SPACE TELESCOPE SCIENCE INSTITUTE

2001 Annual Report

A portrait of the Institute midway in the Hubble program and at the start of our stewardship of NGST.

contents

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 Next Generation Space Telescope, NGST. Our express challenge now is to optimize the scientific return from two major missions.

Our twentieth-year Annual Report is a portrait of the Institute midway in the Hubble program and at the start of our stewardship of NGST.

Annual Report 2001

The opening *Perspective* article reflects on the National Academy of Sciences report that in 1976 recommended establishment of the Institute.

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, provide snapshots of who we are and what we are doing at the start of our third decade, as well as reflections on COSTAR (Corrective Optics Space Telescope Axial Replacement) and our role in finding this solution to correct the spherical aberration of the Hubble primary mirror.

The *Organization* section describes the way in which we organize to meet our strategic objectives and improve our performance. Since the most important organizational challenge before the Institute is adapting to our new multimission environment, we emphasize strategic planning. To reinforce this emphasis, we describe our 2001 *Achievements* in a new format, according to our eight strategic goals.

Finally, as a premier scientific institution, we are pleased to end our 2001 Annual Report with a list of scientific *Publications* by our staff in the last year.

We thank the readers of this 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.

perspective | "Two for One"

Steven Beckwith

The impetus for creating the Institute was a 42-page document produced by a special committee of the National Academy of Sciences in 1976 entitled *Institutional Arrangements for the Space Telescope* ('Hornig committee report'). The Hornig committee examined alternatives for operating what was known then as simply the Space Telescope, one of NASA's most ambitious new programs—an orbiting observatory to serve the community of optical astronomers. Its recommendation to create a special institute, independent of NASA, to run the science program of the Space Telescope was a departure from past practice, in which NASA centers ran such programs. Today's Space Telescope Science Institute is the direct result of that recommendation.

Reading the report after 25 years shows the prescience of the Hornig committee. The qualitative features of the report—that the Institute have a strong science staff, that it be run by an independent organization, that it serve to both support and represent the scientific community in daily interactions with the Hubble project, that it could ensure outstanding scientific excellence and productivity—have been borne out by experience. The quantitative estimate of the size of the Institute's staff, however, fell short of the actual need by almost an order of magnitude. The Hornig committee could not imagine the real complexity of operating the science program for NASA's most complex astronomy mission.

By almost any metric, the Institute has brought great success to the Hubble program and thus proven the wisdom of the Hornig committee's recommendation. Hubble is widely regarded as NASA's most successful scientific mission, even on a 'science per dollar' scale. The Institute has been an essential element of this success through myriad achievements: the rescue of the Science and Operations Ground System (SOGS) software in the mid-80s, the invention of the 'fix' for spherical aberration shortly after launch, the recommendation for the advanced camera to be launched on Servicing Mission 3B to upgrade Hubble's imaging power, the shift toward large programs as the best way to maximize science, and innovative approaches to using the telescope in pursuit of science, the most famous of which resulted in the Hubble Deep Field. A less visible but no less important achievement contributing to mission success has been the establishment of a strong teaming arrangement between the Institute and the Hubble project team at the Goddard Space Flight Center. These achievements were rewarded by NASA's announcement four years ago that the Institute would operate the Next Generation Space Telescope.

NASA followed the principal aspects of the STScI model when it put the responsibility for the science programs of Chandra and SIRTF in institutions outside the NASA system. The Chandra X-ray Center in Cambridge and the SIRTF Science Center in Pasadena provide services to the community similar to those that we provide for Hubble. To cap this trend, NASA has announced its intention to vest the science operations for the International Space Station in an independent organization to be selected in the next year.

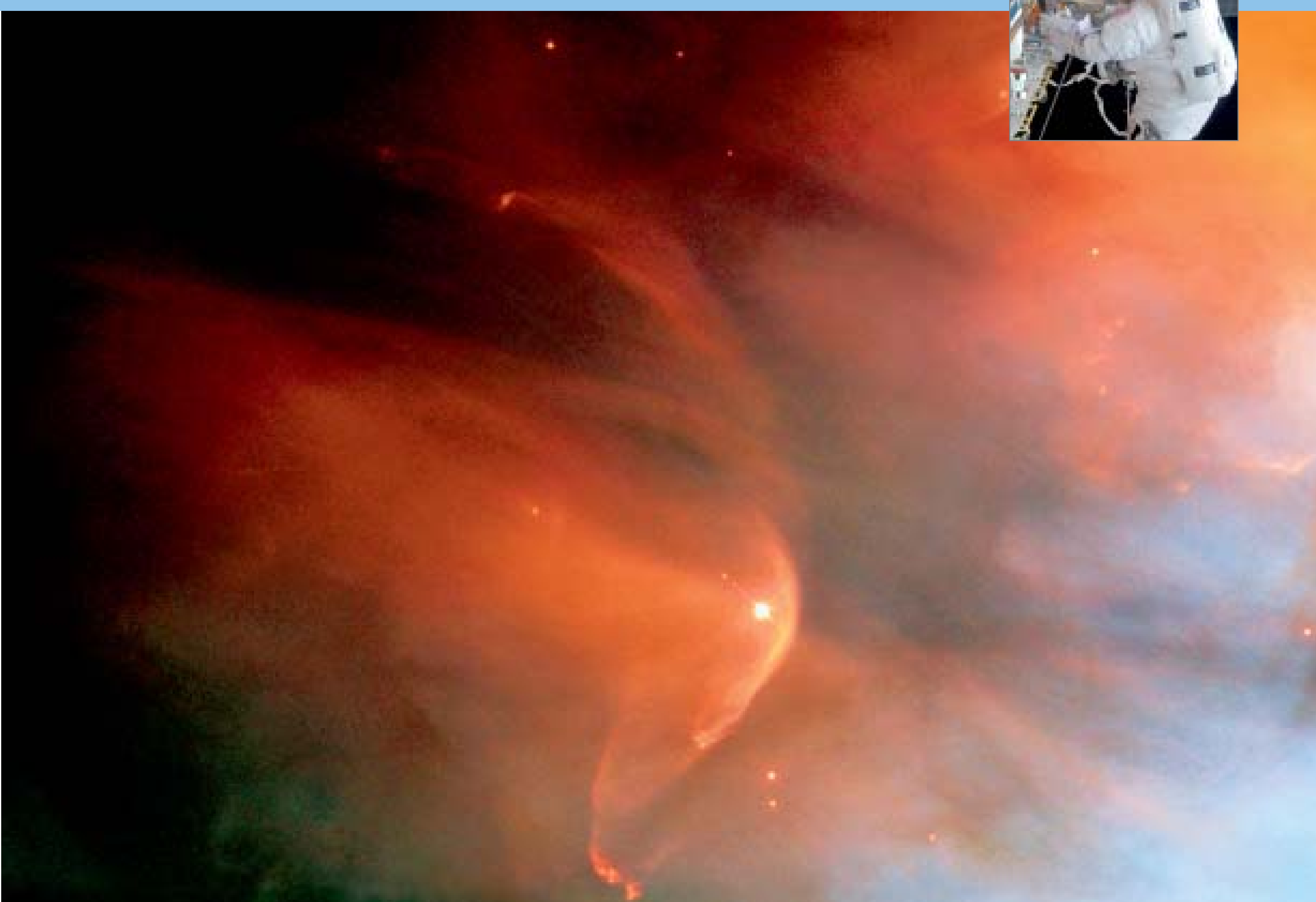
As we face the next ten years,

our most important challenge is to integrate the Institute's experienced team on Hubble with the Next Generation Space Telescope project. Like Hubble, the NGST will be a complex management challenge involving NASA, three outside, multinational instrument teams, multinational contributions to the observatory infrastructure, an industrial prime contractor—and the Institute. Traditional arrangements of NASA contracts for large projects make it difficult to mix teams on two different projects, as we wish to do with our Hubble and NGST staff. Nevertheless, the potential benefits are large. We are constantly improving the systems we use to support Hubble, and we want to adopt the best of these systems at the latest possible times to use on NGST. That was the promise NASA saw in selecting the Institute to operate NGST in the first place.

Over the past several months, I have been engaged with our staff in looking at how we can bring economies of scale to the two projects in our science ground systems. The discussions have been exciting. It is personally invigorating to watch tremendously talented people create new approaches to doing old tasks in ways that improve science and make it easy for scientists worldwide to try out a wealth of new ideas using our space observatories.

With luck, a good teaming arrangement with Goddard Space Flight Center, and a lot of creative energy from our staff, we hope to give the public a 'two for one' deal by doing Hubble and NGST with one team to the mutual benefit of both. Watch this space in the future as the Institute goes beyond the Hornig report and shows how a community-based science organization can increase the value of multiple scientific missions.

news | **profiles**



Mark Abernathy

Mark Abernathy is the Software Testing Team Lead for the Engineering and Software Services (ESS) Division.

Born in 1957 in New York City, Mark grew up in Valley Cottage, a small town about 30 miles to the northwest of the city. He developed a keen interest in astronomy at an early age, receiving his first telescope when he was twelve, and he remains an active observer and amateur astronomer to this day. His interest in science led him to enroll at Rensselaer Polytechnic Institute in 1975, where he majored in physics. He went on to get a master's degree from George Washington University in the program of Science Technology and Public Policy.

After graduating in 1981, Mark went to work at the National Science Foundation for three years, where he worked with scientists and analysts conducting research about how new and emerging technologies were affecting our society. While the work was interesting, job opportunities were few and there were limited career paths for people in this field. So Mark decided to enter the exploding world of computers and software development. He worked for several years at companies developing advanced avionics radar systems. In 1987, he started dating a co-worker named Tammy Lloyd and within a few weeks they both left their jobs. Tammy went to work for the Space Telescope Science Institute, and Mark took a job with a small company in Greenbelt, Maryland, called Nyma, Inc. Mark and Tammy continued to date and, after a long romance, were married in April 1990.

Meanwhile Mark's career was taking off. Nyma's main business was with NASA, and after two years of working on a level-zero data processing system, he joined the proposal team for the major new earth science program called the Earth Observing System (EOS). At that time, this program was one of the largest civilian, object-oriented software development programs ever undertaken. Mark worked with the proposal team and, after selection, joined the project to help integrate and test the ground system component.

Profile

new manager

While on this project he worked with the Systems Engineering Group, the System Integration Team, and the Acceptance Test Team on the first releases of the system. His dedication was rewarded by his selection as Nyma's employee of the year in 1994. It was during this busy time that the couple's two children—Kelsey, a girl, and Dakota, a boy—were born. In this period Mark's interest in astronomy was reinvigorated. Always a keen observer, he purchased several telescopes—to the dismay of his wife, as some of them wound up stored in the living room. After putting up with this for several years, she had a custom storage shed built to hold all of his astronomy equipment!

In the fall of 1997, Mark joined the Institute as a Senior Test Engineer. Two years later he was promoted to Lead of the Software Testing Team within ESS. After almost twenty years as a software test engineer, Mark promotes the field as a long-term career. He feels that people too often treat software testing as a stepping-stone to either systems engineering or software development, whereas it should be viewed as a viable career in itself. Accordingly, one of his first tasks after becoming the Test Team lead was helping ESS define a technical career path for testers at the Institute.

During the past year, Mark has helped develop the system integration and test approach for the Next Generation Space Telescope (NGST) ground system. He worked with the core proposal team to determine cost and staffing profiles for the program. He is currently working with a group of system engineers to determine how best to verify the requirements for the NGST ground system. "Hopefully," he says, "I have learned from the successes and failures encountered on the EOS ground system, and I can apply those lessons-learned to NGST."

Celera Genomics Selects **OPUS for Data Pipeline**

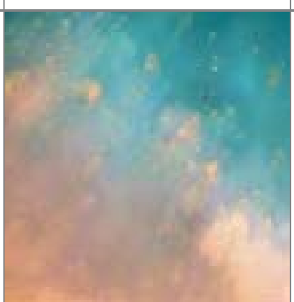
Jim Rose

AURA has licensed Celera Genomics Group to use the Operational Pipeline Unified System (OPUS) software to process biological data. Originally, the Institute's AURA and CSC software engineers developed OPUS to process Hubble data. Many other space observatories and NASA projects use it today in similar applications. The licensing of OPUS is a noteworthy transfer of government-sponsored technology to the private sector with benefits to the Institute and Celera. Celera is the first commercial user of OPUS and the first to use it for biology.

Celera, located in Rockville, Maryland, is a business unit of Applera Corporation. It generates genomic information to understand biological processes. Celera produced the first sequenced and assembled human and mouse genomes, which have been called 'books of life.' Assembling these tomes should be a bit faster and less expensive now, using OPUS.

"Celera has found OPUS to be a cost-effective solution that has cut software system deployment time and saved in-house development effort, thus freeing software engineering resources for other tasks," said John Reynders, Celera's vice president for information systems.

OPUS



OPUS is an example of how the highly talented engineers working on the space program can invent products of practical benefit to such diverse enterprises as biological research, medicine, and industry.

— Steven Beckwith, Institute Director

"OPUS is an example of how the highly talented engineers working on the space program can invent products of practical benefit to such diverse enterprises as biological research, medicine, and industry," said Steven Beckwith, Institute Director. "We are delighted that the Hubble Space Telescope program produced this commercial benefit to complement its scientific research."

Designed and developed with attention to the fundamental requirements of automated data-processing pipelines, OPUS has met the challenges of a wide variety of problems. It is a fully distributed pipeline processing system, usable for any series of applications. It is an environment for running multiple instances of multiple processes in multiple pipelines on multiple nodes. It is a set of monitoring tools to support the user in controlling the distributed pipeline. And it has commendable qualities to be considered in 'make-or-buy' decisions like Celera's: OPUS is extensible, configurable, robust, scalable, and available.

As demonstrated by experience with Hubble, the Far Ultraviolet Spectroscopic Explorer, the Space Infrared Telescope Facility, Chandra, Gemini, Integral, and other missions—and as reconfirmed by its selection by Celera Genomics—OPUS is a proven solution to a wide variety of operational problems. As such, OPUS is a clear measure of the seriousness of the Institute's ability to develop and distribute quality software for the benefit of the scientific community.

Inaugural of the NVO Era

Robert Hanisch

The NVO has the potential to revolutionize the way astronomers work, just as the current generation of information technology services changed modes of astronomy research over the last decade.

The National Virtual Observatory (NVO) is a future federation of astronomical data archives, catalogs, bibliographic services, and encompassing computational infrastructure, which will enable astronomers to use these resources as an integrated system for research. This initiative received 'first light' in the astronomy community with the release of the National Research Council's Decadal Survey, *Astronomy and Astrophysics in the New Millennium,* which rated the NVO as the highest priority among small astronomy projects costing under $100 million. Earlier, the HST Second Decade committee urged the development of "the ultimate, union archive of astronomy," viewing the vast Hubble archive as a cornerstone.

The Decadal Survey committee recognized three factors as creating the NVO opportunity. First, all-sky surveys like GSC-II, SDSS, and 2MASS are producing massive data sets—with more on the horizon as astronomers install ever-larger detector arrays on telescope focal planes. Second, space missions are spawning rich archives of pointed observations, like the Hubble archive, MAST, HEASARC, and IRSA. Third, data storage capacities, network bandwidths, and computing power are increasing rapidly, and software ('middleware') is becoming available to connect distributed computer systems and permit them to work together on a large scale. This technology, the Decadal Survey committee recognized, will permit astronomers to analyze and cross-correlate related results together, drawing on any or all of the surveys and pointed observations.

The NVO vision consists of astronomers conducting desktop research on a vast digital representation of the sky at multiple wavelengths. The integrating technology of the NVO will enable efficient re-use of data and exploration of data sets too large to examine manually. The NVO has the potential to revolutionize the way astronomers work, just as the current generation of information services—the ADS bibliographic system, the NASA Extragalactic Database, and the CDS SIMBAD ▶

database—changed modes of astronomy research over the last decade.

In 2001, working with Johns Hopkins University (JHU), California Institute of Technology (Caltech), and 14 other astronomy and computer science organizations, the Institute helped develop an NVO proposal to the National Science Foundation's Information Technology Research program. The consortium, led by Co-PIs Alex Szalay at JHU and Paul Messina at Caltech, proposed to build the infrastructure for the NVO. The proposal was entitled "Building the Framework for the National Virtual Observatory." In a competitive environment with a success rate of only 10%, this proposal was selected for $10M in funding over the coming five years.

Bob Hanisch has taken responsibility for overall management of the NSF-funded project. Bob and Ethan Schreier are members of the project's executive committee. The project focuses on the development of the overall systems architecture. The architecture will build on enabling technologies, like data models, metadata standards, and grid-based computation and data storage. The project will also provide the means for incorporating existing astronomical data analysis tools into the NVO framework. These components will be integrated into test-beds built upon supercomputer facilities and mass storage systems at the San Diego Supercomputer Center, National Center for Supercomputing Applications, Fermi National Accelerator Laboratory, and the new Distributed Terascale Facility.

