Space Telescope Science Institute

A Living Mission

Annual Report 2002

Space Telescope Science Institute Annual Report 2002 A Living Mission

"Participating in the Hubble Space Telescope program is a highlight of my life. Every time I see one of those beautiful HST images, I feel very lucky that I was able to play a small part in such a great program."

— Ken Bowersox, pilot of *Endeavour* on STS-61 [1st Hubble servicing mission] and commander of *Discovery* on STS-82 [2nd Hubble servicing mission].

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foreword

The Space Telescope Science Institute was established in 1981 to conduct the science program of the Hubble Space Telescope. Since then the Institute has helped bring about excellence in Hubble performance, in the scientific achievements of Hubble's users worldwide, and in our services to NASA and the community. Our success in helping the Hubble telescope become one of the premier scientific instruments of the 20th century has led NASA to name the Institute as the Science and Operations Center for Hubble's successor, the James Webb Space Telescope, JWST. Our express challenge now is to optimize the scientific return from two major missions.

The opening **Perspective** article portrays Hubble as a living mission, sustained on the cutting edge of science by instrument development and shuttle servicing.

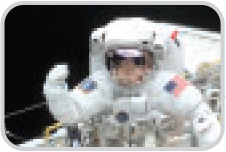
The Institute's staff is dedicated to promoting scientific discovery in their support of space observatories. The **News, Profiles, and Science Essays,** each by or about an Institute staff member, provides snapshots of who we are and what we are doing early in our third decade.

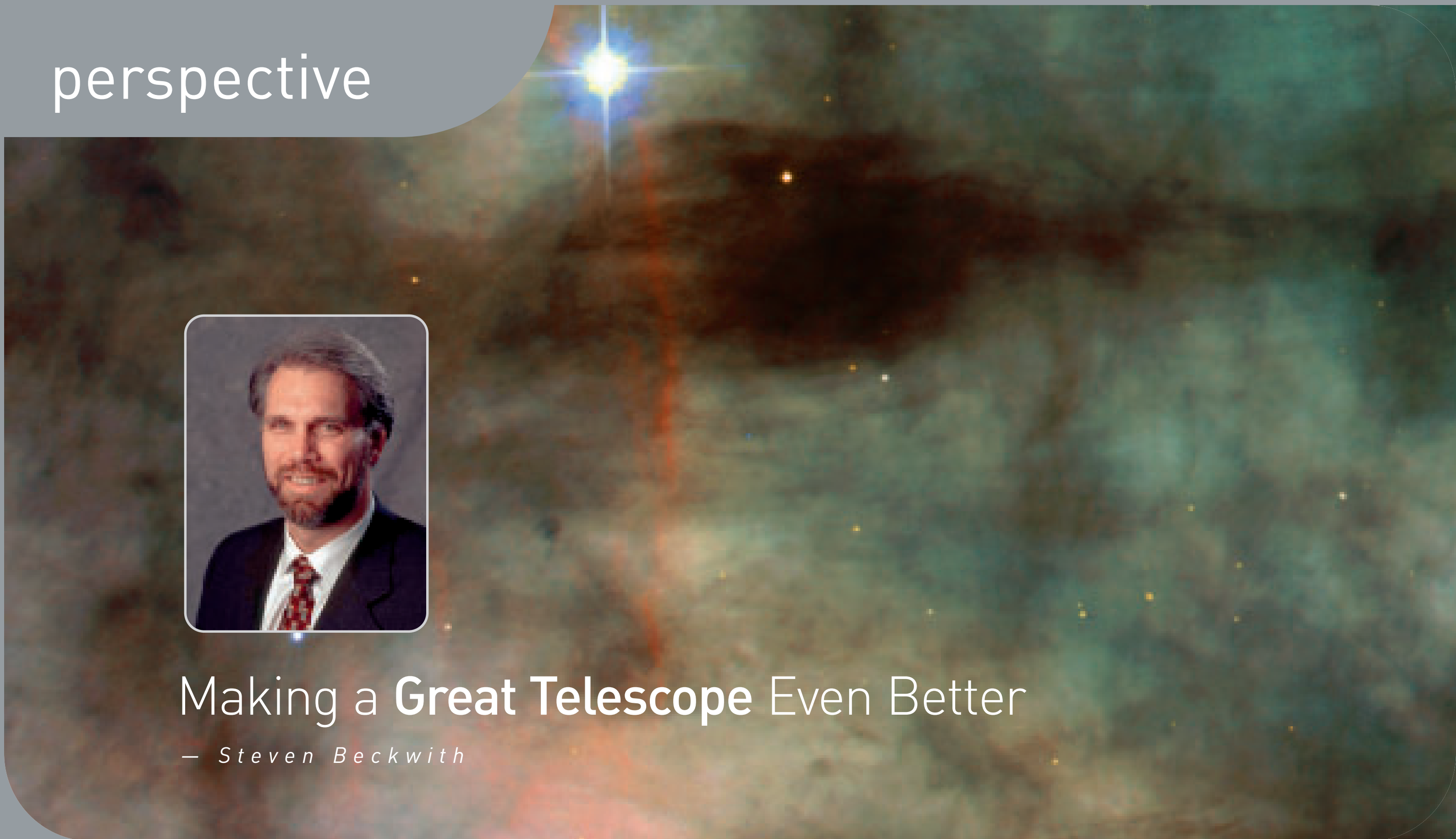
The **Organization** section describes the way in which we join together—in organizational groups and in cross-cutting teams—to meet our strategic objectives and improve our performance.

We state our **Vision and Strategic Goals,** then describe our 2002 Achievements according to our eight strategic goals.

Finally, as a premier scientific institution, we are pleased to end our 2002 Annual Report with a list of Science Publications by our staff in the last year.

We thank the readers of this Annual Report for their support of our Institute as we strive for ever greater success in serving the astronomical community and the nation's science enterprise.





Making a **Great Telescope** Even Better

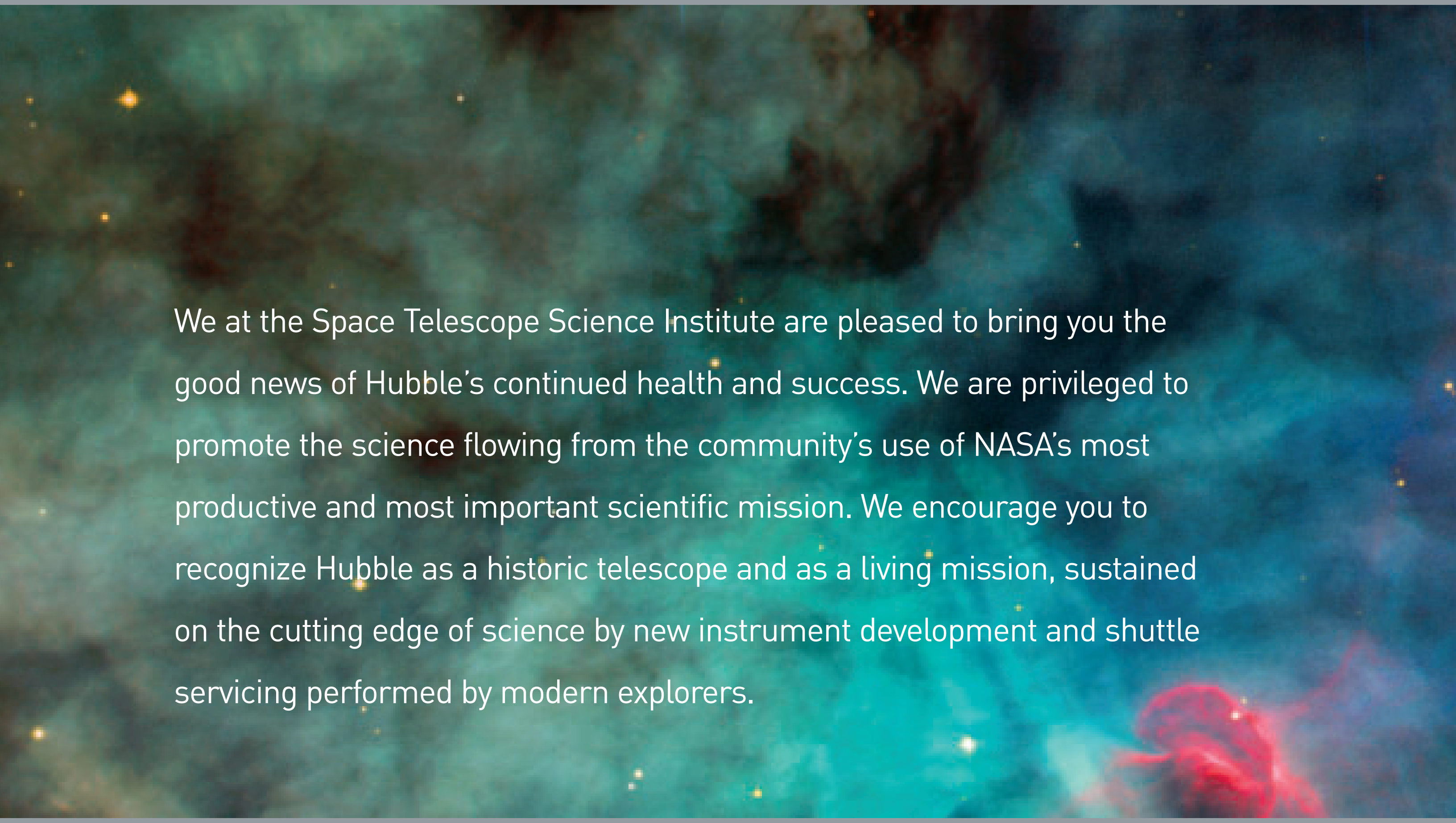
— *Steven Beckwith*

The highlight for the year was the space shuttle Columbia's servicing mission to the Hubble Space Telescope. The terrible tragedy that engulfed Columbia on its very next mission reminds us that courageous men and women risk their lives to make Hubble's unique scientific achievements possible.

The Columbia's crew of seven astronauts visited Hubble in March 2002. They installed a new instrument, the Advanced Camera for Surveys (ACS), fixed a broken instrument, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), repaired the ailing power control unit, replaced the solar arrays and a reaction wheel, and did several other maintenance chores to keep the observatory healthy. **Four servicing missions to Hubble thus far have kept its critical subsystems modern.** As if taking a 19^{th} century mansion of marble and installing new wiring, plumbing, and heating, we have created a masterpiece for today.

More importantly, NASA has improved the scientific capability of Hubble by installing new instruments with unprecedented science capabilities. The ACS is fully 10 times more powerful than the previous camera, Wide Field Planetary Camera 2 (WFPC2): ACS is twice as sensitive to light and has five times as many picture elements. It also gets better resolution over a wider area. Similarly, in 1996, NASA upgraded Hubble's instruments with the Space Telescope Imaging Spectrograph (STIS) and NICMOS. STIS improved Hubble's spectroscopic capability by more than a factor of 40 over the previous spectrographs, and NICMOS extended the wavelength range of Hubble by a factor of two, to a wavelength of 2.5 microns. Most of Hubble's new discoveries over the last few years came from these instruments with improved capability. We are just beginning to see the impacts of ACS, since it has been operating less than a year. The next few years should see an even greater impact as the data become public and more users are able to exploit the new survey capabilities.

Astronomy progresses most rapidly by increasing our observational power through new technology. This maxim has been true since Galileo first turned a telescope to the sky in 1609. **Clearly, our ability to improve Hubble's capabilities through servicing has been the most important factor in keeping it at the forefront of science.**

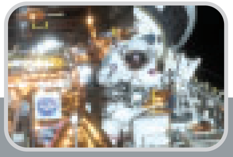


We at the Space Telescope Science Institute are pleased to bring you the good news of Hubble's continued health and success. We are privileged to promote the science flowing from the community's use of NASA's most productive and most important scientific mission. We encourage you to recognize Hubble as a historic telescope and as a living mission, sustained on the cutting edge of science by new instrument development and shuttle servicing performed by modern explorers.

We sometimes hear that Hubble is an old facility, but in many ways it is like that 19th century mansion: the Optical Telescope Assembly is still superb, the pointing control system is still the most accurate ever built, and the computer and power systems have been upgraded to modern standards. And—again, most importantly—**Hubble's scientific capabilities are state-of-the-art and second-to-none because of new instruments.**

We have not reached the end of Hubble's potential, although we may have reached the end of the public's good will in supporting future upgrades. The Institute recently looked at ideas for new Hubble instruments and found two that would easily enhance performance by further factors of ten or more: an optical camera with a much wider field of view and a coronagraph for studying faint sources next to bright objects like planets around nearby stars. These ideas cannot exhaust the possibilities. Such new instruments would spur scientific advances at the end of this decade like those of ACS and the revived NICMOS today. They would create immediate opportunities for discovery and scientific inquiry that are not otherwise achievable in this decade, for they demand the superb Hubble optical telescope, support systems, and operational infrastructure, which are not likely to be recreated for many years after Hubble is turned off.

In the recently released study of the scientific impact of NASA's missions, Greg Davidson writes, "Large astronomical observatories continue to have very high scientific productivity—more than half of the science and technology return for NASA." According to Davidson, "An analysis of 1990-1999 data by this metric (performed in January 2000) indicated that [the NASA Office of Space Science's] large missions had twice the science productivity per dollar as smaller missions, and, if anything, the past three years have seen an even higher contribution from large observatories. With the installation of ACS in 2002 (along with restoration of NICMOS and continued operation of STIS), **Hubble has essentially achieved the full level of instrumentation capability anticipated when the lifecycle servicing program was put into place just before launch in 1990**, and should probably be performing at its peak."



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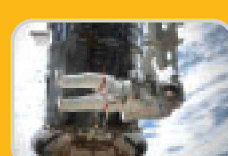

profiles

Melissa McGrath

Melissa McGrath joined the Institute as a staff scientist in the Science Programs Division in 1992 and currently heads the new Community Missions Office.

Melissa was born and raised in Grand Island, Nebraska, and had only passing interest in astronomy until taking a winter-term course entitled "Intelligent Life in the Universe" at her undergraduate alma mater, Mount Holyoke College. Invited speakers in the course included Cyril Ponnamperuma and Carl Sagan, and students in the class were invited to a reception at the college President's house to meet Dr. Sagan. The course and speakers provided the inspiration Melissa needed to change her classes for the up-coming semester to include introductory physics and astronomy courses. She has never looked back nor regretted her choice to switch from being a French major to studying astronomy.

After graduating from Mount Holyoke, Melissa went on to graduate school at the University of Virginia, where she pursued research on starburst galaxies for her master's thesis and in planetary science for her Ph.D. She then moved to a postdoctoral fellowship at Johns Hopkins University, where she continued work in planetary science and became a space observer, eventually leading JHU's extensive and long-running research programs using the International Ultraviolet Explorer satellite to study outer planet atmospheres and satellites.

At the Institute Melissa has served in a wide variety of positions over the last ten years, encompassing most aspects of the Hubble front- and back-end ground systems. She was initially a planning scientist in the Science Program Division, where she moved quickly to branch manager, and then happily out of a management position to better pursue research and tenure. She was a member of the initial Continuous Process Improvement team (HURT—Hubble Undergoing Radical Transformation) led by Mark Johnston, which led to the formation of PRESTO—

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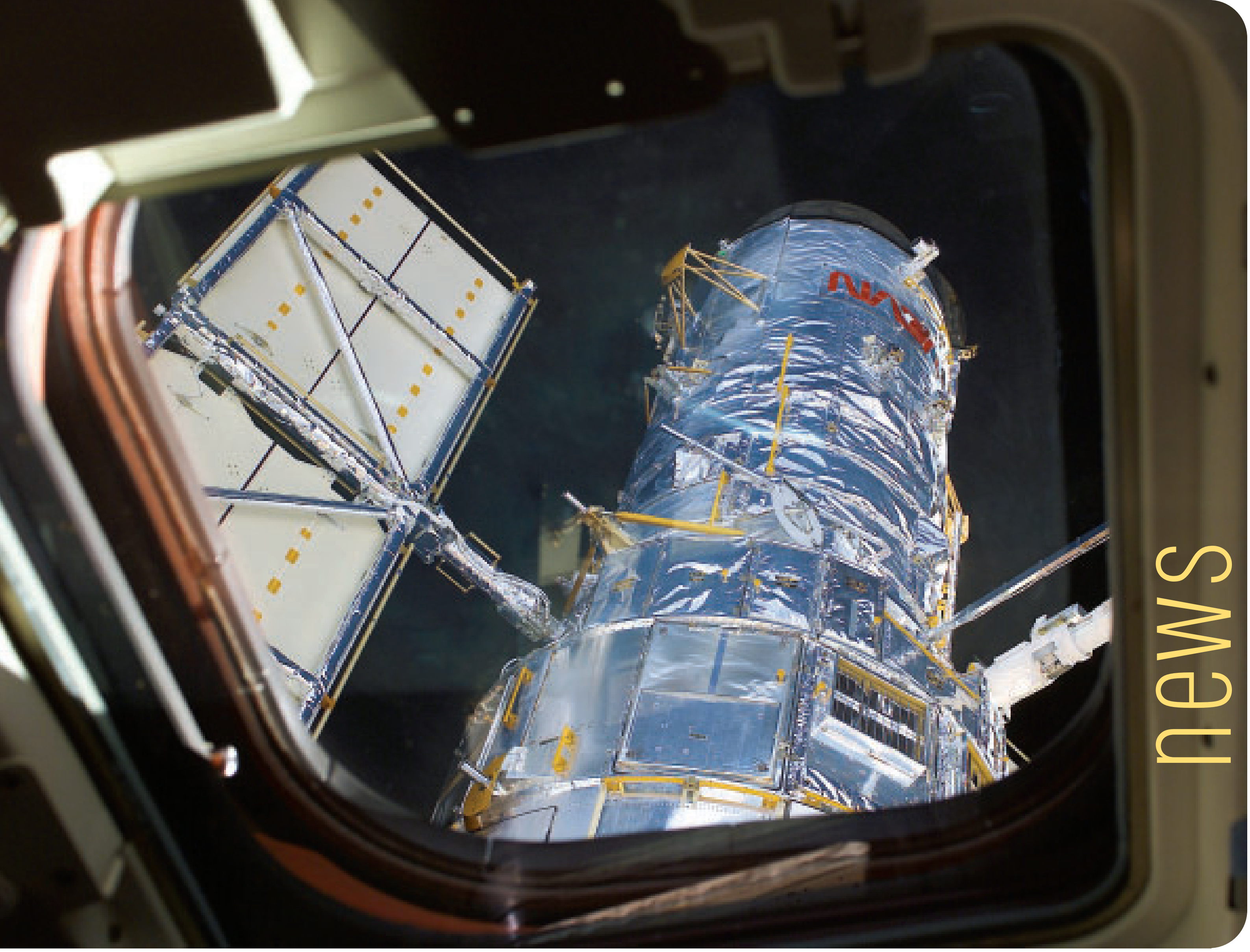


news

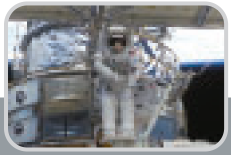
Hubble Made **Even Better** than Before

— *Rodger Doxsey*

NASA serviced the Hubble Space Telescope in March 2002, and it is now a better observatory than ever before. The Space Shuttle Columbia lifted off from pad 39A at Kennedy Space Center at 6:22 AM local time on March 1, carrying a crew of seven astronauts and a payload bay full of equipment destined for Hubble. The crew rendezvoused with the telescope two days later and firmly berthed it to the servicing structure in the payload bay. Over the next five days, the crew successfully completed a series of five space walks to replace and upgrade important components of the observatory. They installed a new camera, the Advanced Camera for Surveys (ACS), and a mechanical cooler that revived the Near Infrared and Multi-Object Spectrometer (NICMOS). In addition to these substantial upgrades to Hubble's scientific capability, the astronauts installed new solar arrays, a replacement power control unit, and a replacement reaction wheel assembly. The crew then 'launched' Hubble again and returned to earth.

After Hubble was deployed, the operations staffs at the Institute and Goddard Space Flight Center tested the new equipment, calibrated the new instruments, and returned the telescope to normal science operations. Everything is working as expected—or better, as in the case of the flat-panel design of the new solar arrays, which completely eliminated the thermally-induced pointing jitter at day-night transitions. ⌑

The astronomical community and the Institute are indebted to the dedicated NASA staff at headquarters and the centers who make these servicing missions possible and do such a wonderful job of upgrading Hubble.



Science with **ACS: A New View**

— Adam G. Riess

EVERYONE APPRECIATES A NICE VIEW, AND ASTRONOMERS ARE NO EXCEPTION. The new Advanced Camera for Surveys (ACS) offers them twice the field of view and five times the depth of the Wide Field and Planetary Camera 2, its predecessor as the primary Hubble imaging instrument. They have used this increased grasp of light for many investigations in its first observing cycle. Although astronomers will need a year or more to analyze and draw conclusions from these early ACS observations, a number of exciting discoveries, confirmations, and controversies are already emerging.

One issue is whether galaxies at redshift $z > 6$ are less numerous than expected from the 1995 Hubble Deep Field North (HDFN) investigation. The team that developed ACS, led by Principal Investigator (PI) Holland Ford and deputy PI Garth Illingworth, reported an abundance of high-redshift galaxies in new images of the HDFN and in the background of their images of low redshift galaxies, like the Tadpole and the Mice, which were early-release observations. Nevertheless, the ACS team found a surprising lack of galaxies at $z > 6$—fewer by factor five to ten than expected from extrapolating the $z \sim 5$ sample in the original HDFN study. Meanwhile, another group has claimed the detection of ~ 30 galaxies at $z \sim 6$ using the 'drop-out' search technique, with the criterion that the object is present in the z-band image but absent in the I-band image.

The ACS team invested 20 Hubble orbits to obtain a stunning deep image of a massive cluster of galaxies, Abell 1689. The image shows red elliptical galaxies framed by spidery blue arcs of strongly lensed background sources. By analyzing the separations of pairs of background sources—including one as distant as $z = 4.9$—they measured the cluster mass within the Einstein radius of its lens to be 1.5×10^{14} solar masses, a value in good agreement with the estimate from X-ray studies.

news

In their re-imaging of the HDFN, the ACS team discovered two type Ia supernovae at maximum light. They identified SN 2002dc (z = 0.47) and SN 2002dd (z = 0.96) by the 'wiggly' appearance of their spectra in a grism image. From quick follow-up observations of the supernova light curves, astronomers found distances to the host galaxies that are consistent with the current paradigm of an accelerating universe.

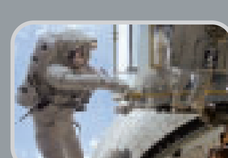
The ACS team obtained coronagraphic images of bright objects to find any faint sources nearby. Images of the nearby quasar 3C273 show multiple, complex structures around the unresolved central source, which may indicate a recent merger. Images of young stars show dust disks. Observations of HD 141569A, a Herbig AE star, discovered a spiral debris disk showing possible tidal distortion by a nearby binary system.

Led by PI Mauro Giavalisco, the Great Observatories Origins Deep Survey (GOODS) program obtained deep, wide, four-color images of two fields centered on the HDFN and the Chandra Deep Field South to study galaxy evolution. The data are shallower by ~ 0.5 to 0.7 magnitude than the original HDFN, but the area covered is 30 times larger, providing a more significant sample statistically for studying the development of galactic complexity. The largest fraction of the GOODS observing time has gone into the z-band observations, a valuable wavelength range not available for the original HDF observations using WFPC2. With careful mosaicing, cataloging, and culling, these images are yielding large samples of 'extremely red objects', 'drop-outs' (candidates for very high-redshift galaxies), Lyman-break galaxies (intermediate redshift), and optical counterparts to bright X-ray sources. Interestingly, most 'extremely red objects' appear to be relatively clean elliptical galaxies, not heavily extincted, post-starburst galaxies.

The GOODS team optimized the sequencing of their z-band images for discovery of type Ia supernovae at higher redshift than can be discovered from the ground. They are taking exposures every 45 days for 5 epochs of 15 pointings. A so-called 'piggyback program' (PI Adam Riess) works with the GOODS team to identify transients rapidly and to analyze theirs colors and photometric redshifts. This is producing a sample of type Ia supernovae at z > 1.2, which Riess is studying for evidence of an earlier epoch of decelerated expansion during the matter-dominated phase of cosmic expansion.

Other ACS programs in Cycle 11 with good potential for interesting results include a deep imaging campaign on Andromeda (PI Tom Brown) to study stellar evolution near the main-sequence turn-off, a light echo from a nova that provides a rare, geometric distance within the galaxy (PI Howard Bond), and z ~ 5.6 to 6.0 Lyman-α emitters from grism imaging of parallel fields (PI James Rhoads).

