture of the most popular object from a list of candidates, the extraordinary "polar-ring" galaxy NGC 4650A.

Located about 130 million light-years away, NGC 4650A is one of only 100 known polar-ring galaxies. Their unusual disk-ring structure is not yet understood fully. One possibility is that polar rings are the remnants of colossal collisions between two galaxies sometime in the distant past, probably at least 1 billion years ago. During the collision the gas from a smaller galaxy would have been stripped off and captured by a larger galaxy, forming a new ring of dust, gas, and stars, which orbit around the inner galaxy almost at right angles to the larger galaxy's disk. This is the vertical polar ring which we see almost edge-on in Hubble's Wide Field Planetary Camera 2 image of NGC 4560A, created using 3 different color filters (which transmit blue, green, and near-infrared light).

The ring appears to be highly distorted and the presence of bluish, young stars below the main ring on one side and above on the other shows that the ring is warped and does not lie in one plane. The typical ages of the stars in the polar ring may provide a clue to the evolution of this unusual galaxy. Because the polar ring extends far into the halo of NGC 4650A, it also provides a unique opportunity to map "dark matter" which is thought to surround most disk galaxies.

The HST exposures were acquired by the Hubble Heritage Team and guest astronomers Jay Gallagher (University of Wisconsin-Madison), Lynn Matthews (National Radio Astronomy Observatory-Charlottesville), and Linda Sparke (University of Wisconsin-Madison).

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)

Acknowledgment: J. Gallagher (U. Wisconsin-Madison)

The Glowing Eye of NGC 6751

Astronomers using NASA's Hubble Space Telescope have obtained images of the strikingly unusual planetary nebula, NGC 6751. Glowing in the constellation Aquila like a giant eye, the nebula is a cloud of gas ejected several thousand years ago from the hot star visible in its center.

"Planetary nebulae" are named after their round shapes as seen visually in small telescopes, and have nothing else to do with planets. They are shells of gas thrown off by stars of masses similar to that of our own Sun, when the stars are nearing the ends of their lives. The loss of the outer layers of the star into space exposes the hot stellar core, whose strong ultraviolet radiation then causes the ejected gas to fluoresce as the planetary nebula. Our own Sun is predicted to eject its planetary nebula some 6 billion years from now.

The Hubble observations were obtained in 1998 with the Wide Field Planetary Camera 2 (WFPC2) by a team of astronomers led by Arsen Hajian of the U.S. Naval Observatory in Washington, DC. The Hubble Heritage team, working at the Space Telescope Science Institute in Baltimore, has prepared this color rendition by combining the Hajian team's WFPC2 images taken through three different color filters that isolate nebular gases of different temperatures.

The nebula shows several remarkable and poorly understood features. Blue regions mark the hottest glowing gas, which forms a roughly circular ring around the central stellar remnant. Orange and red show the locations of cooler gas. The cool gas tends to lie in long streamers pointing away from the central star, and in

a surrounding, tattered-looking ring at the outer edge of the nebula. The origin of these cooler clouds within the nebula is still uncertain, but the streamers are clear evidence that their shapes are affected by radiation and stellar winds from the hot star at the center. The star's surface temperature is estimated at a scorching 140,000 degrees Celsius (250,000 degrees Fahrenheit).

Hajian and his team are scheduled to reobserve NGC 6751 with Hubble's WFPC2 in 2001. Due to the expansion of the nebula, at a speed of about 40 kilometers per second (25 miles per second), the high resolution of Hubble's camera will reveal the slight increase in the size of the nebula since 1998. This measurement will allow the astronomers to calculate an accurate distance to NGC 6751. In the meantime, current estimates are that NGC 6751 is roughly 6,500 light-years from Earth. The nebula's diameter is 0.8 light-years, some 600 times the diameter of our own solar system.

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)

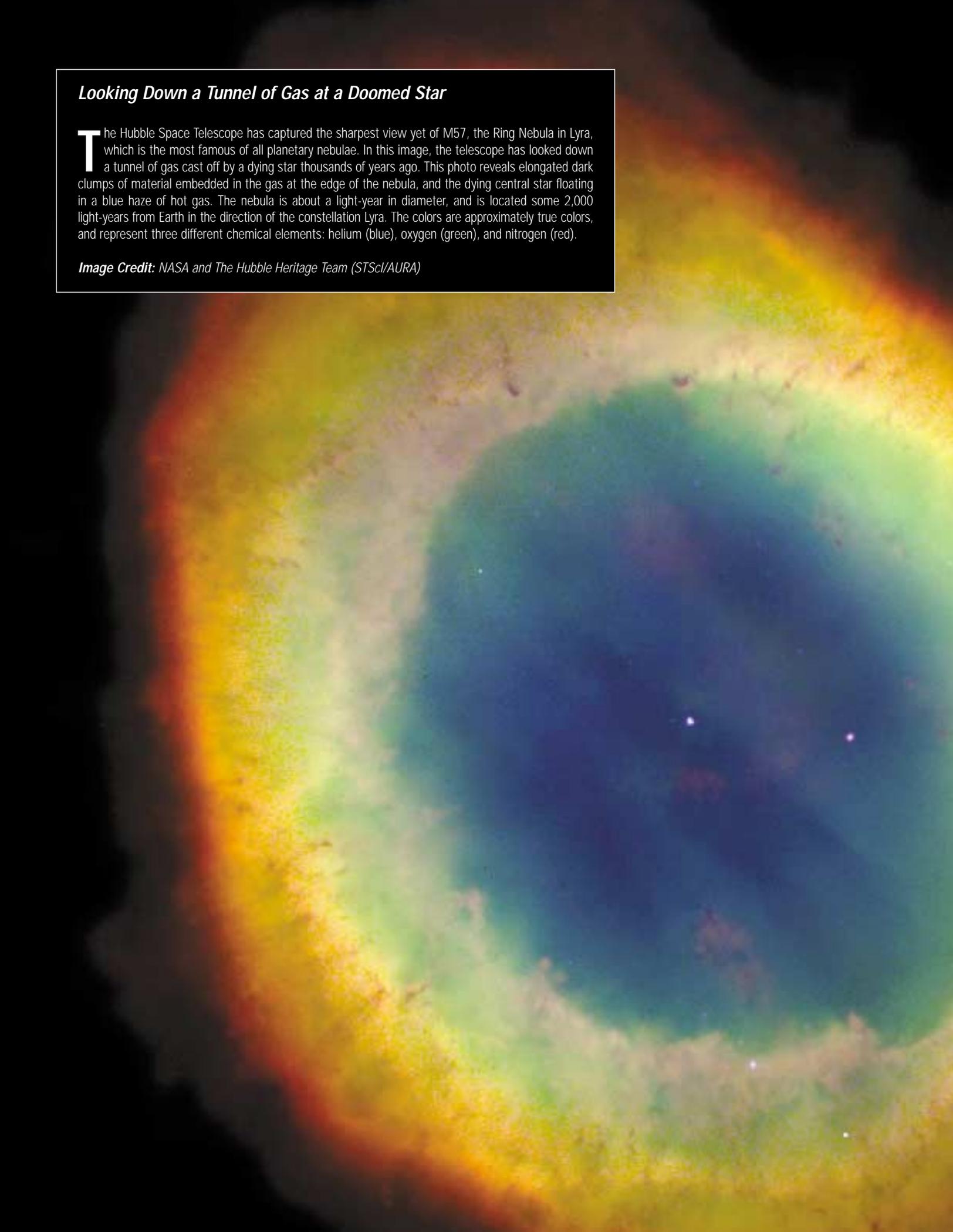
Acknowledgment: A. Hajian (US Naval Observatory) and B. Balick (University of Washington)