The development plan is driven by an aggressive schedule of science demonstrations. The purpose of these demonstrations is to clarify the goals and capabilities of the NVO, ensuring that science requirements will define the technology initiatives. The science demonstrations will also facilitate early and frequent community input to the project, to help ensure that the NVO meets the needs of active researchers.

The NVO framework proposal emphasized the potential benefits of the NVO for public outreach and education based on both astronomy and computer science. To pursue these benefits, the Institute's Mark Voit will lead the development of partnerships with museums, planetariums, commercial software developers, and educators.

European astronomers have also noted the science opportunities of the virtual observatory, and two major initiatives began there in 2001: AstroGrid in the U.K. and the Astrophysical Virtual Observatory, funded by the European Commission. Other projects related to the virtual observatory are getting underway in Germany, Italy, Chile, Australia, Japan, and India. The Institute is using its long-established international relationships to foster collaboration and coordination among these projects. While all of these projects have certain national interests, their leaders are ultimately committed to a truly international virtual observatory —a facility providing open and equal access to data from all observatories.

Massive Data Sets from All-Sky Surveys

GSC-II Guide Star Catalog—II http://www-gsss.stsci.edu/gsc/gsc2/GSC2home.htm

SDSS Sloan Digital Sky Survey http://archive.stsci.edu/sdss/ and http://www.sdss.org/

2MASS 2-Micron All-Sky Survey http://www.ipac.caltech.edu/2mass/

Rich Archives of Pointed Observations

Hubble archive http://archive.stsci.edu/hst/

MAST Multimission Archive at Space Telescope http://archive.stsci.edu/

HEASARC High Energy Astrophysics Science Archive Research Center http://heasarc.gsfc.nasa.gov/

IRSA Infrared Science Archive http://irsa.ipac.caltech.edu/

Astronomy Information Services

ADS bibliographic system Astrophysics Data System http://adswww.harvard.edu/

NASA Extragalactic Database http://nedwww.ipac.caltech.edu/

CDS SIMBAD Centre de Données astronomiques de Strasbourg http://cdsweb.u-strasbg.fr/

Denise Taylor

Denise Taylor, the Lead of the Observation Planning Team in the Hubble Operations Department,

Profile

new manager

grew up near Norfolk, Virginia. Her high school physics teacher sparked her interest in astronomy with field trips to the local planetarium. After obtaining a bachelor's degree in Physics and Astronomy from the University of Virginia, Denise spent a year teaching physics and algebra at a military school in northern Virginia. There, she learned downhill skiing and minor auto repair, thanks to students' practical jokes. She then entered the University of Massachusetts at Amherst, where she studied stellar evolution and star formation in spiral galaxies. She left UMass with an MS in Physics, an MS in Astronomy, and a husband (the Institute's Science Planning and Scheduling Team lead, Dave Taylor). She worked for four years as the Assistant Director of Elementary Physics Laboratories at Mount Holyoke College in South Hadley, Massachusetts, in an otherwise all-male physics department in an all-female college. Her love of teaching brought her to Mount Holyoke's 'SummerMath' program for several summers, where she developed and taught an astronomy class for high school girls.

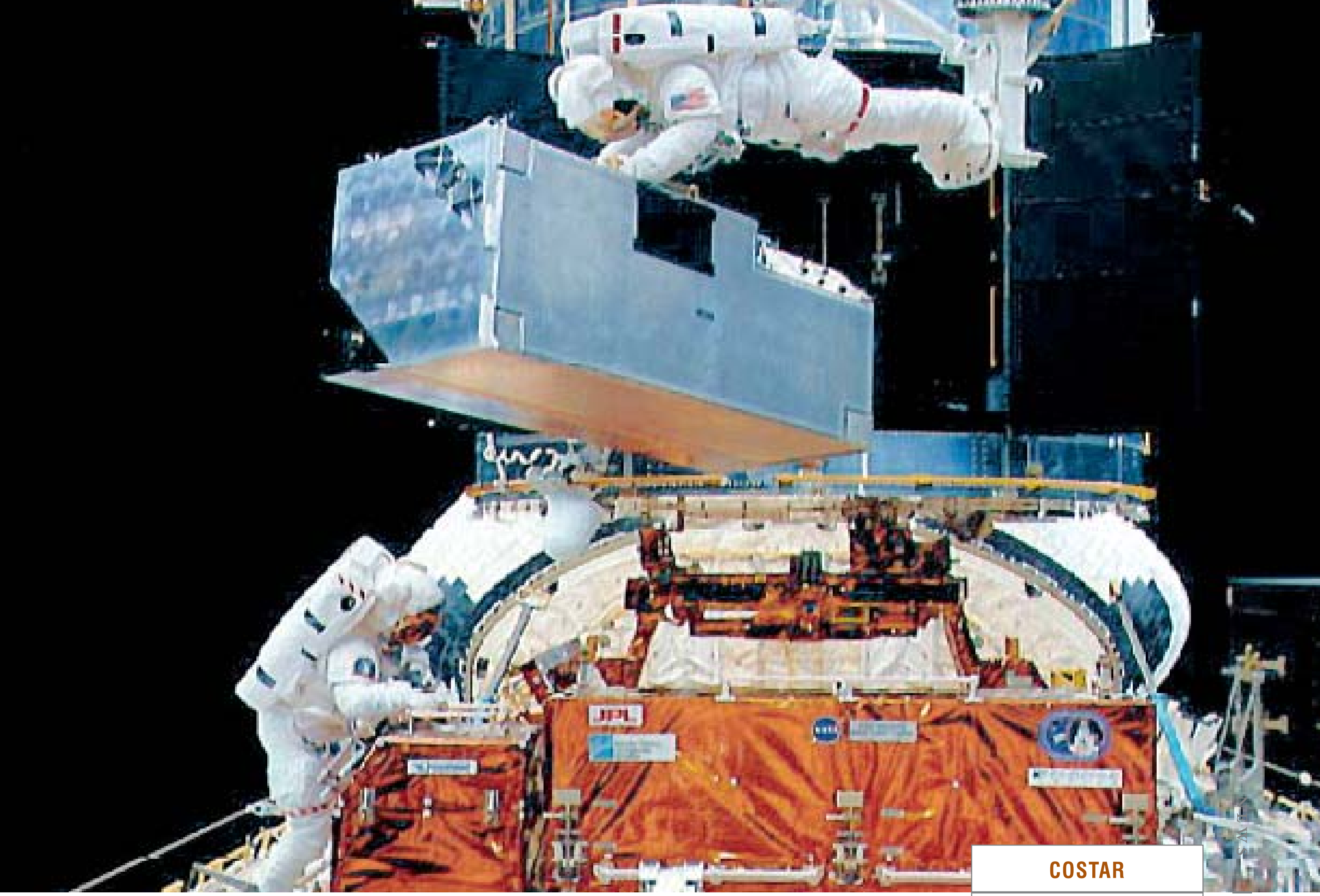
Leaving Massachusetts in 1989, Denise headed to Maryland with her husband and their new son. She became the first Telescope Operations Assistant for the International Ultraviolet Explorer (IUE) at the Goddard Space Flight Center in Greenbelt, Maryland. For over two years, she provided assistance to astronomers in planning their IUE observations.

Denise came to the Institute in 1992 as a Technical Assistant, working on proposal implementation in the Science Planning Branch. She became an expert in implementing proposals using the High Speed Photometer, the Hubble original science instrument that was removed for the COSTAR installation. She then took over all science and calibration proposals using the Fine Guidance Sensors (FGSs), working closely with the Space Telescope Astrometry Team at the University of Texas in Austin.

As part of the 1994 Institute reorganization, Denise became a member of the development team that redefined the role of Technical Assistants in the new PRESTO Division (Project to Re-Engineer Space Telescope Observing). Technical Assistants became Program Coordinators (PCs), expanding their responsibilities from Phase II proposal ingest to observation flight preparation and becoming the primary point-of-contact between Hubble users and the Institute during Phase II observing. As one of the first Senior Program Coordinators, Denise was responsible for implementing FGS, Faint Object Spectrograph, and Wide Field Planetary Camera 2 science and calibration proposals, as well as helping to develop operational processes for analyzing bright object alerts on all instruments. She later worked on Space Telescope Imaging Spectrograph and Near Infrared Camera and Multi-Object Spectrometer proposals, and in 1997, became PRESTO's first official Calibration Manager, coordinating implementation and scheduling of all science instrument calibrations. In 1999, in order to pass more planning responsibilities on to the PCs, the PC Team merged with the Long Range Planning Group and became the Observation Planning Team, with Denise as Lead.

During her years at the Institute, Denise has served on various users' support committees, including the Users' Support Coordination Committee and the Telescope Time Review Board, developing policies and procedures for Program Coordinators and Contact Scientists working with Hubble users. She was one of the original members of the Director's Leadership Forum, which provided advice on the Institute's reorganization in 2000 and identified several areas of needed improvement in Institute internal affairs. She has recently worked with Next Generation Space Telescope (NGST) teams to help define operational planning and scheduling processes and staffing requirements for the NGST science operations proposal.

Denise's outside interests no longer include skiing. She finds reading and quilting to be relaxing, and enjoys spending time with her husband and son.



COSTAR

Corrective Optics Space Telescope Axial Replacement has been emblematic of the Institute's role to integrate science and engineering for Hubble's success.

COSTAR and **Hubble Science**

Shortly after Hubble was launched in April 1990, astronomers and engineers realized that there was a problem with the telescope's images. Their quality failed to improve despite attempts to adjust the alignment of the optics. In June, NASA concluded that the Hubble primary mirror had been manufactured with the wrong shape, causing spherical aberration. During that summer, at a time when there was no organized plan to correct the problem, the Institute stepped in and organized the HST Strategy Panel of experts. The Panel met three times between August and October 1990, conceiving and debating possible solutions. In early 1991, the published Strategy Panel report defined and made the case for a comprehensive solution, which included COSTAR—Corrective Optics Space Telescope Axial Replacement—an instrument box that astronauts could install in Hubble to deploy small mirrors in front of three Hubble science instruments. The optics had precise prescriptions to cancel spherical aberration at the field position of each instrument entrance aperture.

COSTAR was installed during the first servicing mission in December 1993. Over the next years, COSTAR restored most of the utility of the Goddard High Resolution Spectrograph (GHRS), the Faint Object Spectrograph (FOS), and the Faint Object Camera (FOC). The accompanying articles are brief reflections on the meaning of COSTAR for these instruments and Hubble science.

Shortly after 11 AM on 29 November 2001, the Institute's Flight Operations Team sent COSTAR its last command via a real-time link, withdrawing the corrective optics in front of the last remaining instrument to use COSTAR, the FOC.

To the Institute staff, COSTAR has been emblematic of our role to integrate science and engineering for Hubble's success. Its retirement is an occasion both to think back about our collective accomplishments and to look forward to meeting whatever challenges the future may bring.

Ian Griffin

Profile — new manager

Ian Griffin, Head of the Office of Public Outreach, joined the Institute in early 2001. Born in southern England, exposure to the original series of "Star Trek" on TV ensured he developed a passion for astronomy at an early age. Once he obtained his first telescope, he was hooked. He spent many nights using it to gaze at galaxies, planets, and comets from his parents' backyard.

A desire to learn more about the universe made college courses in astronomy a logical and attractive choice. Following six years of study (and much round-the-world travel to observatories in Chile, Australia, South Africa, Hawaii, and the Canary Islands) he graduated with a Ph.D. in infrared astronomy from University College London in 1990. While in college, Ian developed and taught several 'astronomy for everyone' continuing education classes for adult students and gave numerous talks to astronomy clubs around London. He found his interactions with the public unashamed fun, and he developed a real enthusiasm for sharing astronomy.

By quirk of fate, the same year Ian graduated, the Directorship of the Armagh Planetarium, one of the U.K.'s largest astronomy education centers, became vacant. Located in the beautiful cathedral city of Armagh in Northern Ireland, the Planetarium is publicly funded to bring astronomy and science to the widest possible audience. He applied and was appointed Director in October 1990 despite being the youngest candidate, age 24. He spent the next five years working with the amazingly supportive Planetarium Trust Board to upgrade and improve facilities and to create a world-class astronomy education center. In addition to helping raise more than $3 million to fund a large expansion, Ian wrote and produced over 15 educational multimedia shows and a large number of interactive exhibits for the planetarium. He was also involved in the planning of a 25-acre astronomy park in the land around the Planetarium. During his time in Armagh, Ian married Maria, and together they had two daughters, Hope and Merope (named for a star due south at the time of her birth).

In 1995, after five years in Armagh, Ian moved his family to America, to take charge of the planetarium, observatory, and science center at the Astronaut Memorial Hall in Cocoa, Florida. Located on the campus of Brevard Community College, this 50,000-square-foot astronomy complex offered a great opportunity to learn about and become involved in education and public outreach in the United States. Ian wrote several planetarium shows and obtained funds to upgrade the planetarium theater so that it could be used interactively by audiences. In 1997, Ian obtained nightly images of comet Hale-Bopp, which were then web-cast to large audiences via the Internet. Ian's photos were widely used in the media, and to this day the database of Hale-Bopp images he created is still one of the largest available online. Asteroids he saw moving in the images obtained of Hale-Bopp inspired a program of public asteroid hunting and astrometric observation of near-earth objects. Between 1997 and 1999, this program discovered 11 new main-belt asteroids and refined the orbits of dozens of near earth objects. While in America, Ian and Maria's family increased in size again with the birth of their son Aengus in 1998.

His new interest in asteroids and comets and the chance to work at a planetarium and observatory in the southern hemisphere drove Ian to move his family again, in 1999, this time to Auckland, New Zealand. He became Chief Executive Officer for the Auckland Observatory and Planetarium Trust, which operates a science center on the famous One Tree Hill, in central Auckland. Funded partly by the New Zealand department of education to teach the astronomy components of the New Zealand curriculum, the observatory also operates an extensive media and outreach campaign, reaching nearly 100,000 people annually. During his relatively short time in New Zealand, Ian helped produce a new strategic plan, raised funds for upgrading the observatory equipment, designed, installed, and commissioned a robotic observatory, and wrote and produced several astronomy productions for the planetarium. He also wrote a monthly column for the New Zealand Herald and became active in media astronomy, appearing numerous times on national TV and radio. Perhaps the highlight of his time in New Zealand occurred on December 31, 1999, when he was lucky enough to take part in a millennium TV program. He appeared between Sir Edmund Hillary and the New Zealand Prime Minister on the broadcast, which was seen throughout the British Commonwealth.

Although he loved New Zealand, when the opportunity to work in the Office of Public Outreach at the Institute came up, Ian had to take it. Being part of the team working on Hubble and NGST was simply too exciting a chance to miss! Hence, early last year the Griffin family moved once again, this time to Baltimore for what they hope will be a long stay.

COSTAR and the **FOC**

Mark Voit

Hubble's versatile Faint Object Camera (FOC), provided by the European Space Agency, was the only first-generation Hubble camera designed to take full advantage of the telescope's exquisite optics. Sacrificing a wide field of view for the utmost in image detail, it was supposed to act as Hubble's telephoto lens, capturing features on the surfaces of planets and in the atmospheres of stars that no other camera could see. That is why the first FOC images were so devastatingly disappointing—they revealed Hubble's optical flaws with ruthless clarity. Thus, FOC imaging became the acid test for any scheme to correct Hubble's vision. A set of corrective optics good enough to restore the FOC's performance would be more than good enough for Hubble's other instruments.

With the installation of COSTAR, the FOC's long-promised image quality was finally realized. However, one of its first breakthroughs was actually a spectroscopic observation. By passing quasar light through one of the FOC's two prisms, Peter Jakobsen and his team were able to make the first measurements of helium ionization in the early universe. Later milestones included the sharpest-ever pictures of Pluto with its companion Charon, and a direct image resolving the surface of the supergiant star Betelguese, the first to reveal atmospheric details on a star other than our sun. Ironically, a few of the FOC's more notable accomplishments involved high-precision observations of some of the brightest objects in the sky, such as the stars Betelguese, Capella, and Mira.

The removal of the FOC during the 2002 servicing mission marks a changing of the guard, because the new occupant of its instrument bay, the Advanced Camera for Surveys, has a special high-resolution channel. This channel—also designed to deliver the sharpest possible Hubble images—will pick up where the FOC left off. We wish it well.

Some of the sharpest-ever pictures of the supergiant star Betelguese (below) were captured with the Faint Object Camera. We bid it a fond farewell.

FOC

COSTAR and the **GHRS**

David Soderblom

Of all Hubble's original science instruments, the aberrated point spread function affected GHRS least, which meant COSTAR's corrective optics improved its performance less dramatically than for Hubble's other instruments. The GHRS had only two apertures. The Large Science Aperture (LSA) was 2.0 arcsec square, which was large enough to permit accurate spectrophotometry even with spherical aberration. The LSA's line spread function was degraded, but this loss in spectral resolution was partly recoverable by post-observation data processing. On the other hand, spherical aberration did not degrade the spectral resolution of the Small Science Aperture (SSA), but it did reduce the throughput because of the SSA's small size, 0.2 arcsec square. After COSTAR was installed, the throughput of the SSA increased by about a factor of 2, permitting its use on many more objects. COSTAR improved the resolution of the LSA but changed its throughput little, because losses from the two additional reflections and the plate scale enlargement offset the gains from the sharper image.