Although these are still early days with ACS, the expanded view offered by this new camera has already provided a welcomed boost in the scientific capabilities of Hubble.



profiles

Marty Durkin

Marty Durkin joined the Institute staff in 1989 and currently serves as the Process Engineering and Enabling Technologies Deputy in the Center for Process and Technology.

Marty Durkin was born and raised in Baltimore, Maryland. His interest in science led him to pursue a bachelor's degree in Computer Science from Loyola College. After obtaining the degree, Marty spent a year working at a local defense contractor, AAI Corporation. In 1989, he accepted the position of System Administrator for the Proposal Entry Processor and Remote Proposal Submission Systems at the Institute. Meanwhile, he pursued his masters in Computer Engineering from Loyola College during the evenings, graduating in 1993.

As part of the 1994 Institute reorganization, Marty became lead of the Database and System Administration (DBSA) team in the new PRESTO Division (Project to Re-Engineer Space Telescope Observing). This team was responsible for maintaining the Assist database as well as developing and maintaining the multitude of tools necessary to populate, update, and query the database.

Marty was selected to serve on the Director's Leadership Forum (DLF) in 1999. During his three-year tenure, he participated in the Fifth Column, which was responsible for making recommendations to the Director on the reorganization of 2000, and he acted as co-chairperson of the DLF in the third year of service. He also served on the Enhanced Manager Review, Merit Increase, and Housing subcommittees.

Marty led the Database Development Team (DDT), which was formed in the Engineering and Software Services Division (ESS) as part of the Institute reorganization of 2000. This team included PRESTO/DBSA and several other database developers in various software teams. During this time, he also assumed responsibility as technical lead for the database administrators in the Computer Information Services Division (CISD).

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Science with the Re-Commissioned NICMOS

— *Mark Dickinson*

NICMOS, HUBBLE'S WINDOW ON THE INFRARED UNIVERSE, became inoperative at the end of 1998, when its cryogens were exhausted prematurely due to a thermal short circuit in its dewar. The Hubble Project quickly devised a plan to revive the instrument using a mechanical cooling system, which would chill and circulate neon gas through the NICMOS plumbing. Ed Cheng from NASA's Goddard Space Flight Center led a team that designed, built, and tested the NICMOS Cooling System (NCS). All was ready in time for the shuttle launch in March 2002, and astronauts successfully installed the NCS and connected it to NICMOS.

The activation of the NCS was a test of faith for many people associated with the project. The switch was first thrown on 16 March, and the NCS ran smoothly for about eight hours, until a glitch in the turbo-alternator shut it down. The NCS team attempted to restart operations a day later, but the system did not respond. Fortunately, the third time was the charm—the NCS revved up and has been running without a hitch since that day.

The re-commissioning of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) has been one of the great success stories of the Hubble servicing mission 3b early in 2002.

The instrument cool-down was also somewhat nerve-racking. Pre-launch thermal models had predicted that the cool-down would require about ten days. In practice, temperatures dropped much more slowly, and there were signs that they might level off at 110 to120 K, too warm for practical science operations. In order to reduce thermal input to the cooling loop, NICMOS itself was deactivated. With this, temperatures dropped more quickly. One month after NCS activation, the system had stabilized, and the NCS team reactivated the instrument, ready to observe. NICMOS made its first science observations since 1998 on 13 June 2002.

The NCS is maintaining the detector temperatures very stably at the programmed set point of 77.1 K. This is excellent news for instrument calibration, since many detector properties depend strongly on temperature. The new operating temperature—about 15 K warmer than in Cycle 7—has two major consequences for scientific observations. First, the linear dark current is about three-times higher than in Cycle 7, with values of 0.1 to 0.15 $e^- s^{-1} pixel^{-1}$, and produces a larger number of hot pixels peppering the images. Fortunately, however, this downside is more than offset by an increase in quantum efficiency: ~60% at 1 micron, 40% at 1.6 microns, and 20% at 2.2 microns wavelength. Moreover, the 'flatness' of the flat fields has improved, with smaller peak-to-valley excursions. These improvements are a substantial bonus for NICMOS observers, providing higher signal-to-noise ratio in a given exposure time and more uniform sensitivity over the field of view.

As expected, the linear dynamic range of NICMOS is about 10% lower than in Cycle 7. And the 'shading' pattern, a noiseless but highly structured bias term, is significantly different than in Cycle 7, but it appears to be stable and subject to calibration. The thermal background at wavelengths longer than 1.8 microns is slightly higher than it was in Cycle 7, which is attributable to changes in the telescope aft-shroud temperatures rather than to any change internal to NICMOS itself.

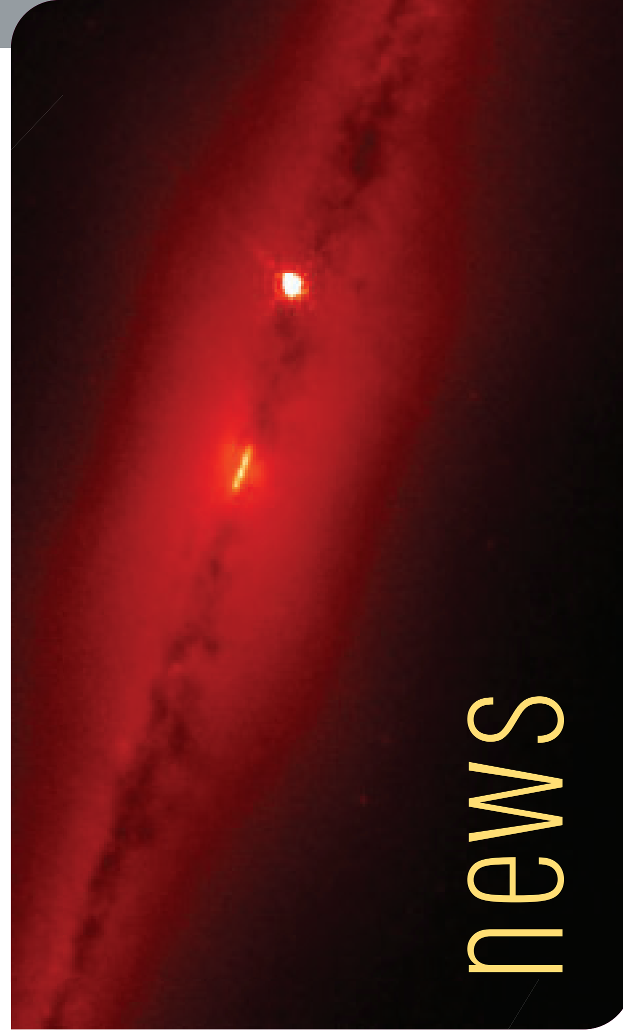
The NICMOS science program for Cycle 11 is rich and varied, with principal investigators studying objects as distant as the highest redshifts and as close as the Solar System. Adam Riess is using NICMOS to follow light curves of distant supernovae to determine their distances and test the apparent acceleration of cosmic expansion. Michael Corbin is measuring spectra of quasars at the highest redshifts known today to study metal abundances at very early cosmic times. Richard Ellis and David Thompson are using NICMOS to study the stellar populations in high-redshift galaxies that have been gravitationally magnified by massive clusters of galaxies along the line of sight. Sangeeta Malhotra and colleagues are making similar measurements for some of the most distant, Lyman α selected galaxies, while Andrew Fruchter is using NICMOS and other Hubble instruments to study the host galaxies of gamma ray bursts. Continuing a successful Cycle 7 program, Christopher Kochanek is studying galaxies responsible for multiple-image gravitational lensing of quasars, which—together with time-delay information—measures the Hubble constant independently of the local distance scale. David Turnshek is using NICMOS and the Advanced Camera for Surveys (ACS) to measure the sizes of the line-emitting regions of lensed quasars. Min Yun is imaging ultraluminous, dusty, starburst galaxies at a redshift z ~ 1 for systematic comparison with similar (albeit rare) objects in the local universe.

Somewhat closer to home, Robert Kennicutt is using NICMOS for a snapshot survey of nearby galaxies in the hydrogen Paschen α line, which traces star formation by cutting through dust obscuration. Seppo Laine is studying the dust-enshrouded nuclei of galaxies drawn from the Toomre merging sequence to understand the final stages of galaxy fusion and their effect driving star formation.

Marcia Rieke is using NICMOS to image the Galactic center to study the distribution and motions of stars around the central black hole. Stephen Eikenberry is using NICMOS imaging, polarimetry, and spectroscopy to monitor the superluminal jets from the unique 'microquasar' GRS 1915+105. Susan Trammel is imaging other Galactic jets—in a young planetary nebula—in Paschen α and H_2 emission to study the outflows in the heavily-obscured inner regions. Bruce Hrivnak is imaging Galactic protoplanetary nebulae (PPNs) in H_2 emission to trace the physical conditions in this important, transitional stage of stellar evolution, between the asymptotic giant branch and the planetary nebula phases. Toshiya Ueta is analyzing the polarization of scattered light from dust shells in PPNs. Robert O'Dell is using NICMOS to study the molecular gas in the cores of 'cometary' knots within the Helix Nebula. Karl Stapelfeldt is searching for Paschen α emission from dense circumstellar regions called 'proplyds' in the young star cluster NGC 2024. Kris Davidson is studying Eta Carinae with NICMOS narrow-band imaging—and with virtually every other Hubble instrument mode—as part of a Hubble Treasury program.

David Golimowski is completing a Cycle 7 NICMOS snapshot survey for low-mass companions to stars within 10 pc from the sun. On the outskirts of the Solar System, Keith Noll is using NICMOS snapshots to study the sizes and compositions of Kuiper Belt objects.

During observations with other Hubble instruments, when NICMOS would otherwise be idle, it instead executes the generic NICMOS parallel program, which Patrick McCarthy manages in Cycle 11. At high Galactic



latitudes, the parallel program executes a mixture of imaging and grism spectroscopy, the latter to search for high-redshift, emission-line galaxies. In rich star fields at low latitudes, NICMOS only performs imaging because the grism spectra would overlap. The NICMOS parallel program is creating a rich archive of serendipitous observations, which are available for analysis by the Hubble user community.

The revival of NICMOS has been successful beyond the most optimistic dreams. After a few hiccups at the start, the performance of the NCS has been nearly flawless, and the instrument stability and performance have been better than in Cycle 7 with the nitrogen cryogens. NICMOS should continue to serve as a uniquely powerful instrument for high-resolution, high-sensitivity, near-infrared imaging and spectroscopy for many years to come.

Riccardo Giacconi receiving his Nobel Prize from His Majesty the King at the Stockholm Concert Hall.

First Institute Director **Wins Nobel Prize** in Physics

— Ethan J. Schreier

ON OCTOBER 8, 2002, THE ROYAL SWEDISH ACADEMY OF SCIENCES AWARDED THE NOBEL PRIZE IN PHYSICS FOR 2002 TO RICCARDO GIACCONI "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources." The award cited Riccardo for the detection of the first extrasolar X-ray source and the discovery of the all-sky X-ray background in a 1962 rocket flight. The Nobel committee also noted Riccardo's vision in proposing imaging X-ray telescopes, so essential for the advancement of the field.

Riccardo was not only the 'father of X-ray astronomy'; he was also the first Director of the Space Telescope Science Institute. With the same drive he applied to creating X-ray astronomy, he took the fledgling organization NASA created to help operate the Hubble Space Telescope and created a first-rate research institution. The same scientific vision he pursued to learn what X-ray astronomy could reveal about nature built the Institute and created new methodologies for carrying out world-class astronomy. Under Riccardo's leadership, and working with NASA and the astronomy community, the Institute played a major role in developing the ground systems for Hubble, creating the policies and procedures for Hubble observing, and understanding and improving Hubble's performance.

"...upon learning that we have become Nobel Laureates there is a feeling of personal pride... the work for which we are honoured is the result of the cooperative effort of many people over the years. We feel a sense of continuity with the quest... we are participating in a great festival of lights... it is a splendid reaffirmation of the human spirit and of our capacity to give meaning and warmth to life."

— Riccardo Giacconi, excerpts from his acceptance speech

Riccardo's Nobel Prize is the first for research carried out primarily on NASA-sponsored facilities. He used X-ray detectors launched on rockets to investigate cosmic X-ray radiation, which is absorbed in the Earth's atmosphere. While the first rocket experiments were funded by the Department of Defense, NASA soon took over as major sponsor of the rocket- and satellite-based X-ray program.

In the 1960s, Riccardo outlined a methodical program to investigate the X-ray universe. Working with his research group at American Science and Engineering, Inc. in Cambridge, Massachusetts, he first built rocket-borne experiments and later developed the first space satellite for X-ray astronomy, Uhuru, which was launched in 1970 and discovered hundreds of X-ray sources. Uhuru's finding that the emission of many X-ray objects varied in time led to the conclusion that these sources were compact objects—neutron stars and black holes—in orbit around other stars. Black holes, which had been hypothesized but never observed, are now known to be present not just in stellar systems but also at the centers of galaxies. Uhuru made many other discoveries, including an amount of gas in clusters of galaxies that dwarfed the mass in stars. It is no understatement that Uhuru revolutionized our view of the universe and paved the way for other satellite observatories.

Riccardo and his group relocated to the Harvard-Smithsonian Center for Astrophysics (CfA) to develop and operate the Einstein X-ray Observatory, which took the first images of astronomical X-ray sources starting in 1978. After Riccardo left to become the first director of the Space Telescope Science Institute in 1981, the CfA group carried forward the program, culminating in the currently operating Chandra X-ray Observatory, which he and Harvey Tananbaum had proposed to NASA in 1976.

Those of us who were fortunate enough to work with Riccardo here at the Institute in the 1980s witnessed his vision leading to many methodologies taken for granted in astronomy today. These include observing program recommendations via discipline panels moderated by an overall Telescope Allocation Committee; electronic proposal preparation and submission tools; a calibration data-

base system; an end-to-end data system including a distributed data analysis system for the community; and an archive.

NASA and the community did not immediately accept all the Institute's innovations. Nonetheless, we persevered with courage Riccardo inspired, and today our methodologies are used at most major ground- and space-based observatories.

Riccardo's thorough, science-driven approach to problems—we fondly called it 'science system engineering'—was essential to the Institute's record of success. The most critical success was that of the Strategy Panel, which recommended the comprehensive solution to Hubble's optical problems discovered after launch. In many other areas—sociological as well as technical—Riccardo also left his mark. Being attentive to process was always important. Riccardo's support and participation were essential to the Institute's workshop on Women in Astronomy, where he introduced the idea of the Baltimore Charter.

Riccardo Giacconi went on from the Institute to play a key role in other astronomy programs. He became Director-General of the European Southern Observatory, building the Very Large Telescope, which is an array of four, 8-meter telescopes atop a flattened mountain in Chile. He advocated European participation in a large millimeter-wave observatory, now the Atacama Large Millimeter Array (ALMA). In 1999, he returned to the United States to become President of Associated Universities, Inc. (AUI), which operates the National Radio Astronomy Observatory, and where he has successfully brought ALMA to the construction phase. And Riccardo has not stopped yet; he is creating a collaboration to tackle perhaps his biggest challenge yet: AUI is currently leading a collaborative effort proposing to establish an institute to manage the research utilization of the International Space Station. ¤

profiles

Bonnie Eisenhamer

Bonnie Eisenhamer joined the Institute in 1996 as Education Evaluation Specialist for the Office of Public Outreach [OPO] and is currently head of the Formal Education Group for OPO.

Bonnie was born and raised in Saugerties, N.Y., a small, rural, one-streetlight town. The town's only claim to fame is that it is eight miles down the road from Woodstock, home of the famous rock music festival. But it was in Saugerties that Bonnie learned the importance of helping people by volunteering in community projects. She was especially interested in how people communicated and processed information.

When performing her volunteer work, Bonnie always displayed her sense of humor. In fact, her high school senior class voted her the "most humorous person," although her parents probably would have preferred "most likely to succeed." Nonetheless, family and friends still look forward to her pranks.

Realizing that becoming a comedian would not be a good career move, Bonnie instead decided to build a career around helping people succeed through learning.

Bonnie headed off to much warmer climates to pursue her career. She completed her undergraduate studies, earning a dual degree in education and psychology at Chaminade University in Hawaii. Bonnie received her M.S. degree in clinical psychology at Loyola Marymount University in California and her M.Ed. degree in educational psychology at the University of Arizona.

The New York native developed an interest in astronomy while studying in sunny Arizona, where she met an astronomy student named Jon Eisenhamer, who was at Steward Observatory. Bonnie did not know much about astronomy; she had never even seen a backyard telescope. Nonetheless, Jon invited her to view the sky through one of Steward's large telescopes. Bonnie never forgot that experience, because, for the first time, she saw the rings of Saturn. Gazing at those rings, she became enchanted with the beauty of space. She also was surprised at what she could

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Scientific **Visualizations**

— Frank Summers

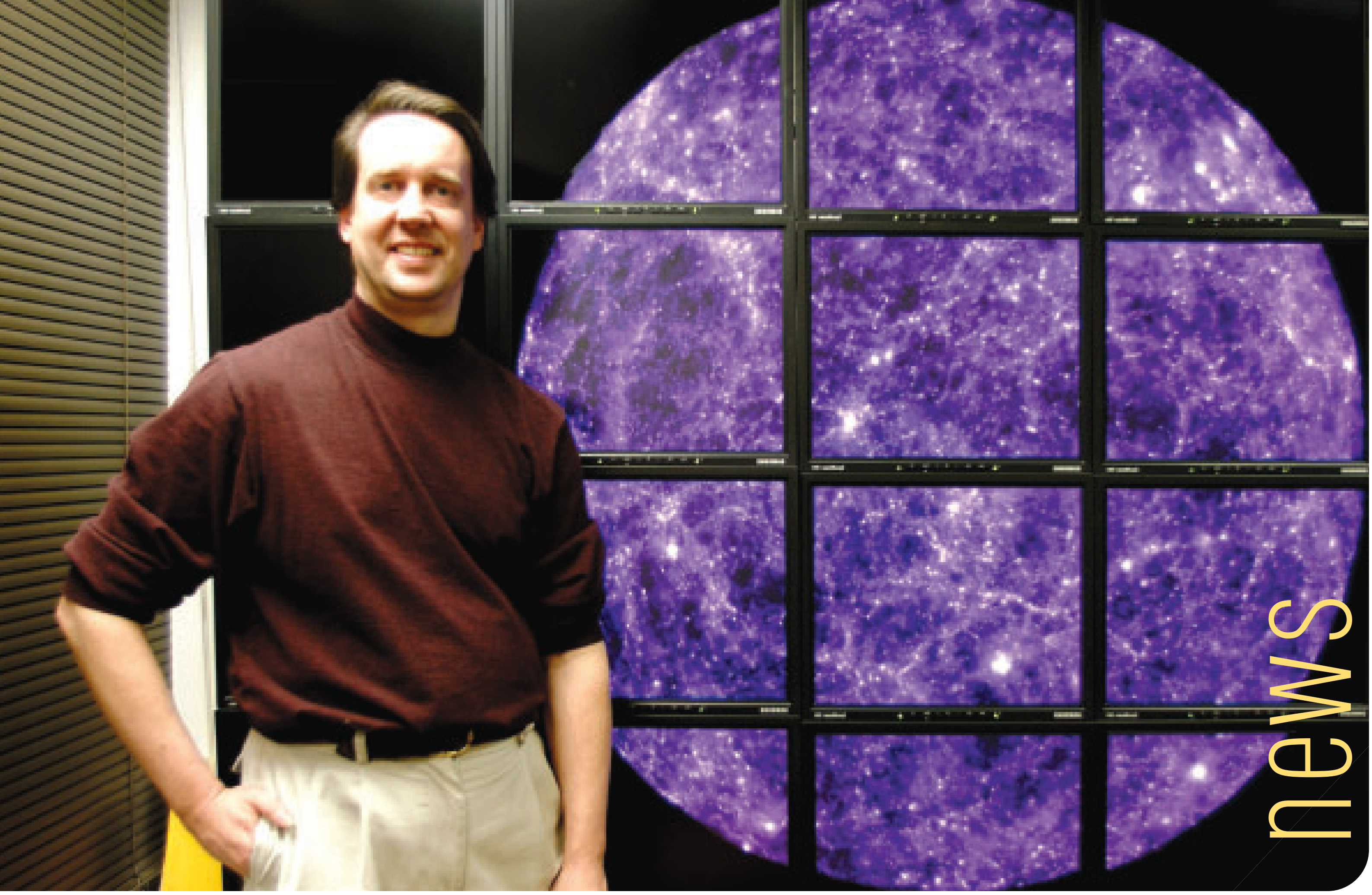
IN 2002, THE OFFICE OF PUBLIC OUTREACH (OPO) BROKE NEW GROUND IN OUR **ABILITY TO COMMUNICATE** THE WONDERS OF **ASTRONOMY VISUALLY**. While we continued our traditionally strong development of scientific visualizations for press releases and the Internet, we opened two new avenues. **The Visualization Wall** project created an unprecedented ability to view high-resolution imagery at the Institute, and our distribution of visualizations to planetariums provided high-quality, scientifically accurate imagery to those important external venues.

OPO's Astronomy Visualization Lab has long provided a wide range of extraordinary visuals in support of our press releases. In 2002, our scientific visualizations illustrated astronomical scenes ranging from icy worlds at the edge of the Solar System to the birth of stars at the early stages of the universe.

In January, a visualization of the 'fireworks' of stellar birth some 12 to 13 billion years ago illustrated the news of Hubble's finding rapid star formation at that epoch. In April, a visualization showing the enormous changes a star goes through during its lifetime illustrated a press release on the oldest stars in the Milky Way. In September, an intriguing animation of the distorted view near a black hole illustrated a release on black holes in globular clusters. Visualizations, illustrations, and artist's conceptions richly illustrated two press releases on new discoveries in the Solar System's Kuiper Belt.

On the Internet side, we used a scientific visualization to experiment with higher bandwidth content delivery. Our Striking Encounters project explained the wholesale destruction and distortion that occurs when two galaxies collide. It used a visualization of a galaxy collision as the centerpiece, packaged with images of observed galaxy collisions, narration, and music. Striking Encounters provides a complete story in a seamless, streaming download. Currently, bandwidth limitations constrain our ability to provide such visualizations to the public over the Internet. Nevertheless, this project ventured 'outside the box' to give us a glimpse of future possibilities.

Our Visualization Wall project explores the impact of displaying high-resolution images, such as those from the Advanced Camera for Surveys (ACS), at full detail. An ACS Wide Field Camera image has 16 million pixels, while the average computer screen has only 1 million. We assembled 16 flat panel computer screens in a 4 x 4 array to create a 20 million pixel display measuring over six feet diagonally. We drive this display with a cluster of 17 Linux computers—one for each screen plus a master, control computer. This cluster also offers significant horsepower for scientific analysis and computation. The results are stunning. The Visualization Wall allows one to stand back and get an overview or walk up to it and examine details—one can see both the forest and the trees.



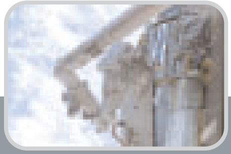
Dr. Frank Summers shows off the Visualization Wall and his scientific visualization of the large-scale structure of the universe.

Planetariums are undergoing a technological revolution related to visualization. The star projector, which has been the mainstay of planetariums since its introduction in the 1930s, offers an Earth-bound experience that is mostly static. Now, many planetariums are being outfitted with all-dome, digital-video technology, which enables them to go anywhere in the universe and create a dynamic, virtual experience that is much better suited to explaining modern astrophysics.

In OPO, we are taking advantage of this new technology and helping foster its adoption. Using the Visualization Wall, we are producing high-quality scientific visualizations for these digital dome planetariums. We take scientific simulations of interesting astronomical phenomena and use Hollywood-level visualization tools to create aesthetic yet accurate dome movies for the public. So far we have produced three such scientific visualizations: a galaxy collision, the evolution of a globular cluster, and the large-scale structure of the universe—the 'cosmic web'. In this way, planetarium audiences can view the same science that appears in the pages of the Astrophysical Journal.

The planetarium community has welcomed our involvement. Our scientific visualization of a galaxy collision was featured in the inaugural show of the new Einstein Planetarium at the National Air and Space Museum. The upcoming opening of the Hansen Planetarium in Salt Lake City will feature two of our sequences. The Minolta Corporation brought their new dome projection system (and a dome) to Baltimore, and we adapted our three sequences for their system. Every major U.S. planetarium vendor now uses our visualizations, either in shows or in demonstrations of their technology.