Looking Down a Tunnel of Gas at a Doomed Star

The Hubble Space Telescope has captured the sharpest view yet of M57, the Ring Nebula in Lyra, which is the most famous of all planetary nebulae. In this image, the telescope has looked down a tunnel of gas cast off by a dying star thousands of years ago. This photo reveals elongated dark clumps of material embedded in the gas at the edge of the nebula, and the dying central star floating in a blue haze of hot gas. The nebula is about a light-year in diameter, and is located some 2,000 light-years from Earth in the direction of the constellation Lyra. The colors are approximately true colors, and represent three different chemical elements: helium (blue), oxygen (green), and nitrogen (red).

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)





Hubble Reveals the Heart of the Whirlpool Galaxy

New images from NASA's Hubble Space Telescope are helping researchers view in unprecedented detail the spiral arms and dust clouds of a nearby galaxy, which are the birth sites of massive and luminous stars.

The Whirlpool galaxy, M51, has been one of the most photogenic galaxies in amateur and professional astronomy. Easily photographed and viewed by smaller telescopes, this celestial beauty is studied extensively in a range of wavelengths by large ground- and space-based observatories. This Hubble composite image shows visible starlight as well as light from the emission of glowing hydrogen, which is associated with the most luminous young stars in the spiral arms.

M51, also known as NGC 5194, is having a close encounter with a nearby companion galaxy, NGC 5195, just off the upper edge of this image. The companion's gravitational pull is triggering star formation in the main galaxy, as seen in brilliant detail by numerous, luminous clusters of young and energetic stars. The bright clusters are highlighted in red by their associated emission from glowing hydrogen gas.

This Wide Field Planetary Camera 2 image enables a research group, led by Nick Scoville (Caltech), to clearly define the structure of both the cold dust clouds and the hot hydrogen and link individual clusters to their parent dust clouds. Team members include M. Polletta (U. Geneva); S. Ewald and S. Stolovy (Caltech); R. Thompson and M. Rieke (U. of Arizona).

Intricate structure is also seen for the first time in the dust clouds. Along the spiral arms, dust "spurs" are seen branching out almost perpendicular to the main spiral arms. The regularity and large number of these features suggests to astronomers that previous models of "two-arm" spiral galaxies may need to be revisited. The new images also reveal a dust disk in the nucleus, which may provide fuel for a nuclear black hole.

The team is also studying this galaxy at near-infrared wavelengths with the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) instrument on board Hubble. At these wavelengths, the dusty clouds are more transparent and the true distribution of stars is more easily seen. In addition, regions of star formation that are obscured in the optical images are newly revealed in the near-infrared images.

This image was composed by the Hubble Heritage Team from Hubble archival data of M51 and is superimposed onto ground-based data taken by Travis Rector (NOAO) at the 0.9-meter telescope at the National Science Foundation's Kitt Peak National Observatory (NOAO/AURA) in Tucson, AZ. [Ω](#)

Image Credit: NASA and The Hubble Heritage Team (STScI/AURA)
Acknowledgment: N. Scoville (Caltech) and T. Rector (NOAO)

News from the Multimission Archive at STScI (MAST)

Paolo Padovani, on behalf of the MAST team
and the ESS Archive Team, padovani@stsci.edu

Hubble Data Archive Status

The Hubble data archive now contains about 7 terabytes of data in about 242,000 science data sets. (These numbers are down slightly from the numbers we gave in the last Newsletter, due to a “clean-up” associated with the media migration to magneto-optical disks.) The Hubble archive ingests an average of 3 gigabytes per day. Lately, the data retrieval rate has been about 6 times higher, reaching levels of about 20 gigabytes per day.

New Additions to the MAST Scrapbook

In the last Newsletter, we described the new MAST Spectral/Imaging Scrapbook, which is available at <http://archive.stsci.edu/scrapbook.html>. This scrapbook is a web tool that permits the user to preview representative spectra or sky images in the UV/optical/near-IR MAST archives for a given source (outside the solar system) or sky position. A press release also announced the existence of this tool for potential nonprofessional users—<http://oposite.stsci.edu/pubinfo/PR/2001/17/>.

The original scrapbook included HST/GHRS, HST/FOS, IUE, HUT, and EUVE spectra and HST/WFPC2 images. We have now added HST/STIS, ORFEUS/TUES, and ORFEUS/BEFS to the spectral scrapbook, and HST/FOC and ASTRO/UIT to the imaging scrapbook. The STIS data extend the scrapbook’s coverage to fainter magnitudes and from approximately Lyman alpha to the near IR in wavelength. The two Shuttle instruments, TUES (Tuebingen echelle spectrograph) and BEFS (Berkeley Extreme and Far-UV spectrograph), extend the scrapbook’s wavelength coverage from the Lyman limit to Lyman alpha for both bright (TUES) and faint (BEFS) sources. The scrapbook catalog is updated periodically to add data from active missions for which the proprietary period has lapsed.

Where a mission or instrument offers multiple spectral modes, we may need to choose one “representative spectrum” from several data sets taken with various filter/grating combinations. In this case, we have usually selected a low-dispersion spectrum rather than a high-dispersion spectrum. The exception is IUE data, for which both low- and high-dispersion data are presented when both exist.