Perhaps the greatest benefit of the first servicing mission for the GHRS was the installation of a device that enabled observations to be made with side 1 of the instrument. Shortly after launch, an electronics failure had disabled the side 1 capabilities, including the short-wavelength detector and two gratings, G140L and Echelle-A. These capabilities were designed to meet important spectroscopy requirements that NASA set on Hubble performance before launch. G140L provided Hubble's best overall throughput for low-resolution spectra of faint sources. Echelle-A provided high spectral resolving power (R=100,000) for bright objects, which is needed to investigate interstellar atoms and molecules along lines of sight in the Galaxy. Because the full resolution of Echelle-A could only be achieved with the SSA, both the restoration of side 1 and the throughput improvement of COSTAR were needed to regain effective high-resolution spectroscopy in the far ultraviolet.

The saddest day for all of us associated with this fine instrument occurred about a week before the GHRS was to be taken out of the telescope on the second servicing mission in 1997, to make way for STIS. An internal electronics component failed, leading to a complete shutdown. This failure lost only a few planned observations, but among them was a last-minute campaign to study potential contamination on the COSTAR mirrors by withdrawing those mirrors and measuring the throughput below Lyman α.

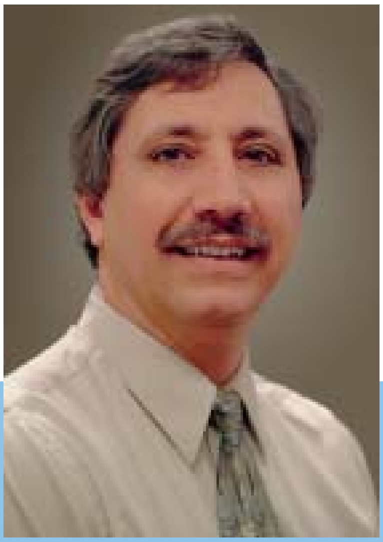
The GHRS will live on in Hubble because some of its components have been recycled into the Cosmic Origins Spectrograph.

Joe Pollizzi

Joe Pollizzi is a 17-year veteran of the Space Telescope Science Institute

and one of the few early staff members native to the Institute's host city, Baltimore, Maryland.

From a young age, the emerging field of computer technology fascinated Joe, and he decided early on that this area of study was his goal. A local, private high school further encouraged him by offering him the opportunity to learn a computer language (BASIC) and providing access to a large timesharing system (the Dartmouth System). By the time Joe entered college, he had already mastered BASIC and taught himself Fortran. Joe went on to Villanova University and pursued a degree in electrical engineering, with the intent of becoming a computer architect. However, in his last year of college he realized his talents lay more in software than in hardware design. Graduating in 1973 with a bachelor's ▼



Profile — new manager

▼ in electrical engineering, Joe entered the computer science graduate program at the University of Maryland at College Park and received his master's in 1977.

While at College Park, Joe and a few colleagues began discussing the application of computing technology to critical care medicine, as at trauma centers and intensive care units. Their discussions led to the creation of a small company, Quantitative Medicine, Inc., and a contract with the renowned Shock Trauma Center at the University of Maryland Medical Center. In this partnership, QMI developed a clinical information management system, Quantitative Sentinel, which integrated all the vital patient information from laboratories, surgical suites, and bedside instrumentation. That system is now the leading such application worldwide.

In late 1983, with the impending birth of his daughter, Kristen, Joe made the decision to look for a new area to apply his talents. Being an admitted space geek, he knew of the Space Telescope program and the selection of the Johns Hopkins Homewood campus as the host site for the institute to operate the telescope.

That interest developed into a job application and Joe joined the Institute in 1984 to work on the Guide Star Selection System.

After the guide star system work, Joe joined the team responsible for the sustaining engineering of the Science Operations Ground System (SOGS). Joe led the Support Software Group, which provided the developmental tools, and core system infrastructure. He eventually became the Project Engineer of the team, with technical oversight of the SOGS work.

In the early nineties, Mark Johnston and Joe wrote a successful Institute proposal to produce StarView—the user interface for the Hubble archive. Joe led the development effort for Starview, and went on to help ensure the completion and deployment of the HST archive.

In the mid-nineties, Joe became the Deputy Head of the Science and Engineering Services Division. Following the most recent reorganization of the Institute, he became Deputy Head of the new Engineering and Software Services Division. Looking to the future directions of the Institute, Joe recently joined the Next Generation Space Telescope Division, as the Ground Systems Development Manager.

COSTAR/**FOS Science**

Jerry Kriss

Black holes have captured the imagination of the public and astronomers alike. Astronomers had invoked their presence in active galaxies and quasars for decades. Material spiraling into the deep gravitational wells of supermassive black holes—a billion times the mass of the sun—could efficiently produce as much energy as a whole galaxy from a region no bigger than our solar system. Yet, before Hubble, the proof of this concept was elusive. Finding evidence that such a small volume contained that much mass required spatial resolution that was just out of reach of ground-based telescopes. The installation of COSTAR during the first Hubble servicing mission gave the Faint Object Spectrograph (FOS) on Hubble the ability to make the first definitive measurements that proved that black holes lie at the centers of active galaxies.

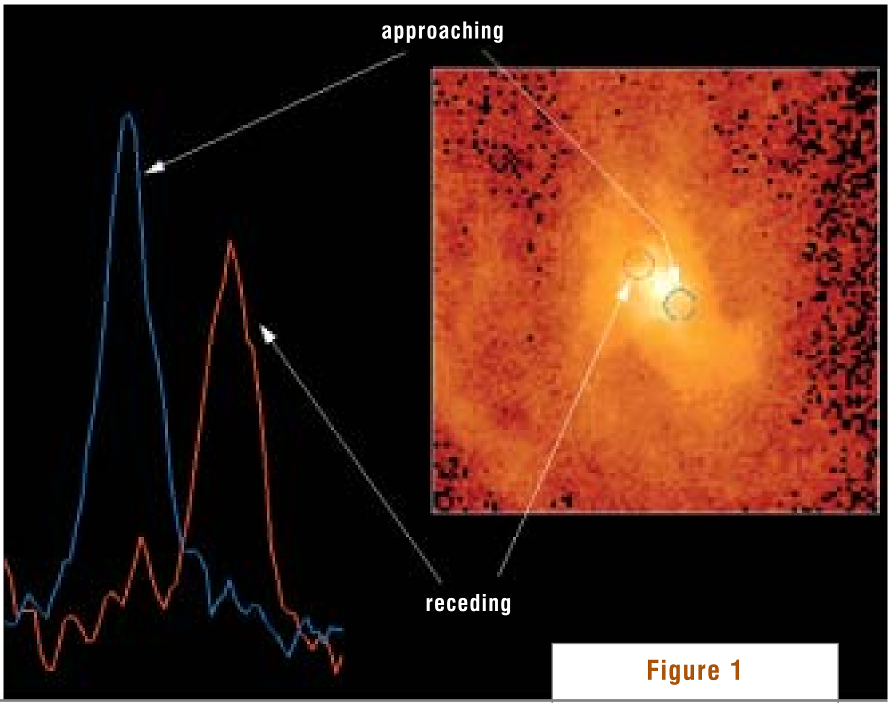
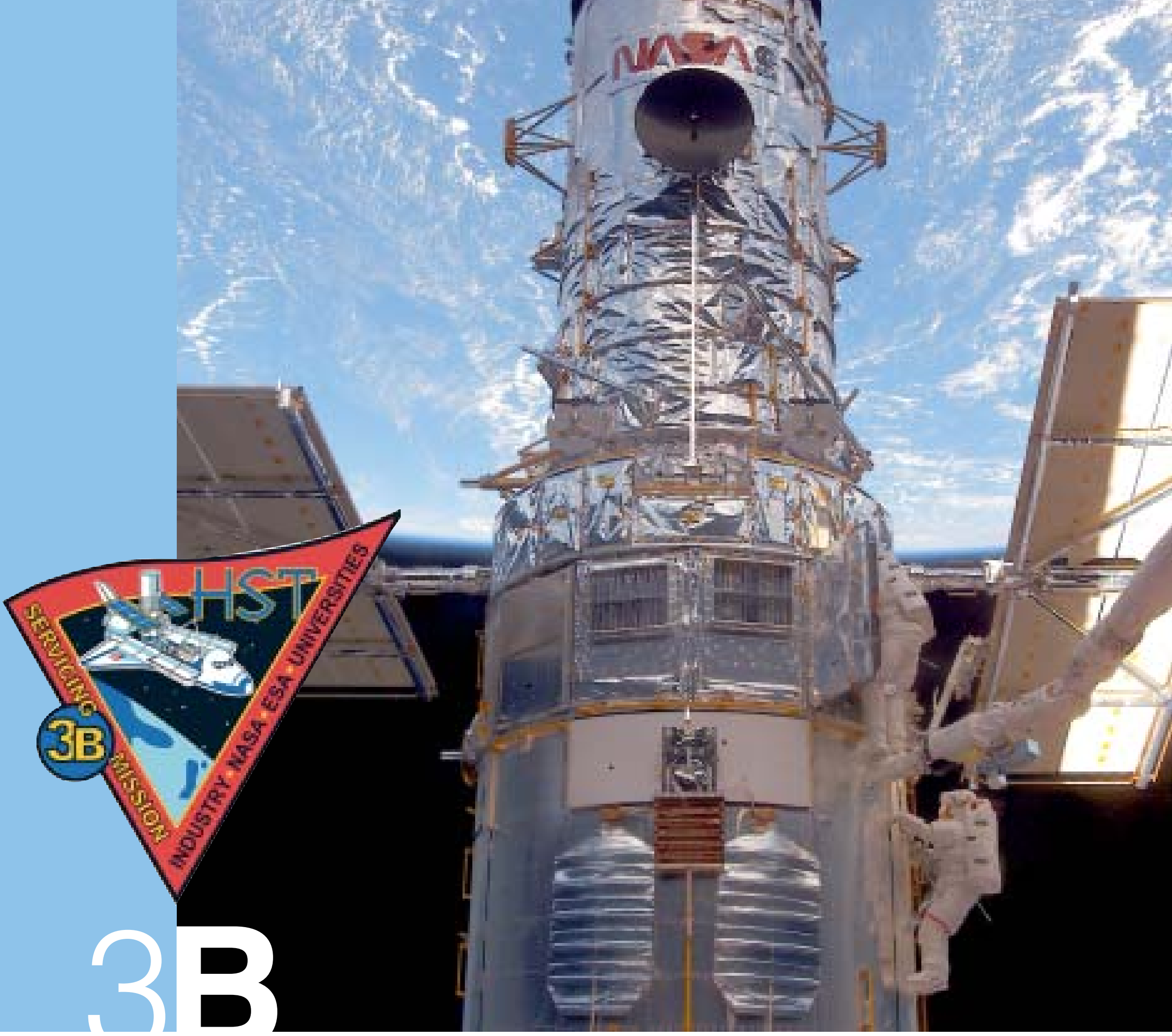


Figure 1

Spatially-resolved spectra of a rotating disk of hot gas in the core of active galaxy M87 obtained using the Faint Object Spectrograph with COSTAR. The gas on one side of the disk is speeding away from earth (redshifted), at a speed of about 550 kilometers per second. The gas on the other side is approaching viewers on earth (blueshifted). This is the spectral signature of the tremendous gravitational field at the center of M87—clear evidence that the region harbors a massive black hole.

Using the newly restored vision of Hubble, the FOS Investigation Definition Team, led by Richard Harms and Holland Ford, quickly observed the center of the nearby radio galaxy M87, which was thought to harbor a billion-solar-mass black hole. Harms used the small apertures of the FOS to dissect the light from the gas disk around the center of M87, which had been discovered earlier by Ford. By measuring the wavelengths of spectral lines formed in the gas at each of these positions, they could measure the velocity of the gas in the disk, prove that it was rotating, and show that a 2.4-billion-solar-mass object in the center was required to explain the velocities they observed. The observations are shown schematically in Figure 1.

These inaugural observations using COSTAR ushered in an era in which the combination of Hubble and the FOS was the ultimate machine for finding black holes at the centers of galaxies. In addition to those found in several more active galaxies, black holes proved to be ubiquitous in the centers of many nearby, normal galaxies. This result confirmed the suspicions of many astronomers that the burned-out remains of luminous quasars prevalent in the early universe still lurked at the centers of otherwise normal galaxies—perhaps awaiting a new influx of stars and gas to trigger a rebirth. The number of known black holes in galaxies has now grown so large that astronomers are able to study their 'demographics,' to learn, for example, how the mass of the black hole is related to the size and shape of the host galaxy. Ultimately, this information will help astronomers understand the role of quasars and black holes in galaxy formation and evolution.



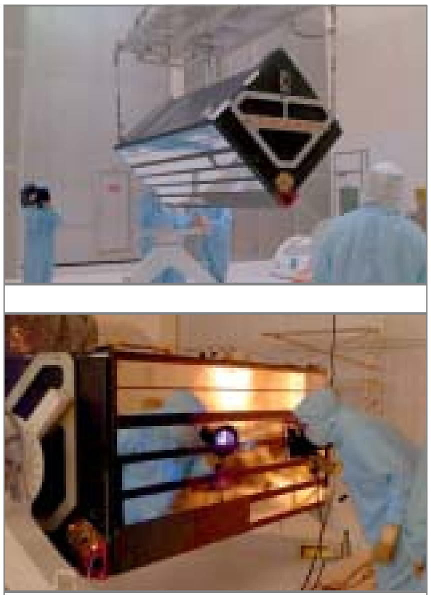
The Institute and **Servicing Mission 3B**

Chris Blades

As the NASA Space Shuttle *Columbia* rolls to Launch Pad 39A and awaits its cargo of instrumentation for Servicing Mission 3B to Hubble in February 2002, the Institute takes pride in its many contributions to this remarkable endeavor. Since launch in 1990, three servicing missions have famously overcome problems and improved Hubble's scientific capability. The Institute's strong participation is based on its responsibility to optimize Hubble's usefulness to the community, for which servicing missions provide the most dramatic and important opportunities. Since 1998, Institute staff have been deeply involved in scientific and technical preparations encompassing all areas of Institute work and touching all operational divisions and departments.

During Servicing Mission 3B, astronauts will install a new optical and ultraviolet camera, the Advanced Camera for Surveys (ACS), for which the Institute has played key roles from inception to completion. Astronauts will also install a high-tech cooling system that will revive the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), which is already onboard.

The origins of the ACS go back to an Institute report published in 1993, entitled "The Future of Space Imaging" (FOSI), which was written when Hubble Deep Fields and evidence of the accelerating universe were still well in Hubble's future. In the FOSI report, a community-based study group of astronomers developed a set of recommendations for the new camera, including a deep, wide-field imaging capability. The prime ACS channel, the Wide Field Camera, ▶



ACS

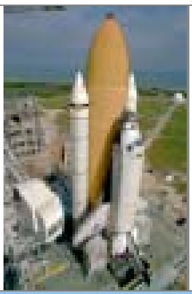
embodies this particular recommendation and should greatly enhance Hubble's capacity to pursue observational cosmology, especially deep-field imaging and probing the accelerating universe. Designing and constructing the ACS has been a group effort by Johns Hopkins University, Goddard Space Flight Center (GSFC), Ball Aerospace Corporation, the Institute, and scientists from universities in the United States and Europe. Members of the Institute scientific staff are on the ACS science team, where they have helped guide the instrument through its development program.

The Institute developed a significant part of the operational procedures and software for on-orbit observations with the ACS. It conceived, wrote, and tested the ground procedures that will receive ACS data from the orbiting spacecraft, calibrate the data, and store them safely in the archive. It supported the hardware integration of the camera, providing much of the expert analysis of the pre-launch test data, and developed the observing scenarios that will be used as part of the initial turn-on, optical alignment, and calibration of the instrument. Teams of scientific, technical, and managerial staff from many Institute organizations carried out this work for ACS.

The astronomical community has shown strong interest in the deployment of the ACS. In Cycle 11, they responded to the first-round opportunity to use ACS with a large number of excellent proposals. The Telescope Allocation Committee awarded ~60% of the total Hubble observing time to ACS science, the largest allocation to a single instrument since operations began in 1990.

Institute staff members have also supported development of the NICMOS Cooling System, NCS. GSFC led this effort. The NCS is an experimental, super-quiet cooling system, which uses micro-turbines capable of spinning faster than 400,000 rpm. It will re-cool the NICMOS detectors, revive their infrared sensitivity, and return this unique, important instrument to duty. During the early NCS development, the Institute organized an independent science review to advise GSFC on the feasibility of the device and the likely utility of a revived NICMOS. This review gave the go-ahead to build and install NCS.

Hubble discoveries have inspired scientists and the public for a decade, and with installation of ACS and NCS, Hubble images are about to get even better.



The Institute's Hubble Division gained valuable experience operating and calibrating NICMOS prior to the exhaustion of its cryogen. This experience has been applied to the design, development, and testing of the NCS. To support the revival of NICMOS, the Institute improved its operational procedures and developed observing programs, which will be used as part of the initial cool-down, alignment, and calibration.