Television and movies shape our society's conceptions of the world and the universe. OPO recognizes the need to enhance the visual aspects of presenting astronomy to capture the attention and wonder of the public. We are also aware of the disservice of visuals that are not infused with accurate narratives of the science presented. Therefore, we are increasing our efforts to create and distribute scientific visualizations while aggressively ensuring their scientific accuracy. We strive to remain on the cutting edge of visual information technology in support of the astronomers worldwide using Hubble to explore and understand the universe. ⌑



profiles

Lisa Wolff

Lisa Wolff joined the Institute in 2002 and serves as the Chief Information Officer.

Lisa attended the University of Maryland's Clark School of Engineering in College Park. She joined the Institute in 2002, after making the decision to leave an 18-year career in the research and engineering field. Lisa's decision to join the Institute was heavily influenced by her interest in mathematics, physics, and software engineering.

The appeal of electrical engineering surfaced in the early 1980s, while Lisa was employed at IIT Research Institute (IITRI). She designed RF (radio-frequency) shielded enclosures, developed printed circuit cards for avionics systems, and worked on various research initiatives. Lisa took on the technical and cultural challenge of introducing Computer Aided Design (CAD) to IITRI's engineering staff. Although an emerging technology at the time, Lisa recognized the revolutionary change that this technology would bring to the engineering and manufacturing industry. Clearly, expertise in this technology would be a critical element to an engineer's success. Lisa set both educational and career courses to gain that expertise.

One year after the successful introduction of CAD at IITRI, Lisa accepted employment with US Design, a subsidiary of Maxtor Corporation. She designed cache controllers and managed the design environment. The breadth of CAD technology was growing wider, encapsulating the art of electrical circuit design. CAD had become CAE (Computer Aided Engineering) in recognition of the new functionality. The CAD industry's move to automate more than the physical layout of printed circuit boards opened new opportunities for Lisa. Now that the tools were capable of modeling the behavior of a circuit, Lisa set a new target: to dramatically improve the design quality and cycle time required to develop a product. She hit her target through the broad application of circuit modeling and simulation, improving information management methods and re-engineering processes.

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Roeland van der Marel

Roeland van der Marel came to the Institute in 1997 as the first Institute Fellow and currently leads the Advanced Camera for Surveys Team.

Roeland grew up in The Netherlands. After a few years in The Hague, he moved to the suburb of Wassenaar, where he spent most of his childhood. He acquired a love of the exact and abstract already at an early age. His brother was devoted to chess, puzzles, and mathematics and enthusiastically taught his kid brother whatever he would absorb. As a consequence, Roeland participated in his first chess tournament at age seven, with many more to follow. However, despite moderate successes, the interest in chess would not stick. While the chessboard was permanently stored in the closet, a passion for science in general and astronomy in particular has remained to this day. Roeland recalls: "I was never an amateur astronomer. However, I recently came across some old high school notebooks. Amongst the soccer teams and rock stars of the day, I noticed a picture of the Hubble Space Telescope. Apparently, already then I had a good sense of what I wanted to do in life."

After high school, Roeland chose to pursue a double major in astronomy and mathematics at nearby Leiden University, where Lorentz, de Sitter, Oort, and others had established a rich tradition in astronomical research. Although he enjoyed mathematics, it did not draw him in the same way that astronomy did. "Astronomy uses advanced, multi-million-dollar telescopes in exotic places to address questions that humans have pondered for centuries," so he explains. "Mathematics is more abstract and to me just doesn't radiate the same entrepreneurial spirit." Roeland chose to pursue a graduate degree in astronomy. He had been introduced to the field of galaxy dynamics during an undergraduate summer project at Oxford University and chose to make this the topic of his Ph.D. research.

Some galaxies display pronounced activity in their centers, which had long been believed to be due to

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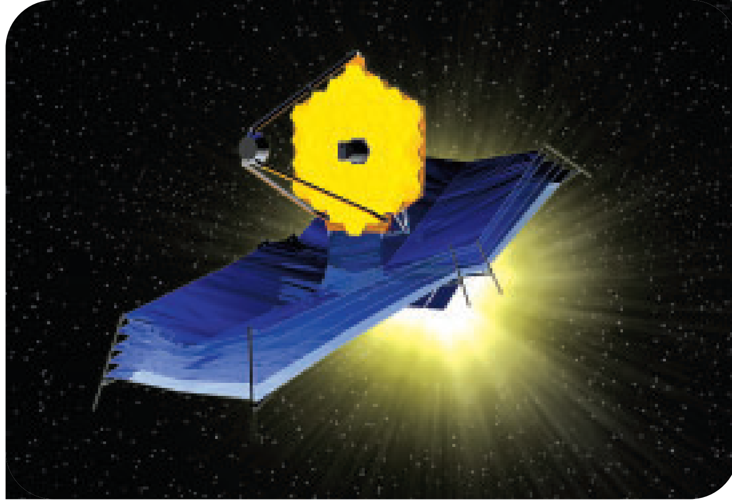


Figure 1

JWST and STScI

— *Peter Stockman*

news

YEARS FROM NOW, WE MAY SAY THAT THE 'NEXT GENERATION SPACE TELESCOPE' TRULY WAS BORN IN 2002. A glimmer in the eye of the astronomy community and NASA for many years, it took on a life of its own with the creation of the science team, the selection of the prime contractor, and the telescope's formal renaming as the James Webb Space Telescope (JWST). In the coming years, the Institute and a virtual 'village' of partners, including the Science Working Group (SWG), NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA), will guide the development of JWST to become the proper successor to Hubble.

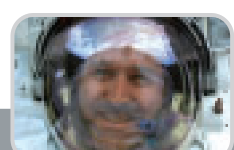
NASA released the results of the competitive selection of the science team in June. The University of Arizona was the big winner, with the choice of Marcia Rieke as Principal Investigator for the Near Infra-Red Camera (NIRCam) and her husband, George Rieke, as the U.S. lead of the Mid-Infrared Instrument (MIRI) team. Marcia and George have considerable experience with the NICMOS instrument on Hubble and the far-infrared photometer on the Space Infrared Telescope Facility (SIRTF). From the Institute, the SWG and instrument teams include Massimo Stiavelli (first SWG Co-Chair), Margaret Meixner (MIRI team member), Stefi Baum (NIRCam team member), and Peter Stockman (Institute Project Scientist). The SWG immediately set to work refining and prioritizing the science goals for the observatory.

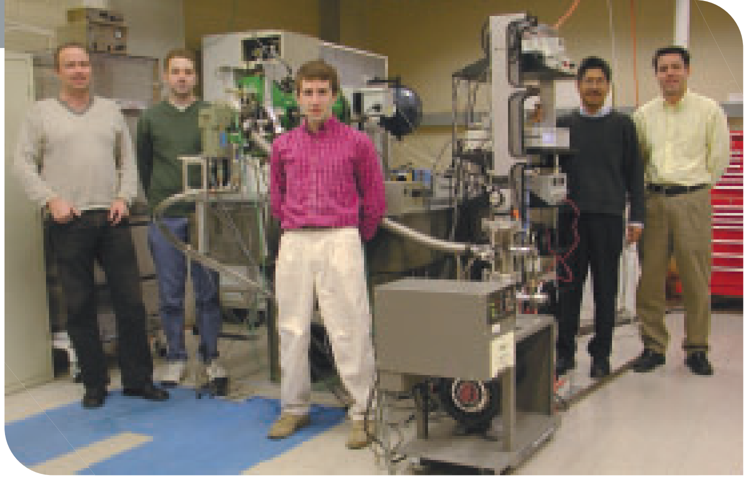
The birthday of the telescope may be September 10, 2002, when NASA announced both the new name for JWST and the prime contractor, TRW. With the name choice, Sean O'Keefe, the current NASA Administrator, honored James Webb, NASA's second administrator, who was responsible for the Apollo program and the strong NASA science program that continues to this day. TRW and its major corporate partners, Ball Aerospace and Kodak, proposed an innovative design for the telescope and already have proven many of the key technologies needed for its development.

As illustrated in Figure 1, the TRW telescope features a 'drop-leaf table' design for the deployable primary mirror. The 36 hexagonal segments that comprise the mirror are mounted on a central backing structure and two hinged structures, which fold backward during the launch phase. After launch, the two structures swing forward and lock without further adjustment. Each of the hexagonal segments has four mechanisms to adjust for tip, tilt, piston, and focal length. In the shadow of the five-layered, deployable sunshade, the primary and secondary mirror optics will cool radiatively to approximately 50 K. The TRW design features reliable deployment mechanisms and provides excellent optical stability.

Even with so much decided, the JWST Project is still changing. In November, Phil Sabelhaus took over the reins from Bernie Seery as JWST Project Manager for the upcoming development phase. Mr. Sabelhaus led the development of two major Earth-observing missions, Aqua and Aura, as well as a number of smaller missions. TRW—which after merging with Northrop Grumman is now Northrop Grumman Space Technologies (NGST!)—made the Aura and Aqua spacecrafts.

The hardest task the new Project Manager faces is squeezing the total project cost into a highly constrained budget. As a first step toward assisting in this regard, the Institute revised its plan for the development and operations of the JWST Science and Operations Center (S&OC) in September. The scrubbed S&OC plan reduces support for NASA and the instrument teams and relies heavily on continued Hubble software development. In early 2003, the Project must recommend to NASA Headquarters several options for a leaner JWST observatory. Because both the Institute and the SWG are involved with the development and review of these options, we have confidence that the eventual JWST will retain its great scientific potential for infrared astronomy and that it will succeed in discovering the origins and evolution of the first galaxies. ¤





IDTL personnel and detector characterization system. From left to right: Bernard Rauscher (project scientist), Ernie Morse (data analyst), Eddie Bergeron (data analyst), Sito Balleza (systems engineer), and Don Figer (PI). Not pictured: Mike Regan (software systems scientist) and Gretchen Green (detector head engineer).

Independent **Detector Testing** Laboratory

— Don Figer

Detectors are at the heart of scientific discovery, whether as 'simple' as the human eye or as complex as the sensors on the Hubble Space Telescope. In recognition of their importance to astronomy, the Institute and Johns Hopkins University (JHU) created the Independent Detector Testing Laboratory (IDTL), located on the JHU campus in the Department of Physics and Astronomy's Bloomberg building.

The vision of the IDTL is to provide world-class testing and development facilities for astronomical detectors and associated technology. While not an easy vision to fulfill, its success will bring several benefits. First, the IDTL enables the James Webb Space Telescope (JWST) Project Office, instrument teams, and wider community to select the best flight detector designs for JWST by evaluating prototype near-infrared detectors. Second, the IDTL serves the astronomical community by publishing all designs, software, procedures, raw data, analyses, and publications on its website, as well as in appropriate journals. Third, the IDTL provides the hardware, infrastructure, and local expertise that enable Institute and JHU scientists to participate in forefront space-based and ground-based astronomy missions. Lastly, the IDTL trains JHU and Institute staff, graduate students, and interns in the design and use of cutting-edge detector applications, and this training will ultimately benefit the development and operation of the JWST and future missions.

NASA has selected the IDTL to verify comparative performance of prototype near-infrared JWST detectors developed by Rockwell Scientific (HgCdTe) and Raytheon (InSb). The IDTL will obtain an independent assessment of the ability of the two competing technologies to achieve the demanding specifications of the JWST program within the 0.6 to 5 µm bandpass in an ultra-low background environment. In this project, we are measuring first-order detector parameters—dark current, read noise, quantum efficiency (QE), persistence, intrapixel sensitivity, and linearity—as functions of temperature, well size, and operational mode.

We have tested a half dozen prototype JWST detectors during 21 cool-downs of our system. During these runs, we have established that the IDTL system is 'darker' than the most stringent requirements for JWST, verifying ultra-low background levels of $< 0.005\ e^-\ sec^{-1}\ pixel^{-1}$. This achievement demonstrates extraordinary baffling, given that at room temperature the instrument walls emit over 10^{20} photons sec^{-1} in the instrument bandpass! In addition, we have verified low-noise electronics performance, allowing us to measure detector noise levels below the JWST requirements. Our QE measurements show that candidate detector materials can offer significant response from blue wavelengths (0.4 µm) to the desired long-wavelength cutoff near 5 µm. Finally, we have found that the detector material can trap persistent charge, which leaks out in subsequent images, appearing as a ghost image of previously observed targets. Certain detector reset schemes do appear to ameliorate the effects of persistent charge.

In the future, we look forward to enabling detector technology for other missions, on the ground and in space, like the Large Synoptic Survey Telescope (LSST) and the Supernova Acceleration Probe (SNAP). LSST is a proposed ground-based, 8-meter class, wide-field, synoptic survey telescope. The combined collecting power and field of view will be much greater than any existing telescope. Astronomers will use LSST to survey large regions of the sky to unprecedented depth to probe the nature of dark energy and to detect near-Earth objects. The IDTL is part of a proposal to develop the billion-pixel focal plane for LSST.

SNAP is a proposed space-based, two-meter telescope with a mission to determine the expansion properties and dark energy characteristics in the universe. The IDTL is currently working with the SNAP team to develop the best near-infrared detectors for use in this ambitious mission. ¤

science essays

The Lessons of **Deuterium**

Scott D. Friedman

One way for astronomers to 'observe' astrophysical processes is to study isotopes, which are nuclear variations of an element with the same number of protons but differing numbers of neutrons. Isotopic abundances can reveal the special conditions and processes that created or destroyed the nuclei of atoms in the Big Bang, inside stars, by cosmic ray collisions, and in other astrophysical environments. Using high-resolution spectroscopy, such as with Hubble's former Goddard High Resolution Spectrograph (GHRS) or current Space Telescope Imaging Spectrograph (STIS) or the Far Ultraviolet Spectroscopic Explorer (FUSE), astronomers can observe signature spectral lines of isotopes located in interstellar or intergalactic space; then, they can use models of spectral line formation to derive abundances. In this way, we have developed an understanding of the original creation of light elements in the Big Bang and of the synthesis of heavy elements inside stars.

Although hundreds of isotopes surround us today, only seven nuclear variations of four light elements survived the Big Bang in significant quantities: ^{1}H, ^{4}He, ^{2}H (deuterium, D), ^{3}He, ^{7}Li, ^{7}Be, and ^{6}Li. (Standard nomenclature identifies an isotope by a preceding superscript to the element's chemical symbol giving the 'mass number' or total count of nucleons—protons and neutrons.) No heavier elements survived because no isotope with mass number 5 or 8 is stable, which created a bottleneck for the reactions underway during the Big Bang. Only later, after the first stars formed out of the original isotopes, were the heavier elements (metals) created by nucleosynthesis in the new and necessary temperature and pressure conditions of the stellar interior. Mass loss from mature stars has continuously enriched space with metals since that time, giving rise to later generations of stars, planets, and life itself.

Deuterium is simple and special, and its cosmological story is unique. It is a fragile nucleus, consisting of a proton and a neutron, and has a small binding energy, which means that it is easily destroyed inside stars. Because we believe it has no significant source other than the Big Bang itself, the abundance of deuterium should decrease steadily everywhere over the age of the universe, as matter is processed through stars.

Among the seven original isotopes, deuterium is first in importance as a probe of the Big Bang. This is due both to its simple evolutionary path of steady disappearance since its formation and to its special diagnostic value. While the primordial abundance of any of the light original isotopes provides constraints for important cosmological parameters, deuterium is the most sensitive of all. Measuring the primordial value of D/H—the ratio of the deuterium to hydrogen abundance—is the best way to estimate the baryon-to-photon ratio in the early universe and, from it, to determine Ω_B, the fraction of the critical density contributed by baryons. The critical density—a benchmark of cosmology—is the dividing line between an open (forever expanding) and closed (eventually contracting) universe.

Astronomers detect H and D by observing Lyman-series absorption lines caused by interstellar or intergalactic atoms along sight lines toward background light sources, either stars or quasars. At rest wavelengths, these lines occur in the far ultraviolet portion of the spectrum, from 1216 Å (Lyman α) to 912 Å (Lyman limit). The deuterium lines are slightly shifted towards shorter wavelengths, by 82 km s^{-1} or 0.33 Å at Lyman α. For sight lines without excessively complicated component structure, the D and H lines can be measured separately, yielding the D/H ratio.

Since the same stellar processes that destroy deuterium also manufacture metals, which are scattered through the interstellar medium (ISM) by stellar explosions and winds, astronomers expect to find an anticorrelation between the D/H ratio and metallicity, usually measured as the ratio of the oxygen or silicon to hydrogen abundance. Observation of such an anticorrelation would provide strong support for our ideas of the source of deuterium and general principles of galactic chemical evolution.

The first measurements of D/H in the ISM were made with the Copernicus satellite in the 1970s. The best of these sampled sight lines toward targets out to a distance of about 200 pc. The data hinted at the possibility of spatial variability in D/H, but they were also consistent with the single value of D/H = 1.5×10^{-5}.

GHRS made the most accurate ISM measurement, D/H = $(1.46 \pm 0.05) \times 10^{-5}$, observing the cool star HR1099, 36 pc away. Hubble measurements toward other targets, all closer than 80 pc, gave similar results. Since Hubble's short wavelength limit is about 1150 Å, the only transition of the H and D lines available is Lyman α. This limits Hubble deuterium measurements to relatively short sight lines with modest H column densities, in order that the damping wings of the H Lyman α line do not encompass the D line, which would render the latter impossible to measure.

In 1996, the space shuttle-based Interstellar Medium Absorption Profile Spectrograph (IMAPS) measured D/H toward three stars at distances of 260, 430, and 500 pc. One sight line had significantly higher D/H—and one had significantly lower—than the mean ISM value. At that time the questions of how the D/H ratio varied, over what distances, and, most importantly, how it related to metallicity and galactic chemical evolution could not be answered. Recent results from FUSE and from ground-based observatories have renewed interest in these issues.

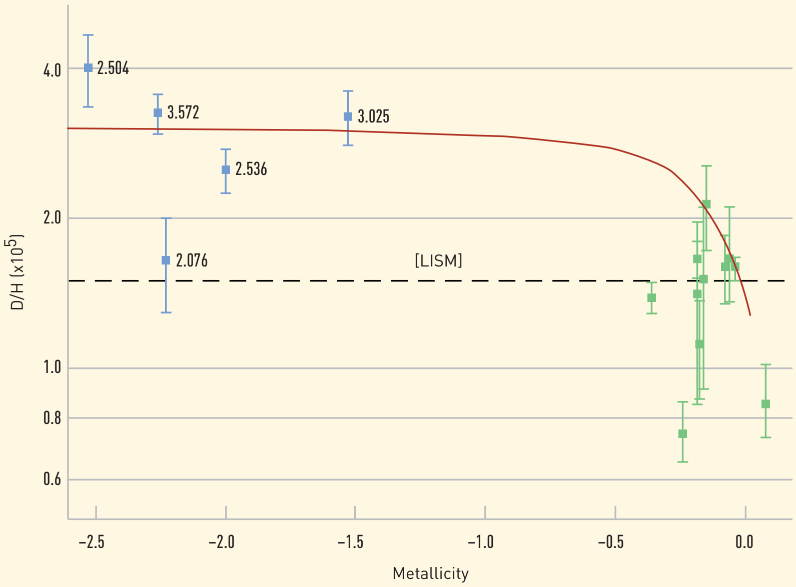


Figure 1: The D/H ratio is plotted as a function of metallicity. Galactic ISM measurements are shown in green. High redshift measurements are shown in blue, with the numbers indicating the redshift of the absorbing clouds. The dotted line is the mean local ISM value of D/H. The red line is a theoretical prediction of how D/H is expected to decrease as the metallicity increases.

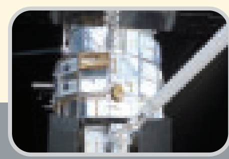
Because FUSE operates between 1187 Å and the Lyman limit, it can measure all H and D Lyman-series transitions except Lyman α, as well as many transitions of neutral oxygen, which allows a measurement of metallicity along the sight lines. Interestingly, FUSE is much better suited to measuring the column density of D rather than H, since some of the measurable, high-order Lyman lines are on the linear portion of the curve of growth for D, but on the flat portion for H. The column density of H is usually best determined by fitting the damping wings of the Lyman α line, and STIS is the only instrument today that can be used to do this.

FUSE has measured D toward both local and more distant Galactic objects. The combination of these and the earlier D/H results are consistent with the properties of the 'Local Bubble', a cavity of hot, low-density gas bounded by a wall of higher density hydrogen, and extending out 100 to 150 pc from the Sun. Within the cavity, the material is well mixed, and sight lines have approximately the same value of D/H. By contrast, sight lines extending outside the Local Bubble find varying values of D/H. Furthermore, the first hints of the expected anticorrelation of D/H and the oxygen abundance may be just starting to appear, although the number of targets is too small to be certain.

Meanwhile, large ground-based telescopes have measured D/H in environments using quasars as the background light sources. Because the absorbing clouds are at high redshift, their Lyman series absorption lines appear in the visible portion of the spectrum. These clouds all have much lower metallicity than the Galactic clouds, and we expect the D/H values to approach the primordial value. Surprisingly, however, the most precise measurements show that D/H varies by more than a factor of two, and in one case it is nearly as low as the mean value in the Local Bubble (see Figure 1).

The existing measurements of the D/H ratio challenge theorists with at least three questions. First, can hydrodynamic models of mixing processes and time scales in the ISM account for the uniformity of D/H values within the Local Bubble? Second, can models of galactic chemical evolution account for both the observed mean local ISM value of D/H as well as the variation seen along different sight lines outside the Local Bubble? Third, what is the explanation for the large D/H variation in high redshift environments, all of which have relatively low metallicity?

At the start of 2003, considerable effort is being made to answer these questions. Ground-based observers are searching for additional sight lines, which require the rare combination of bright background quasar, simple absorption component structure, and absorbing column density within measurable limits. The FUSE D/H team is making more measurements, stressing sight lines toward objects well outside the Local Bubble, to better sample the D/H variability. Also, they are vigorously pursuing STIS measurements of Lyman α profiles toward several targets already observed with FUSE to increase the precision of the D/H ratio values. These measurements will promote our understanding of the evolution and mixing of material in interstellar and intergalactic space. ¤



Bar-Driven **Evolution of Disk Galaxies**

Shardha Jogee

Once considered anomalies, barred galaxies are now established as the norm, making up at least 70% of spiral galaxies in the local universe. As early as the 1880s, astronomers recognized large-scale bars, several kiloparsec (kpc) in size. These were further characterized later in the seminal works of Edwin Hubble and Gerard de Vaucouleurs. Today, we recognize that bars redistribute mass and angular momentum on all spatial scales by exerting gravitational torques and may well play a fundamental role in shaping the dynamical, morphological, and chemical evolution of local galaxies.

A driving objective of astronomy is to chart the assembly and evolution of the diverse galaxies that lie along the Hubble sequence as well as the outliers with more irregular morphologies. Prominent in the Hubble and related hybrid classification schemes is a sequence of spiral galaxies that shows an increasingly prominent central condensation or bulge, a higher bulge-to-disk luminosity ratio, tighter spiral arms, and lower levels of star formation in the disk. Some studies contend that bars can cause these spiral galaxies to evolve along the Hubble sequence. Central to such secular evolution scenarios is the fact that large-scale bars efficiently transport molecular gas from the outer disk of a galaxy down to the inner few hundred parsecs (pc), increasing the central mass concentration. The ensuing high gas densities and short dynamical timescales in the inner region culminate in spectacular starbursts, which often dominate the luminosity of the entire galaxy. Using the Caltech's Owens Valley Radio Observatory (OVRO) millimeter-wave array, the author and colleagues have mapped such gas-rich starburst rings near the dynamical resonances of barred galaxies (see Figure 1). Michael Regan and co-workers find similar features using the Berkeley Illinois Millimeter Array.

The compact stellar disks or rings built by the bar-induced starbursts may account for some of the 'pseudo-bulges' with exponential light profiles that Roelof de Jong and Marcella Carollo have identified in late-type galaxies. This echoes an earlier idea of John Kormendy, that certain bulges may in fact be closer to disks. Furthermore, 'real' spheroidal bulges may also be built via bending instabilities, vertical bar resonances, and chaotic orbits that drive stars well above the plane of the disk. Observed boxy bulges and peanut-shaped bars could be intimately linked to such processes. Simulations even suggest that after a bar raises the central mass concentration above a critical level, it can weaken and self-destruct into a large bulge! This could transform a strongly barred spiral into a weakly barred or even unbarred galaxy.

Yet, our understanding of bars is far from set in stone and unanswered questions remain. Can a disk regenerate a bar once it has been destroyed, or will the inhospitable conditions left behind—such as a large central concentration and a hot disk—inhibit any subsequent bar formation? How are bars influenced by the external environment, particularly in the early universe, when interactions with both small and large galaxy companions may have been more frequent? Does the fate of bars change dramatically when they are embedded in halos that are responsive and triaxial rather than rigid and spherical?