Our future plans for the spectral scrapbook include: (1) adding FUSE data as new calibration and preview data products become available, (2) constructing STIS preview plots with flux ranges tailored to the specific observations, (3) providing superior flux calibrations for FOS, and (4) providing a secondary tool to permit the user to co-plot selected data sets returned from the initial query.

The image scrapbook includes WFPC2, FOC, and Astro/UIT data for positions/sources taken through various band and line filters as well as polarizers. Although the size of the FOC images is small (28 x 28 arcseconds maximum), they provide better spatial resolution and UV sensitivity than WFPC2. The Astro/UIT scrapbook provides far- and near-UV previews with a large (40 arcminutes) field of view.

The DADS Re-Engineering Project

A project to completely re-engineer the Data Archive and Distribution System (DADS) has been underway for some time. The new archive subsystem and current migration of data from optical platters to magneto-optical (MO) disks were the first implementations of that process. This re-engineering project will gradually replace all the components of the old system. The next portion to be implemented will be the distribution subsystem. According to the current schedule, we expect this to be accomplished before the end of this year. Subsequent project phases will replace the ingest subsystem and will modify and enhance the database subsystem.

Why are we re-engineering DADS and what will be the impact on archive users?

The old DADS is inadequate in a number of respects. It is based on antiquated assumptions and requirements, and it uses outdated hardware and operating systems. The DADS software architecture is also obsolete, and the system is difficult to maintain. As a result, DADS is costly in both dollars and lost research opportunities. The infrastructure of the re-engineered DADS will permit technical innovations now being discussed for on-the-fly-reprocessing, more complex types of data associations, and the National Virtual Observatory (NVO) project.

Initially, DADS users will benefit from improved responsiveness and more options in retrieving data, such as CD-ROM or DVD media, choice of compression, and the ability to specify more precisely the content of the files delivered. For example, the user could specify only calibrated files for associations or could include or exclude certain categories of files.

The re-engineered DADS will afford better operational control. The substantive changes will be entirely internal. A major design goal is ensuring the internal system architecture is simple and flexible.

Recalibrated FOS Blue-Side Data

The Space Telescope European Coordinating Facility (ST-ECF) is undertaking the Post-Operational Archives (POA) project. This project, based on a NASA/ESA agreement, aims to improve the scientific value of Hubble legacy instruments after their retirement. The Faint Object Spectrograph (FOS) blue channel (1,100 to 5,000 Angstroms) was chosen as the first instrument mode for POA. The first POA activity was a feasibility study for improving the data archive by resolving important calibration issues for this mode.

The results of this first POA study are now available to the astronomical community. The approximately 11,000 FOS data sets recalibrated by the POA project have greatly enhanced scientific value. Improvements include curing the zero-point uncertainties in the dispersion direction and fixing related problems with the wavelength dispersion relations. The POA project also derived new flat fields. The impact on FOS/BLUE data has been dramatic, particularly, for example, in the study of radial velocities.

A new calibration pipeline, `poa_calfos`, is also available. Details on the re-ingest of the reprocessed FOS data in the Hubble archive will be provided in the next issue of the Newsletter. For more details on the POA FOS recalibration project, check the July 2001 ST-ECF Newsletter article by Michael Rosa et al. or go to <http://www.stecf.org/poa>.

Explore the WFPC2 Archive with the Pointings Table

The Wide Field and Planetary Camera 2 (WFPC2) archive is now sufficiently large that serendipitous searches may reap large scientific benefits. To facilitate such searches, the Hubble archive group has created the new Pointings Table, which has a web-based interface. WFPC2 aficionados will enjoy this new search service. A table of WFPC2 observations has been developed that divides the sky into pointings and provides counts of observations at each of these pointings. This enables new categories of questions to be addressed, such as, "How many pointings have more than 2 I-band exposures and 2 B-band exposures?" or, "How many pointings have observations in at least 2 unique bands in U, B, V, R, or I?" or, "How many pointings at low galactic latitude have observations at least 100 days separated in time?" Such questions were impossible to ask before the existence of this table, which will be updated weekly.

The Pointings Table and its interface allow searches not only by position but also by ranges in galactic latitude, ecliptic latitude, right ascension, and declination. The retrieval screen itself has some unique features. For example, it allows the user to inspect parameters of all the "R-band" exposures that satisfied the search criteria. To try out the interface and discover further details, visit: <http://archive.stsci.edu/hst/pointings.html>.

By expanding to include other instruments, we plan to increase both the amount of information in the Pointings Table and the general power of this kind of search. Future enhancements may include cross-correlating this table with standard catalogs, which would enable users to ask such questions as, "How many NGC galaxies have been observed more than twice in the I-band with the WFPC2?" or, "How many pointings at high galactic latitude, excluding pointings of NGC galaxies, have I-band data?" In its recommendations, the Second Decade Committee discussed and supported such "data mining" capabilities for the archive. (http://sso.stsci.edu/second_decade/recommendations/index.html)

StarView 7.0

In fall 2001, we will release a new version of the archive search and retrieval tool, StarView 7.0. The significant advance in version 7.0 will be the ability to search observations and retrieve data for IUE, FUSE, and EUVE. In the future, StarView's multi-archive capability will be generalized even further, enabling searches of other NASA mission archives, utilization of the StarView client by other NASA mission archives, and enabling two site-specific text configuration files. StarView 7.0 will also take advantage of the new services offered by the reengineered DADS: retrieval of compressed data, more flexibility in extension choices, and expanded choice of hard media. 



The Continuing Relevance of Morphology in Astronomy

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My astronomical research career was launched in the direction of morphological studies by W. W. Morgan. He devoted his long career at the Yerkes Observatory to the classification of astronomical objects by their form and structure, strictly separating this empirical process from that of theoretical interpretation. Morgan taught me the remarkable power of morphology to organize and describe complex phenomena, largely free of measurement and modeling uncertainties, and often leading to the discovery of new classes and relationships. I have not yet exhausted the research potential of Morgan's guidance.

As applied to astronomy by Morgan, morphology comprises the study of structure and patterns in, e.g., stellar spectra or galaxy images, to establish similarities, differences, relationships, and trends. By organizing the phenomena systematically, morphology defines normal (i.e., typical) behavior and distinguishes the peculiar (i.e., exceptional). The methodology involves the differential description of the phenomena in terms of themselves, by means of a reference frame of standard objects. Thus the process involves a minimum of assumptions and external information, which could introduce confusion and noise. Measurement, calibration, and interpretation are left as subsequent steps, to avoid convolving their uncertainties with the description of the phenomena themselves. In this way, the validity of the results is permanent, independently of revisions to the subsequent operations.