Toward the end of the actual servicing mission, the Institute will re-acquire control of Hubble and begin a program of instrument verification. A team drawn widely from the Institute staff has been preparing this program since 1998. The team is dedicated to ensuring the safe and timely recommissioning of existing instruments and installation of the ACS prior to the first science observations.

The possibility of contamination during a servicing mission is always a concern. Contamination could degrade the ultra-violet performance of the observatory. The Institute will monitor the level of contaminants with care and exercise caution in turning on and cooling the instruments. The cooling period for NICMOS will be one month, which will affect the timelines for all other instruments. During this time, the Hubble Division will monitor NICMOS closely. Once a basic alignment and focus of ACS and NICMOS have been achieved, the Institute will obtain a variety of science images to assess the performance and demonstrate the science capabilities of the instruments. These images will be part of the early release program. Working with scientists close to the data, the Institute will prepare press releases and help NASA disseminate these early results to the press, the public, and the astronomical community at large.

As the verification process continues into the late spring of 2002, the Institute will resume scheduling science observations, initially for the ACS science team but soon thereafter for general observers, too. In this phase, the Institute will start acquiring a detailed understanding of the real, on-orbit nature of the new instruments, which it will use to revise the exposure calculators and update the instrument handbooks. With more experience and after detailed and exhaustive calibrations, the Institute will revise and improve its operations and software calibration procedures, fine-tuning the instruments and preparing for future observing cycles.

Hubble discoveries have inspired scientists and the public for a decade, and with the installation of ACS and NCS, Hubble images are about to get even better. The Institute plays many roles in each servicing mission, with staff throughout the Institute contributing to the collective effort. The staff recognizes the importance of this work and finds great satisfaction in guiding the new instruments over their hurdles, readying the ground systems to operate them, and sharing in the excitement of the new data.

Mark Clampin

Mark Clampin is the Group Lead for the Advanced Camera for Surveys (ACS) Group

in the Hubble Division's Science Instruments and Support Department. He grew up in the English seaside town of Clacton-on-Sea, which fostered a lifelong interest in travel. An early love of astronomy led him to undergraduate study in London, followed by graduate study in astronomy at the University of St. Andrews, where he managed to spend four years without playing a single round of golf.

At the invitation of Francesco Paresce, Mark came to the Institute in 1986 under a European Space Agency (ESA) fellowship to work on the development of microchannel-plate-based detectors for ground-based astronomy. During this period he also worked with Paresce on the development of ground-based coronagraphs. In 1988, he moved to the Center for Astrophysical Sciences at Johns Hopkins University, ▼

Profile

new manager

▼

where he joined a team led by Sam Durrance to build a coronagraph incorporating adaptive optics for high contrast imaging of circumstellar environments. Mark led this team for two years while Sam was training as a payload specialist for the Astro mission. During this time, Mark oversaw the building of the first generation Adaptive Optics Coronagraph (AOC) with a tip/tilt image motion correction system. He used it to conduct the first study of the inner β Pictoris disk. He also used the AOC to study the environments of luminous blue variables and to search for brown dwarf companions. Others have continued to use the AOC for high angular resolution coronagraphy after its permanent relocation to Mount Palomar, where it was most recently used to discover the first brown dwarf, GL229B. In parallel with the AOC science program, Mark built a prototype deformable mirror for a wavefront curvature system.

In 1992, Mark moved back to the Institute to become an Instrument Scientist supporting the development of new instruments for Hubble. Initially, he supported the first servicing mission as a Wide Field Planetary Camera 2 (WFPC2) Instrument Scientist, moving on to become a STIS Instrument Scientist after WFPC2 completed its Orbital Verification (OV). Mark's work on STIS focused on supporting the STIS detector development program, and he played a major role in characterizing the bright object protection requirements for the photon counting Multi-Anode Microchannel Array (MAMA) detectors through the second servicing mission OV. He collaborates with the STIS Investigation Definition Team using the STIS coronagraph to image the environments of Ae/Be stars. He developed and built a coronagraph for the New Technology Telescope in the Institute's instrument laboratory and used it to continue studies of the environments of luminous blue variables, subsequently continuing this program with WFPC2 and Near Infrared Camera and Multi-Object Spectrometer (NICMOS) imaging.

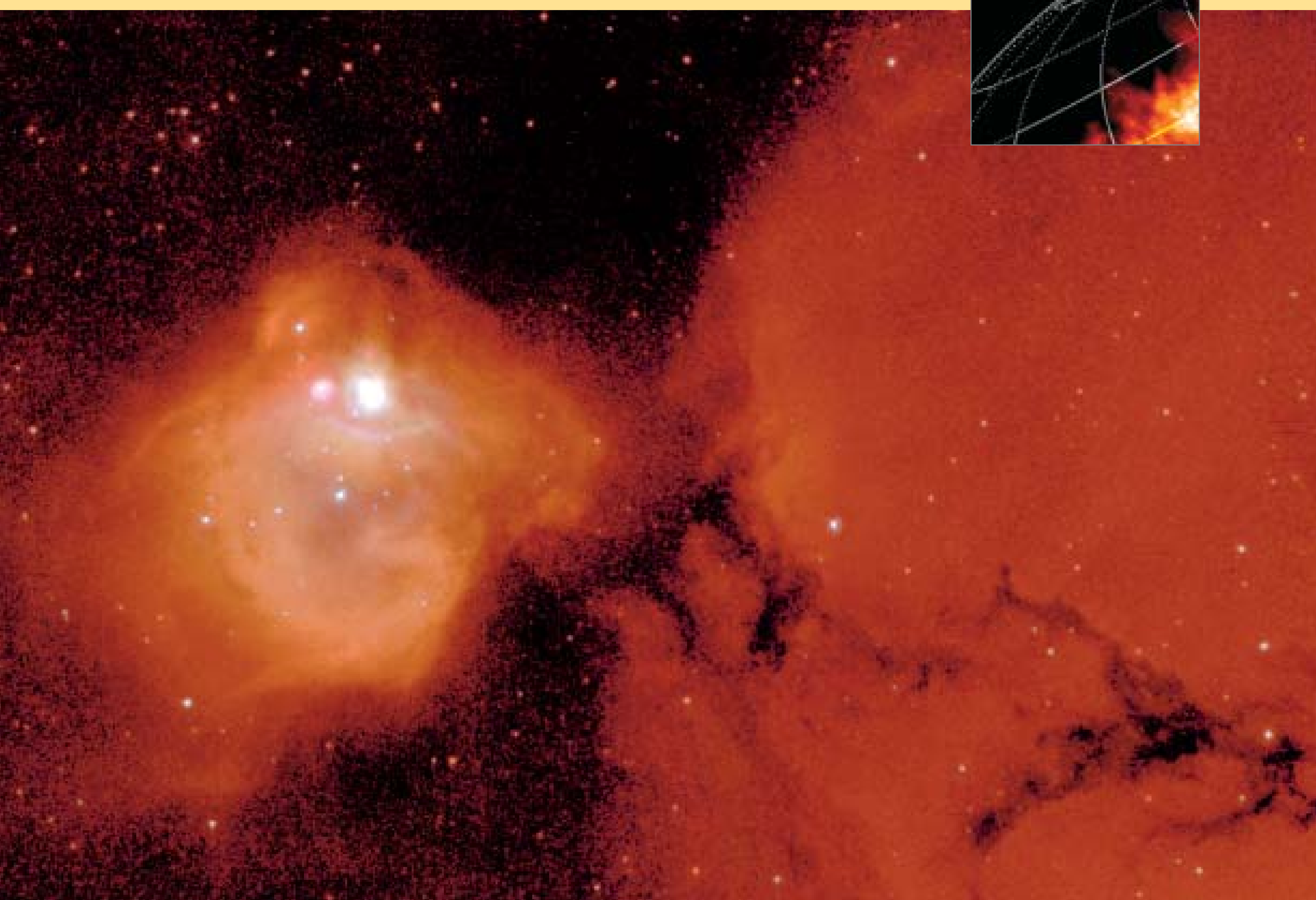
In 1994, Mark was a member of the science team awarded the contract to build ACS. He played a major role in developing ACS as the detector lead, responsible for coordinating the procurement and delivery of the ACS detectors.

During this time he served the Institute as an ACS Instrument Scientist, working to implement support for ACS science operations. Mark became the Group Lead for ACS in 1998.

In the last few years, Mark has become interested in the problem of direct planet detection and recently formed a science team to develop a MIDEX proposal. The Jovian Planet Finder, a 1.5 meter aperture coronagraph, is designed to survey nearby stars for the presence of Jovian planets. He is also involved in the development of a new deformable mirror technology appropriate to the demands of imaging terrestrial planets with a coronagraph in the Terrestrial Planet Finder mission.

Outside of work, Mark's main interest has always been scuba diving. He started diving in the U.K. in 1974 and has dived all over the world. At university, he ran the university dive club and led several large diving expeditions. The culmination of his diving career came in 1998, when he spent two weeks diving the Bismark Sea and Dampier Straits in Papua New Guinea. Mark is also a keen skier and has recently started to learn to fly. He is married to ESA Astronomer Antonella Nota at the Institute, with whom he is trying to master the ultimate extreme sport, parenting. They have an 18-month-old daughter, Simona.

science**essays**



SNaZzy Science and **Natural Philosophy**

Steven Beckwith

It is by now oft-remarked that Einstein's greatest blunder, the invention of the cosmological constant, may well turn out to be a more significant advance than every other scientist's best work. The possibility that the cosmological constant is real with a value other than zero became more than idle speculation when two groups of astronomers discovered that the expansion of the universe appeared to be accelerating in response to some cosmological pressure. This discovery, if borne out through other measurements, will be seen as one of the most important in physics or astronomy in the 20th century. Discoveries in one field of natural science with deep ramifications for others tend to be as profound as they are rare, and this one is no exception. The top theoretical physicists in the world have noted that the nature of the stuff causing the universe to accelerate is now the most important issue in physics. Although the existence of a cosmological constant is not at odds with prevailing theories, predictions of its value differ from observations by more than 55 orders of magnitude!

Establishing the time history of universal expansion involves measuring the distances to far-off objects using supernovae as 'standard candles.' Standard candles are sources of light with a known intrinsic brightness. Because the observed brightness depends only on the intrinsic brightness and the distance to the source, observations of the sources are useful to calculate the distances.

Supernovae are among the brightest individual objects in the universe. At their peak, they are almost as luminous as an entire galaxy of more than 10 billion stars and can be seen as far away as typical galaxies. Members of a particular subtype, SN Ia, are effective as standard candles and thus provide the means by which observers can measure distances to objects at very early times in the universe.

By measuring both the distance and recessional velocity to an object, we can tell how fast the universe was expanding when it emitted the light we see. Crudely speaking, if the universe is 15 billion years old and the distance to the object is 10 billion light-years, then we are observing the object when the universe was only 5 billion years old. Thus, observations of distant supernovae let us map the expansion history of the universe by comparing its rate of expansion to its 'size' using the distance to the supernovae.

When Adam Riess and Saul Perlmutter separately plotted the observations of SN Ia as distance against recessional velocity, they found that the ones receding fastest appeared fainter than they should have been if the universe had been expanding in the absence of any forces. The universe had grown even larger during the time the light was traveling from its first emission than it would have if it were freely expanding, and so its expansion rate must be growing with time: the universe has been accelerating!

This surprising result went against the conventional wisdom about how our universe could evolve. Moreover, there are at least two effects on the light that could have produced a false signature of universal acceleration. One would be if, for some reason, supernovae at early epochs in the universe were intrinsically fainter than nearby ones; that is, the standard candles were not standard. A second would be if the light were dimmed by a screen, a thin fog of dust between us and the distant supernovae that produced ever more dimming as the sources were more distant from us.

The key to understanding if there was something wrong with the supernovae was to find them at the most extreme distances in the universe. One such supernova, SN 1997ff at a redshift of 1.7, had been discovered by Institute astronomer Ron Gilliland in the Hubble Deep Field North. Subsequently, Adam Riess, now at the Institute, worked with Ron to test the light dimming hypothesis using SN 1997ff and found its characteristics to be consistent with the accelerating universe interpretation and not with the light-dimming hypothesis. However, this was only one distant supernova, and the data were not ideal for making the necessary measurements.

SN 1997ff is so distant that only the Hubble Space Telescope could have observed it. To test properly the accelerating universe hypothesis requires many more such distant supernovae, but using Hubble as a search tool is prohibitively expensive. Typically, Hubble would have to observe between 20 and 40 different fields on the sky before turning up a single SN Ia; 95% of the observations would be wasted, and the demand for telescope time is too great to allow such a waste. Yet this problem is arguably one of the most important that Hubble could attack right now.

We turned the problem around and asked if we could piggyback on other scientific programs while searching for distant supernovae. Hubble makes many deep observations of the sky every day, quite a few of sufficient depth to pick up distant supernovae serendipitously. To discover a supernova, Hubble would need to observe the same field at two times separated by a few weeks. Any new supernova in the field would show when the images at the different times were compared. By splitting planned observations into two parts, or supplementing some fields with additional exposures a few weeks later, we could leverage existing exposures into a supernova search. Since the planned exposures were for good scientific programs, Hubble would be carrying out excellent science in all cases, even if supernovae were not found.

Thus the SNaZ (SuperNovae at high Z) program was born. We asked observers who had already been allocated telescope time for permission to split their observations or (in most cases) supplement their planned program with additional time from the Director's Discretionary pool. The SNaZ team looks at the difference images and alerts the community to any new supernovae that were found. The community can follow up the discoveries. All observations go to the original General Observers to supplement their data sets for their original science programs, an added benefit to the community of General Observers.

To date, SNaZ has observed 15 fields and discovered 3 new supernovae. One of these, SN 1998ff, is at a redshift of 1.2, making it the second most distant supernova discovered to date. However, because we only caught it after it had faded from view, it was not useful for cosmology. Nevertheless, this discovery and our other 3 supernovae have stimulated the community to think of Hubble as a search engine for new objects. There have been some new insights gained even from this limited number. All the new supernovae are very close to the centers of distant galaxies, meaning that only Hubble could resolve the slight offsets between the sources and the galactic nuclei. The expected rates are based on ground-based searches that typically had to ignore variable sources that appeared coincident with the nuclei of distant galaxies, since such nuclei are often variable themselves.

The method of SNaZ should be especially productive with the new Advanced Camera for Surveys. There is already one large program planned for Cycle 11 that will take advantage of ACS for supernova searches. We have not decided whether to continue SNaZ to supplement the approved time. SNaZ has already stimulated observers to think about dual-use science with their programs, and we expect that it will set the stage for many more such programs in the future.

The SNaZ team at STScI includes Steven Beckwith, Francesca Boffi, Stefano Casertano, Rodger Doxsey, Harry Ferguson, Andy Fruchter, Mauro Giavalisco, Ron Gilliland, Ian Griffin, Anton Koekemoer, Mario Livio, Bruce Margon, Georges Meylan, Nino Panagia, Vera Platais, Adam Riess, Kailash Sahu, and Dave Soderblom.

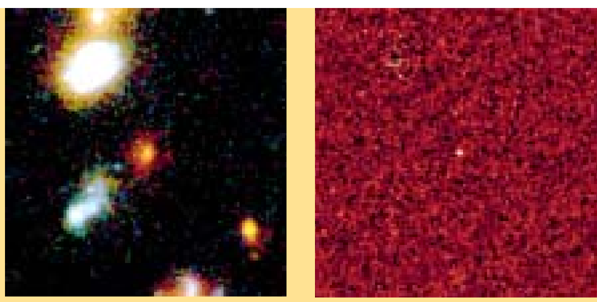
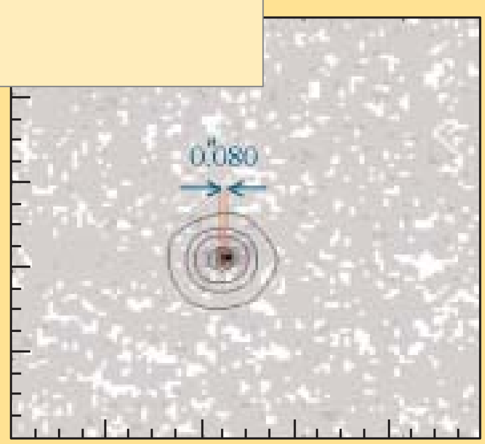


Figure 1

The left-hand image is a small section of the Hubble Deep Field North with a faint red galaxy in the center containing a supernova. The image on the right shows the result of subtracting two images of this region taken several months apart. The super-nova, which was not present in the early image, is easily seen in the subtraction. It lies very close to the center of the galaxy, an effect easily seen in the Hubble image but which would be impossible to discern from ground-based images.

Figure 2

This image shows SN 1998ff, discovered by SNaZ, with the contours of the host galaxy overlain. The supernova is only 80 milliseconds of arc displaced from the center of the galaxy. As with SN 1997ff, this effect is easily seen in the Hubble image, but it would be impossible to separate the light from the supernova from the galactic nucleus in ground-based images.