In the last decade, Hubble and high-resolution, ground-based, near-infrared images have brought attention to a new component of disk galaxies: small-scale nuclear bars—typically kpc or sub-kpc in size—nested

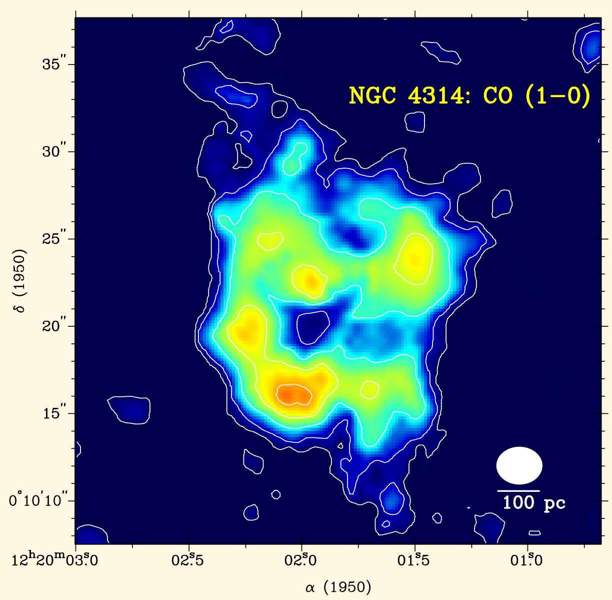


Figure 1: At left, the Hubble Wide Field Planetary Camera 2 composite of the barred galaxy NGC 4314 showing a spectacular ring of star formation and young compact star clusters in the inner few hundred parsecs. At right, the OVRO carbon monoxide map shows that this ring contains hundreds of millions of solar masses of molecular hydrogen, which have piled up near the dynamical resonances of the bar. (Hubble image courtesy of Zolt Levay and Fritz Benedict.)

inside large-scale bars. The fraction of nuclear bars is hard to pin down because they are generally obscured in dust, colliding clouds, and blazing star formation. Nonetheless, first statistics suggest that at least 20% to 40% of all barred galaxies host a secondary nuclear bar.

As illustrated in Figure 1, gas driven toward the inner part of a galaxy by a large-scale bar does not make it all the way to the center. Instead, it tends to stall in massive rings near the dynamical resonances of the bar because the shocks and torques weaken in this region. As first pointed out by Isaac Shlosman, when a nuclear bar forms inside the primary bar it can drive gas from the ring down to the central tens of pc, potentially igniting nuclear starbursts and an active galactic nucleus (AGN). Using Hubble and OVRO millimeter observations of the nearby spiral NGC 2782, the author and collaborators studied one of the first cases of a nuclear stellar bar caught in the act of feeding gas into a powerful central starburst.

While at present there is no compelling evidence for an excess of nuclear bars in local AGN hosts, the statistics are poor and the nuclear bar lifetimes are probably short, so the nuclear bar-AGN connection is not disproven. In any case, the fueling of AGN needs not rely only on nuclear bars because other processes—such as magnetic torques, turbulence and viscosity, and mergers of gas clumps—will dominate on smaller, pc and sub-pc scales. The possibility of nuclear bars driving the symbiotic growth of the bulge and the central black holes (BHs) is of particular interest, given the recently reported tight correlation between the properties of bulges and central BHs in galaxies.

Studies of the Hubble Deep Fields (HDFs) with the Wide Field Planetary Camera 2 find that a remarkably low fraction—below 20%—of disk galaxies at higher redshifts ($0.5 < z < 1.0$) have large-scale bars. This result may not be representative due to the small sample size and systematic biases in the data. Large surveys, such as GOODS (Great Observatories Origins Deep Survey) carried out with the Advanced Camera for Surveys, provide an improved data set with better resolution, coverage, and number statistics for reevaluating the bar fraction at high redshifts (see Figure 2). The intrinsic difficulty in correctly identifying certain types of bars must also be folded into the equation. By redshifting local galaxies, the author and collaborators find that strong, extended bars (radius > 4 kpc) can often be identified even out to redshift ~1, while shorter and weaker bars are washed out into diffuse-looking inner disks. Another pertinent effect is that cosmological dimming can 'fade' the outer disk beyond detection and cause a system with a weak bar encompassing a spiral pattern of star formation to be misidentified as an inclined disk. A classic example—and cautionary flag for identifying bars at high redshift—is the misidentification of the 'grand-design' spiral galaxy NGC 5248, right in our backyard. For decades this galaxy had been considered to be either unbarred or to host a short bar of radius 1.6 kpc. Nevertheless, evidence presented last year revealed that the feature previously thought to be the inclined disk is in fact an extended bar of radius 7.1 kpc (see Figure 3). The actual outer disk lies beyond this bar, out to a radius of at least 17 kpc!

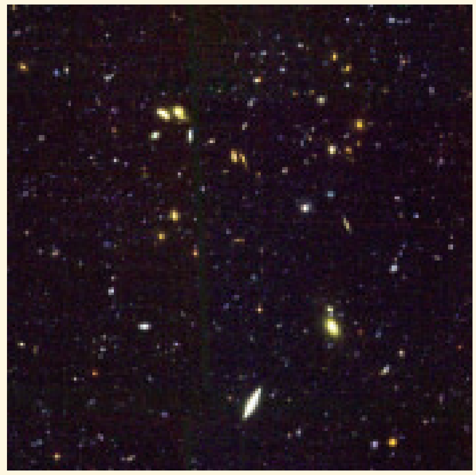


Figure 2: Composite of a 50 arcsec x 50 arcsec region in the GOODS Chandra Deep Field South from the first epoch B-,V-, I-, and z-band ACS images. The author and collaborators—including Johan Knapen, Bahram Mobasher, Isaac Shlosman, Chris Conselice, Swara Ravindranath, and other members of the GOODS team—are working on the evolution of bars and disks at intermediate redshifts from the rich, panchromatic, high-resolution data set provided by GOODS.

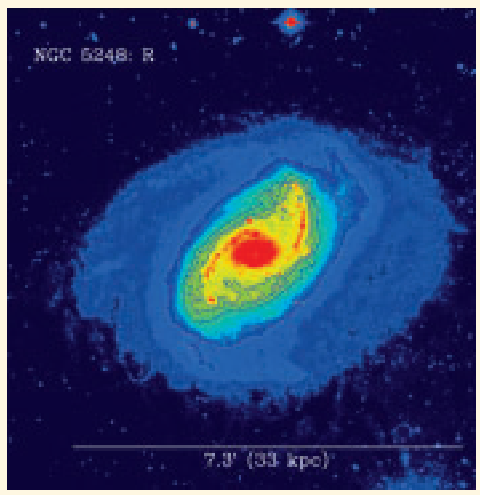
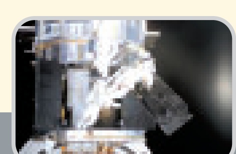


Figure 3: The R-band image of NGC 5248 reveals that the feature previously thought to be an inclined disk is a prominent stellar bar, with a radius of 7.1 kpc. The true outer disk is fainter and much more extended, with a radius of at least 17 kpc. (This image is based on the work of the author and collaborators, including Johan Knapen, Isaac Shlosman, Seppo Laine, and Nick Scoville.)

Bars are gaining importance for understanding morphological evolution, nuclear activity, and global connections between the central regions and large-scale properties of disk galaxies. Future high-resolution, sensitive, wide-field infrared imaging (e.g., with the Wide Field Camera 3) and spectroscopy will better characterize large-scale bars in high redshift galaxies and nuclear bars in their local counterparts. Concurrent theoretical works are yielding new insights into how bars and disks may evolve in dark-matter halos and external environments typical of earlier cosmological times. As exciting results unveil in the near future, we may well need to revisit what we took for granted about the formation, evolution, and impact of bars on galaxy evolution. ¤



Molecular Hydrogen around **Young Stars**

Jeff Valenti

When star forming clouds dissipate enough to reveal young T Tauri stars, the stars have already achieved nearly their final mass. On the other hand, a residual disk of dust and gas often still surrounds T Tauri stars at one million years of age. Although the amount of material in the disk is a tiny fraction of the stellar mass, it is still enough to form planetary systems. By the time low-mass stars are ten million years old, they generally show no evidence of warm circumstellar dust, perhaps because the grains have combined to form asteroids or even planetary cores.

Even small amounts of warm circumstellar dust raise infrared emission dramatically above the level expected for the star alone. Gaseous disks are more difficult to detect, so we do not yet know how long circumstellar gas typically persists after the dust is gone. This question is important because some planet formation theories require gaseous disks to last for at least ten million years in order to build up planets as massive as Jupiter.

Hubble continues to yield spectacular images of extended disks around young stars, but even its superb angular resolution is not adequate to image the innermost regions of disks, where planets are likely to form. The James Webb Space Telescope will be able to image disks at infrared wavelengths, where the inner regions of disks outshine even the star. In the meantime, astronomers are using ultraviolet spectroscopy with Hubble to study the unresolved inner regions of circumstellar disks.

Because of its overwhelming abundance, molecular hydrogen is the most important gaseous species in disks. Nevertheless, the structure of this molecule makes detection difficult. The energy levels of molecular hydrogen are widely spaced, so only shocks and strong radiation, not ordinary thermal heating, can excite the upper levels. Because infrared spectral lines of molecular hydrogen are intrinsically weak, detected emission comes from volumes much larger than the planet formation zone. Fortunately, ultraviolet spectral lines of molecular hydrogen are intrinsically strong and form in response to strong radiation, which makes them ideal for studying unresolved gas close to young T Tauri stars.

Currently, Hubble and the Far Ultraviolet Spectroscopic Explorer (FUSE) are the only facilities capable of observing ultraviolet radiation from outside the Solar System. The Space Telescope Imaging Spectrograph (STIS) on Hubble has been used to obtain ultraviolet spectra of several T Tauri stars. Many of these spectra are dominated by emission lines of molecular hydrogen, rather than atomic ions, as in older stars of similar surface temperature.

At a distance of only 56 pc, TW Hya is the closest known T Tauri star with an accretion disk. The complete STIS spectrum of TW Hya contains well over a hundred molecular hydrogen lines. These emission lines are caused by downward transitions from only nineteen excited states, even though molecular hydrogen has thousands of states with comparable energy. Not coincidentally, each of the nineteen excited states is connected to the ground electronic state by an upward transition that overlaps the Ly-α emission line of atomic hydrogen near 1216 Å, which is very strong in T Tauri stars.

When molecular hydrogen absorbs Ly-α photons, it is pumped into particular excited states. As the molecules relax back down to the ground electronic state via a limited number of allowed transitions, they create recognizable families of emission lines. Each upward, pumping transition can produce up to a dozen observable emission lines. This process is known as 'fluorescence'. Figure 1 shows an example from a STIS spectrum of TW Hya.

Molecular hydrogen emission lines in the spectrum of TW Hya provide interesting information about gas around T Tauri stars. Even Hubble's superb angular resolution does not resolve the emission region spatially. Therefore, the fluoresced molecular hydrogen must be located within 3 astronomical units of TW Hya, which is about the size of the asteroid belt in the Solar System.

Molecular hydrogen emission lines also have approximately the same Doppler shift as TW Hya itself, which means the gas probably orbits the star. Doppler shifts due to orbital motion broaden the observed line profiles by an amount that depends on how we view the disk. If we view the disk nearly face-on, as in TW Hya, lines are relatively narrow—11 km s^{-1} full width at half maximum. If we view the disk at a 45-degree angle, as in DF Tau, lines are twice as broad.

Interestingly, the complete STIS spectrum shows fluorescent emission lines that can only form if Ly-α photons are absorbed by molecular hydrogen at a couple thousand degrees. This is remarkable because molecular gas is generally found in much cooler environments. The star formation process forces molecular gas very close to newly formed stars, where intense radiation heats the gas.

These STIS observations confirm the presence of molecular gas in the planet-building zone around young stars still surrounded by dust. Hubble's next challenge is to search for this gas in slightly older systems, where the dust has coalesced into rocky cores, but planets like Jupiter may still be forming. This search will require the factor of ten improvement in sensitivity promised by the Cosmic Origins Spectrograph, which will be installed on Hubble near the end of 2004.

The author is working with various investigators to understand molecular hydrogen fluorescence in STIS spectra, including Greg Herczeg (JILA), Christopher Johns-Krull (Rice), Jeffrey Linsky (JILA), and Fred Walter (SUNY).

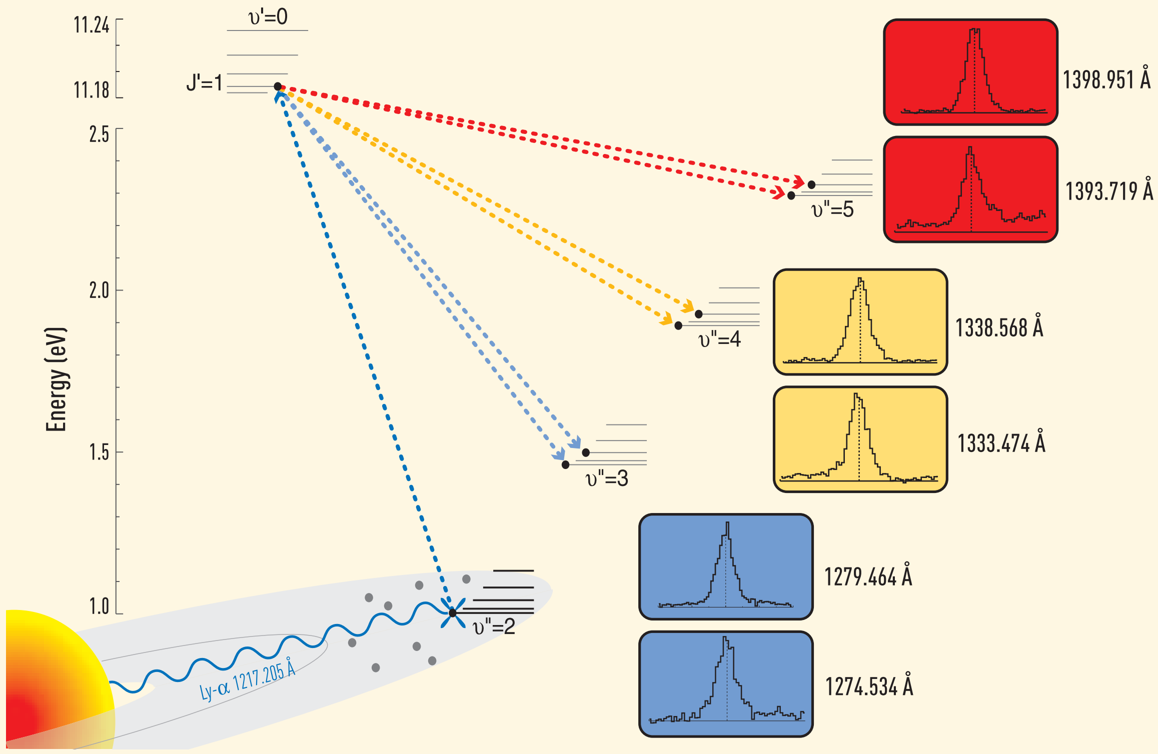


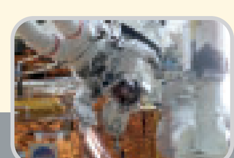
Figure 1: These segments of a STIS spectrum of TW Hya illustrate the process of molecular hydrogen fluorescence, which converts photons at a particular wavelength into a family of ultraviolet emission lines. In this case, Ly-α emission at 1217.2 Å excites molecular hydrogen from the ground electronic state (with vibrational quantum number υ"=2 and rotational quantum number J"=0) into an excited electronic state (with quantum numbers υ'=0 and J'=1). Six of the possible downward transitions are shown, each connecting the excited state with different ground electronic states. Insets show emission line profiles for each transition as observed by STIS.

Cosmic **Butterflies**

Margaret Meixner

The formation of a planetary nebula parallels the metamorphosis of a caterpillar into a butterfly. At the end of their lives, massive stars enshroud themselves in dusty, molecular cocoons and disappear from view at optical wavelengths. Later the cocoon opens, and the most beautiful of cosmic apparitions emerges—an envelope of ejecta illuminated by the hot central star. As with the caterpillar, the morphology of this envelope evolves from simple and round to complex and axisymmetric, like the wings of a butterfly. Indeed, almost all planetary nebulae exhibit axisymmetry, with subclasses of 'bipolar', 'elliptical', and 'point-symmetric'. How and why this morphological transformation occurs has been a big mystery for almost a century. Recently, space-based optical imaging, ground-based mid-infrared imaging, and ground-based millimeter interferometry have produced breakthroughs in our understanding of the butterfly mystery of planetary nebulae.

A Hubble imaging survey of protoplanetary nebulae by the author, Ueta, and Bobrowsky reveals the enveloping structures early on, just after the intensive mass loss associated with the asymptotic giant branch (AGB) stage of stellar evolution and before the radiation and stellar winds of the central star disrupt the envelope. Unlike planetary nebulae, which shine in emission lines of hot plasma, protoplanetary nebulae are reflection nebulae of tiny grains of dust



blown off by the star, which act as crude mirrors scattering starlight. The Hubble survey of 27 objects detected the reflection nebulosity of 21 protoplanetary nebulae, all of which showed an axisymmetry in the circumstellar environment. This work supports the idea that the appearance of axisymmetry in planetary nebulae precedes the protoplanetary nebula phase and most likely originates during the mass loss in the AGB stage.

The Hubble survey also discovered two new morphological types of protoplanetary nebulae: 'star-obvious low-level-elongated' (SOLE) nebulae and 'dust-prominent longitudinally extended' (DUPLEX), which are illustrated in Figure 1. The SOLE and DUPLEX protoplanetary nebulae are probably the precursors to the elliptical and bipolar planetary nebulae. Hubble's excellent point spread function was critical for revealing the detailed structure of these nebulae and, for the SOLE nebulae, for improving the contrast between the central star and the nebula.

Mid-infrared images of protoplanetary nebulae trace the thermal emission from the circumstellar dust shell. SOLE nebulae display optically-thin toroids perpendicular to the elongated reflection nebulae, while DUPLEX nebulae show optically-thick, compact cores and elongations aligned with the bipolar reflection nebulae. These morphological differences translate into spectral energy distribution differences: SOLE nebulae have two peaks, one in the optical due to the bright star and one in the infrared due to the thermal dust emission; DUPLEX nebulae have one dominating peak in the infrared from the dust shell and an optical excess due to the reflection nebula. Radiative transfer model calculations by the author, Ueta, and collaborators support the conclusion that SOLE nebulae are physically distinct from DUPLEX nebulae, with shells of lower optical depth that permit the starlight to leak out to all viewing angles. We believe that DUPLEX nebulae experienced higher mass-loss rates, with higher equator-to-pole mass-loss ratios, than SOLE nebulae. Interestingly, the DUPLEX nebulae have a larger range of dust grain sizes (0.001 to 200 microns), which suggests more dust processing. Independent studies suggest that the presence of long-lived disks can support grain growth in these sources.

Millimeter interferometry of protoplanetary nebulae by Fong, the author, and collaborators reveals differences in the kinematics of the molecular gas surrounding the central star. SOLE nebulae appear to have simple expanding envelopes, whereas DUPLEX nebulae have bipolar—or multiple—collimated outflows of molecular gas that collide with the slower moving, expanding wind. This difference in kinematics suggests completely different shaping mechanisms for the two types. AGB mass loss, which is probably driven by radiation pressure on dust grains, shapes both SOLE and DUPLEX nebulae. However, DUPLEX nebulae appear to have some additional physical mechanism that creates collimated mole- cular outflows that shape the nebulae. The DUPLEX nebulae appear to have disks, which suggests that the disk winds driving bipolar outflows in star formation regions may do the same in these objects.

Stars that develop planetary nebulae distribute most of the carbon in the universe—and in us. So, the next time you view a planetary nebula, be in awe of its butterfly-like beauty and be thankful for its enrichments of space and life. ¤

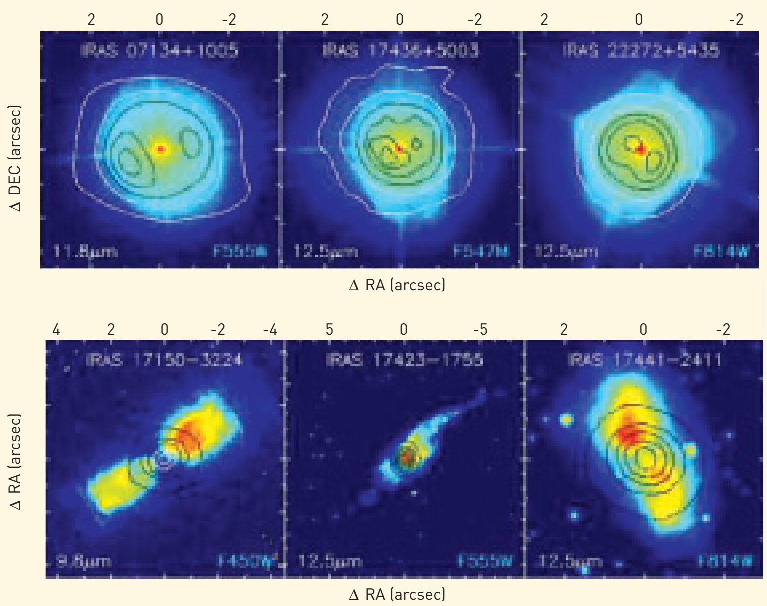
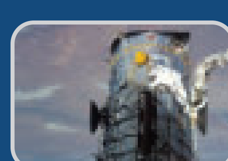


Figure 1: The morphological dichotomy of protoplanetary nebulae shown by Hubble images (color scale) and ground-based mid-infrared images (contours). On top, the SOLE nebulae, with prominent central stars surrounded by elliptical, low-level reflection nebulosity and by limb-brightened, mid-infrared emission from dust tori. On the bottom, the DUPLEX nebulae, with exquisite, bipolar, reflection nebulosity and centrally-peaked, mid-infrared emission images. In each image, the (Infrared Astronomical Satellite) IRAS names for these sources are on top and the filters are on the bottom (mid-infrared on left and Hubble on right).

STScI organization



DO

Director

Steven Beckwith

Deputy Director

Michael Hauser

Director's Office [DO]

The DO is responsible for the overall performance of the Institute. ¤ At the current time, the DO performs five tasks to guide the Institute's work to achieve the goals of the Strategic Plan: First, it promotes and protects Hubble's pace of scientific discovery and potential for the future. Second, it strives to maintain the scientific integrity of Hubble and the James Webb Space Telescope (JWST) under NASA's changing budget constraints. Third, the DO seeks to improve the culture and environment within the Institute at all levels. Fourth, it ensures that the Institute remains NASA's choice and the choice of the community to implement the science and operations of Hubble, JWST, and their successors. Fifth, the DO delegates authority, instills responsibility, and ensures accountability in the organization. ¤ The ***Director*** is the leader of the Institute and is responsible for its performance to the AURA President, the AURA Board, NASA, the community of scientific users, and the public. He is the selecting official for time on the Hubble Space Telescope and the associated grant funding to support scientific research with the data. He recommends to AURA the promotion of scientists to tenured appointments. He approves budget plans for the Institute as well as large capital expenditures and use of the discretionary funds. The Director represents the Institute to the AURA oversight committees—the Space Telescope Institute Council (STIC) and the Institute Visiting Committee (IVC)—the AURA Board, and the public at large. ¤ The ***Deputy Director (DD)*** serves as Acting Director in the Director's absence. The DD is responsible for oversight of the Divisions that directly support the missions: Instruments, Operations and Data Management, and Engineering and Software Services. The DD presides over regular reviews of the Divisions and their work plans, and is responsible for ensuring that the staff can meet the commitments of the Institute. ¤ The ***Director*** is the head of the ***Director's Office***, which includes the Deputy Director, the Associate Director for Science, the Chief Information Officer, the Head of Program Management, and the Head of Business Services. ¤ The DO is responsible for leading the Institute. By defining the organization, strategy, policies, plans, and management team, the DO guides the work of the staff and guarantees the Institute's commitments to NASA, the scientific community, and the public. The goal of the DO is to make it easy for everyone to contribute their best capabilities to the Institute's missions. The DO obtains the resources needed by the staff to do their work, and it allocates those resources to optimize the productivity of the Institute. The DO represents the Institute by conducting its external relations, reporting to AURA and its oversight committees, and receiving guidance from advisory groups.

ADS

Associate Director for Science

Bruce Margon

Associate Director for Science [ADS]

ADS is the Institute's senior officer for science staffing and science policy. He is responsible for oversight of the Science Division, Science Policies Division, and the Office of Public Outreach. The ADS coordinates scientific hiring, renewal, and promotion, and oversees policies applying to the science staff and their research activities. He acts as a scientific representative of the Institute in initiatives with other organizations.