My thesis project was a re-examination of the blue-violet spectra of O and B stars, with a higher resolution and thus information content than used by the Morgan-Keenan (MK) system of spectral classification. In addition to a refined spectral classification scheme, the outcomes included two qualitative discoveries about these hottest stars. First, that anomalous carbon-nitrogen-oxygen (CNO) features occur in OB spectra: the dichotomy between the OBN and OBC spectral classes indicates processed material in the atmospheres of the stars and provides an evolutionary diagnostic. Second, that a new earliest spectral class—O3—was needed to describe the hottest, most massive stars in the Carina Nebula.

Later, applying these morphological techniques to the yellow-red region of OB spectra, I found that an unusual Balmer-alpha emission feature of hydrogen varies periodically in the prototype helium-rich star, Sigma Orionis E. This finding contributed to the star's eventual interpretation as a magnetic oblique rotator. Still later, investigating the morphology of far-ultraviolet spectra in the International Ultraviolet Explorer (IUE) archive, I resolved the then-current (1982) controversy about whether or not OB stellar winds are correlated with the fundamental stellar parameters. (They are, in amazing detail!)

Two current projects are direct descendants of this earlier work on the spectra of OB stars. With data contributions from most of the world's specialists in the subject, a substantial sample has been collected of high-quality, blue-violet digital spectrograms for the enlarged O3 spectral class. Careful comparisons in this sample show the need for new spectral types O2 and O3.5 to describe the displayed range in classification criteria. Again, the early limit has moved earlier.

On the space ultraviolet front, I was kindly invited by the Far Ultraviolet Spectroscopic Explorer (FUSE) team to assist with the initial atlases of their unprecedented database of OB spectra. Concentrating on the Magellanic Cloud sample, I have developed designs to present and describe separately the systematics of the stellar-wind profiles in the Large and Small Magellanic Clouds (LMC, SMC). Many of these same stars were studied previously, at longer ultraviolet wavelengths, with data from the Faint Object Spectrograph (FOS) and Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope. Because FUSE is sensitive at shorter wavelengths than Hubble, the FUSE spectra add a wealth of new ionic species, including the very high ionization stages O VI and S VI.



The applicability of morphology in astronomy is by no means limited to stellar spectra. Morgan's sharp eye was cast on any and all phenomena in view. When I first showed him the original photographic data set revealing the O3 stars, which was obtained at the Cerro Tololo Inter-American Observatory (CTIO), Morgan expressed surprise at the large range of interstellar Ca II line strengths among the members of the Carina Nebula association. It was soon ascertained that the strongest interstellar lines were found toward stars in the center of the nebula, with the weaker ones toward the periphery. That required following up! With instrumentation of increasing power—from the CTIO 1.5m coude and 4m echelle, through IUE, and now with the STIS high-resolution echelles—the most extreme high-velocity interstellar profiles in the Galaxy have been found. In fact, they resemble some narrow-line systems in quasars. Their properties include as many as 26 resolved velocity components in the same line of sight, a total velocity range exceeding 550 km/sec, and large temporal variations in less than 2 years (Figure 1). There is ample evidence that these characteristics are generated within the nebula, likely by the stellar winds from the O stars, and are related to the diffuse X-ray emission that permeates the region.

It would be hard to study O stars in regions like the Carina and 30 Doradus nebulae without becoming fascinated by the rich phenomenology observed in their environments. Thus, I have branched out into studies of the mysterious Keyhole Nebula, the inscrutable Eta Carinae, and triggered second-generation star formation, which seems to be ubiquitous in giant H II regions. I participated in collaborative spectral-classification studies of the stars in the second-ranked H II region of the LMC—the giant shell Henize N11—including spatially resolved spectroscopy of compact groups using the FOS. The data show that the age of the association in the central, evacuated cavity of Henize N11 is ~3.5 million years (Myr), with an earliest spectral type of O6, while the surrounding nebulae contain O3 stars no older than 1 Myr. I have called such regions “two-stage starbursts” to emphasize the strong inference of triggered, sequential star formation.

30 Doradus also displays a two-stage starburst, but 1 to 2 Myr younger in evolutionary time. The central O3 + WN cluster in 30 Doradus is excavating a cavity, and a new stellar generation is being triggered at the current interfaces with the surrounding molecular clouds. Observations with Hubble's Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) reveal remarkable structures in the interface regions. These structures include stellar jets, luminous infrared sources within pillars oriented toward the central cluster, and one massive pillar—the “Mt. St. Helens” pillar—whose summit has already been blown off by the newborn O stars within, rendering them observable at optical wavelengths. Figure 2 shows the inner 30 Doradus nebula, completely covered by the Wide Field Planetary Camera 2 (WFPC2). In another 2 Myr or so, 30 Doradus is predicted to become a giant shell H II region like N11.

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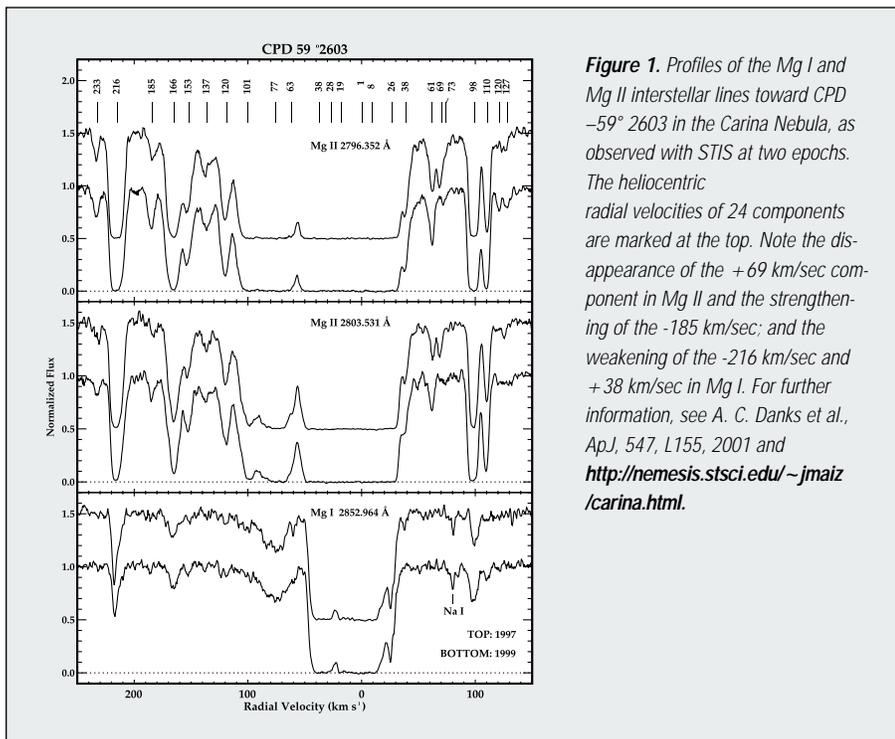