Anatomy of an **Extrasolar Planet**

Transits of HD 209458

RONALD L. GILLILAND

The 1999 discovery that the companion to the star HD 209458 transits the disk of its host star sent a wave of excitement through the rapidly growing community of extrasolar planet researchers. During such a transit, the projection of the companion's disk onto the host star occults a fraction of light proportional to the ratio of the area of the companion to the area of the star. Thus, the light curve of a transit provides a measurement of the radius of the companion body. Furthermore, the very fact of the transit proves the inclination angle of the orbit is near 90 degrees, which permits the true mass to be computed for companions like HD 209458b that were discovered by the radial velocity technique. In the case of HD 209458b, the results are a radius of 1.35 +/- 0.06 Jupiter radii and a mass of 0.69 +/- 0.05 Jupiter mass, proving that the companion is indeed a planet.

Because the intensity of the stellar surface varies due to limb darkening, the occultation light curve displays a rounded bottom as the obscuring body sweeps across the stellar disk. In this way, a transit observation also provides a sensitive measure of the stellar atmosphere. In the case of HD 209458, the results constrain limb darkening to a relative value of ~5%, with small color terms, consistent with solar values.

Most important for the long-term prospects of eventually understanding details about individual planets outside our solar system, the presence of transits provides an interesting opportunity to obtain observations that are uniquely sensitive to the fine details of a planet and its nearby environment. In 2001, Timothy M. Brown (NCAR), David Charbonneau (Caltech), Robert W. Noyes (CfA), and the author reported results from using the Space Telescope Imaging Spectrograph (STIS) on Hubble to obtain time-series spectrophotometry of transits of the planet HD 209458b at very high signal-to-noise ratio and high time resolution, to probe for the existence of large moons, ring systems, and—impressively at this early date for extrasolar planet research—atmospheric constituents.

It seems likely that space-based observations will always hold a huge competitive advantage over ground-based for probing extrasolar planet atmospheres, because variable telluric lines formed in earth's atmosphere tend to swamp the relatively smaller exoplanet signature.

In the future, under some fortunate circumstances, NGST could provide the first measurements of the atmosphere of a transiting terrestrial-class extrasolar planet and test for evidence of life.

The presence of a moon orbiting HD 209458b would block additional light proportional to its area, which could precede or follow the ingress or egress of the planet proper. Since the Hubble observations detected HD 209458b at a signal-to-noise of about 2,000, a moon with 1/20th the planet radius would still provide a significant signal. In this fashion, the Hubble observations have ruled out the presence of a moon of HD 209458b nearly down to an earth radius in size. Upper limits on ephemeris timing changes for multiple transits provide comparable mass limits—about three earth masses—for a moon.

A system of rings around HD 209458b would alter the light curve shape, producing extended shoulders before ingress and after egress and introducing small changes of shape near the contacts. A system of rings comparably scaled from the Saturnian rings would have been evident in the Hubble observations of HD 209458b, but none was found.

The interesting discovery space for moons and rings around HD 209458b has not yet been searched exhaustively. Modest extensions of the HD 209458b observations would eventually discover any moons down to the size of the largest Galilean satellites of Jupiter and opaque rings greater than 50% the area of Saturn's rings.

Because its mass is comparable to those of the solar system's gas-giant planets—and its temperature significantly higher, due to close proximity to the star—HD 209458b is expected to have an atmosphere. Another motivation for the Hubble observations was to search for spectral signatures of the atmosphere.

The STIS observations were a series of spectra taken at medium resolution and centered on the sodium D resonance lines. The presence of sufficient sodium in the atmosphere of HD 209458b would block tangential rays in those resonance lines to a higher altitude than is blocked in the nearby continuum. As shown in Figure 1, this effect would make the transit deeper at the sodium D lines, due to the greater effective radius and area.

Theoretical predictions had suggested that the sodium D doublet at the observed resolution could deepen by up to one part in a thousand during the transit, a subtle but approachable observational goal. Summing some three hours of exposure during transit and comparing to a slightly longer exposure outside of transit, a deeper sodium absorption was detected during transit —by 0.25 parts per thousand at a 4-sigma level of confidence. This is the first direct detection of an extrasolar planet atmosphere. Remarkably, it was obtained with a telescope and instrument not designed for such an observation as a science goal. In the future, astronomers will use Hubble to probe the atmosphere of HD 209458b further for additional atomic and molecular constituents.

It seems likely that space-based observations will always hold a huge competitive advantage over ground-based for probing extrasolar planet atmospheres, because variable telluric lines formed in earth's atmosphere tend to swamp the relatively smaller exoplanet signature. In the future, under some fortunate circumstances, NGST could provide the first measurements of the atmosphere of a transiting terrestrial-class extrasolar planet and test for evidence of life. A mission designed specially for this purpose, having a larger aperture than NGST, could detect biomarkers on more earth-like planets to even greater distances.

The current planet detection experiments, so successful over the past several years in detecting nearly 100 extrasolar planets via radial velocity measures, hold little prospect for extending detections to real analogues of earth. Kepler, the recently approved Discovery-class mission, may detect many terrestrial planets and should firmly establish their frequency of occurrence. Kepler will watch the same ensemble of 100,000 stars for four years to detect transits. William Borucki at NASA/Ames is the Kepler Principal Investigator. The Institute is a partner in the mission, responsible for data receipt, calibration, and archiving, with science participation by the author. Prospects are excellent for exciting new developments in extrasolar planet research.

Hubble detects additional sodium absorption due to light passing through planetary atmosphere as planet transits across star

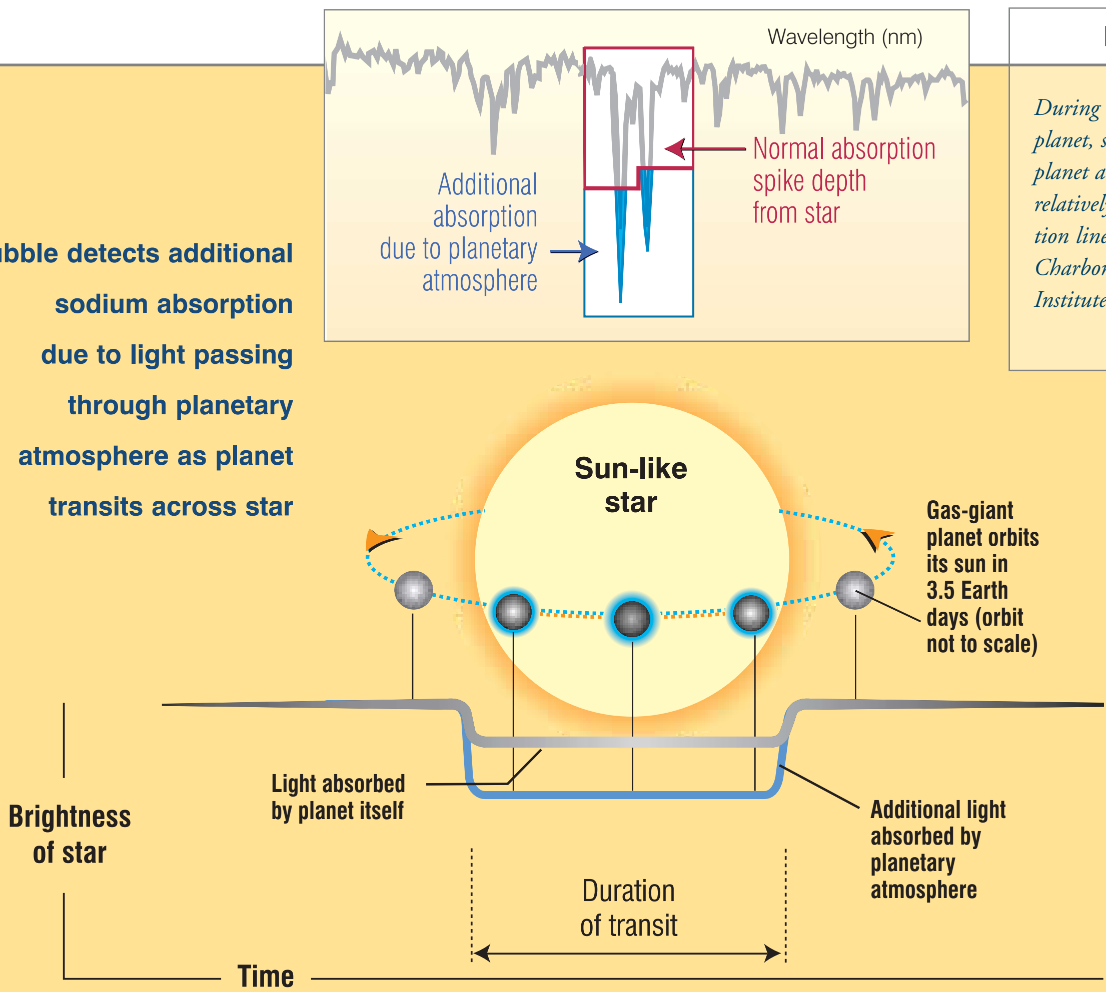


Figure 1

During transit of the planet, sodium in the planet atmosphere causes relatively deeper absorption lines. [Courtesy of D. Charbonneau, California Institute of Technology.]

Galaxy **Formation**

Harry Ferguson

In the mid 1990s the combination of deep Hubble images and deep spectroscopy from the Keck Observatory ushered forth a revolution in our understanding of high-redshift galaxies. Prior to 1995 one of the holy grails of astronomy was to find the 'epoch of galaxy formation.' Over the past six years, observations of hundreds of high redshift galaxies ($z>1$) demonstrate that this epoch is in fact a broad period of time, extending from redshifts $z>6$ down to $z\sim1$ and spanning roughly 5 billion years. By redshifts $z\sim1$, the familiar pattern of spiral and elliptical galaxies has settled into place. Galaxies at higher redshift tend not to have such well-defined shapes, and their colors are generally indicative of rapid star formation. The fact that the intergalactic medium is ionized out to redshifts $z>5.5$ indicates that galaxy formation began even earlier. The challenges now are to extend study of galaxy formation to the earliest phases, at $z>6$, and to chart the progress of galaxy formation in detail down to lower redshifts.

Mass is one of the most important attributes of distant galaxies to measure because the related theoretical predictions are robust. Theory says that the mass distribution of collapsed objects should depend only on the spectrum of primordial dark-matter fluctuations and on the basic cosmological parameters. Unfortunately, the mass is extremely difficult to measure, even for nearby galaxies, and we must rely on indirect techniques to infer galaxy masses at high redshift.

Recently, Johns Hopkins University graduate student Casey Papovich, working with Mark Dickinson and Harry Ferguson at the Institute, used one such indirect technique to determine the masses of 31 distant galaxies in the Hubble Deep Field North (HDF-N). These galaxies have spectroscopic redshifts in the range $2<z<3.5$. The investigators measured radiation from old stars using infrared observations from Hubble's Near Infrared Camera and Multi-Object Spectrometer (NICMOS), and they obtained complementary measurements of young, massive stars from shorter-wavelength observations from the Wide Field Planetary Camera 2 (WFPC2). The investigators modeled these observations to determine the characteristic stellar mass—the mass at the break in the luminosity function—by exploring a wide range of star-formation histories, extinction parameters, metallicities, and initial mass functions. They found a characteristic stellar mass of roughly $10^{10.5\pm0.3}$ solar masses, which is in line with theoretical expectations and means that galaxies must grow by about a factor of 10 in mass between $z\sim3$ and the present day.

HDF-N

The Great Observatories Origins Deep Survey (GOODS) will conduct deep imaging on an area 60 times larger than the HDF-N using the Space Infrared Telescope Facility (SIRTF) and Hubble's Advanced Camera for Surveys (ACS).

Another way to try to measure the total mass (baryonic plus dark matter) of high redshift galaxies is to observe how strongly they cluster. Relying only on simple gravitational physics, theory can predict the probability that a dark-matter halo will have a nearby neighbor or, more precisely, the distribution of separations between pairs of galaxies (the correlation function). In standard hierarchical clustering theory, higher peaks in the mass spectrum of gravitationally-bound objects (dark-matter halos) are more strongly clustered than lower peaks. Thus, measuring the correlation function of high-redshift galaxies provides a powerful test of whether they trace the underlying dark-matter halos. The measurement also tests how well correlated luminosity is with dark-matter-halo mass.

Mauro Giavalisco and his collaborators have been studying galaxies and dark-matter halos by measuring correlation functions of high redshift galaxies that were discovered from the ground or using Hubble. Albeit with large error bars, his analysis indicates that optically-selected galaxies are strongly clustered, at about the level expected from theory—if there is a one-to-one correspondence between galaxies and dark-matter halos. Furthermore, the tendency to cluster appears to increase with luminosity, as expected if light is proportional to mass. The characteristic halo mass inferred from the clustering measurements is of order 10^{12} solar masses, suggesting that the high-redshift galaxies being studied lie at the centers of large concentrations of dark matter, destined to become giant galaxies. This rules out 'christmas tree' models, which conceived high-redshift galaxies to be low-mass objects flickering on and off in successive bursts of star formation.

At the measured star-formation rates, galaxies at redshift $z=3$ would have formed all their stellar mass within a few hundred million years. This is significantly younger than the age of the universe, and the result would seem to imply that galaxies observed at $z=3$ had not yet been formed at $z=4$. This is a rather puzzling result in that (a) galaxies are observed at $z=4$ at roughly the same space density as at $z=3$, and (b) the ▲

ultraviolet luminosity density needed to re-ionize the universe at redshift z>6 is at least as great as that produced by star-forming galaxies at z=3. Ferguson, Dickinson, and Papovich have looked at this issue and suggested that star formation occurs in stochastic bursts, with a top-heavy initial mass function. This mode of evolution can provide the necessary ultraviolet photons at higher redshift without overproducing the number of low-mass stars in z=3 galaxies.

Sangeeta Malhotra and James Rhoads have arrived at a similar conclusion from a completely different direction. Using the mosaic imager on the Kitt Peak 4-m telescope, they have been finding Lyman-α emitting galaxies at redshifts z=4.5 and z=5.7. Strong Lyman-α emission is expected in very young galaxies, but the line will be strongly quenched by dust within a few hundred million years. More than half of these galaxies have Lyman-α equivalent widths greater than 240 Ångstroms. If the ionizing radiation is due to starlight, there must be a much higher proportion of massive stars relative to low mass stars than is found in typical environments in our Galaxy.

These developments will be subject to further study over the next few years. The Great Observatories Origins Deep Survey (GOODS) will conduct deep imaging on an area 60 times larger than the HDF-N using the Space Infrared Telescope Facility (SIRTF) and Hubble's Advanced Camera for Surveys (ACS). These observations will provide measurements of stellar masses, morphologies, and clustering of galaxies out to redshifts z~6. At the same time, the ACS Pure-Parallel Lyman-α Emission Survey (APPLES) will use the ACS grism to conduct the most sensitive survey yet for Lyman-α emitters between redshifts of 4 and 7. From these and a number of other exciting surveys getting underway, we can expect a further explosion in our understanding of galaxy formation. We may remain ignorant, but we will be ignorant at a much deeper level.

The Sizes of **Comet Nuclei**

Keith Noll

How large are the nuclei of comets? The 1986 encounter of the Giotto spacecraft with comet Halley gave the first definitive answer to this question, albeit for a single comet. But is the 8 x 16 km potato-shaped Halley typical? Models of solar system formation, planetary risk assessment, and extrasolar zodiacal disks depend, in part, on knowing the size distribution of comets. The year 2001 marked a milestone in this endeavor with the dramatic confirmation of a pioneering technique using the Hubble Space Telescope.

Investigators trying to measure the size of cometary nuclei are faced with a dilemma. When comets are near the earth, they are surrounded by a thick coma of gas and dust being shed by the comet as it is warmed by the sun. The bright and extended coma makes picking out the small nucleus a daunting,

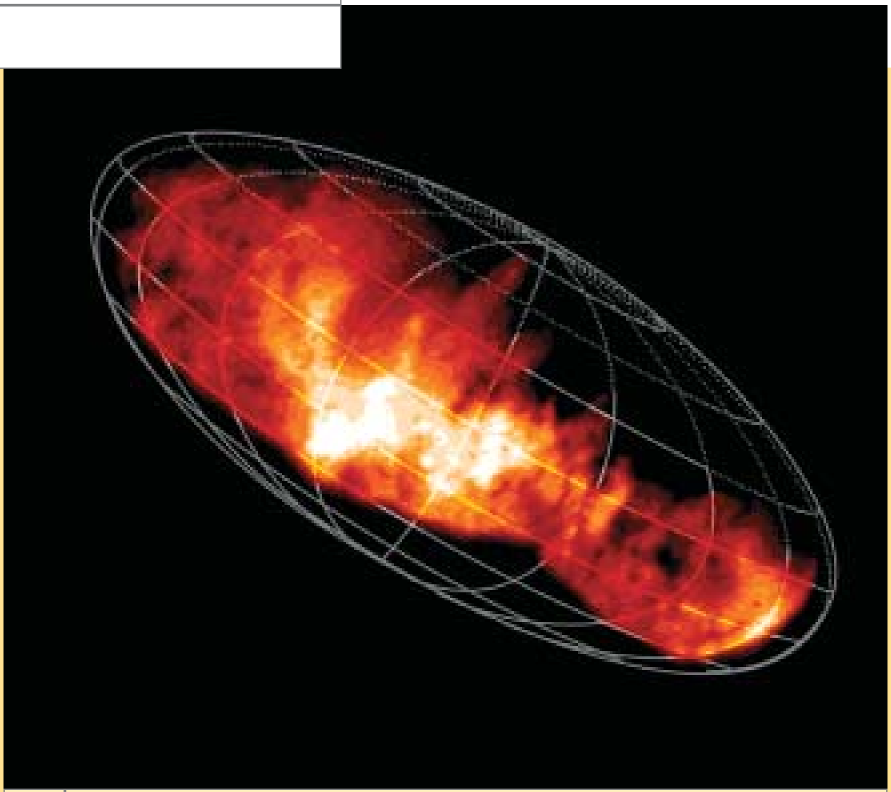


Figure 1

A grid the size determined by Hubble observations of comet Borrelly is superimposed on an image of the nucleus obtained in September 2001 by the Deep Space 1 spacecraft. The correspondence in both size and shape is remarkable. It dramatically confirms the accuracy of Hubble size determinations for cometary nuclei.