PM

Program Management

Thomas Lutterbie

Program Management [PM]

The Head of PM is responsible for planning, allocating, and tracking the budgets of the major missions. The Heads of the Hubble Mission Office, JWST Mission Office, and Community Missions Office report to the Head of PM, who works with NASA to establish and maintain the contracts needed to carry out the Institute's work. He works with the Mission Heads to ensure that their goals for the missions are met as required by NASA. ¤ The Program Management function comprises groups responsible for financial and resource management and developing innovative programs throughout the Institute. ¤ The ***Resource Management Group*** leads financial and business planning activities Institute-wide. It prepares and helps negotiate and administer contract cost proposals, prepares and administers budgets and staffing plans, and generates government reports such as budget variance analyses. ¤ The ***Operations Management Group*** provides a managerial and programmatic integration between Divisions, Mission Offices, and the DO. It is a focal point for managing staffing and work plans as well as schedules and requirements. This group's program managers also participate in process improvement activities and lead special projects, where they promote effective integration, coordination, communication, and conflict resolution.

CIO
Chief Information Officer
Lisa Wolff

Chief Information Officer [CIO]

The CIO develops Institute plans and policies that address the information management and technology needs of science research, engineering, management, and business. She coordinates strategic software and technology improvement projects for the operational environments and Institute-wide business systems, and she is responsible for innovation studies, assessing both technology trends and emerging technology. The CIO ensures Institute compliance with information and network security regulations. She oversees the work of the Center for Process and Technology (CPT). She makes recommendations on mission-critical systems architectures and works with the Engineering and Software Services Division to coordinate approaches to software engineering. She represents the Institute to NASA regarding major information technology purchases, funding models, and security.

HBS
Head of Business Services
George Curran

Head of Business Services [HBS]

The Head of HBS manages the Business Resource Center and is responsible for planning, developing, and implementing policies that provide for comprehensive business management solutions. The HBS represents the Institute in major procurements and contract negotiations, including those with NASA and the Johns Hopkins University.

CPT
Center for Process & Technology
Doris McClure
Marty Durkin, Deputy
Glenn Miller, Deputy

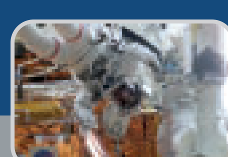
Center for Process and Technology [CPT]

CPT is responsible for the Institute's computing and communications infrastructure. It provides process engineering, develops technology-based solutions, and supports information systems for the Institute's missions, scientific research, and business functions. CPT also delivers additional technical services that complement the Help Desk and provide a bridge between the process engineering, development, integration, and production branches of CPT. ¤ The ***Information Technology Services Branch*** operates the Center's Help Desk and provides call management for supported platforms, applications, and the infrastructure. ¤ The ***Technology Infrastructure Management Branch*** manages the Institute's computing infrastructure. It provides system, network, security, database, and web administration to keep the overall computing environment operating reliably and efficiently. ¤ The ***Technical Services Branch*** applies technical solutions to address the varying requirements of Institute staff. It supports ongoing product development efforts, engineering and business information systems, information management, electronic conferencing, and training. ¤ The ***Technology Systems Development Branch*** develops technology-based solutions, integrates new or improved processes into the Institute's information systems processes, and develops architectural solutions for the Institute's computing and information infrastructure. ¤ The ***Strategic Initiatives and Process Engineering Branch*** evaluates and develops new methods, processes, and technologies to improve productivity and promote breakthroughs in science and engineering.

BRC
Business Resource Center
George Curran
Susan Boynton, Deputy

Business Resource Center [BRC]

BRC provides business and administrative services to the Institute in the areas of finance, human resources, accounting, contracts, grant administration, procurement, facilities management, property administration, administrative support, and staff support services. It partners with the Center for Process and Technology to improve information technology support for BRC internal operations and communications. It also provides expertise and support to the AURA corporate office and other AURA centers. BRC is organized into branches and groups according to its major functions and responsibilities. It has a customer-service orientation, as it is involved directly or indirectly in almost every endeavor at the Institute as well as in the careers of Institute staff and in providing funds to General Observers (GOs) and Archival Researchers (ARs). ¤ The ***Administrative Support Group*** comprises administrative staff members, who are deployed by matrix assignments to the operating divisions, where they provide comprehensive administrative support and coordinate between BRC, Institute management, and the divisions. ¤ The ***Finance Branch*** maintains all Institute financial records, prepares and monitors performance against indirect budgets, and produces management financial statements. It tracks property, provides travel support services for Institute staff and visitors, and ensures that procurements of products and services are competitive. ¤



The ***Grants Administration Branch*** provides funds to GOs and ARs to support their scientific research based on Hubble observations. It facilitates the financial review of submitted budgets and makes funding recommendations to the Director for final approval. ¤ The ***Contracts and Sponsored Programs Branch*** supports Institute staff members in preparing proposals and in administering awarded grants and contracts. ¤ The ***Human Resources Department*** provides personnel services to Institute staff and management, including recruitment and employment, relocation, salary administration, benefits administration, development of Equal Employment Opportunity/Affirmative Action plans, employee-management relations, and various forms of training. ¤ The ***Building Operations and Services Group*** manages the facilities infrastructure and provides a variety of staff support services, including security, housekeeping, parking administration, food services, document reproduction, and other logistical support. The physical plant comprises the 130,000 square foot Muller building and a 300-car parking facility. Logistical support services are also provided to off-site leased office space at the Rotunda and The Johns Hopkins University's Bloomberg Building.

SD
Science Division
Mario Livio
Antonella Nota, Deputy

Science Division [SD]

SD fosters the research environment of the Institute. It supervises the functional assignments of individual scientists. To encourage career growth, it promotes research opportunities, provides mentoring and advice on professional development, and conducts annual science evaluations. The SD conducts visitor programs to foster collaborations, to enrich journal clubs, and to support distinguished astronomers for extended visits. It manages the Director's Discretionary Research Fund, which supports staff research projects and investments in the Institute's research infrastructure. The SD conducts a spring symposium each year on a major area of astronomy as well as smaller scale workshops on specific scientific topics and issues. It organizes brainstorming sessions on scientific topics, supports science initiatives, and forms agenda groups to develop issues affecting the productivity of Institute scientists. ¤ The SD includes the ***Library***, which procures and provides access to a large collection of paper and electronic resources in support of astronomical and correlative research, and which conducts citation studies to help measure the productivity of scientific staff and the Hubble observatory. The SD produces the Annual Report and the Newsletter.

SPD
Science Policies Division
Duccio Macchetto

Science Policies Division [SPD]

SPD manages the allocation of Hubble observing time, conducts the process of selecting the science program, including General Observers and Archival Researchers, and establishes science metrics to evaluate success. It is the Institute point of contact with oversight committees. It also manages the Hubble Fellowship Program and the Institute Postdoctoral Fellowship Program.

Office of Public Outreach [OPO]

OPO
Office of Public Outreach
Ian Griffin
Peg Stanley, Deputy

OPO develops astronomy-related educational products and services and delivers them to classroom students, the public, the media, and the astronomical community. It supports individual scientists in developing educational contributions based on their research. ¤ The ***Formal Education Team*** develops educational materials that address national education standards and are relevant to K-12 curricula. It provides pre-service and in-service teacher training on the use of space science educational materials in the classroom. ¤ The ***Online Outreach and Public Information Team*** develops and hosts a variety of Internet sites that provide first-hand information about Hubble and its discoveries to the general public and the news media. ¤ The ***Informal Science Education Team*** brings the excitement of scientific discovery and technological accomplishment to a wide audience through science museums, planetariums, libraries, and the Internet. ¤ The ***News Team*** develops press releases, photo releases, and Space Science Updates to disseminate Hubble discoveries via print, electronic, and broadcast media. ¤ The ***Origins Education Team*** operates a forum to coordinate the education and public outreach efforts of all of the NASA missions within the Origins theme. ¤ The ***Education Grants Team*** empowers individual scientists to conduct their own education and public outreach programs. ¤ The ***JWST Community Outreach Team*** provides the astronomical community with information about James Web Space Telescope.

organization

ESS

Engineering & Software Services

Joe Pollizzi

Carl Johnson, Deputy

Engineering and Software Services Division [ESS]

ESS is responsible for systems engineering and software development support at the Institute. ESS is organized into three departments. ¤ The ***Science User Systems Department*** develops and maintains the software used by the astronomical community for proposal submission and processing, data analysis, calibration, and archival research, and by the pipeline and archive infrastructure. ¤ This department is made up of the ***Science Software Branch***, which is responsible for the calibration and data analysis software, the ***Astronomer's Proposal Software Branch***, which is responsible for the extensive user interfaces used to prepare proposals and to structure observations, and the ***Data Systems Branch***, which provides the pipeline and archive infrastructure software and the external archive interface software. ¤ The ***Planning and Scheduling Systems Department*** is responsible for planning and scheduling software products used for Hubble, the Far Ultraviolet Spectroscopic Explorer, Chandra, and James Webb Space Telescope and for several large ground-based optical observatories. This department is made up of the ***Planning Systems Development Branch***, which is responsible for the front-end planning and scheduling software, the ***Scheduling Systems Development Branch***, which provides the short-term scheduling software, including the Guide Star Selection System, Moving Object Support System, and Science Commanding System, and the ***Spacecraft Scheduling and Commanding Branch***, which develops and maintains the system that prepares command loads for uplink to the Hubble spacecraft. ¤ The ***Engineering, Test, and System Services Department*** is responsible for the stored commanding, health, and safety of the Hubble science instruments and provides general systems engineering and systems infrastructure support as well as all testing support for the Division. ¤ This department is made up of the ***Test Engineering at Space Telescope Branch***, which provides software testing and is responsible for the quality and productivity of testing as a fundamental process at the Institute, the ***Mission Ground Systems Engineering Branch***, which ensures that Institute software projects conform to requirements and employ robust methodology for development and testing, the ***Flight Systems Engineering Branch***, which supports the development and maintenance of mission flight software and stored commanding, and the ***Database Engineering and Systems Infrastructure Branch***, which develops and maintains databases throughout the Institute, various infrastructure and tools used by the Division, and the Space Telescope Grants Management System, which is used by astronomers to submit Hubble budgets—and by institutions to administer them. ¤ In the ***ESS Division Office***, the ***Systems Integration Management Branch*** provides technical project management support to cross-divisional initiatives, such as the integrated schedule for ground systems development for new Hubble instruments.

ODM

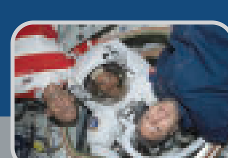
Operations & Data Management

Jim Etchison

Peg Stanley, Deputy

Operations and Data Management Division [ODM]

ODM processes and schedules the selected Hubble observing programs and provides around-the-clock monitoring of the spacecraft. It processes Hubble data in the pipeline, distributes data products to the community, and operates the Multimission Archive at Space Telescope (MAST). It maintains and upgrades the Guide Star Catalog and Digitized Sky Survey. It is responsible for the project management of the NSF-funded Information Technology Research program, "Building the Framework of the National Virtual Observatory," and for coordinating the Institute's technical, scientific, and outreach contributions to this initiative. ¤ The ***Observation Planning Branch (OPB)*** works with Hubble users to ensure the optimal translation of their scientific requirements into the technical instructions necessary to operate the observatory. ¤ The ***Science and Mission Scheduling Branch***, with the support of OPB, prepares the master, multi-year science-observing plan, which reconciles Hubble science program requirements and operational constraints at a high level. It then fits candidate observations into optimal weekly observing schedules with instrument calibration and engineering activities, and creates the detailed command loads that are executed by the telescope. ¤ The ***Flight Operations Branch*** is responsible for spacecraft and instrument housekeeping, monitoring and maintenance, and the health and safety of the Hubble mission. ¤ The ***Observation Processing and User Support Branch (OPUS)*** is responsible for pipeline processing of all Hubble data. It also provides offset-slew and real-time target acquisition support for Hubble observers. ¤ The ***Archive Branch*** operates the Institute's archive systems, provides data delivery services and technical support to users, ensures the scientific integrity of the data, and enhances the scientific utility of the archive. ¤ The ***Catalogs and Surveys Branch*** produces all-sky digital images and deep object catalogs to support observatory operations worldwide and to provide a research resource to the community.



INS
Instruments
Chris Blades
Bill Sparks, Deputy

Instruments Division [INS]

INS is home for the scientific and engineering staff that work directly on Hubble Space Telescope, James Webb Space Telescope (JWST), and future missions. It supervises functional assignments of individual scientists to each of the three Mission Offices and is responsible for career growth and professional development of its staff, for all personnel decisions, and for establishing and developing expertise in its technical domain. INS supports Hubble observers to use the science instruments with maximum effectiveness, providing scientific and technical advice in developing observing programs and interpreting data. It calibrates and characterizes the science instruments. It facilitates the use of new science instruments by participating in their development, by capturing and transferring information about instrument operation and calibration to the Institute, and by coordinating the commissioning of all the instruments following a servicing mission. ¤ The ***ACS Branch*** is responsible for utilization of the Advanced Camera for Surveys. ¤ The ***NICMOS Branch*** is responsible for utilization of the Near Infrared Camera and Multi-Object Spectrometer. ¤ The ***Telescopes Branch*** maintains the Hubble focal plane model, monitors telescope focus, and supports use of the Fine Guidance Sensors (FGSs) as astrometry science instruments. It also characterizes the anticipated imaging performance of JWST and its scientific capabilities. A small engineering team maintains engineering knowledge of the Hubble instruments and spacecraft, monitors health and performance of the instruments, and tracks the status of their limited-life items. ¤ The ***Spectrographs Branch*** is responsible for use of Space Telescope Imaging Spectrograph (STIS) and for supporting archival analysis of data from the retired spectrographs. ¤ The ***WFPC2 Branch*** is responsible for use of the Wide Field Planetary Camera 2 (WFPC2). ¤ The ***WFC3 Branch*** is responsible for the Wide Field Camera 3. ¤ The ***COS Branch*** is responsible for the Cosmic Origins Spectrograph. ¤ The ***JWST Instruments Branch*** participates in the development of instruments for JWST. ¤ The ***Data Analysts Branch*** supports the technical work of the Hubble and JWST Missions as well as the scientific research of Institute staff.

HST
HST Mission Office
Rodger Doxsey
Helmut Jenkner, Deputy

Hubble Space Telescope Mission Office [HST]

HST is responsible for maximizing the science return from the mission by managing the Institute activities specific to the conduct of the Hubble Space Telescope program. It develops the overall Institute plans for Hubble science operations and system enhancements, working with the team leads in the operating divisions and centers. The Hubble Mission Office is responsible for establishing performance and development requirements, monitoring performance and schedules, and prioritizing the expenditure of resources. It works with the divisions, centers, and Program Management to develop and monitor yearly and long-term budgets. It is also responsible for establishing effective scientific, technical, and operational interfaces with the Hubble Project at Goddard Space Flight Center and associated contractors.

WMO
JWST Mission Office
Peter Stockman
David Hunter, Deputy

James Webb Space Telescope Mission Office [WMO]

WMO collaborates with NASA to develop the scientific, technical, and operational vision for the James Webb Space Telescope (JWST). It manages the development of the JWST Science and Operations Center. It works with the community to ensure the best JWST observatory possible within the cost constraints of this challenging program. It works with the Institute divisions to ensure proper support to NASA, the science instrument teams, and other JWST partners, including the prime contractor, Northrop Grumman Space Technologies.

CMO
Community Missions Office
Melissa McGrath
Carol Christian, Deputy

Community Missions Office [CMO]

CMO manages the Institute's involvement in missions and projects other than Hubble and JWST. CMO facilitates new initiatives and coordinates their review by the New Initiatives Panel and the New Starts Group. For missions arising in the community, CMO promotes new applications for Institute products and services customized to meet specific mission needs. CMO strives to maximize the scientific usefulness of Institute involvements by engaging scientific staff members directly in the support of community missions.

A Team of **Teams**

Institute staff and outside stakeholders join in various groups, councils, and committees to maintain the vitality of the Institute and to promote the science from our missions. The following 'teams' complement the divisions on our organizational chart and illustrate other ways that individuals come together to benefit science and improve the Institute.

Teams Inside

The **DIRECTOR'S LEADERSHIP FORUM** involves staff in Institute planning, aids the Director on policy issues affecting the work of the Institute, puts the Director in touch with staff who are not members of the Management Council, and addresses grass-roots issues for consideration by the Management Council and Director.

The **INFORMATION TECHNOLOGY COUNCIL**, composed of experienced members of the technical staff, provides advice on technology directions and readiness, conducts technical reviews, and promotes the professional development of the technical staff.

The six science **AGENDA GROUPS**, each consisting of scientific staff on a shared career path and at the same stage, develop issues of professional concern to their group, which they raise to the Science Division Office for resolution.

The **NEW INITIATIVES PANEL**, with representatives from each division and led by the Community Missions Office, supports new-business proposals by coordinating and evaluating division input, facilitating work plans, recommending bid and proposal funding, and shepherding proposals through the New Starts Group and AURA approval processes.

The **SHARK CAGE TEAMS** conduct focused studies to discover new, technology-based approaches to improve Institute services to the community.

The **COMPUTER PLANNING COMMITTEE** develops the annual Computer Augmentation Plan, which is a three-year forecast of computer hardware and software purchases for all operational and functional computer systems as well as the Institute's general computing infrastructure.

The **SCIENCE RECRUITMENT COMMITTEE** conducts the recruitment process for AURA scientists, including advertising, screening applications, formulating a short list, arranging interviews, and producing a ranked list of candidates for the Senior Scientific Staff, which makes its recommendations on hiring to the Director.

The **SCIENCE PERSONNEL COMMITTEE** conducts the promotion and tenure processes for AURA scientists, including documenting each case, reviewing the candidate's scientific and functional performance, and presenting a decision package with a recommended action to the Senior Scientific Staff, which makes its recommendation on promotion to the Associate Director for Science or on tenure to the Director.

The **SENIOR SCIENTIFIC STAFF** advises the Director on the hiring, promotion, and tenure of AURA scientific staff and on issues regarding the scientific health and future of the Institute.

The **TELESCOPE TIME REVIEW BOARD** evaluates Hubble's readiness for science observations following a servicing mission, and it reviews exception requests from General Observers—to repeat observations, to make major program changes, or to resolve data duplication issues—and makes recommendations to the Head of the Science Policies Division.

The **HOUSING COMMITTEE**, consisting of division representatives and supported by the Building Operations and Services Manager, advises the Head of Business Services, who assigns office space based on policies and procedures approved by the Management Council.

The **SAFETY COMMITTEE**, consisting of division representatives, brings forward safety concerns, discusses issues of compliance with regulations and standards, and advises the Building Operations and Services Manager, who is responsible for the Institute's safety program.

The **NEW STARTS GROUP**, which consists of the members of the Director's Office, a senior contracts manager, and a senior technical manager, approves requests for bid and proposal funding, approves proposals for new business opportunities, and advocates proposal approval by AURA when necessary.

Teams Outside

The **TREASURY PROGRAM ADVISORY COMMITTEE** advises the Director on the Hubble Treasury Program by identifying scientific opportunities that merit large investments of Hubble time and fostering multidisciplinary, multiobservatory collaborations.

The **OPO EXTERNAL ADVISORY COMMITTEE** drawn from OPO's diverse user community of astronomers, educators, journalists, and planetarium and science center directors—provides feedback on OPO products and services and counsels OPO management on ways to advance its mission, goals, and objectives.

The **SPACE TELESCOPE INSTITUTE COUNCIL**, our primary management oversight committee, is selected by the AURA Member Representatives and reports to the AURA Board of Directors.

The **SPACE TELESCOPE ADVISORY COUNCIL** is available to the Director for advice on any subject related to the Hubble science program.

The **INSTITUTE VISITING COMMITTEE** evaluates the management productivity, working environment of the Institute, and the morale of the Institute staff and reports to NASA through AURA.

The **SPACE TELESCOPE USERS COMMITTEE** reviews the scientific utility of Hubble Space Telescope and the quality of the Institute's services and makes recommendations to both the Director and the NASA Project Scientist.

The **TELESCOPE ALLOCATION COMMITTEE** evaluates proposals for observing time and proposals for archival research that request funding and makes recommendations to the Director, including the allocation of Hubble orbits to selected observing programs.

The **MAST USERS GROUP** provides advice to increase the scientific utility and productivity of the Multimission Archive at Space Telescope and recommends priorities for new services, data sets, and interarchive collaborations.

The **WFC3 SCIENCE OVERSIGHT COMMITTEE** provides scientific oversight and direction on choices, like filter selection, and trades during the development and testing of the Wide Field Camera 3.

The **JWST SCIENCE WORKING GROUP**, consisting of the first users of the James Webb Space Telescope and including Institute staff members, advises NASA on the scientific priorities for the mission.

Teams Inside/Outside

The **FINANCIAL REVIEW COMMITTEE** reviews all budgets submitted by General Observers and Archival Researchers and recommends appropriate funding to the Director.

The **SERVICING MISSION OBSERVATORY VERIFICATION WORKING GROUP**—consisting of Institute scientists and engineers, NASA engineers, and instrument developers—defines, designs, and executes in-orbit verification activities to commission the Hubble observatory after servicing missions.

The **COS OPERATIONS WORKING GROUP**, including engineers and scientists from the Cosmic Origins Spectrograph team, Ball Aerospace, NASA, and the Institute, sets the requirements for the flight and ground software needed to operate the instrument.

The **COS CALIBRATION WORKING GROUP**, including engineers and scientists from the Cosmic Origins Spectrograph (COS) and Far Ultraviolet Spectroscopic Explorer teams, Ball Aerospace, NASA, and the Institute, discusses COS calibration issues, sets calibration pipeline requirements, and advises on implementation aspects, such as keywords, data formats, reference files, and reuse and sharing of algorithms and code from previous applications.

The **WFC3 OPERATIONS WORKING GROUP**, including engineers and scientists from Ball Aerospace, NASA, and the Institute, sets the requirements for the flight and ground software needed to operate the Wide Field Camera 3 instrument.

The **WFC3 INSTRUMENT CALIBRATION TEAM**, with scientific leadership from the Institute and including engineers and scientists from NASA, Ball Aerospace, and the Institute, is developing the plans and procedures for the ground testing and pre-launch scientific calibration of Wide Field Camera 3.

The **ACS PHOTOMETRIC CALIBRATION WORKING GROUP**, including members of the Advanced Camera for Surveys Instrument Definition Team and representatives from other instrument groups, studies issues that affect the photometric performance and overall calibration of the ACS.

improvements

Constant improvement is deeply imbedded in the Institute culture. The discipline of continuous process improvement, sometimes referred to as CPI, took root in the 1980s as we prepared to operate Hubble. Its flagship success was PRESTO (Project to Re-engineer Space Telescope Observing), which greatly streamlined the scheduling of Hubble observing programs. Since that time, managers throughout the Institute have focused energy on process improvement as a means to enhance the quality of products and services as well as a way to reduce operational costs. These efforts strengthen the Institute's ability to meet customer needs, whether the customer is outside the Institute—the astronomical community, NASA, or AURA—or within our organization. We are always trying to improve our processes, products, services, and ultimately our value in the pursuit of breakthrough science.

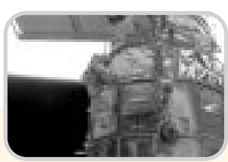
2002 Process Improvement **Initiatives**

New Proposal Preparation Tools

The Institute has streamlined the processing of Phase I proposals and made it easier for astronomers to prepare optimized Phase II proposals. Beginning with Cycle 12, the Astronomers Proposal Tool (APT) replaces the former LaTeX template and the Remote Proposal System 2. APT constrains the choice of parameters to valid values and those values are parsed more readily, saving time for both users and the Institute. In Phase II, astronomers can use APT's interactive, graphical tools to pack exposures into orbits and explore the effects of constraints on scheduling their observations. The APT project engaged users at all stages of the engineering process and provided prototypes for evaluation and refinement. As a result, APT delivers useful functionality in a form effective for the user community.

Shortening the Proposal Process

Working with the Space Telescope Users Committee, the Science Policy Division developed the case for shortening the interval of time between submitting Hubble observing proposals and executing the observations. The benefits include the possibility of using new results from the current cycle to inform proposals for the next, better accommodation of changing instrument performance, and quicker pace of discovery. The Operations and Data Management Division reviewed every aspect of the timeline and improved procedures wherever possible, ultimately reducing the lag between a cycle's proposal deadline and the start of observations by as much as four months. The Institute passed on this gain to the astronomical community by postponing the submission deadline for Cycle 12 proposals to late January 2003. Meanwhile, the time allowed for successful proposers to provide Phase II information will not change, and the Cycle 12 observations will commence in July 2003, the same month as in the previous cycle.