Figure 1. Profiles of the Mg I and Mg II interstellar lines toward CPD -59° 2603 in the Carina Nebula, as observed with STIS at two epochs. The heliocentric radial velocities of 24 components are marked at the top. Note the disappearance of the +69 km/sec component in Mg II and the strengthening of the -185 km/sec; and the weakening of the -216 km/sec and +38 km/sec in Mg I. For further information, see A. C. Danks et al., *ApJ*, 547, L155, 2001 and <http://nemesi.stsci.edu/~jmaiz/carina.html>.

In 1973, on the basis of morphological analogy with the similar central object in the Galactic giant H II region NGC 3603, I predicted that R136, the dense core of the 30 Doradus ionizing cluster, would be resolved by interferometry or space imaging into a compact multiple system. Around 1980, several astrophysical studies suggested that R136 instead might be a single 3000 solar mass object. Subsequent speckle interferometry and Hubble imaging have amply vindicated the morphological prediction. Hubble images have also revealed giant dust pillars oriented toward the central object in NGC 3603, and groundbased studies have found numerous infrared sources associated with the pillars. Luminous sub-millimeter sources have been discovered in the heads of the Eagle Nebula pillars, which are also oriented toward the relatively older, young optical cluster in M16. At least six pillars in three sequential evolutionary stages point toward R136 in the Hubble images. Thus, triggered second generations, often associated with dust pillars, are ubiquitous. This interpretation can be applied even to galaxy-wide starbursts, such as the dwarf irregular NGC 4214 at 3 megaparsec (Mpc) distance, which the WFPC2 resolves into substructures of different ages, entirely analogous to 30 Doradus and N11. The detailed studies of the latter two objects establish them as standards for their successive evolutionary states, with respect to which more distant objects can be classified.

These current examples of astronomical morphology demonstrate that it remains a vital technique. Far from being rendered obsolete by astrophysics, morphology complements it by organizing new phenomena, e.g. from higher resolution and expanded wavelength domains, preparatory to theoretical analysis based on physics. Morphology does not explain anything, but it can bring the key phenomena to be explained into sharper focus. Morphology can formulate the observational information with adequate accuracy and completeness for useful investigation, suggesting viable hypotheses while eliminating others. To state the point in a different way, our image of nature must not be confused with nature itself. Developing the image is a nontrivial task and a prerequisite to the ultimate objective of understanding nature. Ω

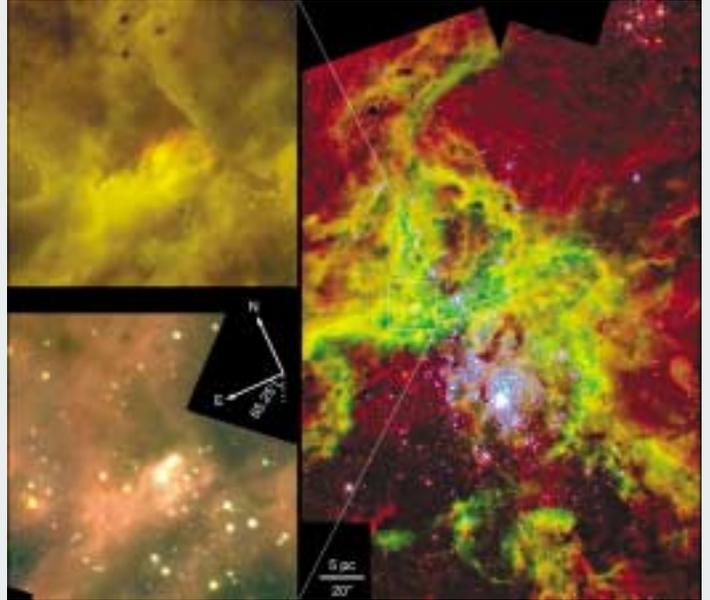


Figure 2. Hubble images of 30 Doradus. The field at right shows the entire inner nebula covered with 5 WFPC2 pointings. Blue is (approximately) U-band, showing the hot stars (the saturated cluster core in white is R136), green is H-alpha + V-band, and red is [S II] + I-band. Thus, green represents hot gas, and red shows cool regions, with yellow delineating the interfaces between the two. Several pillars pointing toward R136 can be seen along the interfaces, most of which contain newborn stars detected in the infrared. The enlargements at left depict the "Mt. St. Helens pillar", whose top has been blown off to reveal the new stars at the optical wavelengths. The top left frame is a dithered PC image with 30 milliarcsec resolution. Here, green is [O III], and red is Balmer-alpha. The bottom left frame is a NICMOS image with J-, H-, and K-band in blue, green, and red, respectively. Note the faint, very red source in a dark globule above the pillar and a very luminous IR source still within an adjacent pillar to the left. For more information, see N. R. Walborn et al., *AJ*, 117, 225, 1999, <http://opposite.stsci.edu/pubinfo/pr/2001/21/>, and <http://www-int.stsci.edu/~jmaiz/30dor.html>.

part of this effort, CSA has been developing mechanical slit ideas for NIRSPEC, and a magnetically clamped mechanism is under investigation at Victoria, BC. CSA plans to provide a member of the NIRSPEC team in due course. The results of these studies will be presented and discussed at a meeting at ESTEC in the Netherlands, September 24-28. All NIRSPEC options will be carried through the first 6 months of phase B, after which the ESA team will make a selection with the concurrence of the NGST Project and the Science Working Group (SWG).