▼ continued from page 23

if not impossible, task. When comets are far from the earth they become much less active, and it becomes possible to observe bare nuclei without their shroud of gas and dust. But at large distances from the sun, comet nuclei are exceedingly faint. Furthermore, there is no guarantee, even well beyond the orbit of Saturn, that the nucleus is inert.

Hubble offers real advantages to both approaches. Its combination of resolution, sensitivity, and photometric stability has been used in several programs aimed at the detection of distant comet nuclei and the closely related objects in the newly-discovered Kuiper Belt.

The most dramatic improvements apply to observations of nearby comets. The 45 milliarcsecond pixels of the Wide Field Planetary Camera 2 (WFPC2) cover an area that is about 100 times smaller than is typically possible from ground-based telescopes. While the comet nucleus remains unresolved, even with WFPC2, the total amount of light from the coma in each pixel is greatly reduced, due to its small angular subtense. This advantage opens up the possibility of picking out the light reflected from the comet's nucleus —*if* the light from the coma can be accounted for and accurately subtracted.

A team including Phillipe Lamy (Laboratoire d'Astronomie Spatiale du CNRS), Imre Toth (Konkoly Observatory) and Harold Weaver (Johns Hopkins University) has pioneered this technique, beginning with observations of short period comets early in Hubble's lifetime. Their first target after the successful first servicing mission was comet 19P/Borrelly, imaged by WFPC2 on November 28, 1994. They were able to detect the nucleus. In their simplest model for the coma, they assumed spherical symmetry and a surface brightness decreasing in proportion to the distance from the nucleus. Real comets are rarely this simple, so the team devised more detailed models that took into account the azimuthal asymmetry of the coma. After removing the coma and making an assumption about the albedo—the fraction of light reflected from the nucleus—they could estimate the size of the nucleus.

Because multiple exposures of Borrelly had been obtained over an 11- hour period, Lamy, Toth, and Weaver could derive additional information about the shape of the nucleus. During this interval, the brightness of the nucleus varied in a regular pattern, consistent with the rotation of an elongated object. The investigators concluded that the nucleus of comet 19P/Borrelly could be approximated by a prolate spheroid 4 x 8 km in size.

Because of the modeling inherent in the Hubble technique, skeptics could, and did, remain unconvinced of the accuracy of Hubble determinations of nuclear sizes. However, the flyby of comet Borrelly by the aging Deep Space 1 (DS1) spacecraft in September 2001 has dramatically and unambiguously confirmed the accuracy of the conclusions of Lamy, Toth, and Weaver. Figure 1 shows an image of Borrelly's nucleus obtained by DS1 with the Hubble-determined spheroid superimposed. The correspondence in both size and shape is nothing less than astounding.

In the seven years between the Hubble and DS1 measurements of Borrelly's nucleus, the Hubble comet team was not idle. By 2001 Lamy, Toth, Weaver, and colleagues had used Hubble to measure the sizes of nearly 30 short period comets. Somewhat surprisingly, most of the measured comet nuclei have been considerably smaller than either Halley or Borrelly; they are mostly less than 2 km in diameter.

It is easily within Hubble's capability to measure the sizes of virtually the entire known population of short-period comets—170 objects in all. This remarkable accomplishment would represent a significant advance in our understanding of the origin and evolution of comets, cometary lifetimes, the risks of comet impacts, and the source of zodiacal and exo-zodiacal material. While spacecraft encounters with comets, including the upcoming missions CONTOUR, Stardust, Deep Impact, and Rosetta, will provide detailed in-situ data that cannot be obtained any other way, Hubble observations permit researchers to compare and contrast the flyby targets with other comets that will never be visited by spacecraft. With newfound confidence coming from the DS1's confirmation of Hubble's sensitivity, learning the sizes of comet nuclei is simply a matter of time.

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Planetary Nebulae in the **Magellanic Clouds**

Probing Stellar Populations and Evolution

Letizia Stanghellini

Planetary nebulae (PNs) are the relic envelopes of intermediate-mass stars, ejected toward the end of stellar life. Intermediate-mass stars and their remnants are common components of most galaxies, and they have also been observed in intergalactic space. Thus, understanding the formation and evolution of PNs and the quantity and composition of the material they eject is an essential part of astrophysics.

Hubble has revealed the fascinating shapes and structures of the Galactic PNs, yet the researchers in this field have struggled for decades to determine their physical properties with accuracy. The sources of the problem are that the distances to Galactic PNs are very uncertain and that interstellar reddening in the Galaxy hinders observations of the Galactic PNs in unexpected ways.

Extensive studies of Galactic PNs show that PN morphology is intimately related to the mass and evolution of their central stars and to the nebular chemistry. If the uncertainty in distance could be eliminated, such results would become milestones in our understanding of intermediate-star evolution.

An optimal way to achieve such quantitative results is to study PNs in the Large and Small Magellanic Clouds (LMC, SMC), where the targets are at uniform, known distances. Since the MCs are galaxies with different metallicities, they also offer the additional benefit of extending the 'metallicity baseline' of the investigation. The Hubble cameras are ideally suited to spatially resolve the MC PNs, which are unresolved from the ground. Furthermore, space observations have the unique capability of separating the radiation from the nebula and that from the stellar remnant (the central star).

During the past two years, I and my collaborators have implemented a project with Hubble to characterize the morphology, nebular physics, and stellar parameters of all the known PNs in the MCs. The scientific rationale is to derive a complete description of the formation and evolution of PNs according to their environment, by confronting the observational data from Hubble and ground-based telescopes with stellar and hydrodynamic models of PN evolution.

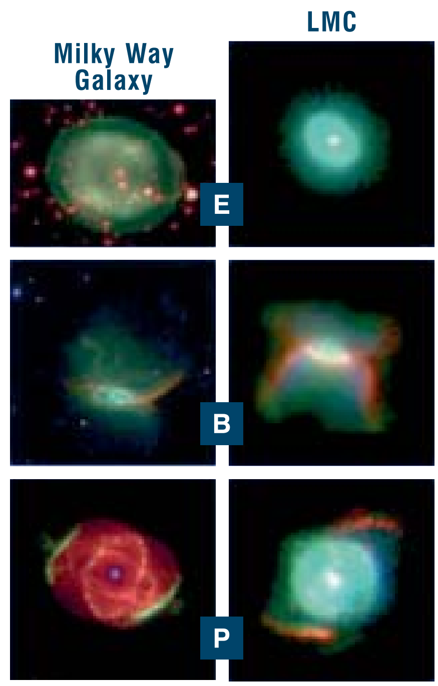
The Hubble observing strategy invokes STIS slitless spectroscopy coupled with STIS broad-band imagery. The technique provides nebular 'narrow-band images' in the major emission lines (e.g., H_{α}, H_{β}, [O III] 5007 Å, [N II] 6584 Å, [S II] 6716-6731 Å) to derive the size, the ionization stage, the gas density, the extinction, and the morphology of the nebulae. The observations, which are performed in snapshot mode, gather morphological and stellar information in less than one orbit for each MC PN, making this a cost-effective Hubble program.

To date, about one third of the MC PN targets have been observed. The analysis of the Hubble data is in progress, and several exciting preliminary results are worth describing.

First, PNs in the MCs have substantially the same morphologies as Galactic PNs. Figure 1 shows observed examples of symmetric (round and elliptical) and asymmetric (bipolar, bipolar core, and point-symmetric) PNs. Round PN images are circles within the observational errors. Bipolar PNs have a central 'waist' or ring and one or more sets of lobes. Bipolar core PNs (not shown in the figure) have bipolar rings but undetected lobes. Point-symmetric PNs show a series of features that are center- rather than axi-symmetric. There is a larger ratio of asymmetric to symmetric PNs in the LMC than in the Galaxy. Since most asymmetric Galactic PNs are

Figure 1

A sampler of morphological PN types. Left column, from top to bottom: Galactic PNs IC 1295 and He 2-428 (ground-based), and NGC 6543 (Hubble Space Telescope). Right column, from top to bottom: Large Magellanic Cloud PNs SMP 4, SMP 16, and SMP 10 (Hubble Space Telescope). E, B, and P stand for elliptical, bipolar, and point-symmetric.



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Galactic disk objects, this result may simply disclose the selection effects that play against the detection of Galactic disk PNs. Also, the ratio of asymmetric to symmetric PNs in the LMC is different than that of the SMC, indicating different mixes of PN populations from galaxy to galaxy.

Second, the surface brightness of MC PNs in the light of [O III] 5007 Å—typically the brightest PN emission line—correlates with the photometric radii of the nebulae, as shown in Figure 2. The photometric radius of a PN roughly traces the rate of its dynamical evolution (velocities of PNs are within a very narrow range), and therefore the correlation can be used to constrain the hydrodynamic models. From Figure 2 we infer that asymmetric PNs have a more rapid dynamic evolution than round PNs. Elliptical PNs cover a wider range in this plane, hinting at a population with intermediate dynamical characteristics.

Third, asymmetric PNs in the LMC are rich in neon and sulfur compared to round and elliptical PNs. This result is broadly consistent with the predictions of stellar evolution if the progenitors of asymmetric PNs have larger masses on average than the progenitors of symmetric PNs.

This result bears on the question of the formation mechanism for asymmetric PNs. To date, PN researchers have generally invoked the presence of a companion to the PN progenitor to explain PN asymmetry. However, binarity alone would not explain the higher neon and sulfur abundances, and thus the binary interpretation should be revised.

Other mechanisms can be invoked to explain PN asymmetry, such as magnetic fields and stellar rotation. Since these mechanisms are enhanced in higher mass stars, we feel models that include them should be favored in the future.

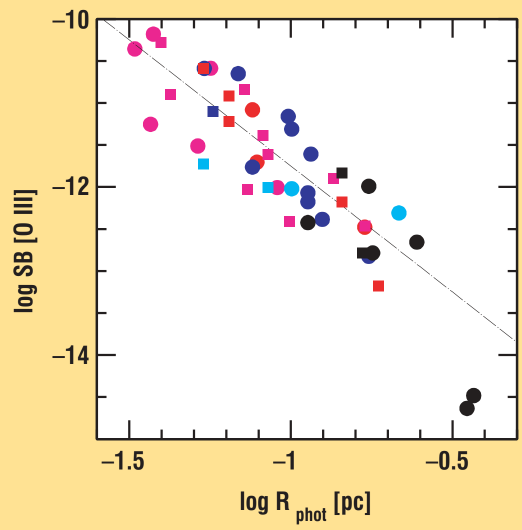
As more Hubble data on MC PNs become available, the statistical significance of these findings will increase. In the future, the detailed study of the central stars will be related to the properties of the nebulae and hosting galaxy. An important product of this Hubble program is the prepared data set, which is available from the Hubble data archive.

Letizia Stanghellini is affiliated with the Astrophysics Division, Space Science Department of the European Space Agency.

Figure 2

The [O III] 5007 Å surface brightness (SB) versus the physical photometric radii for LMC (filled circles) and SMC (filled squares) PNs.

Color coded morphology: magenta= round; red= elliptical; blue= bipolar core; black= bipolar; cyan= point-symmetric. The dashed line, SB ~ R^{-3}, represents a rough fit to the data.



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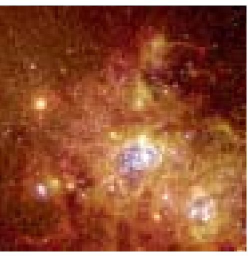
Organization **Descriptions**

DO | Director's Office

The DO's responsibility is to lead the Institute. By defining the organization, strategy, policies, plans, and management team, the DO supports the work of the staff and guarantees the Institute's commitments to NASA, the scientific community, and the public. It strives to make it easy for everyone in the Institute to contribute their best capabilities to its mission. It obtains the resources needed by the staff to do their work, and it allocates those resources to optimize the productivity of the Institute. It represents the Institute by conducting its external relations, reporting to oversight committees, and receiving guidance from advisory groups.



Four groups involving the Director's Office coordinate and conduct the management business of the Institute. | The *Director's Office Group (DOG)*—consisting of the Director, the Deputy Director, the Associate Director for Science, the Chief Information Officer, and the Heads of Program Management and Administration—coordinates Institute business at the highest level and conducts an ongoing forum on matters of policy, strategy, and leadership. | The *Management Council*, which consists of division heads and the DOG, deliberates on management issues, debates and decides Institute policies and procedures, and shares information and coordinates the working relationships between divisions. | The *Missions Directorate Management Council*, which is led by the Deputy Director and includes the heads of the Hubble, the Next Generation Space Telescope, the Archive, Catalogs, and Data Services, and the Engineering and Software Services Divisions, meets to coordinate planning for all of the Institute's mission responsibilities. | The *New Starts Group,* which consists of the DOG 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.

PM | Program Management

PM 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 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. | *Development, Technology, and Innovation Projects* engages the Institute's expertise in pursuit of new challenges within the AURA charter, productivity enhancements, and innovative approaches to improving our products and services.

ADM — Administration Division

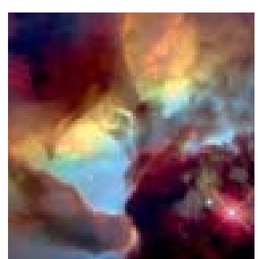
ADM provides business and administrative services to the Institute in the areas of finance, human resources, accounting, contracts, grant administration, procurement, facilities management, property administration, administrative support, and staff support services. It is organized into branches, groups, and offices according to its major functions and responsibilities. ADM 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 administrative support of all kinds and coordinate between ADM, 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, makes travel arrangements for Institute staff and visitors, and ensures that procurements of products and services are competitive. | The *Grants and Contracts Branch* provides contract and grant administrative services for the Institute. | The *Grants Administration Office* 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 Office* 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 *Facility Operations Group* manages the Institute's facility operations, comprising the 130,000 square foot Muller building and a 300-car parking facility. They also contribute logistical support services to off-site leased office space at the Rotunda and The Johns Hopkins University's Bloomberg building. | The *Staff Support Services Group* provides a variety of services, including security, housekeeping, parking administration, food services, document reproduction, and other logistical support.

CISD — Computing and Information Services Division

CISD provides solutions for information and computing needs of the Institute and the user community, and it leads planning for meeting future computer, networking, and information needs. | The *Security and Network Group* supports the underlying network and security infrastructure. | The *CISD Help Desk* provides the first line of support to users with questions or service issues. | The *Windows, Macintosh, and Unix Support Teams* provide desktop and server support for all science, operational, and business systems. | The *Application Support Team* provides cross-platform support of application software. | The *Information Services Team* provides information architecture, web, and documentation services.

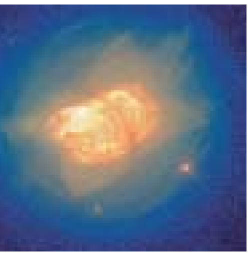
• Missions Directorate

The Missions Directorate plans, develops, and implements science and mission operations for all missions for which the Institute is responsible. The Directorate includes the Hubble Division, the Next Generation Space Telescope Division, the Archive, Catalogs, and Data Services Division, and the Engineering and Software Services Division.