Better Management of Anomaly Reporting

Anomalies sometimes affect the quality of science data from Hubble. When this occurs, the responsible Institute staff members and astronomers using the data must be informed. In the past, anomaly reporting involved unrelated tools, manual effort, and various locations for storing information, which, for example, made data collection for trending evaluations difficult to accomplish. **An Institute initiative called PROMPT— PRoblem Observation Management ProjecT—has improved anomaly reporting by automating processes to ensure completeness and consistency and consolidating information in one database.** PROMPT has three components: AlertObs collects anomoly information through a graphical user interface, places it in a database, and distributes an alert message to Institute staff; AlertPI generates the Observation Exception Report, which is sent to the proposal contact and placed in a database; and AlertAQ processes new or updated AlertObs anomaly entries and documents them in the archive catalogue.

PHASTGMS Improves Hubble Proposing

The Institute organized the PHASTGMS (PHASe I to Grants Management System) project to resolve problems encountered in Cycle 10 when the Phase I proposals were processed. Four groups joined in this effort— the Science Policies Division, the Grants Administration Branch, the Engineering and Software Services Division, and the Program Coordinators. The PHASTGMS project established new procedures for proposal processing, set requirements for tools to maintain the Principal Investigator and Co-Investigator addresses, created an interface control document to rationalize transitions between systems and responsible groups, and supported the use of the Astronomers Proposal Tool (APT) for Phase I submission, which was in place for Cycle 12. The PHASTGMS improvements will ensure rapid and efficient processing of proposals as well as the creation of an accurate database for proposal management and tracking.

Improvements in the Hubble Program Selection Process

The Institute began the Hubble Treasury Program, which the HST Second Decade committee recommended, to increase the number of large programs and to pursue strategic science objectives, such as synergism with other missions and acquiring important data sets that otherwise would not be available for many years after the end of the Hubble mission. The Director appointed the Hubble Treasury Program Advisory Committee to provide advice on ways and means, strategic directions, and opportunities to promote community participation in the Hubble Treasury Program. After considering the various ways to facilitate large collaborations, we conducted a well-attended Hubble Treasury workshop in fall 2002, in which numerous possible Treasury projects were enunciated. We then formed interest groups, which began the work of formulating proposals for large observing programs based on these ideas. We plan to repeat this activity every year in connection with the summer meeting of the American Astronomical Society. Data sets from Hubble Treasury programs are non-proprietary and immediately available to the community. After processing, observing teams will provide 'science-ready' data sets to the archive plus ancillary data products, such as catalogues. Because supporting observations at other wavelengths add value to these programs, we will continue to work with other important national facilities—such as Chandra, SIRTF, NOAO, and Gemini—to coordinate observing projects on multiple telescopes.

Institute Reorganization

The Institute undertook a comprehensive review of its organizational structure to meet the challenges of developing and operating multiple missions. As a result, **we have completed our reorganization into a classic matrix arrangement.** This clarifies the roles of mission and division management, eliminates conflicts between managing people and managing work, promotes better communications, enables flexible work opportunities, and allows long-term planning of the expertise needed to support our missions and other projects.

Improved Community Mission Support

The Institute created the Community Missions Office (CMO) to foster support for missions other than Hubble and James Webb Space Telescope, both within and outside the Institute. Whereas previously the management of our support work for other missions was scattered throughout the Institute, it is now under a single umbrella, giving it a higher level of visibility and attention. CMO also serves as a focal point for staff efforts to pursue new initiatives, which were previously coordinated only in an informal manner. CMO finds and distributes information about opportunities to which the Institute might propose participation. It provides information to the community about the many unique products and services developed at the Institute over the years in support of Hubble.

Streamlined Time Reporting

The Business Resource Center (BRC) led an effort to reduce the burdens of staff members reporting their time and of collecting this information from the timecards. The solution was Electronic Timecards (ET), which bring time reporting to the computer desktop via the Internet, allowing staff members to record their work hours more easily, and at any time or location. ET allows employees and their managers to sign and approve timecards online as well as review historical timecards for charge detail. We also achieved significant savings in the biweekly processing of timecards, which had been plagued by data input mistakes and misinterpretations. Now, ET uploads data directly into the accounting system and receives back automatic updates to stay current with respect to charge numbers, staff turnover, and staff/manager reporting relationships.

Centralized Mass Storage

Building on an Engineering and Software Services (ESS) study of database storage requirements, **the Center for Process and Technology (CPT) led an investigation of centralized mass storage technology to meet Institute needs.** Several areas of computing at the Institute demand massive storage capacity—multiple teabytes—including the Hubble data pipeline, the archive, and the environment for software development and testing. This storage must be available across operating system platforms, perform at high speed, and cost little to maintain. The study team recommended a SAN (Storage Area Network) technology solution. The SAN chosen provides connectivity for different operating systems through high-speed, fiber-optic connections, eliminating the inefficiency and reliability issues associated with cross-mounting disks between operating systems. CPT, ESS, and Operations and Data Management jointly deployed a SAN in the data pipeline and archive area for development and testing. We plan deployment in operations in spring 2003. This deployment will retire 170 disk drives attached to 14 servers spread across 3 different operating systems.

WWW and Information Technology

Hubble science instrument groups produce thousands of pages of technical documentation for use by observers. **Managing this information and delivering it to users in the most useful form is a challenge, which we have met by adopting a new technical strategy coordinated by the Center for Process and Technology (CPT)**. Under the new scheme, we create a single master copy of the information from which we can produce a variety of formats for the user. For example, in the case of the Space Telescope Imaging Spectrograph (STIS), the STIS group edits the master copy of the STIS instrument handbook to reflect the state of that instrument for the upcoming proposing cycle. Subsequently, the CPT converts the handbook to a single Portable Document Format (PDF) file for distribution over the Internet. Also, CPT translates each section of the STIS handbook to HyperText Markup Language (HTML), which, in turn, the STIS group integrates into the STIS instrument website for easy browsing. For Cycle 12, we created JavaHelp versions of the STIS instrument characteristics for bundling with the Astronomers Proposal Tool. Thus, by working from a master copy of documents and following a standard procedure, the Institute now delivers consistent instrument documentation in a variety of formats to support Hubble observers.

Delivering Good News

To better serve the needs of the news media and the public, OPO has entirely retooled its current news media website. **We developed the NewsCenter** after extensive discussions with members of the community it serves—science journalists, reporters, documentary producers, and others who need quick and easy access to all our news material. In addition to vastly improving access to Hubble press releases, the NewsCenter incorporates a full glossary, conversion tables, and media contacts. A key part of the NewsCenter is the Press Release e-Servicing System (PReSS), which converted the existing press release archive from a collection of non-uniform paper products and web pages to a standardized, database driven system. Now for the first time, every press release ever issued by OPO is available online. PReSS serves web pages dynamically and supports full keyword searches. Also, it saves staff time in posting Hubble news items. We will conduct a survey of media users after 3 to 6 months of regular use to identify and prioritize future enhancements to the NewsCenter.

In 1994, following the first servicing mission and the restoration of Hubble's capabilities, the management of the Institute paused to reflect on its opportunities and formulated a strategic plan to navigate the years ahead.

We reaffirmed our first commitment, to serve the astronomical community with a Hubble program as scientifically productive and technically powerful as possible. We planned to expand our efforts in education and public outreach. We looked forward to other missions, particularly to a role in defining the successor observatory to Hubble.

Measuring our achievements against our first strategic plan—indeed, by almost any measure—the Institute had become fully successful as the 1990s drew to a close. Perceiving new circumstances and enjoying the approval of our stakeholders for our contributions to the Hubble program in the 1990s, we began developing a new strategic plan at the turn of the millennium. Distributed in 2001, this new plan takes into account our strengths, opportunities, and philosophy of partnership with the community. It portrays an appropriate leadership role for the Institute, in which we adopt some unique tasks while enabling the community to do others. It is a plan to help ensure both the future of space astronomy and the vitality of the Institute.

vision

The 2001 strategic plan proclaims the Institute's vision: We bring the **cosmos to Earth.**

We bring the cosmos to the desktops of astronomers across the country and around the world. In doing so, we empower the astronomy community to make scientific discoveries. In striving to excel, we seek to improve the utility and productivity of our observatories and to promote new missions with the greatest potential for unlocking the secrets of the universe. Through the achievements of astronomers using our observatories, we bring the cosmos to the public, through the media, over the Internet, in museums and planetariums, and in homes and classrooms. We share the excitement of astronomical discovery with our ultimate sponsors, the supporting citizens who prize exploration and benefit from it. We have pursued this vision for Hubble, and we will do the same for the James Webb Space Telescope, JWST. We will promote this vision when new missions and new tools and resources for research are discussed and planned. To implement our vision successfully, we must have a first-rank astronomy research staff, which itself is engaged in forefront research. We must have an excellent technical staff to develop and maintain innovative systems to implement the missions. We must have an outstanding outreach staff to engage the public in forefront intellectual questions of our time. We must have proficient business, computer, and information services staffs to support the Institute and the community.

goals

Goal 1. Hubble is our first telescope. In 1990, it launched a new era of astronomical research from space with unprecedented capability, data quality, and data volume. *We will optimize the science program of Hubble's second ten years and continue to serve the community in its best scientific use of the facility.*

Goal 2. JWST will be our second major telescope. Starting in this decade, it will explore the universe at infrared wavelengths. *We will help develop—then operate—the best JWST possible, with full inheritance of Hubble lessons-learned and full engagement of the community in its development.*

Goal 3. Our archive has become a first-rank research facility in its own right, providing unique research and outreach opportunities. *We will continue to run a world-class data archive, adding new data sets, providing new research tools, and collaborating with other data centers to provide an international astronomy data system.*

Goal 4. Our education and public outreach programs have engaged the public and made Hubble a household word. *We will improve these programs, extend them to JWST, and make them available to the rest of astronomy, ensuring maximum benefit from the research enterprise to the public.*

Goal 5. Our new technologies to improve Hubble operations have been applied beyond astronomy; we expect this trend to continue, increasing the benefit to society as a whole. *We will continue to facilitate the transfer of our technical innovations to other fields of research and to the private sector.*

Goal 6. Our approaches and solutions to technical, operational, and procedural challenges have changed the way astronomy is done and have been adopted by observatories worldwide. *We will continue to attract the best technical staff to advance and apply the state of the art for astronomy.*

Goal 7. Our excellent astronomy and support staff has made us a first-rank research institute. *We will continue to attract excellent scientists and provide them with an academic environment that nourishes excellence in research.*

Goal 8. We recognize the importance of supporting and advancing all of our missions and programs—Hubble, JWST, the archive, our outreach programs—to enable our vision. *We will continue to work with the community to investigate and advocate new missions that will enable further scientific advances.*

Goal 1. **Optimize** the science program of the Hubble Space Telescope

We will optimize the science program of Hubble's second ten years and continue to serve the community in its best scientific use of the facility.

One of the primary responsibilities of the Institute is to optimize the science program of the Hubble Space Telescope. This responsibility is carried out by all involved in the Hubble program—scientists, engineers, and technical staff in organizations across the Institute. There are several major areas where the Institute adds value to the Hubble science program, and these naturally are the focus of our improvement activities. These areas include stimulating the best possible science program from the astronomy community via the proposal selection process, squeezing the highest possible observing efficiency from the telescope, providing timely and accurate calibration of the Hubble data, stimulating the use of the Hubble data archive for additional scientific results, and providing tools to support the astronomy community's use of the telescope and the archive.

After the successful completion of servicing mission SM3b, with the installation of the Advanced Camera for Surveys (ACS) and the reactivation of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), Hubble offers the astronomy community greater capability in sensitivity and spatial and wavelength coverage than ever before.

In 2002, the first major challenge for our staff was bringing the observatory back on line quickly after SM3b and commissioning the ACS and NICMOS for scientific observations. After this, our next challenge was to put the observatory to work carrying out the Cycle 11 science program, including the Hubble Treasury programs, which were a major innovation in this cycle. Also during the year, we made major changes to the processes and procedures for Cycle 12, shortening the time from Phase I proposal submission to the start of observations by nearly half.

FIG 1: Refereed Papers Based on Hubble Data

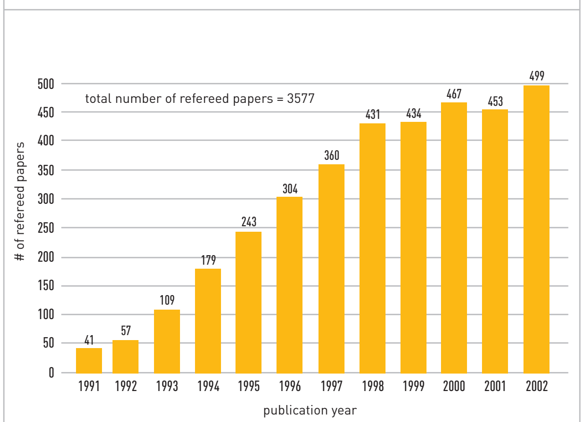
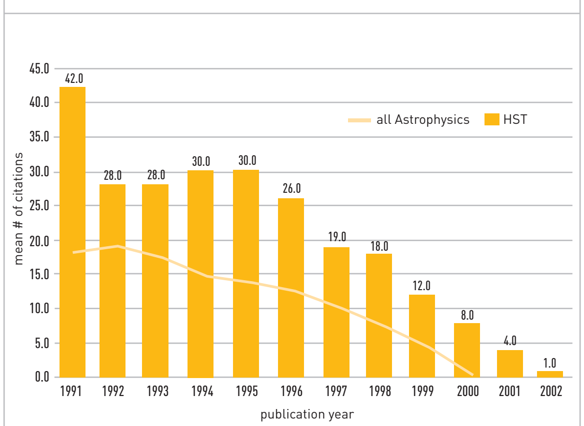


FIG 2: Citations of Refereed Hubble Papers



Stimulate the best Hubble science program

To assess the impact of Hubble observations on astrophysical research, we have developed and begun to track standard, objective measures of productivity and impact. Among these measures are the annual number of published papers based on Hubble data (see Figure 1) and the mean annual number of citations based on Hubble data [see Figure 2]. Following a strong and regular increase of publications during the first eight years of Hubble, the number of papers keeps increasing, although at a slower pace, during the last four years, and reached a value of 499 for the year 2002.

The current total is over 3570 refereed papers. During the last four years, the number of refereed papers based on Hubble data constitutes about 5% of all refereed papers published in astrophysics, as represented by these journals.

Figure 2 shows the histogram by year of the mean number of citations of refereed papers based on Hubble data. For comparison, the curve shows the mean number of citations for all refereed astrophysics papers. This shows the impact of Hubble science clearly: the average paper based on Hubble data received twice the citations of the average astronomy paper.

FIG 3: Refereed Hubble Papers Without Citations

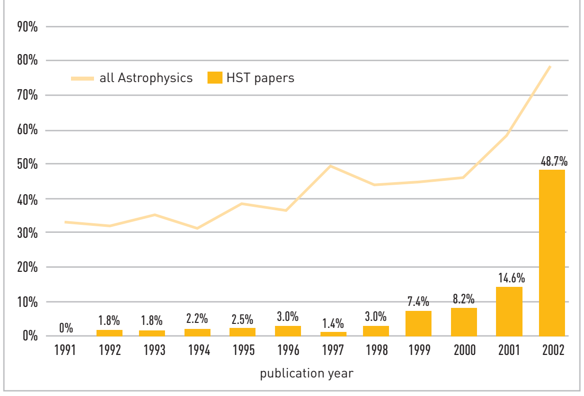


FIG 4: Citations Per Refereed Paper

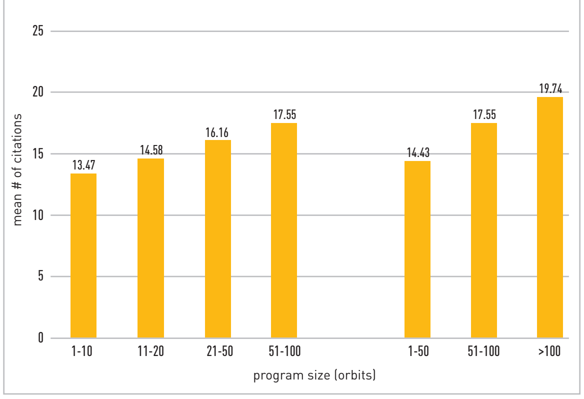


Figure 3 displays the histogram by year of the number of refereed papers based on Hubble data that have not been cited. Understandably, there is a time delay between the publication of a scientific paper and the first paper citing it. After allowing a few years time, only about 2% of the Hubble based papers have no citations, whereas about one third of all refereed papers in astrophysics are never cited.

This high level of productivity and impact reflects, in part, the care with which we select the science program.

This year saw continued evolution in the process for selecting the Hubble science program. We made a major improvement with Cycle 12, reducing the time between submitting proposals and starting observations in an observing cycle. In prior cycles, the Phase I deadline occurred in mid-September, with observations starting the following July. For Cycle 12, we moved the Phase I deadline to the end of January 2003, with observations still starting in July. As a consequence the Telescope Allocation Committee did not convene in 2002 but will meet in March 2003 for Cycle 12. Shortening the time between proposal deadline and cycle start will ensure that recent findings have greater influence on new Hubble observations, quickening the pace of scientific advance.

We began the Hubble Treasury Program in the Cycle 11 proposal solicitation. The HST Second Decade committee recommended this Program based on the observation that many of the highest impact results came from the largest programs. Recently compiled metrics (see Figure 4) support the conclusion that papers from larger programs have higher impact: large programs produce about 30% more citations than small programs.

Treasury programs are large programs to create major data sets with long-term significance and relevance to multiple scientific problems. The Treasury data sets are non-proprietary and immediately available to the community. In addition, we expect the observing teams to provide processed (science ready) data sets, catalogues, and other data products to the archive for the community's use. Accepted Cycle 11 Treasury programs are now being carried out.

For Cycle 12, we have taken several steps to further strengthen the Treasury Program. The Director established a Treasury Program Advisory Committee to provide continued advice on matters related to the selection and conduct of the Hubble Treasury Program.

In November, the Institute organized a three-day workshop to foster high-quality Treasury proposals. The workshop examined scientific areas requiring large investments of Hubble time and aired science objectives, targets, and observing strategies, and brought potential collaborators together. More than 70 scientists attended the workshop, which by all indications was successful in promoting community ideas and collaborations. In the future, we will hold Treasury Workshops in conjunction with the summer meeting of the American Astronomical Society.

In Cycle 11, we created a new class of Archival Research (AR) proposals, called 'Legacy', to take advantage of the growing size of the Hubble data archive and develop the potential of large, homogenous data sets. Selected Legacy programs analyze specific data sets in a uniform manner, to deliver data products like catalogs, software tools, and web interfaces to the archive for the community to use.

In Cycle 11 we also created the Hubble Theory Program, funded as part of the Hubble AR Program, to improve the interpretation and understanding of Hubble data. The Astronomy and Astrophysics Survey Committee of the National Research Council recommended funding such targeted theoretical research in conjunction with major observing facilities. Selected Cycle 11 programs in both these categories are being carried out.

Optimize Hubble science operations

A Hubble servicing mission always adds complexity and challenges for operating the observatory, and SM3b, carried out in March of 2002, was no exception. The Institute did much preparatory work. We took steps to accommodate the large increase in data volume we anticipated when ACS and NICMOS became active. We defined the operations to commission the new hardware and re-commission the old. We developed contingency plans for difficulties that might arise during the mission. This advanced planning paid off, and we quickly returned Hubble to science observations after SM3b.

Institute staff members began supporting SM3b directly in the week prior to the shuttle launch, while observations were still underway. Because of the potential for launch delays, we generated an observing schedule that kept Hubble working whether or not the launch was on time. We achieved this by scheduling Hubble to slew briefly, once a day, to the shuttle rendezvous attitude. If the shuttle launched, we would stop observations at that point. If not, we would let Hubble slew to the next science target and resume observations. (High winds at the launch pad did delay the launch one day.)

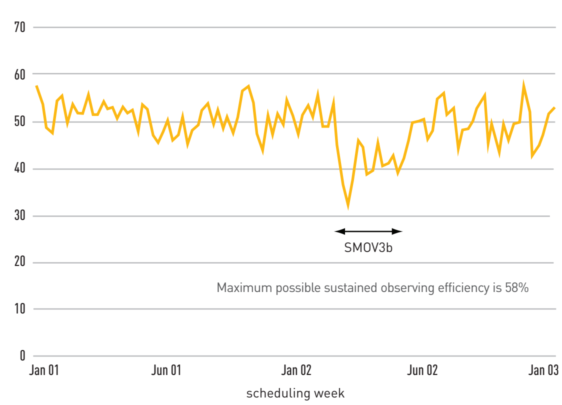
During the servicing mission, we monitored the instruments, analyzed ACS data to check performance, and verified that the Space Telescope Imaging Spectrograph (STIS) showed no increase in electronic noise. All went well. The shuttle astronauts released Hubble as planned on March 11, which started the commissioning period, SMOV (Servicing Mission Orbital Verification).

Engineering and calibration measurements dominated the first two weeks of SMOV. The purpose was to verify the performance of the observatory and the old instruments. We took care to ensure that any outgassed organic material did not polymerize and contaminate the optics, which would degrade ultraviolet performance. We resumed General Observer (GO) science observations with Wide Field Planetary Camera 2 (WFPC2) and STIS on March 26. Then we began to interleave the commissioning activities for the ACS and the NICMOS with its new cryocooler.

The cryocooler took weeks longer than expected to reach the planned operating temperature. We moved up some ACS activities to compensate, initiating ACS science observations on April 8. After its detectors were cold, we activated and tested the NICMOS itself, which had been dormant for about 3 years.

After SMOV, we started executing the Cycle 11 program. Because the Telescope Allocation Committee had selected many large programs (> 100 orbits), including three Hubble Treasury programs, the pool of observations contained many more long and/or constrained observing programs than in the past. We developed a year-long plan to accommodate these observations, which began in earnest in August with the first epoch of Great Observatories Origins Deep Survey (GOODS) observations with ACS. At year's end, large programs dominated the Hubble schedule.

FIG 5: Weekly Scheduling Efficiency



A particularly challenging aspect of GOODS is the need for Target of Opportunity (ToO) follow-up observations when a type Ia supernova is detected in the ACS images. The GOODS observations are typically made at the end of a week, and the ToO team provides decisions on the following Monday or Tuesday, with any follow-up observations included in the following week's schedule.

Figure 5 shows the scheduling efficiency in 2002 remained high, averaging 49.4% after the completion of SMOV.

Calibrate Hubble data

The Institute holds occasional Calibration Workshops for Hubble users, Institute staff, and instrument developers to exchange information about instrument characterization, calibration, and performance. In 2002, we held the workshop on October 17 and 18 at the Institute. It featured reports on the commissioning of ACS and the re-commissioning of NICMOS. It included approximately 30 invited talks, 40 posters, demonstrations, and splinter meetings on various topics. About 120 astronomers attended. The workshop proceedings will be published in 2003.

At the workshop, the ACS group described a geometric distortion model. They reported that the anneal rate of hot pixels on the ACS Wide Field Camera (WFC) is lower than other Hubble CCDs (charge-coupled devices). The flat-fields provide ~ 1% photometric accuracy over the entire field of view. On-orbit measurements indicate higher than expected sensitivity for WFC, up to 20% in the blue.

The NICMOS group reported that the cryocooler is providing a very stable temperature, which facilitated re-calibration. The new operating temperature has increased the instrument's sensitivity.

Others at the workshop presented new calibrations and insights about existing or retired instruments—STIS, WFPC2, the Faint Object Spectrograph (FOS), and the Fine Guidance Sensors (FGS). The Institute previewed calibration plans for the Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3), which will be installed on the next servicing mission.

During 2002, we improved the accuracy of the pipeline flux calibration of STIS MAMA (Multi-Anode Microchannel Array) spectroscopic modes. From the time of its installation on Hubble, the throughputs of these modes have varied by wavelength-dependent amounts ranging between 1% and 3% per year. Now, we have calibrated this time variation, and the STIS pipeline calibrates the fluxes for first order spectra with an accuracy ~ 1%. Also, there had been a problem with the blaze function shifting on an echelle spectrum when it was offset on the detector. This produced an incorrect flux calibration, which was especially severe at the ends of an order. We introduced an algorithm, developed by the STIS instrument team, that dramatically improves the flux calibration for all primary STIS echelle settings.

We improved STIS background corrections. The transition to the backup side-2 electronics in mid 2001 had left STIS without a working temperature-control circuit for the CCD detector. The resulting temperature fluctuations cause significant variations in the detector's dark current and hot-pixel intensities. Fortunately, we could show that the read out of another temperature sensor on the CCD housing is well correlated with the CCD dark current, and we now use these readings in the pipeline to scale the reference dark file to the appropriate temperature to correct each data set.