Another major topic for this meeting was the status of the US/ESA/CSA MIRI consortium. The ISWG reviewed the MISC recommendations and concluded that these constitute an excellent starting point for the Phase A design study. The MIRI will be developed by a lead NASA Center with major contributions from ESA and a collaboration of European national space agencies. Reflecting the international nature of the development, the MIRI science team (MST) will have representatives from the US, Europe, and Canada. The lead scientist will be selected through a NASA Announcement of Opportunity.

Three NASA Centers (JPL, GSFC, and ARC) have expressed interest in developing the MIRI, and each will submit a management proposal for review and selection at NASA-HQ in September. The review committee will include an ESA observer. Since interaction with the MST is a significant factor, NASA HQ will add scientists to the review committee. The NASA center lead scientist and the ESA counterpart from the mid-infrared consortium would be members of the MST.

In the coming year, ESA will formulate the European MIRI consortium and fund a Phase A design study of the MIRI optics, which will run from October 2001 to June 2002, after which the actual module construction will start. The delivery of the completed optics module is expected in mid-2006.

Finally, the ISWG discussed the requirement for NGST to be able to track moving objects, such as planets, satellites, asteroids, and comets in the solar system. In the context of the Origins theme, the ISWG concluded that particles captured from the interplanetary dust (IPD) and comets, which have spectra resembling interstellar dust, can be analyzed by means of NIR/MIR spectroscopy, helping clarify the ISM-IPD link in the solar neighborhood. Moderate resolution ($R \sim 2000$) spectroscopy will be able to resolve molecular line series, thus allowing study of both solid and gaseous phases. NGST's unique ability to observe comets beyond 5-10 AU would complement the capabilities of SOFIA, SIRTf, and other infrared facilities. As a result, the ISWG strongly recommended that NASA include a tracking capability of at least 0.015 arcsec/sec for 500 seconds duration in the upcoming telescope and guider design studies. Ω

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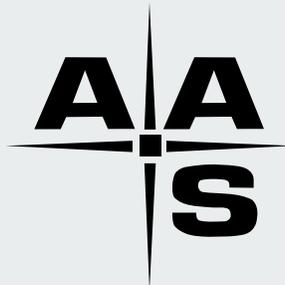
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AAS Meeting

**NGST Town Hall at 199th, Washington, D.C.
International Perspectives
1:00 to 2:00pm
Thursday, January 10, 2002**

- The Next Generation Space Telescope (NGST) is on the brink of major announcements. This "NGST Town Hall" will present the latest developments and the working relationships among the teams.
- John Mather, Moderator (the NASA NGST Project Scientist) will report the project status and inform members of latest contract awards. Stay tuned. He may be discussing the status of the Prime Contract.
- Peter Stockman (the Institute NGST Project Scientist) will present the Science & Operations Center—Why was the Space Telescope Science Institute chosen for the job? He will highlight the NGST operations concept—How does it differ from Hubble operations?
- Eric Smith, NASA NGST Program Scientist, will introduce the tripartite agreement among the international partners: USA, CSA and ESA—What are the teams' roles and progress? Also, he will cover the US current progress with the Near-Infrared Camera (NIRCAM) and the Mid-Infrared Instrument (Camera/Spectrograph; MIRI).
- Peter Jakobsen (ESA NGST Project Scientist) will discuss ESA plans for the MIRI and the Near Infrared Spectrograph (NIRSPEC) and describe their participation in the Mid-Infrared Steering Committee (MISC).
- John Hutchings (CSA's NGST Project Scientist) will present the Canadian contribution to the NIRCAM and the guider.

Overview

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The most significant bit of Hubble instrument news is the restoration of Space Telescope Imaging Spectrograph (STIS) to full functionality, as described in an accompanying article by Paul Goudfrooij and Jeff Valenti. The blown fuses and loss of the "Side 1" electronics are reminders that instrument failures of one kind or another are a fact of life in space astronomy. The fact that the instrument could be reconfigured and brought back to life testifies to the robust design and the skillful work analyzing the failure and developing procedures to operate STIS using the "Side 2" electronics. Even with the happy outcome, we must recognize a sobering message in this story: STIS has no "Side 3" electronics, and we must perform the most important observations with the Hubble instruments *now*, while they are in their prime.

The next servicing mission will bring us the Advanced Camera for Surveys (ACS) and will restore the Near Infrared Camera and Multi-Object Spectrograph (NICMOS) to life. Both projects are proceeding well. While both instruments will be given a fairly thorough checkout over the first few months of operations, planning for the longer-term calibration effort is just getting underway. Observers proposing for these instruments may wish to keep apprised of the evolving calibration plans in future Newsletters or by checking the instrument web sites via <http://www.stsci.edu/instruments/>. Suggestions for specific calibrations are always welcome, and can be sent to help@stsci.edu.

On-The-Fly Reprocessing (OTFR) is improving the quality of data retrieved from the archive for both new and old observations. In an accompanying article, Sylvia Baggett

describes what OTFR means to astronomers interested in Wide Field Planetary Camera 2 (WFPC2) data. The OTFR system is also working for STIS and will soon be available for NICMOS.

We are all looking forward to the Cycle 11 programs. Noteworthy for those who operate the observatory will be the new Hubble Treasury programs. It will be interesting to see how we may need to adjust our user support and planning processes to accommodate this new class of larger programs in the best manner. Even though we have not seen any proposals yet, we foresee approved Treasury programs that are challenging to schedule but potentially offering new flexibility to improve the efficiency of Hubble. Ω

What On-The-Fly Reprocessing Means to You

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The On-The-Fly Reprocessing (OTFR) system replaced On-The-Fly-Calibration (OTFC) system for the Wide Field Planetary Camera 2 (WFPC2) on May 16, 2001.

The change has been effectively transparent to Hubble archive users: requests for data are submitted as usual via Starview or WWW; raw and calibrated data are delivered. All requests for WFPC2 (and STIS) data are now handled by the OTFR system. The OTFR data headers do contain a new keyword, PROCTIME, which records the date and time the data was processed through the system.

The former system, On-The-Fly Calibration (OTFC), was released in December 1999 and recalibrated data at the time a user submitted

a retrieval request to the archive. OTFC processing provided several advantages to an observer, including the automatic application of improved calibration files and switches, use of the most recent calibration software (allowing users rapid access to improved algorithms, new capabilities, and software fixes), and correction of header keywords if needed. A major benefit for the Hubble archive was the reduction in data volume, as calibrated data no longer required archiving.