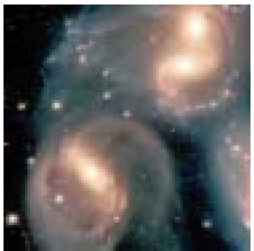
HD | Hubble Division

HD carries out the science program of the Hubble Space Telescope. It supports the astronomical community with scientific and technical advice on observing programs as well as on the use of archival data. It processes and schedules the selected observing programs and ensures the proper calibration of Hubble data. It prepares the community and the Institute for the most effective use of future Hubble instruments. | The *Information Technology Team* provides electronic documentation and web support for all elements of the Hubble Division. | The *Hubble Operations Department* implements Hubble observations to provide observers with data of the highest possible quality. | The *Observation Planning Team* works with Hubble users to ensure the optimal translation of their scientific requirements into the technical terms of the operating observatory. | The *Long-Range Planning Group* prepares the multi-year, master observing schedule, which reconciles observing requirements and operational constraints at a high level. | The *Science Planning and Scheduling Team* fits candidate observations into an optimal observing sequence and creates the detailed command loads for each week of the Hubble science program. | The *Flight Operations Team* is responsible for spacecraft and instrument housekeeping, monitoring and maintenance, and for the health and safety of the Hubble mission. | The *Science and Instrument Support Department* helps Hubble observers use the science instruments with maximum effectiveness. It provides scientific and technical advice in developing observing programs and interpreting data. It calibrates and characterizes the science instruments. | The *ACS Group* is responsible for the utilization of the Advanced Camera for Surveys. | The *NICMOS Group* is responsible for the utilization of the Near Infrared Camera and Multi-Object Spectrometer. | The *Observatory Support Group* maintains the Hubble focal plane model, monitors the telescope focus, and supports the use of the Fine Guidance Sensors as astrometry science instruments. | The *Spectrographs Group* is responsible for the use of the Space Telescope Imaging Spectrograph (STIS) and for supporting archival analysis of data from the retired spectrographs. | The *WFPC2 Group* is responsible for the use of the Wide Field Planetary Camera 2. | The *New Instruments and Servicing Department* 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 *WFC3 Group* is responsible for the Wide Field Camera 3. | The *COS Group* is responsible for the Cosmic Origins Spectrograph. | The *Data Analysts Group* supports the technical work of the Hubble and NGST Divisions and the scientific research of the Institute staff.



NGST | Next Generation Space Telescope Division

NGST collaborates with NASA to develop the scientific, technical, and operational vision for NGST. It is responsible for developing the NGST Science and Mission Operations Center, which will operate the telescope and implement its science program. The NGST Division also provides technical and scientific support to the science instrument teams and other development partners. As a member of the NASA project team for NGST, it shares the challenge of constructing and operating Hubble's successor at a fraction of Hubble's cost.



ACDSD — Archive, Catalogs, and Data Services Division

ACDSD processes Hubble data in the pipeline, distributes Hubble data products to the community, and operates the Multimission Archive at Space Telescope. 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 education/outreach contributions to this initiative. | The *Observation Processing and User Support Branch* is responsible for pipeline processing of all Hubble data, including procedural evaluation of observation quality. 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.

ESS — Engineering and Software Services Division

ESS is responsible for systems engineering, software development, and engineering support at the Institute. ESS is organized into three departments. | The *Science User Systems Department* develops and maintains software used by external astronomers for proposal work, data analysis, calibration, and archival research, as well as the pipeline and archive infrastructure. | The *Science Software Group* develops calibration and data analysis software used by the instrument groups, the pipeline data processing team, and Hubble observers and archive users. | The *Astronomer's Proposal Software Team* develops the software used by astronomers to develop proposals and plan the structure and execution of their Hubble observations. | The *Data Systems Team* develops the pipeline and archive infrastructure software as well as 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 NGST, as well as several large ground-based optical observatories. It is responsible for the Space Telescope Grants Management System (STGMS), used by astronomers to submit Hubble budgets and by institutions to administer them. It also provides testing and systems infrastructure support to the rest of ESS. | The *Planning Development Team* develops and maintains front-end planning and scheduling software, including the applications known as Spike, Transformation, and the Parallel Observation Matching System. | The *Scheduling Development Team* provides the short-term scheduling software for operating Hubble, including the Guide Star Selection System, Moving Object Support System, and Science Commanding System. | The *Spacecraft Scheduling and Commanding Team* develops and maintains the system that prepares command loads for uplink to the Hubble spacecraft. | The *Software Testing Team* provides software testing for the ground system and is responsible for the quality and productivity of testing as a fundamental process at the Institute. | The *Systems Infrastructure Team* investigates, tests, and deploys new technologies, products, and tools used by the engineering organization for development of the ground system; it also develops and maintains the STGMS. | The *Mission and Flight Engineering Department* is responsible for the stored commanding, health, and safety of the Hubble science instruments and provides general systems engineering. | The *Engineering Team* maintains engineering knowledge of the Hubble instruments and spacecraft, monitors the health and performance of the science instruments, and tracks the status of limited-life items within the instruments. It also develops astronomical instrumentation and explores new hardware technologies to support Institute astronomers. | The *Ground Systems Engineering Team* supports Institute projects with systems engineering and ensures that software projects conform to requirements and employ a robust methodology for development and testing. | The *Flight Systems Engineering Team* provides systems engineering support to the development of mission flight software and develops stored commanding. | In the *ESS Division Office*, the *Database Development Team* develops and maintains databases throughout the Institute, like the archive and the planning and scheduling operations databases. | The *Systems Integrated Management Team* provides technical project management support to cross-divisional initiatives, such as the integrated schedule for ground system development for new Hubble instruments.

• Science Directorate

The Science Directorate promotes scientific research at the Institute, performs scientific reviews and oversight, conducts observing time allocation, and facilitates the communication of Hubble discoveries within the scientific community as well as to public audiences. The Science Directorate comprises the Science Division, the Science Policies Division, and the Office of Public Outreach.

SD Science Division

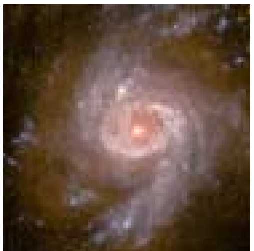
SD fosters the Institute as a research environment. It supervises the functional assignments of individual scientists. To promote career growth, it fosters research opportunities, provides mentoring and advice on professional development, and conducts annual science evaluations. The SD conducts visitor programs to foster collaborations, enable journal clubs, and support distinguished astronomers for extended visits. It manages the Hubble Fellowship Program and the Institute Postdoctoral Fellowship Program. It manages the Director's Discretionary Research Fund, which supports 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 scientific interest groups to conduct workshops and seminars and 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

SPD manages the allocation of Hubble Observing time. It is the Institute point of contact with oversight committees. It conducts the selection process for the Hubble science program, including General Observers and Archival Researchers, and establishes science metrics to evaluate its success.

OPO Office of Public Outreach

OPO develops astronomy-related educational products and services and delivers them to classroom students, the public, and the astronomical community. It supports individual scientists in developing educational contributions based on their research. | The *Formal Education Branch* 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 Branch* 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 Branch* brings the excitement of scientific discovery and technological accomplishment to a wide audience through science museums, planetariums, libraries, and the Internet. | The *News Branch* develops press releases, photo releases, and Space Science Updates to disseminate Hubble discoveries via print, electronic, and broadcast media. | The *Origins Education Branch* operates a forum to coordinate the education and public outreach efforts of all of the NASA missions within the Origins Theme. | The *Education Grants Branch* empowers individual scientists to conduct their own education and public outreach programs. | The *NGST Community Outreach Branch* provides the astronomical community with information about NGST.



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.

inside

Inside teams, which involve staff from various divisions.

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 Initiative Officers**, with representatives from each division, support new-business proposals by coordinating division inputs, 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 or functional computer systems as well as the Institute's general computing infrastructure.

The **Science Recruitment Committee** conducts the annual 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 Manager, advises the Head of Administration, 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 Manager, who is responsible for the Institute's safety program.

The **Training Committee**, consisting of division representatives, discusses management training needs, develops curriculum options for developing skills and competencies, and advises the Human Resources Manager, who recommends to the Management Council training programs to be implemented by the Human Resources Department.

inside | outside

Inside/outside teams, which are led by the Institute and include strong community participation.

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.

outside

Outside teams, which advise or review us, or in which we participate and are critical to our missions.

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 inter-archive 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.

Self-Improvement **Processes**

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.

In 2001, the Institute pursued a number of process improvement initiatives.

Easier Travel Arrangements.

The Administration Division (ADM) has a vision of placing as much control and information as possible in the hands of management and staff. The goal is to increase effectiveness and efficiency. In pursuit of this vision, ADM partnered with Development, Technology, and Innovation Projects (DT&I) to improve how travel arrangements are made. They sought to remove the impediments and unnecessary barriers that can frustrate prompt execution of travel arrangements for the staff. Through user interviews and an exhaustive look at the flow of travel requests through the system, ADM and DT&I identified key activities that add value for travelers. They staged a trial of web-based commercial software that allows users to define and control their trips while preserving the necessary Institute travel guidelines. In this limited test, the system is proving flexible and easy to use. Frequent travelers benefit from the integration of travel planning tools into their working environment. ADM will open this system to the whole Institute in early 2002.

New Outsourced Services.

For several years, the Institute has had a successful relationship with Xerox Business Services for operation of our Central Copy Center. Following this model, ADM outsourced to Xerox the Institute's Reception Desk and Guard Service. This arrangement has enabled cross training of staff between these service functions and resulted in high staff morale, which translates into customer service excellence, and an annual cost savings of approximately $20,000 per year.

Full Implementation of STGMS.

The Grants Administration Office (GRA) implemented the electronic Space Telescope Grants Management System (STGMS) in time for handling Cycle 10 budgets. GRA activated 113 grantee institutions in five months for the February 2001 budget deadline. In one year, we went from a fully paper process to one that accepted over 400 electronic budget requests, with only 12 paper submissions. Currently, we have activated 135 institutions on STGMS. The system provides an external interface for General Observers (GOs), Archival Researchers (ARs), and institutional research administrators to access financial information about their proposals and grants. It facilitates the creation and submission of budgets electronically and makes the award and administration of grants more efficient. In addition, the new system shortens the funding allocation process by three months, which enabled awarding Cycle 10 funds to GOs just as Hubble obtained the first observations in April 2001.

More Transparent Hubble Data Flow.

DT&I launched an innovation process, referred to as Shark Cage, to improve Institute services to the community using advanced technology. The first process evaluation by Shark Cage focused on Hubble data flow from the observer's perspective. Shark Cage sought to create a single portal for observers to track the detailed status of their Hubble observations. The Shark Cage team, drawn from across the Institute, studied the flow of data from the planning stage, through observation execution, to the pipeline, and on to the archive. They traced the various transitions of the data as they are acquired, calibrated, and recorded in the archive. Through user interviews, the Shark Cage team determined the key features desired by GOs to locate data at different stages of progress through the observatory system. They prototyped reporting scripts and brainstormed on new, easy-to-use interfaces for the user. The first stage of their implementation provides a core functionality for users during the data-collection phase. A second stage is folded into the new release of the Institute's archive system. An anticipated third phase will revamp the user interface, transforming it into a more engaging and comprehensive portal into GO programs.

New Website.

The Institute's website had been designed more than four years ago. Since which time both the amount and the complexity of the information available through the site had increased dramatically. It had become increasingly difficult and labor-intensive to maintain information in this outdated framework. Led by the Computing and Information Services Division (CISD), a 'web team' embarked on a systematic program to upgrade the Institute's information management and website. After laying a foundation based on the principles of information architecture, the team adopted a web-management software package (called Zope, based on Python), and began the website redesign. The most obvious change was the introduction of the new Institute 'front door' website, which is crafted to speed Internet users to the information they seek. The many underlying Institute websites have been incorporated into the new system, including the Hubble, Next Generation Space Telescope (NGST), Space Telescope Imaging Spectrograph, and Advanced Camera for Surveys websites. A number of internal information services have been incorporated, including CISD support and management. Designated content curators ensure that the information in each area is accurate and timely. From an internal perspective, the new framework makes it much easier to capture and provide information, with no further need for anyone to hand-craft HTML.

Evaluations of New Technology.

Institute information systems must stay current with the evolving computer industry. CISD conducted two major technology studies in 2001 to ensure this currency: an evaluation of Macintosh OS X operating system and a study on the future of Unix computing.

The Mac OS X evaluation team carried out a comprehensive review of the strengths and weaknesses of this new, Unix-based operating system. They also looked carefully into cost-of-ownership and cost-of-migration issues. They noted that Mac OS X could provide a robust platform for general, technical, and scientific computing. It combines the strengths and versatility of a solid Unix core with the ease of use and familiarity of the Mac user interface. The evaluation team concluded that Mac OS X is likely to satisfy or even surpass the current interest in dual-boot Linux/Windows systems.

The 'future of Unix' study team took a broad look at the Institute's information technology (IT) needs. They focused on IT requirements, rather than desires or preferences, and developed a comprehensive business model to determine optimal solutions. They recommended moving toward a 'data center'-type IT infrastructure. In such an environment, most IT needs are satisfied by a core system of interconnected file and computational servers. Data storage is accommodated through large-scale storage area networks, which provide high-bandwidth access for all servers to all data. Users connect to the data center resources via desktop systems that require little or no maintenance.

New Mail Server.

Electronic mail is the most widely used communications medium at the Institute. CISD led a cross-divisional technology study team to recommend improvements to our e-mail services. As a result, CISD has deployed a new e-mail server and debuted a new user-support website. Users can now access all e-mail from any location on the Internet via either full-function clients or standard web browsers. User support provides comprehensive instructions on configurations and usage. The new system offers simpler administration, more security, easier backup, and smoother accommodation of other e-mail clients and platforms. About 60% of Institute staff migrated to the new system in 2001, with the remainder (including all Unix e-mail users) scheduled to transition next year.

Upgraded Information Technology Security.

Security threats to the Institute's computing environment have increased in number. Such threats can disrupt the work of users for days if left unchecked. CISD has taken several steps to ensure the security of our overall computing environment. It has implemented virus detection on the new mail server, which screens all e-mail coming into the Institute—whether or not the recipient reads his or her mail on this new appliance. The virus detection software proved its worth during the 'badtrans' attack, when 2500 instances of the virus were detected in less than a week. A detected virus is not passed on to the recipient. CISD improved the security of the PC environment by upgrading the Norton anti-virus software, which now performs regular scans for viruses on all PC systems. This software is updated quickly as new viruses appear. Goddard Space Flight Center has imposed new, stringent security guidelines on the Institute to ensure compliance with government-wide IT security regulations. CISD is currently working to comply with these guidelines by updating and implementing Institute security policies, implementing additional host- and network-intrusion detection systems, scanning all systems biannually, and keeping system security patches up to date.

Enhanced Computing Services.

The CISD Help Desk now provides a central location for users to report all computer-related problems and to request assistance by phone or walk-in. Front-line staff members close almost half of all calls, which has greatly reduced the number handled by the next tier of support—system, network, and security administrators. Institute staff members have come to recognize the benefits of the centralized support model with a staff member always present. For them, the Help Desk is a 'one-stop shop,' for example, to find out the status of ongoing problems, report a problem, or drop off a laptop for service.

Improved Costing Methodology.

The need to propose accurate costs for the Institute's part of developing NGST led the Engineering and Software Services (ESS) Division to investigate several commercial products for development-cost estimation. We ultimately chose the Cost-Expert system and adjusted the parameters to match our extensive experience with similar work for Hubble. We applied this improved costing methodology to both the Hubble Option 3 proposal and the NGST proposal.

Improved Systems Engineering and Testing Methodologies.

ESS takes an end-to-end approach to software design and development. In 2001, we applied this approach to improve our methodologies in two critical areas, systems engineering and testing. We published a high-level systems engineering process for the Institute. We selected and implemented DOORS, a commercial product, to serve as a requirements development and tracking tool. We established a monthly Systems Engineering Technical Seminar. On the testing front, we published a software test process methodology, enhanced and ported testing scripts, and developed the requirements for a software discrepancy tracking and reporting tool.

The Institute is... **guided by strategic thinking toward our goals**

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.

OUR 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 Next Generation Space Telescope, NGST. We will promote this vision when new missions and when 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 a first-rank technical staff to develop and maintain innovative systems to implement the missions. We must have a first-rank outreach staff to engage the public in the forefront intellectual questions of our time. We must have first-rank administrative, computer, and information services staffs to support the Institute and the community.

Our 2001 strategic plan sets goals to guide our work and evaluate our progress as we pursue our vision.

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

NGST 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 NGST 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 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.*

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 NGST, and make them available to the rest of astronomy, ensuring maximum benefit from the research enterprise to the public.*

OUR GOALS

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, NGST, 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.*

ACHIEVEMENTS

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 provides 'value added' 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.

The process of optimizing the Hubble science program is both incremental and episodic. In some areas, such as scheduling the telescope, the overall improvement is generally the result of an accumulation of many individual improvements. The installation of new science instruments during a servicing mission always results in huge improvements in the scientific potential of the observatory. With the planned installation of the Advanced Camera for Surveys (ACS) and the cryocooler to reactivate the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), Servicing Mission 3B in February 2002 will be one of these occasions. Consequently, the year 2001 saw a large amount of work in anticipation of the new scientific capabilities of Hubble, as well as continued optimization of our overall processes.

Stimulate the best **Hubble science program**

We offered a number of important new opportunities to the astronomy community in the Cycle 11 proposal solicitation. We began the Hubble Treasury Program, which is designed to stimulate science that might not naturally be proposed through the existing process. It also is meant to promote the creation of important data sets before Hubble is ultimately de-commissioned. Treasury programs are expected to focus on observations that address multiple scientific problems with a single, coherent data set. The Treasury data sets are non-proprietary and the observing teams are expected to provide processed data sets to the community and the archive. Treasury programs were one of the major recommendations of the HST Second Decade committee.