The phosphorescence of impurities in the MgF_2 faceplate dominates the dark current of the near-ultraviolet MAMA detector. This dark current varies in a complex way depending on the thermal history of the detector. In mid 2002, we introduced an algorithm in the pipeline that delivers a new dark reference for each data set based on the tracked record of detector temperatures. This calibration is correct to within 5% to 10% about 95% of the time, which largely eliminates the bright edges previously visible in many dark-limited near-ultraviolet MAMA images.

For the first time in four years, the Institute has revised the data handbooks (DHBs), which are the primary user's guides to understanding and analyzing Hubble data. Now, each instrument has its own DHB, describing data acquisition, pipeline processing, archiving, file formats, and software for analyzing data. Each DHB provides an overview of the instrument, the structure of its data files, calibration, and data analysis details. The Institute website offers the DHBs in PDF and HTML formats. This new publication scheme makes it easier to incorporate new information and get it to users quickly.

Stimulate the use of Hubble data

The Institute provides the astronomy community with easy access to the entire suite of Hubble data. After an observation, we process, calibrate, and archive new observational data promptly. Also, we make all non-proprietary science data available to the public.

The Treasury and Archive Legacy programs, begun in Cycle 11, will result in new forms of data products for distribution to the community via the Archive. The Institute has defined standards and procedures for the winning Treasury and Legacy teams to provide these processed materials to the archive. The ACS Early Release observations were extremely popular in the community, as first demonstrations of the capabilities of the new camera. The GOODS survey images, which have no proprietary period, have also proven to be very popular. To support the interest in these data sets, the archive set up an ftp site for easy access to these data products.

We upgraded services to archive users through our ongoing collaborations with the Canadian Astronomy Data Centre (CADC) and Space Telescope European Coordination Facility (ST-ECF). In November, this partnership announced the availability of over 16,000 WFPC2 'associations', which are co-added, cosmic-ray rejected images drawn from observations of the same target for different programs. This provides a quick method for astronomers to get the deepest images possible for a target, without having to extract and process all the sub-images.

achievements

We processed 96,069 observations in 2002. Figure 6 shows that the rate of observations has doubled this year. This dramatic increase in the rate of observations is due to ACS and NICMOS coming online, their commissioning activities, and the new availability of four instruments for simultaneous pointed observations, parallel observations, and calibrations.

We normally deliver new science data to the archive within 18 hours of the observation, at which time it becomes available to users. As shown in Figure 7, our performance suffered in April and May due to several factors, including special data formats for some SMOV observations, increased system loads from doubling in data volume, and a disk corruption problem. Over the summer, performance recovered when we installed additional CPU and memory boards for the systems.

By the end of 2002, the total amount of data archived since Hubble launch was 11.42 terabytes. In 2002, the average data retrieval rate doubled, to ~ 40 GBytes per day, which is the most active use of the archive since Hubble was launched. (See Figure 8.) This increase demonstrates even greater community use of the Hubble archive, as it grows and additional facilities become available.

The increased retrieval load led to increased downtime of the archive system, especially with the jukeboxes that hold the data. We took several steps to reduce these impacts, including adding hardware and off-loading the task of distributing publicly available ACS data to an ftp site.

As a consequence of the high loads on the calibration pipeline and the archive, the Institute began modernizing the computer systems used for data processing. We are reducing from three to one the number of operating systems involved and improving the archive software to afford operators more flexible control of the data processing.

We have essentially completed the production of the Digitized Sky Survey (DSS), with only two remaining survey plates to be taken at the Anglo-Australian Observatory. The DSS images are available to the astronomical community through the Multimission Archive at Space Telescope (MAST) and continue to be one of the most popular resources for modern observational astronomy. We estimate that MAST and the other major data centers combined perform over 100,000 image retrievals per month. Processing of these images to produce a second-generation Guide Star Catalog (GSC-II) is also approaching completion. The first public (magnitude-limited) release of the GSC-II last year provided a significant resource for the community with its improved depth and astrometric precision. It is enabling observers to better determine the positions of objects for observing with major ground-based telescopes such as Gemini and the Very Large Telescope. The complete GSC-II, when released in 2003, will contain over a billion objects to the magnitude limits of the survey plates and provide the foundation for the NGST guide star catalog.

FIG 6: Hubble Observations Obtained Per Month

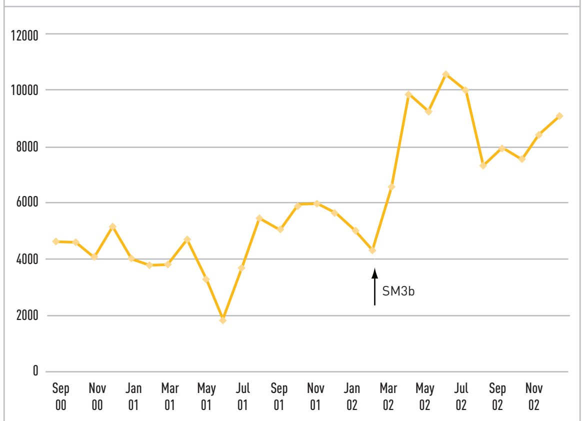


FIG 7: Monthly Averages of the Delays from Execution to Data Receipt and to Processing Completion

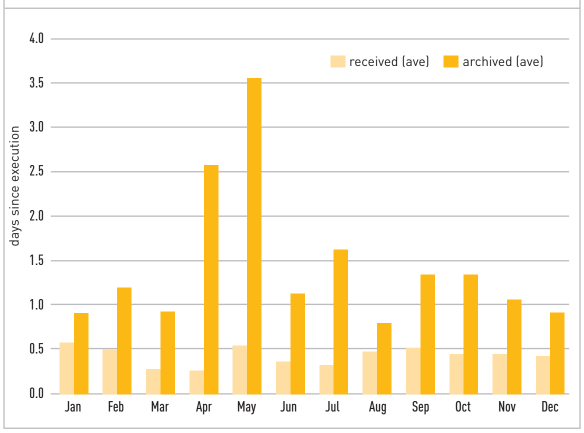
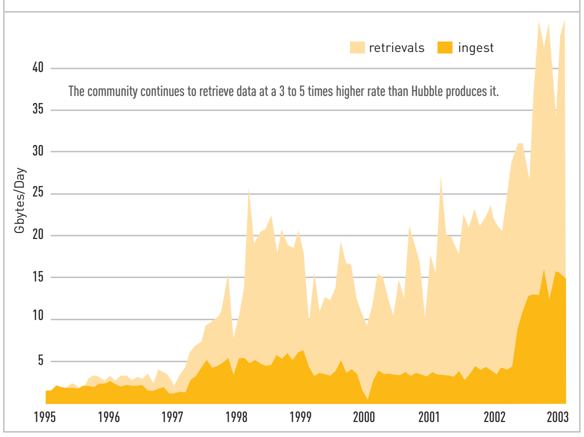


FIG 8: Hubble Data Archive, showing the increase in data volume this year.



Provide user support

In 2002, we improved our infrastructure to support users in making best use of Hubble data and opportunities to observe with Hubble. These improvements include upgrades to the Hubble web portal, new software for developing proposals, enhancements to the data analysis environment, and initiating user support for future instruments.

We transitioned all instrument websites to the portal infrastructure established in 2001. This infrastructure features 'process-oriented' navigation and 'dynamic' generation of content, which increases utility and timeliness of information and reduces cost. The portal now includes an internal metrics site to track operational data.

In Cycle 12, the Astronomer's Proposal Tool (APT) became the only way to submit a proposal. Developed with strong community involvement and tested in previous cycles, APT has a sophisticated graphical interface, which allows users to see how their observations will be arranged on the sky. Written in the Java computer language, APT is supported on many computer operating systems, including Windows and Macintosh.

In 2002, we released a number of enhancements to our data-analysis environment and tools: PyRAF is our new Python-based command language for IRAF; 'numarray' is our IDL-like array package; and PyFITS is a FITS input-output module. We released STSDAS/TABLES v3.0, which includes PyDrizzle, a new module that handles drizzling automatically. We released Specview, a Java GUI application, which performs multi-component fits of spectra.

The Institute began WFC3 and COS user-support activities. We distributed the WFC3 and COS Instrument mini-Handbooks with the Cycle 12 Call for Proposals. Both groups responded to community questions through the Institute Help Desk, supported initial planning phases of the COS team science program, and actively provided information to the community about the instruments at American Astronomical Society meetings.

Prepare for future science instruments

The Institute develops both pre-observation and post-observation components of the ground system for new Hubble instruments, drawing on our experience and capabilities from previous instruments. In 2002, our preparations advanced for the instruments to be installed in the next servicing mission, COS and WFC3.

For the COS, we coordinated with the science team led by the Principal Investigator. The Institute successfully completed the scheduling system for all internal and external calibration and science exposure modes. We completed automatic and GO-specified wavelength calibration exposure capabilities, flat field exposures, and generalized support for specific science sub-exposures to remove fixed-pattern detector noise.

We developed COS science data processing software on an expedited schedule to support instrument thermal vacuum testing, which will use the Institute pipeline and archive to process and store test data. We put in place the framework and initial implementation of the STSDAS-based COS calibration software suite (CALCOS).

For the WFC3, we coordinated our activities with the GSFC Project Scientist for the instrument and with the WFC3 Science Oversight Committee, which provides input into WFC3 development from the astronomy community. Institute and GSFC scientists, organized as an 'integrated product team', provide day-to-day scientific support to the WFC3 project. In 2002, the project installed key components and subsystems into the optical bench. The Institute assessed detectors for the infrared channel and planned for instrument calibration, operating the instrument, and developing flight and ground software. We completed all command database definitions and the instrument-reconfiguration command instructions. We implemented most of the instrument capabilities in the Hubble scheduling systems, which we have tested from proposal specification through to command-load generation, including all basic science and calibration capabilities for both the ultraviolet/visible and infrared channels of WFC3. We developed WFC3 science data processing software on an expedited schedule to support instrument thermal vacuum testing, which will use the Institute pipeline and archive to process and store test data. We put in place the framework and initial implementation of the STSDAS-based WFC3 calibration software suite.

Goal 2: **Develop** best possible James Webb Space Telescope

We will help develop—then operate—the best JWST possible, with full inheritance of Hubble lessons-learned and full engagement of the community in its development.

The James Webb Space Telescope (JWST) is the 'First Light Machine', an observatory that can peer back into the era when the first stars, galaxies, and massive black holes were formed. Since 1996, the Institute and the Goddard Space Flight Center (GSFC) have been partners in defining this mission according to its scientific promise and the details of achieving it.

In 2001, NASA, the Institute, and the scientific community set performance goals for the observatory. The telescope must have a high quality, large diameter mirror (> 6 m) to see a supernova at redshift z ~ 8, an epoch less than one billion years after the Big Bang. To detect the rare, faint star clusters or mini-QSOs at z~15, which is when the first generations of stars were forming from the collapsing filaments of primordial hydrogen and helium gas, the primary camera on JWST must have a large field of view (~ 40 square arc minutes). To see the weak gravitational distortion of galaxy images in order to measure the total masses of galaxies and clusters at the time of peak star formation (z ~ 1 to 3), the telescope quality must be stable for many days. To achieve this stability, the telescope will have a large, multi-layered sunshade to provide a million-fold rejection of solar heating.

At the Institute, the Science and Operations Center (S&OC) will take advantage of Hubble tools and experience as well as JWST's favorable orbit at the second Lagrange point to provide efficient scientific use of the observatory to the community for an affordable cost.

During 2002, NASA completed its selection of development partners to join the Institute in the design and implementation of JWST and the S&OC. In June, NASA announced the selection of the Near Infrared Camera (NIRCam) team, led by Marcia Rieke, the U.S. members of the Mid-Infrared Instrument (MIRI) team, and a number of interdisciplinary scientists. This announcement broke the first part of a procurement 'blackout' during which neither NASA nor the Institute could communicate new technological information to the community or aerospace contractors. With the selection of the two instrument teams and the creation of the Science Working Group, the Institute began to provide technical and scientific support to assist these teams in their design efforts and in planning for science operations. In September, the selection of TRW as the prime contractor removed the remaining blackout restrictions. Within weeks, the Institute and NASA met with TRW and its major corporate partners—Ball Aerospace and Kodak—to exchange information and to coordinate future activities.

During the year-long blackout, the Institute had not been idle. To prepare for the development of the S&OC, we completed detailed studies of the entire ground system and drafted an operations concept that addressed dozens of different operations scenarios and corresponding requirements documents. We completed studies on optical performance, pointing stability, the operation of the fine guidance sensor, and the use of astronomical targets for on-orbit calibration. Using our Hubble experience, the Institute defined the commanding rules and operation of the on-board Observation Plan Executive, the flight software that will run the JWST scientific instruments.

Once the development partners were selected, NASA faced the difficult task of coordinating their plans and reducing the overall cost of the mission to meet the financial guidelines provided by NASA Headquarters. Beginning in November 2002 and with completion planned for March 2003, the re-planning process consists of a large number of tradeoff studies involving the contributions of the three international space agencies, the prime contractors, the science instrument team, and the Institute. With regard to possible reductions in the scientific capabilities of the mission (e.g., reducing the primary mirror diameter or eliminating an instrument), the Institute and the JWST SWG provided technical and scientific impact assessments to the JWST project and NASA Headquarters. NASA will set the ultimate course of the mission following consultations with the two international partners—ESA and the Canadian Space Agency (CSA)—in February and March 2003.

Prior to the re-plan effort, the Institute submitted a revised proposal for developing the S&OC that reduced its costs significantly by using government-provided commanding software and communications services. In addition, the Institute will delay the development of the JWST ground system until after the next Hubble servicing mission. Although the Institute will not play a major role in the early development and testing of the science instruments and the spacecraft avionics, we will complete the S&OC system in time for end-to-end testing with the completed spacecraft in 2009.

The Institute had originally proposed a National Virtual Observatory extension to the JWST archive. That work is now postponed until several years after launch. With this exception, the revised observatory should provide the full scientific capabilities of JWST to the astronomy community.

The Independent Detector Testing Laboratory (IDTL, a collaboration of the Institute, the Johns Hopkins University, and a number of ground-based observatories) accomplished several milestones in 2002. NASA funded the IDTL to test and verify independently the low background performance of near infrared detector technologies for JWST.

In June 2002, the IDTL demonstrated its low-background capabilities with a 1 K x 1 K HgCdTe imager, obtaining dark currents of less than 0.02 e^- $pixel^{-1}$ sec^{-1}. The lab joins the very small list of facilities that are capable of testing such devices in the challenging operating regime of JWST. The lab team completed a suite of performance tests on the 1 K x 1 K and 2 K x 2 K HgCdTe devices and demonstrated the ability to operate the readout portions of similar InSb devices, which will become available in 2003. The IDTL test results will help NASA and the Principle Investigators decide in November which technology will be used on JWST. Within the constraints of the ITAR (International Trade in Arms Regulations), the IDTL makes its test procedures and results available to the astronomical community for independent review and assistance.

Throughout 2002, the Institute has supported the NASA JWST Project in public outreach. JWST exhibits at the semi-annual American Astronomical Society meetings have encouraged hundreds of interested astronomers to learn about the JWST science mission and the new technologies that enable it. At the 2002 summer meeting in Albuquerque, the Institute unveiled a new exhibit featuring a sunshield-inspired tent and a large science mural capturing the NASA origins theme. The public-oriented website and the astronomer-friendly website now reflect the mission's new identity, the new JWST architecture, and the selected instrument teams and members of the Science Working Group.

Goal 3: **Operate** a world-class data archive

We will continue to run the best astronomical data archive in the world, adding new data sets, providing new research tools, and collaborating with other data centers to provide an international astronomy data system.

The Multimission Archive at Space Telescope (MAST) is one of the world's best and most widely used data archives. It offers users convenient search and retrieval utilities that access data from 17 missions and surveys, including Hubble. Even as MAST's data holdings have grown to over 15 terabytes, our data retrieval rate regularly exceeds our ingest rate. This high demand is a tribute both to the value the community places on these data and the success of our efforts to make archival research easy and scientifically productive.

To keep MAST on the cutting edge, we strive to improve the key functions of a modern archive. We ensure the preservation of astrophysical data into the indefinite future with reliable storage technologies. Our scientific and technical expertise guides the processing, re-analysis, and interpretation of the data holdings. We develop multimission analysis and support tools. We define data, software, and access standards. We coordinate with other national and international data centers to enhance inter-archive communication.

When investigating the physical processes in the formation and evolution of stars, galaxies, and large-scale structure, astronomers use data from a wide range of the electromagnetic spectrum. The MAST holdings—ultraviolet, optical, and near-infrared images and spectra—are a key resource for these investigations.

In 2002, we undertook to expand access to important astrophysics data holdings, increase the productivity of our user community, make it even easier to access data, and enhance the scientific value of our data.

With the deployment of the Advanced Camera for Surveys (ACS) and the initiation of the Hubble Treasury Program, we implemented an easy process for users to provide their high-level science products to MAST for general distribution to the astronomical community. High-level science products include fully reduced and processed images and spectra from all supported MAST missions as well as closely related ground-based observations, theoretical data products, object catalogs, and original reduction and analysis software. Science-ready products currently available include atlases, sky surveys, and catalogs created using various MAST mission data sets including Hubble, International Ultraviolet Explorer, Far Ultraviolet Spectroscopic Explorer, Extreme Ultraviolet Explorer, Copernicus, and the Sloan Digital Sky Survey. In addition, major contributions are expected from the Archival Legacy, Hubble Treasury, and other large programs begun in Cycle 11. The Great Observatories Origins Deep Survey (GOODS) ACS program is one such example. To expedite access to such popular data, we provided a fast-access ftp site where users can directly download the data to their host machines. An important, related development in enhancing archive operations was the acquisition of a 34 terabyte storage system. This massive data storage facility will enable us to transfer all Hubble data from our magneto-optical jukeboxes to spinning disks, enabling faster data retrievals and more robust archive performance.

The Wide Field Planetary Camera 2 'association products'—co-added, cosmic-ray-cleaned images—are exciting additions to our inventory of high level science products. These images, produced by the Canadian Astronomical Data Center in collaboration with the Space Telescope European Coordination Facility, do not require additional processing prior to initiating scientific analysis. They also provide previews that are much more informative than before.

We expanded the capabilities of our Spectral Scrapbook utility to include the ability to co-plot spectra from multiple missions. This allows users to mine the archive for objects that exhibit variability or to preview the spectral energy distributions over a much larger wavelength range than would be possible from any single data source.

We enhanced the archive search interface to provide a larger variety of output formats for the query result, including the new Virtual Observatory standard: VOTable. The new interface design also provides the user with more control over the contents and arrangement of the returned query results. We have also automated Hubble archive registration so that new users can gain access to our data anytime, not just during working hours.

We continue to work actively with our colleagues at other NASA data centers to improve the interoperability between all major astronomical data archives. We provide links between MAST data holdings and the on-line publications hosted by NASA's Astrophysics Data System. This linkage permits immediate access to the data behind published results. We also provide seamless access to data stored at other sites, even beyond the ultraviolet/optical/near-infrared range—such as ROSAT (Röntgen Satellite), Chandra, and VLA (Very Large Array) FIRST (Faint Images of the Radio Sky at Twenty-One Centimeters) data—that are relevant to interpreting our current holdings.

We are preparing to host data from the GALEX (Galaxy Evolution Explorer) mission, which is scheduled for launch in March 2003. GALEX is a NASA ultraviolet imaging and spectroscopic survey mission designed to map the global history and probe the causes of star formation over the redshift range $0 < z < 2$. GALEX will be the first mission to produce an all-sky ultraviolet survey. The GALEX archive is expected to contain approximately 4.5 terabytes of data.

We will archive the data from the Kepler mission, which is a Discovery Program mission designed to detect terrestrial planets around stars in the sun's neighborhood. The Kepler instrument will detect transits by planets across the disk of the host star, from which investigators can calculate the sizes of the orbit and the planets from the period and depth of the transit, respectively. Kepler will monitor 100,000 stars for 4 years and produce approximately 5 terabytes of data. Kepler is scheduled for launch in 2007.

The Cosmic Hot Interstellar Plasma Spectrometer (CHIPS), a University-Class Explorer mission launched in January 2003, and the Spectroscopy and Photometry of the IGM's Diffuse Radiation (SPIDR), a Small Explorer mission to be launched in 2006, both plan to archive their data with MAST as well.

We continue to work with other data centers to define the data standards and models for the Virtual Observatory concepts being developed nationally and across the world.

Goal 4: Stimulate education and public outreach

We will improve our education and public outreach programs, extend them to NGST, and make them available to the rest of astronomy, ensuring maximum benefit to the public from the research enterprise.

The Office of Public Outreach (OPO) shares Hubble Space Telescope's breathtaking images and discoveries with the public through diverse products and programs that inform and inspire. An OPO team of communication professionals from a range of disciplines—including web, multimedia and database programming, video production, graphics, illustration, curriculum development, and science writing—provides the practical skills needed for developing products.

To help guide our program, the OPO External Advisory Group held their first meeting in July 2002 at the Institute. The Group reviewed the OPO Strategic plan, a draft of our implementation plan, and provided useful advice on our programs.

News & public information

The OPO News Program communicates the latest information about Hubble discoveries to the public via the print, broadcast media, and Internet news sites. Besides reaching these traditional mass media outlets the News Program provides Hubble images and intellectual content to textbooks, popular astronomy books, educational documentaries, astronomy websites, and other OPO products. The News Program is recognized as a leader in quality science communication and as a model for NASA space science missions, and other research institutions.

In 2002, we produced four Space Science Updates (SSUs) and two special press conferences associated with the Early Release Observations (ERO) from the Advanced Camera for Surveys (ACS) and the Near Infrared Camera and Multi-Object Spectrometer (NICMOS). We prepared twenty additional press releases. Major news topics covered included new measurements for the age of the universe, the rate of star formation in the early universe, and the landmark discovery of black holes in globular clusters.

NASA's 2002 science-news metric study found that Hubble led all other NASA science programs in news coverage. Hubble SSUs and press conferences alone generated over 300 stories in major newspapers, reaching an estimated 40 million people in the United States alone.

To better serve the needs of the news media, OPO re-tooled its NewsCenter website to provide journalists, reporters, documentary producers, and the public even faster access to Hubble images and findings. The NewsCenter incorporates a full glossary, conversion tables, and media contact details. The site contains over 2,000 Hubble images and nearly 2.5 million words of text aimed at lay readers.

We helped extend Hubble images to sight-impaired people by working with the National Academy of Sciences, the National Federation for the Blind, and DePaul University to publicize and disseminate a unique book, Touch the Universe. This landmark project converted Hubble images to tactile relief maps for use by school children and adults.

Formal education

The OPO Formal Education Program develops online and hard copy curriculum-support products for the K-12 education community. A rigorous evaluation program and strict compliance with national educational standards ensures the success of these products.

In 2002, we showcased the Hubble Deep Field (HDF) lesson plan at the NASA/Office of Space Science Education Products Workshop. A NASA review panel selected the HDF package as an exemplary NASA product for students in grades 6-8.

The Amazing Space website offerings grew with the addition of several education modules this year. Amazing Space now reaches 212 U.S. school districts and 126 colleges, including the New York City public schools and Princeton University.

Amazing Space materials were also packaged in a CD version, allowing us to reach U.S. classrooms without Internet connections and to distribute Amazing Space at conferences and to school districts and universities. To improve the quality of Amazing Space, we initiated an impact study to identify and understand the audiences that use the online materials. We also developed a data collection program for tracking how our educational products are used.

The astronomy education community submitted 51 IDEAS proposals in 2002, which was a 29% increase in participation from 2001. The 13 winning proposals were awarded a total of $430K. The community submitted 15 Education and Public Outreach proposals in connection with Cycle 11, representing 27 science programs and 2 Hubble Fellows. Following peer review, we selected 11 proposals and awarded $220K. Our education team also collected and analyzed final reports for IDEAS grants to ascertain the impact of that program. The OPO External Advisory Group reviewed this evaluation effort positively and recommended its continuation.

Online **outreach**

Our Online Outreach Program provides a suite of resources for disseminating key scientific results to the general public. Our premier online site, Hubblesite, received more than 19 million visitors over the year. We updated Hubblesite to inform visitors about the servicing mission, SM3b. We also updated Hubblesite with a full suite of information on ACS. We developed a new feature in Hubblesite's 'discoveries' section. Entitled "Striking Encounters", it showcased the ACS science capabilities for understanding colliding galaxies as illustrated by the ERO image of the 'Mice' galaxies.