The primary difference between the two processing systems is that the new OTFR system begins earlier in the Hubble data path. OTFR starts with the original telemetry files ("POD" files) received from Goddard Space Flight Center and performs all pipeline processing steps, including data partitioning, drop-out corrections, generic conversion to raw science files, population of header keywords, and calibration. The previous OTFC system performed only the last pipeline processing step, calibration, on raw files retrieved from the archive. The OTFR system as a whole also requires significantly less software maintenance than OTFC, which will produce savings at the Institute in the long-term.

While some of the improvements in the new OTFR system might seem minor, they can have large benefits to some users. For example, WFPC2 observers who intend to use the pointing information in the image headers no longer need to run the STSDAS task UCHCOORD on their data. Improved knowledge of the detector plate scales and chip rotations, and changes in reference pixel locations, have resulted in periodic changes in the pointing parameters, especially early in the instrument's lifetime. The new OTFR system automatically calculates the best values for these parameters when the data are requested from the archive. Ω

STIS Update

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On May 16, 2001, the so-called "Side 1" set of electronics, which had been used since the Space Telescope Imaging Spectrograph (STIS) was installed into Hubble, failed irrevocably. STIS was not in use at the time this failure occurred. It has been determined that the failure was caused by a short circuit within STIS, which blew the fuse in the primary power feed for Side 1. As a result, only the redundant Side 2 electronics are now usable. STIS has now resumed normal operations, with all detectors and mechanisms performing well.

The presence of a short circuit on Side 1 was confirmed on June 19, 2001, when a carefully designed test blew a second fuse in an alternate power path ("Bus C") to Side 1. Analysis of high-rate telemetry obtained as the second fuse failed has determined the most probable cause of the Side 1 failure to be a short circuit in a tantalum capacitor in a low-voltage power supply.

Although the Side 1 fuses can be replaced during servicing missions, the short circuit in the Side 1 power feed cannot easily be repaired on orbit. Consequently, STIS will operate using Side 2 electronics for the remainder of its lifetime.

Significant ground and flight software modifications were required to enable Side 2 electronics. Side 2 has different motors and resolvers, as well as a different power management scheme. Side 2 operations commenced successfully on July 10, 2001.

Ground calibration tables for Side 2 turned out to be sufficiently accurate for the optical Mode Select Mechanism (MSM). However, an in-flight table update was required for the aperture wheel. Relative aperture positions must be known

to a small fraction of a CCD pixel to keep targets centered when switching apertures.

STIS performance using the Side 2 electronics is excellent. The performance of the Multi-Anode Microchannel Array (MAMA) detectors is indistinguishable from that on Side 1. The only (minor) changes in performance are for the CCD are as follows.

The CCD read noise has increased from 4.4 to 5.4 electrons RMS (using the default GAIN=1 setting). The STIS Exposure Time Calculator (ETC) on the web was updated on August 15, 2001 to reflect this change in performance. (http://garnet.stsci.edu/STIS/ETC/stis_img_etc.html)

CCD temperature was controlled on Side 1 by a temperature sensor. The analogous sensor on Side 2 failed before launch, so that we cannot track the CCD temperature on that side. Therefore, constant current is now applied to the CCD thermoelectric cooler. As a result, the actual CCD temperature will vary due to environmental changes (e.g., the Hubble pointing attitude and thermal drifts during the orbit.) In order to enable a stable subtraction of the CCD dark current on Side 2, we have studied the behavior of the CCD dark current as a function of the CCD housing temperature. During the first 2 weeks of Side 2 operations, the CCD housing temperature ranged between 16.6 and 19.8 deg C, and it was well correlated with the CCD dark rate, which ranged between 0.0040 and 0.0050 electrons/second/pixel. Temperature-dependent CCD dark subtraction will be added to the STIS calibration pipeline as soon as possible. (We currently estimate this will occur in November 2001.) Observers using the CCD should regularly check the STIS instrument web site for updates. (<http://www.stsci.edu/instruments/stis>)

After measuring and updating aperture locations, STIS science operations resumed for imaging on July 16, 2001 and for spectroscopy on August 6, 2001. Ω

Gravitational Lens Helps Hubble and Keck Discover Galaxy Building Block

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

<http://opposite.stsci.edu/pubinfo/pr/2001/32>



Credit: NASA, ESA, Richard Ellis (Caltech) and Jean-Paul Kneib (Observatoire Midi-Pyrenees, France)

The Evolution of the Hubble Proposal Processing Systems

Andrew Gerb

Andy Gerb joined the Institute in 1988 and has held a variety of positions involved with the development of the front end systems, most recently as the lead of the Planning Development Team in the Engineering and Software Services (ESS) division. He left the Institute on August 10, 2001. On August 2, 2001, Andy gave a PowerPoint presentation on the same topic, which is posted at <http://www.stsci.edu/apsb/doc/evolution-of-front-end.ppt>

The original NASA contract to write the software to operate Hubble, dating back to 1981, went to TRW Inc. in Redondo Beach, California. TRW was contracted to deliver the Science Operations Ground System (SOGS) to plan, schedule, and process data from Hubble. The original SOGS design envisioned a central data base to store detailed information about each observation—the Proposal Management Data Base (PMDB). Today, the PMDB is still a central information repository for the Hubble ground system. It includes hundreds of informational relations, most of which have dozens of data fields.

The original plan called for Institute staff to use display screens to directly enter detailed information about each exposure into the PMDB, potentially many hundreds of parameters per observation. There was no real understanding of how the Institute would get that information from observers, other than by having them fill in the paper versions of the same forms. Fortunately, this “plan” was never implemented.

It quickly became clear that manually entering all parameters for Hubble observations into the PMDB from screen forms would be operationally impractical. Following that realization, a group of scientists and software developers, led by Mark Johnston, formed the Experimental Planning Systems group to develop a prototype of the Proposal Entry Processor (PEP). Working with the General Observer Support Branch, they developed the concept of target lists and exposure logsheets for observer input—similar in content to the types of observing logs filled out by observers at ground based telescopes. These logsheets would then be processed by PEP to provide the detailed information needed to populate the PMDB. As this was before the time of ubiquitous email, ftp, and the web, it was initially expected that these simplified forms would be filled out on paper and sent to the Institute for data entry.