With an unprecedented number of visitors drawn by the first ACS images, the OPO web servers became completely subscribed only 20 minutes into the ACS ERO press conference. The Online Outreach team worked around the clock to handle the extreme load. We distributed to a server farm at seven other locations, including NASA HQ and the Kennedy, Johnson, Ames, and Goddard centers. In six days we took more than 40 million hits and transferred half a terabyte of data from the OPO servers alone.

We worked extensively with the News team to develop the Press Release e-Servicing System (PReSS) for archiving all Hubble news material. We also updated the James Webb Space Telescope (JWST) public website.

Informal **science education**

The OPO Informal Science Education Program assists museums, science centers, and planetariums to showcase and explain Hubble discoveries and images. We offer science-content review and consultation to informal science education organizations that are developing exhibitions and programs.

A major component of our program is ViewSpace, which is a unique multimedia product for large-screen video display in museums and planetariums. Using colorful images, digital movie clips, and simple language in captions, ViewSpace tells Hubble science stories. Host institutions provide their own playback system, which can consist of an inexpensive PC and image projector. We provide ViewSpace on CD at no cost. The science museum community has welcomed ViewSpace, which was active at over 100 sites in 2002.

We produced a short video mini-documentary, "Hubble Reborn", which dramatically depicts the challenges faced by space shuttle astronauts on SM3b. It culminates in the release of dramatic new images from the repaired NICMOS instrument and the newly installed Advanced Camera for Surveys. We disseminated the video widely on VHS tape and DVD following SM3b.

In cooperation with the National Air and Space Museum in Washington, DC, we took a big step toward the new world of 'immersive' or 'fisheye' astronomy visualizations. We prepared a high-resolution visualization of a supercomputer simulation of a galaxy collision and showcased it at the Smithsonian's renovated Albert Einstein Planetarium. The visualization is now available for delivery to other planetariums using digital planetarium projection systems. Later in 2002, we added a visualization of globular star cluster and a flight through the large scale structure of the universe.

We distribute first-rate quality 35-mm slides from our photo lab to support the more traditional needs of the planetarium community. The International Planetarium Society distributes the slides at low-cost.

We are pioneering the use of the mpeg-2 digital-video format for providing astronomical video animation from our Astronomy Visualization Lab to museums and planetariums. We post the downloadable video files on our website, where it is available 'on-demand' to program and exhibition designers.

We completed a major redesign of the JWST exhibit for outreach to the professional science community. The redesign focuses on the basic science goals of the mission. It uses backlit boxes and video materials showcasing the latest news.

We began work with the National Park Service to produce a resource CD for park rangers who give interpretive night-sky talks.

Origins Education Forum

OPO is the home to the Origins Education Forum, a part of the NASA Office of Space Science Education and Public Outreach support network. We help missions communicate and coordinate outreach activities with each other. Also, we provide unique services to enhance the value of their outreach efforts.

We organize monthly telecons, splinter meetings at astronomical meetings, and an annual outreach retreat for the Origins missions, which are scattered around the country. We capture and disseminate lessons learned by missions about developing and disseminating educational products. We also provide program- and product-evaluation services. We coordinate exhibits, staffing, schedule, and material dissemination at numerous conferences each year.

In 2002, the Origins Education Forum provided evaluation services to the Space Infrared Telescope Facility, Space Interferometry Mission, NASA Astrobiology Institute, and Stratospheric Observatory for Infrared Astronomy. We held 'tag-up' meetings in conjunction with each American Astronomical Society meeting.

We released a new version of the NASA Space Science Education Resource Directory (SSERD), improving usability for the missions entering products into the directory.

We initiated developing a new strategic plan for the Origins Education Forum. We began with in-depth interviews with our stakeholders to develop a consensus on the role and charter of the Forum.

Goal 5: Facilitate technology transfer

We will continue to facilitate the transfer of our technical innovations to other fields of research and to the private sector.

The astronomical community recognizes our software products for operating Hubble for their effectiveness, efficiency, and quality. Several other NASA space astronomy missions have adopted our planning and scheduling software and our distributed data processing pipeline software. Such reuse of our software has permitted those missions to become operational with lower cost and lower risk, and it has afforded the community of astronomers the benefits of multiple missions performing efficiently.

While our first commitment is to the advancement of astronomical science, as called for in the charter of AURA, we know there are wider applications for our software systems than their originally designed purpose. Already, commercial industry has two of our systems—our fully distributed data processing pipeline system and our multi-mission planning and scheduling system—for help in running their enterprises. We seek to make our software products available to this wider spectrum of industry.

This year, we provided greater focus to technology transfer by vesting our Community Missions Office with responsibility to coordinate our response to industry enquiries and to manage any resulting activity to provide products and services. This office provides a centralized, unified approach for dealing with potential clients in a professional and helpful way.

We also made our products more visible on the website of our Engineering and Software Services Division (ESS). There, interested parties—both within the scientific community and in other industries—can find clear and up-to-date descriptions of the range of products we have developed and use today on Hubble. Because our systems were designed to deal with changing suites of science instruments on Hubble, and to accommodate different generations of computer hardware at the Institute, their built-in flexibility and resilience makes them easily adaptable to other uses.

To support our users around the world, ESS has initiated 'help-desk' type support for our software systems currently employed on other missions and in commercial industry. Aimed at responding to problems, this support is also effective answering community enquiries about the technical characteristics of these products. With such information available, we believe the commercial world will find our systems attractive and useful—benefiting both themselves and the science community through the continued evolution of these products.

Goal 6: **Attract** and **retain** outstanding technical staff

We will continue to attract the best technical staff to advance and apply the state of the art for astronomy.

The Institute has long recognized that the partnership between its outstanding technical staff and its world-renowned scientific staff is the cornerstone to the Institute's future. The keys to retaining technical staff are providing them opportunities to grow professionally and recognizing their accomplishments with meaningful rewards. In 2002, Engineering and Software Services (ESS) advanced the Institute technical staff's awareness of their field by hosting ten engineering colloquia with topics ranging from "Software Development Processes" to "Upgrading Computers on the International Space Station." ESS also supported 12 in-house mini-sabbaticals to permit technical staff members to explore some technical capability or process for a two-week period.

The Center for Process and Technology (CPT) created the position of Principal Technologist to extend its technical career path. This position is similar to and at the same level as the Principal Engineer position in ESS. These positions provide a non-mangement alternative for technical staff promotion. We currently have two Principal Technologists in CPT and four Principal Engineers in ESS.

CPT added a new management-level position—Technical Supervisor—that allows a technical staff member to work in management while continuing to maintain their technical skills by allocating approximately 40% of their time to technical work. At the end of 2002, the CPT had 5 Technical Supervisors.

In 2002, CPT, ESS, and the Director's Office extended the Principal Engineer concept by establishing the new positions of Consulting Engineer and Consulting Technologist. Filled from time to time through a selective process, these titles acknowledge the superlative abilities of particular engineers and technologists. The award of these titles will allow members of the technical staff to rise to the top levels of the Institute without leaving their technical roles.

The AURA Technology and Innovation Award is given to an individual at an AURA center who has demonstrated excellence in an area of technology and who has made a significant innovative contribution during the last year. In 2002, AURA selected Dr. Warren Miller for this award in recognition of his invaluable contributions to the development of the Operational Pipeline Unified System (OPUS), which governs the processing of Hubble data and performs similar applications at many other space observatories and science projects.

Goal 7: **Attract** and **retain** outstanding scientific staff

We will continue to attract excellent scientists and provide them with an academic environment that nourishes excellence in research.

We embrace this strategic goal, which lies at the heart of the Institute. Our programs provide our scientists stimulation, opportunity, and incentives for research at the forefront of astronomy and astrophysics. Within this environment, we serve individual scientists with mentoring and professional advice based on annual review. We match scientists to functional assignments that develop their technical skills while ensuring the success of the Institute's missions. Our promise to Institute scientists matches the Institute's commitment to the outside community: we will enable you to do your best, for your career in astronomy and for the advancement of science.

Our academic **environment**

Our fellowship programs infuse the Institute and the Hubble program with the freshness of youthful exploration and discovery. Our visitor programs promote intellectual exchange and research connections with the world community. Our symposia, colloquia, and topical sessions promote discourse and debate about emerging results. We invest in the Institute research infrastructure and provide competitive access to funding for promising research projects.

We manage the Hubble Fellowship Program, selecting recipients on the basis of their excellence in scientific research and appraising them annually. In 2002, we selected 12 new Hubble Fellows and supported approximately 30 Hubble Fellows nationwide. We organized the yearly Hubble Fellowship Symposium, which allows all Fellows to present their latest scientific results.

We also managed the Institute Postdoctoral Fellowship Program, selecting the recipients based on the strength of their proposed research. In addition, we host many regular postdoctoral fellows and graduate students, whose research is guided and supported by individual staff members. In 2002, we had 2 Institute Fellows and hosted approximately 30 regular postdoctoral fellows. We also hosted 22 graduate students, including those enrolled in the Physics and Astronomy Department at The Johns Hopkins University.

We conduct a variety of programs to host scientific visitors at the Institute. Our Collaborative Visitor Program supports collaborators on research projects with Institute staff members for visits of one to four weeks. Our Journal Club Visitor Program supports external scientists who come to give one or more seminars during visits of one to two weeks. Our Distinguished Visitor Program supports outstanding astronomers to join the Institute for typically one month. In 2002, we hosted 2 Distinguished Visitors, 12 Journal Club Visitors, and 39 Collaborative Visitors.

Each spring, we organize a symposium on an astronomical topic of major interest with important new developments. Usually, 100 to 200 astronomers attend these symposia, drawn by the offerings of cutting-edge research and invited speakers of the first rank. The 2002 symposium, entitled "Astrophysics of Life," brought together biologists, geologists, and astronomers to work on understanding the foundations upon which searches for life in the universe must be based, and which bear on the nature and origin of life.

The Director's Discretionary Research Fund (DDRF) supports both short- and long-term staff research programs as well as infrastructure investments to bolster our research capabilities. In 2002, the DDRF supported about 50 scientific projects and allocated approximately $475,000 in funding to 25 new projects.

Services to **scientists**

In order to maintain staff excellence and to continue to attract first-class scientists from the outside community, we are committed to fostering the careers of the individual staff scientists, especially junior scientists, by providing mentoring, advising on professional development, and conducting annual science evaluations. We collect issues that may affect whole categories of scientific staff and address them through the Institute's management structure.

We perform an annual evaluation of each AURA scientist based on his or her summary of scientific achievements for the past year. A committee consisting of the Associate Director for Science and a selection of junior and senior science staff members evaluates the summaries and determines the salary merit increases.

We instituted Agenda Groups to address career-related issues for all categories of our science staff, from graduate students and postdoctoral fellows to senior astronomers. The Agenda Groups have continued to raise a variety of issues affecting the productivity of the Institute staff. We strategize about the resolution of such issues at regular meetings between the Science Division Office and representatives of the Agenda Groups. When appropriate, we coordinate solutions within the Institute management structure. In 2002, most practical issues were resolved successfully.

Goal 8: **Promote** new missions

We will continue to work with the community to investigate and advocate new missions that will enable further scientific advances.

The Institute has a special responsibility to foster new missions and mission concepts, both for the vitality they afford the astronomical community and for the means they offer us to share the expertise we have developed in support of our prime mission, the Hubble Space Telescope. Institute staff members have honed the technique of 'science systems engineering', which encompasses a full range of capabilities in science operations, engineering, systems architecture, programming, and outreach. These skills have matured during the course of operating Hubble.

The Institute has built several productive partnerships to provide our expertise and products to other missions, including the Far Ultraviolet Spectroscopic Explorer, the National Virtual Observatory, and the Kepler Discovery mission. Individual scientists are members of numerous science working groups for community-based missions, including James Webb Space Telescope, Space Interferometry Mission, and Terrestrial Planet Finder. Others are members of science teams on missions selected for flight within the past year, such as Spectroscopy and Photometry of the IGM's Diffuse Radiation (SPIDR), chosen in 2002 as a Small Explorer Mission.

Also in 2002, the Institute established the Community Missions Office to provide focused support to individual scientists and to missions developed and led by members of the external science and technical communities. This office seeks to build new partnerships and to manage our diverse portfolio of smaller-mission involvements.

Melissa McGrath (cont'd)

Project to Re-Engineer Space Telescope Observing. The HURT team spearheaded many innovations for Hubble proposal processing, including the then-new Phase I LaTeX template, the switch to visit-based observing allocations, and the birth of the RPS2—Remote Proposal Submission 2—software system. She then served, successively, as an instrument scientist for the Goddard High Resolution Spectrograph, the Space Telescope Imaging Spectrograph (leading the implementation of its data processing pipeline and on-the-fly calibration), and the Cosmic Origins Spectrograph. Before her recent move to head the Community Missions Office, she was in the Engineering and Software Services Division, where she led several projects, including PROMPT—PRoblem Observation Management ProjecT—and the Institute's involvement in the Kepler Discovery mission.

Scientifically, Melissa's primary areas of research expertise include imaging and spectroscopic studies of the upper atmospheres and magnetospheres of the outer planets, satellite atmospheres (specifically Io, Titan, Europa, and Ganymede), and the Io plasma torus. She also has expertise in basic atomic physics cross-section calculations and in the atomic physics of sulfur and oxygen. She was one of the six principal investigators of the Hubble team that led the Comet Shoemaker-Levy 9 impact observations in 1994.

Although there have been many exciting moments in her career so far, the SL9 campaign was Melissa's experience of a lifetime. Never before nor after had so much public and press attention been focused on the Institute and Hubble. Security at the Institute was very tight during impact week, numerous TV trucks were parked at the curb in front of the building, and tension and anticipation ran very high. Several last minute predictions held that the event would be a 'fizzle'. Nevertheless, ever optimistic, Melissa was the member of the Hubble team that purchased two bottles of champagne the day the impacts were to begin. One was opened at the last Hubble science team meeting the afternoon before the first impact, and one was saved for later. The celebration that ensued after the scar from the first impact became visible in Hubble observations was spurred on by the second bottle of champagne, and the scenes of Melissa and Heidi Hammel opening the bottle—and then later Gene Shoemaker drinking from the bottle—have been immortalized on numerous TV documentaries. And Melissa has the infamous bottle in a safe place along with the other bottles in her astronomical wine bottle collection on top of a filing cabinet in her office.

In addition to Institute functional and scientific work, Melissa has also performed a good deal of service for the astronomical community, including membership on numerous review panels, users committees, science working groups, and most recently taking leadership positions in the American Astronomical Society's Division for Planetary Sciences, first as an executive committee member, and currently as the secretary-treasurer. She was recently asked to serve as a member of the search committee for a new Astronomical Journal Editor. In her 'spare time' she enjoys pursuing local history, gardening, her two dogs (Calli and Cady), sewing and needlework, and sports—both as participant and fan.

Roeland van der Marel (cont'd)

the presence of supermassive black holes. However, convincing evidence and mass determinations for such black holes from the observed dynamics of stars near galaxy centers was still very scarce. To improve upon this situation, Roeland pioneered new methods for the dynamical modeling of galaxies and for the extraction of kinematical information from galaxy spectra. This work on 'two-integral models' and 'Gauss-Hermite expansions' built on his background in mathematics. While Roeland considered himself an aspiring theorist, his thesis adviser managed to convince him to try observing as well. Successful observing runs on the William Herschel Telescope on La Palma, combined with Roeland's newly devised methodologies, led to improved constraints on the supermassive black holes in several nearby galaxies. His thesis earned him the Leiden University Kok Prize and a Hubble Fellowship. Detailed comparisons of observation and theory have continued to characterize his research to this day.

After crossing the ocean in 1994, Roeland spent three years at the Institute for Advanced Study in Princeton. During these years he became a frequent user of the Hubble Space Telescope. The Faint Object Spectrograph allowed high spatial resolution spectroscopy of galaxy centers, which yielded some of the best evidence for supermassive black holes. Roeland focused on the stellar motions in M32 and on the gas motions in NGC 7052 and found compelling evidence for supermassive black holes in both galaxies. The axisymmetric, numerical, orbit-superposition models that he constructed have since become the standard approach for the interpretation and analysis of galaxy kinematics. Models of this type have proven to be particularly important for the modeling of data from the Space Telescope Imaging Spectrograph, which have since revolutionized our understanding of the demography of supermassive black holes.

In 1997 Roeland came to the Space Telescope Science Institute as the first Institute Fellow. He is now an Associate Astronomer and also an Adjunct Associate Professor at Johns Hopkins University. He has continued to broaden his research interests, which now include the formation and evolution of all sorts of galaxies (ellipticals, spirals, dwarfs, irregulars, radio galaxies, brightest cluster galaxies, and interacting and merging galaxies), the structure and dynamics of their constituent components (disks, bulges, dark halos, star clusters, and black holes), and the clusters of galaxies in which they often reside. Much of his research centers on data from Hubble, but Roeland is also interested in modeling large ground-based surveys such as CNOC, 2MASS and DENIS.* Most recently he has become fascinated with attempts to understand the structure and dynamics of the Large Magellanic Cloud.

For the past few years Roeland was a member of the Institute's Science Policies Division. In this role he worked on the organization of the Hubble peer review process and the editing of documents such as the Hubble Primer and the annual Call for Proposals. He has served the Institute on a variety of committees and has maintained a close interest in the calibration and use of the Hubble instruments. He wrote a target acquisition simulator for the Faint Object Spectrograph, software for 'pedestal bias' correction in images with the Near Infrared Camera and Multi-Object Spectrometer, and algorithms for determination of Advanced Camera for Surveys flat fields from repeated observations of star fields.

Roeland is married to Alessandra Aloisi, an astronomer at Johns Hopkins University. In his spare time he likes to play golf. He loves movies, various rock music, and books. Roeland is looking forward to the challenges provided by his new management position. "One of the most exciting things about work at the Institute is the opportunity to work together as a team with people that have different skills and backgrounds. I feel fortunate to be given the chance to lead a team of talented people on such an important task."

* Canadian Network for Observational Cosmology (CNOC), Two Micron All Sky Survey (2MASS), Deep Near Infrared Survey of the Southern Sky (DENIS).

Marty Durkin (cont'd)

In the summer of 2001, Marty was given the opportunity to act as backup for the ESS Program Manager, which led to an interest in this new role. By the spring of 2002, he accepted a new position as the lead of the Systems Integration Management Team in the ESS Division office. Here, his responsibilities included handling the labor and non-labor budgets, ESS liaison with Program Management, and systems integration for large projects.

Also in mid 2001, CISD was preparing to reorganize to meet the needs of its large customer-base more effectively. Marty participated in defining the role and structure of the new organization, which would be called the Center for Process and Technology (CPT). Marty accepted the position of Process Engineering and Enabling Technologies Deputy in CPT in the summer of 2002.

Marty enjoys snorkeling in the Caribbean, tropical fish, and gardening.

Bonnie Eisenhamer (cont'd)

learn simply by looking at the sky. Her sky-watching experience did not persuade her to give up her career and become an astronomer. She did, however, become fascinated with how people learn math and science. And she didn't give up Jon, either. She married him. Jon Eisenhamer also works at the Institute, as a computer specialist in OPO.

Bonnie's initial career path led to fulfilling jobs that were far afield from astronomy, math, and science. Prior to coming to the Institute, she worked as an educator, an evaluation specialist, and an education program developer. Two memorable projects stick out. Both fulfilled her goal of helping people achieve success in life through learning. She was an evaluation specialist for the research and development of the national certification examination for the Federal Court Interpreter Project at the University of Arizona, a federal program to certify court translators. Bonnie learned that education and evaluation methods could have an impact on society. She also developed the Cognitive Skills Development program for the Los Angeles Community College District, identifying student learning styles and providing tools to increase the likelihood of first-generation college students graduating from college. This program was so successful that the community college expanded it to include adults who reenter college after many years away.

In Maryland, Bonnie developed math and science education programs for at-risk students in communities throughout Baltimore. She tailored the programs to fit the needs of learners. She instructed educators on how to implement such education programs in science and math. In addition, she was a program evaluation consultant for various education programs throughout the State of Maryland.

Bonnie finally was able to combine her enjoyment of astronomy with her goal of helping people learn when OPO came calling. The office needed an evaluation specialist. And Bonnie applied for and was given the job. While at the Institute, Bonnie has strived to make astronomy an enjoyable learning experience by providing education programs such as Amazing Space. Using her expertise, she expanded the focus to include providing educators with the tools necessary to integrate Hubble's discoveries in the classroom.

Bonnie and her husband have a nine-year-old son, Jonathan, who teaches them new things every day about astronomy. She enjoys gardening, the opera, and family snorkeling trips.

Lisa Wolff (cont'd)

In 1986, Lisa's modeling and process improvement efforts came to the attention of Litton in College Park, Maryland. Litton offered her an opportunity to develop their electrical design process. Her 16-year career with Litton included several promotions, culminating in the role of chief technology advisor and having responsibility for the management of the personnel developing and supporting electronic design automation (EDA). EDA encompassed not only CAE but all aspects of automated product development. Lisa's responsibilities included the selection of technologies and processes used for system, software, electrical, mechanical, and reliability engineering and product data management, manufacturing, and logistics. Lisa also worked closely with the physicists and mathematicians involved in research funded through NSF, providing technical solutions to facilitate their research. When information technology became a critical factor in the success of engineering, manufacturing, and research, Lisa accepted the management challenge of the information technology infrastructure. Lisa's accomplishments, as well as those of many other talented staff members, were the basis for the prestigious Center of Excellence for Product Development Automation designation for her division of Litton Industries. This special designation led to numerous opportunities to help other Litton divisions make dramatic improvements to their engineering, manufacturing, business and information technology approaches.

Lisa's involvement with Litton corporate initiatives became a launching ground for industry-wide lobbying activities. Many of the software licensing options currently available from companies like Mentor Graphics, Rational, CoCreate, Mathsoft, Synopsys, and Globetrotter are the result of organized efforts that Lisa led or in which she participated during the early 1990s. Helping software vendors recognize that licensing models needed flexibility and adaptation to the globalization of businesses was at the core of many discussions. By the mid 1990s, more flexible licensing agreements were available and the software cost per engineer decreased.

Faced with a shortage of local engineers and software developers skilled in the use of design tools upon graduation, Lisa leveraged her role in various users groups to challenge industry's top executives to increase funding in their education business sectors. Lisa worked directly with Hewlett Packard, Mentor Graphics, and Rational to create or improve their educational sales programs. The outcome of her efforts set the stage for affordable pricing of software and computers, which ultimately made their way to university engineering and computer science laboratories. Eventually, Litton's new-graduate workforce was better prepared and required much less initial training.

Believing there is much more to life than a job, Lisa devotes several hundred volunteer hours a year to educational causes. She teaches physics for an enrichment program at her son's middle school. Lisa is a member of the Living Classrooms Board of Advisors and a member of EDUCAUSE. Living Classrooms provides hands-on education for disadvantaged youths. EDUCAUSE is a national alliance of information technology professionals from educational and research institutions. Married and the mother of two children, Lisa also makes time to enjoy her family, although the 'tech-talk' doesn't end when she goes home. Her husband Doug, is an RF systems engineer, her daughter Chris, is an electrical engineer, and her son Ben routinely proclaims his desire to become a mechanical engineer. Ben is 13 and Chris is 23 years old.

Since joining the Institute, Lisa has focused her efforts in several key areas: computing and data storage for the Hubble data pipeline and archive, risk assessment, understanding technology challenges and goals, establishing working relationships, forming the framework for technology governance, and strategic planning.

She has worked closely with the division heads of the Institute's information technology organizations to focus staff resources on increasing the collaboration between the organizations, improving support services, and addressing critical Hubble computing systems issues. Lisa's overall goal is ensuring that the Institute's information technology strengthens the ability to perform scientific research, fully supports the missions, and meets business objectives.

These are exciting times from Lisa's perspective. Just as information technology transformed the engineering and manufacturing industry, so will it provide opportunities to transform the science community's technical capability. Day by day, innovative applications of technology provide astronomers better tools and methods to conduct research at their desktop and work with collaborators from other research institutions. Database and network technology will enable global access to vast sources of astronomical data and enrich the researcher's experience well beyond today's possibilities. Software innovation will enable next-generation data reduction pipelines, opening new avenues of research to scientists. With information technology positioned as the 'bridge', stimulating initiatives such as astrobiology have the potential to bring entire science cultures together. Lisa feels privileged to be at the Institute as the technology revolution takes on momentum, and she is committed to providing the resources that will enable science excellence.

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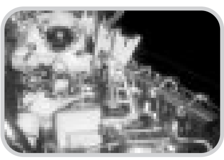

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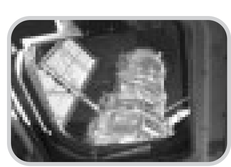

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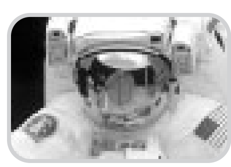

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