PEP had three basic components: Entry, Validation, and Trans. Entry was a series of entry screens, which allowed the information from the proposer’s logsheet of exposures—now called the “phase 2 proposal”—to be entered directly into a new database. Validation was a syntax checker, which alerted the data entry clerk about syntax errors and illegal combinations of instrument parameters in the proposal. Trans was a software system that replaced the manual process of determining each of the PMDB parameters. Trans executed a series of “scripts” which parsed the input data and consistently determined the parameters

for the fields in the PMDB. Trans embodied all the instrument-specific rules which defined, in detail, the information that the scheduling system needed to schedule an observer’s exposure. The Scripting Guide, a somewhat plain-English description of these scripting processes, served as a requirements document for the development of Trans. Trans broke up a phase 2 proposal into Scheduling Units (SUs) with validated observing parameters, to be stored in the PMDB.

PEP was installed and operational for the first phase 2 proposal deadline, prior to launch. After the Space Shuttle Challenger accident, when it became clear that Hubble would not be launched in 1986 as planned, the Institute identified a number of ways to use the delay to improve the front-end ground systems. These improvements included the Remote Proposal Submission System (RPSS) and Spike.

The first version of PEP still required that observers submit their phase 2 proposals to the Institute on paper logsheets, which remained a source of problems. Syntax errors were often not caught until after the logsheet information had been entered into the system—possibly months after the proposal had been prepared and submitted by the observer. To address this issue, RPSS was designed to allow the observer to run the validation software at his or her remote location. Now, the observer prepared the intended observations in the new “RPSS” file format, then ran validation softwares, after which he or she could email a syntactically correct phase 2 proposal to the Institute, ready to run through PEP into the PMDB to be scheduled.

At this time, the Institute began development of a scheduling tool, Spike. It was designed to provide the capability to build a long range observing plan, covering a full cycle or more. This tool focussed on the *schedulability* aspects of observations (e.g., sun avoidance, orientation requirements, etc.), and incorporated innovative algorithms

for generating a balanced yearly plan.

For the first several years after Hubble’s April 1990 launch, the front-end systems maintained a fairly stable appearance from the observer’s point of view. This started to change in 1993, when the Institute launched a process improvement effort to better serve Hubble observers and more smoothly plan observations. The objectives included: simpler creation of phase 2 proposals, better feedback to proposers as they crafted observations, the ability to change observations later in the planning process, and better information to proposers about when observations were planned. Subsequently, the Project to Reengineer Space Telescope Observing (Presto) introduced a number of changes to further these objectives, including the concept of “program coordinators”, the Remote Proposal Submission 2 (RPS2) facility, and the concepts of “visits” and “Plan Windows”.

Before Presto, different organizational groups within the Institute were responsible for the various aspects of observation planning. The observer worked with one group while writing the phase 2 proposal; a second group performed feasibility analysis after submission; a third group was responsible for long range planning. Now, Presto rolled all these functions into a single team. Under the new scheme, each phase 2 proposal was assigned a program coordinator to serve as a single point of contact and to be responsible for all observations from creation through execution.

To reduce the frequency of changes in observations due to proposal problems, in fall 1994 Presto released the RPS2 software system. This made the Spike and Trans software available to observers. RPS2 provided a process controller that fed observations through a feasibility analysis by Trans and a schedulability analysis by Spike, both of which issued diagnostic messages about discovered problems. Also, a graphics generator in RPS2 presented plots representing

the orbital layout and the schedulability of the observations. Using these diagnostics and plots, proposers could fix problems and fine tune observations prior to submitting the phase 2 proposal.

In 1995, a graphical proposal editor (PED) was added, which allowed observers to create observations interactively by selecting from menus and responding to dialogues—rather than having to type in a proposal.

Before Presto and RPS2, Trans broke phase 2 proposals into SUs, which proved vulnerable to proposal changes. That is, any change to a proposal could potentially change the way in which exposures were divided among the SUs—requiring that all associated SUs be recreated. Because this could be a huge problem for changes made long after submission, it was not permitted without extraordinary justification.

Leading up to Presto's formation, it became clear from user surveys that Hubble science would benefit by enabling proposal changes late in the process. Observers strongly desired this ability, and they presented valid scientific reasons for it. In response, under the new RPS2 format, observers could break their proposals into smaller units called "visits". Trans now made each visit into a SU, rather than breaking a proposal into SUs. As a result, a change to a single visit no longer affected more than one SU, making it easy to redeliver a visit with a change. Late modifications, once anathema, became routine.

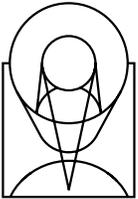
Although the RPS2 tools provided observers detailed information, they required Trans and Spike modules to be run in batch mode, which caused minutes of delay before the user could see the result of a change. In 1998, the then Presto Project

Scientist, Anuradha Koratkar, began working with the Systems and Software Environments section at Goddard Space Flight Center to develop prototypes for a new generation of truly interactive observation preparation tools, which would provide feedback in seconds rather than minutes.

The group at Goddard developed prototypes for a series of tools under the umbrella name of the Scientist's Expert Assistant (SEA). The most popular such prototype was the Visual Target Tuner, which presented an image of a target on the sky with an outline of the relevant aperture. This depiction allowed the observer to tune the pointing and orientation of the aperture with respect to the target. Other prototype tools included graphical exposure time calculators, an orbit planning tool (which allowed click-and-drag modification of exposure times), and a visit planning tool

(which allowed graphical manipulation of timing relationships between visits.)

In fall 1999, enthusiasm for the SEA prototypes led to the approval of the Institute's Astronomer's Proposal Tools (APT) project, which aimed to make graphical, interactive, proposal-creation tools an operational reality. These tools are now being developed for use not only by Hubble but for other observatories as well. Because APTs are designed using an object-oriented, observatory-independent core in the Java language, they will be adaptable to future observatories. The Institute plans to introduce APTs in upcoming proposal cycles. Judging by history, there is little doubt that these new tools will improve the Hubble user's experience and enhance Hubble science, just as RPS2 improved on RPSS and as RPSS improved on the paper logsheets of yore. Ω



Contact STScI:

The Institute's website is: <http://www.stsci.edu>

Assistance is available at help@stsci.edu or 800-544-8125. International callers can use 1-410-338-1082.

For current Hubble users, program information is available at: <http://presto.stsci.edu/public/propinfo.html>.

The current members of the Space Telescope Users Committee (STUC) are:

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ST-ECF Newsletter

The 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.

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Phase 2 proposals due	<i>February, 2002</i>
Budgets due	<i>February, 2002</i>
Routine Observing Begins	<i>July, 2002</i>

Space Telescope Users Committee Servicing Mission 3B Launch

*October 25-26, 2001
January, 2002*



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