There were several other initiatives in Cycle 11. Given the rate of increase in the size of the Hubble data archive and the value of large, homogeneous data sets, we created a more ambitious Archival Research (AR) Program via the new Legacy programs. Legacy programs will perform a homogeneous analysis of a well-defined data set in the Hubble archive and will generate data products of use to the scientific community, such as, catalogs, software tools, and web interfaces. Another important addition in Cycle 11 was the start of the Hubble Theory Program, funded as part of the Hubble AR Program. The Theory Program follows on the recommendations of the Astronomy and Astrophysics Survey Committee of the National Research Council, which stressed the importance of funding theoretical research in conjunction with major observing facilities in order to improve the interpretation and understanding of the data from these facilities.

These Cycle 11 initiatives were widely advertised and the community's response to them was overwhelmingly positive. We received a total of 1,078 proposals! There were 859 GO proposals for a total request of approximately 25,000 orbits. Of these, ~10,000 orbits were requested for Treasury and Large programs. Comparing the requested orbits to the total of 3,000 orbits available for Cycle 11, the oversubscription was a factor of 8. Slightly smaller, but still very significant over-subscription factors of 6 for SNAPS and 3.5 for AR and Theory proposals made the work of the Cycle 11 Telescope Allocation Committee (TAC) and panels the most difficult in Hubble history. The TAC and panels met in Baltimore on 12-17 November 2001 to select and recommend to the Director the suite of programs to be executed in Cycle 11. The TAC recommended the approval of ten Treasury and Large programs for a total of 1,280 orbits. About 1,800 orbits were made available to and allocated by the 11 panels to smaller programs.

An additional innovation from previous cycles was the off-site location of the Cycle 11 review process. It was held in a hotel near Baltimore-Washington International Airport rather than at the Institute. This move allowed us to host all eleven panels simultaneously, shortening the stay of the TAC members by three full days while increasing efficiency and communications between panel chairs. There was a broad consensus that this change of venue was very positive. With the Cycle 11 review now completed, we have received extensive feedback from the panel and TAC members that reflects broad approval of the present system, while including useful suggestions for further improvement in the future. The scientific program for Cycle 11 will be truly outstanding, and it will continue the Hubble tradition of breaking new ground across the frontiers of modern astrophysics.

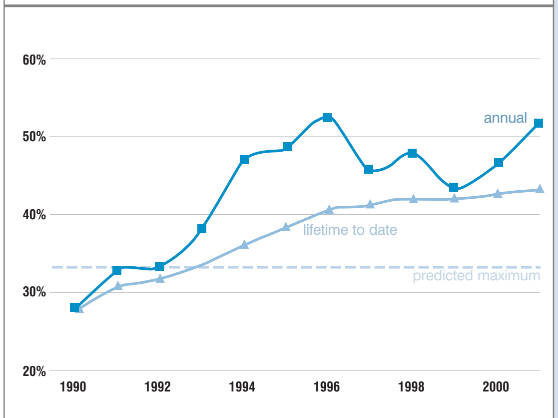
Optimize **Hubble Science Operations**

On Wednesday, May 16, 2001, we were reminded of the delicate and sometimes fickle nature of space hardware. With no indications of prior problems, a fuse blew on the primary input power feed to the Space Telescope Imaging Spectrograph (STIS). The instrument entered safe mode and the event triggered an intense investigation into the possible causes. This activity drew on the expertise of engineers at Goddard Space Flight Center and Ball Aerospace as well as Institute staff. The engineering team from the Engineering and Software Services (ESS) Division worked with the Hubble project to analyze STIS engineering telemetry and perform on-orbit diagnostic tests. The results pointed to a short circuit somewhere in the STIS side 1 electronics, which could not be worked around operationally. The ESS flight systems engineering team modified the STIS commanding to operate the instrument on its side 2 electronics, and the engineering team analyzed the instrument performance expected for side 2 operations.

Meantime, the Hubble observing schedule was reworked, moving Wide Field Planetary Camera 2 (WFPC2) programs forward to keep the observing efficiency high. STIS was recovered on Tuesday, July 10.

Yearly averages of Hubble observing efficiency. Given the constraints of Hubble's orbit, the maximum sustainable observing efficiency is about 58%.

Figure 1 | HST Scheduling Efficiency



The only significant difference found in STIS operations on side 2 was the temperature control of the STIS Charge Coupled Device (CCD) detector. Side 2 electronics do not have the capability to perform closed-loop temperature control of the CCD detector. The CCD thermoelectric cooler had to be set to a constant current level, thus allowing the detector temperature to vary slightly as the thermal environment of the instrument changes. Thermal analysis indicated that the effect on the STIS science data would be minimal, and this has been borne out. The STIS data reduction pipeline was revised to carry out a temperature-dependent dark correction. There is also extra noise in the electronics on side 2, resulting in a subtle pattern noise (and consequently higher readout noise) for the CCD. An interactive software tool was constructed to filter out this noise for some science programs.

Despite the difficulties with STIS, the observing efficiency for Hubble was kept high throughout the year. As shown in Figure 1, the average efficiency was over 50% for the period.

In 2001, process improvements led to several important new capabilities for Hubble. In February, we reduced the lead time for creating calendars of observations from 21 days to 14, which was reduced to 11 days in September. This large reduction was enabled in part through the advent of 'generic' scheduling for the Tracking and Data Relay Satellite System (TDRSS), which allows us to decouple the planning of the science timeline from requests for TDRSS communication links. Further, the reduced lead time permits us to respond more quickly for Targets of Opportunity, which are now carried out within 48 hours of an observer's request. Such rapid response will enable Hubble to obtain optical follow-up images of gamma-ray bursters and supernovae, for example.

Two solid-state recorders (SSRs) were installed on Hubble during the previous servicing missions, but only one SSR has been needed given current data volumes. However, after the installation of the ACS on SM3B, the data volume will increase substantially. Using two SSRs for on-board data buffering will allow the scheduling system to handle the expected ACS data volume. We have recently begun operating with both SSRs, so the capability will be fully tested and in routine operation before it is needed.

Calibrate **Hubble data**

This past year saw the release of On-the-Fly Reprocessing (OTFR) for STIS, WFPC2, and NICMOS. When a user requests calibrated Hubble data from the archive, the OTFR system now starts with the original telemetry to construct new raw data in FITS format, then carries out pipeline processing with the most up-to-date calibration reference files and software available. OTFR has the immediate benefit of relieving the user community of the burden of checking whether the pipeline calibration has used procedures or reference files that have since been superceded. For NICMOS, for example, OTFR ensures that the data retrievals will take advantage of updated nonlinearity corrections and, soon, a temperature-dependent bias 'shading' correction. Enhancements to the STIS pipeline include an iterative correction for scattered light in echelle data—which had often been a limiting factor in analysis—and improved treatment of STIS time-tag data.

In 2001, we made some advances in instrument operations, most notably for the Fine Guidance Sensors (FGSs). In Cycle 10, a number of GO observations pushed the limits of FGS capabilities for faint stars. This usage revealed two unrelated problems, one in 'position' mode and one in 'transfer' mode. In position mode, observations of very faint (V>16) targets encountered problems locking onto the star's interferometric fringes. This problem was traced to a slight evolution in the amplitude of the y-axis interferogram, and a magnitude-dependent adjustment was introduced, which now allows precise position measurements for the faintest stars yet. In transfer mode, to measure a binary separation, the FGS scans across a target. For faint targets, we discovered a timing problem in the command procedure, which would allow the FGS to track noise for 1.6 seconds—enough to allow faint targets to drift out of the 5-arcsecond scan box. Our fix allows shorter scans on fainter targets, which improves the signal-to-noise ratio, allows more targets per orbit, and makes stars with V>16.5 accessible for high angular-resolution investigations.

Stimulate the use of **Hubble data**

The Institute provides the astronomy community with access to the entire suite of Hubble data. We promptly process and calibrate fresh observational data for the General Observers (GOs), as well as provide access to the entire non-proprietary archive of science data.

In 2001, we processed 53,376 observations, down 7% from 2001. Typically we delivered a new science observation into the archive for access by users within 18 hours of the observation itself. This 'wait time' for data is about 40% less than in 2000 due to two factors: an improved system at Goddard for capturing and delivering the data to the Institute and a reduction in major-system downtimes compared to the previous year. The average interval between data receipt by the Institute and ingest into the archive is only 8.2 hours. As illustrated in Figure 2, during 2001 96.5% of all observations were completely processed within 48 hours of receipt.

The average Hubble data ingest and retrieval rates during 2001 were ~3 gigabytes per day and ~19 gigabytes per day, respectively. Figure 3 shows the trends for the past 7 years. The year 2001 saw some of the most active use of the archive since Hubble was launched. The total amount of data archived since launch is 7.6 terabytes; the total amount of data distributed since launch exceeds 30 terabytes.

Archive scientists and technicians at the Institute worked together to develop several enhancements to our archive user interfaces. The entire archive website was redesigned to provide easier navigation, faster access to Hubble query pages, and better integration of Hubble data to other NASA astrophysics data holdings. The WFPC2 Unique Pointings Tool was developed to allow users to submit more scientifically motivated queries to the archive. For example, one can now easily request to see all WFPC2 data obtained in at least two passbands with exposure times in excess of 5,000 seconds, which is useful if one wants to study the colors of faint astronomical objects. If one wants to search for serendipitous supernovae, this tool can help find WFPC2 images of the same area of sky but separated in time by a specified amount. We are in the process of adapting this pointings tool for use with other Hubble instruments.

The Astrophysics Data System in Cambridge, Massachusetts, hosts a database that links Hubble-related publications to the corresponding data in the Institute archive. These links are now 100% complete through the calendar year 2000. These literature links allow users to electronically access the first publications resulting from a given Hubble observing program. Users can get to data from the publications or visa versa. We are now expanding the database to include links to all Hubble-related publications.

We are continuing the production of the Digitized Sky Survey (DSS) and deriving a second-generation Guide Star Catalog (GSC-II) from these images of the entire sky. The DSS images are available to the astronomical community through the Multimission Archive at Space Telescope (MAST), and indeed have become 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. The first public release of the GSC-II this year also 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- and space-based instruments. GSC-II is being used operationally for Hubble bright-object protection, as well as for the Gemini telescopes and the Very Large Telescope (VLT). Ultimately, GSC-II will provide the basis for the NGST guide star catalog.

Monthly averages of the delays from execution to data receipt and to processing completion. The monthly-average times at which 98% of the data have been processed are indicated.

Figure 2 | Availability of Hubble Science Data

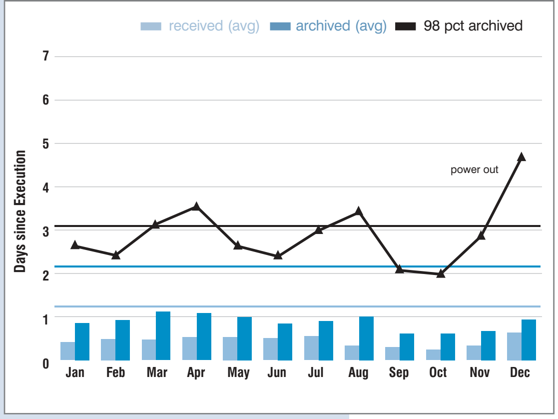
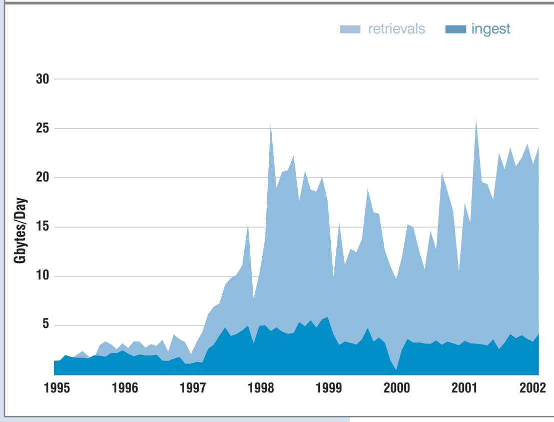


Figure 3 | Hubble Data Archive



The daily ingest and retrieval rates for the Hubble archive. This shows that the majority of the deliveries are bound for archival researchers.

Provide User **support**

We provide software to astronomers to support all aspects of their Hubble research, from the preparation of science proposals through the analysis of data returned from the telescope. We upgraded several major components of this user software during 2001. The Astronomer's Proposal Software team is developing a new suite of proposal preparation tools. Our old proposal software, which was designed before the advent of the World Wide Web, makes limited use of the Web's possibilities and runs on only a few types of computers. The new Astronomer's Proposal Tool (APT) software is written in Java, making it portable to many more systems, including Windows and Macs. It has a sophisticated graphical interface, which allows users to see how their observations will be arranged on the sky. It also integrates previously separate computer programs into one suite of tools. We released two versions of the software in 2001. Although the tool suite will not be complete until January 2003, the current version already makes it easier for astronomers to optimize their Hubble observations.

We are in the midst of a major upgrade to our data analysis software. In 2001 we released a beta-test version of PyRAF, a new command language, scripting environment, and front-end to the STSDAS/IRAF system. PyRAF, which is based on the open-source scripting language Python, retains the ability to use the thousands of data analysis programs from STSDAS/IRAF yet provides new opportunities for efficient application development. PyRAF provides much better scripting facilities, the ability to create new data analysis programs directly in the scripting language, and access to an enormous variety external libraries for the worldwide Python community

In 2001 we introduced an all-new Hubble web portal, http://hst.stsci.edu, which features 'process-oriented' navigation, dynamic content generation, and a completely different underlying infrastructure. This environment increases usability and timeliness of the information, while rendering maintenance more efficient and less time consuming. A number of main pages below the portal have also been redesigned, and more are addressed every day. In particular, the websites for STIS, ACS, and NICMOS are greatly enhanced by this new, dynamic model for web pages.

We have updated and redesigned the Hubble Data Handbook and much of the Cycle 11 documentation, including the Call for Proposals, Primer, and Science Instrument Handbooks. We strive for greater modularity and organization of the information and greater flexibility in dissemination. For the user, this means less redundancy and more paths to the information shared by various systems. We still offer well laid-out, print-optimized versions of the documents for users who may prefer the paper document.

Prepare for the **ACS and NICMOS**

Much work has been done in the past year to prepare for the ACS and the reactivation of the NICMOS. Ground system modifications have included changes to the Institute scheduling systems and to the processing and archiving of data.

We have tested ground system modifications with the actual flight hardware to ensure that we can properly operate the equipment after it has been installed. We validated the Institute scheduling system and command procedures with flight hardware during the NICMOS Cooling System (NCS) Thermal Vacuum Test, the ACS Servicing Mission Ground Test (SMGT), and the ACS/Aft Shroud Cooling System compatibility tests. We continued to update the stored commanding of ACS and NCS as operations were refined as a result

of this testing. Institute instrument scientists and data analysts participated in the testing and calibration of ACS. They have converted the ground-test data into reference files for the ACS pipeline, which they have evaluated to anticipate problems in achieving the desired precision for flight science data.

We completed development of the calibration pipeline, science data processing pipeline, engineering data processing pipeline, and archive enhancements for ACS. We executed two Integrated Pipeline Tests to test this software with ACS simulated data. This paved the way for successfully processing, calibrating, and archiving of science and engineering data from the actual ACS instrument during the SMGT. The data were then successfully retrieved from the Hubble data archive using the On-The-Fly Reprocessing system.

One innovation in the ACS pipeline is image rectification. The geometric distortions of ACS are sufficiently large that most observers will probably want to rectify the data. Furthermore, we expect that

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many observers will take multiple shifted exposures to fill in the area of the detector gap, and these images must be rectified before they can be combined. The new pipeline procedure uses the Python scripting language to invoke the 'drizzle' code, which has been used extensively for WFPC2.

The Institute has led the definition and implementation of the observing program to verify the performance of the old instruments and commission the new instruments after SM3B. These observations will test major observing modes; measure detector behavior, point spread function quality, sensitivity, and geometric distortion; and obtain early calibration data needed for the pipelines.

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. Our preparations are well along for the instruments to be installed in the last servicing mission, the Cosmic Origins Spectrograph (COS) and the Wide Field Camera 3 (WFC3).

For the COS, we coordinated with the science team led by the Principal Investigator. The Institute leads the COS Calibration Working Group, which also includes calibration experts from the COS science team, as well as from GSFC, the Far Ultraviolet Spectroscopic Explorer (FUSE) team, and previous Hubble spectrograph teams. The working group has established science calibration requirements, algorithms, and procedures for use in both the post-observation pipeline processing and data analysis. Based upon our extensive experience with spectrograph target acquisition, we have worked to include an imaging target acquisition capability for COS, which we estimate should add at least 40 additional orbits for science exposures per cycle.

We are developing COS capabilities in the Hubble scheduling systems on schedule to support the COS SMGT early in 2003. The command database definitions and the instrument reconfiguration command instructions are complete. We have implemented half of the instrument capabilities in the Hubble scheduling systems. We have tested the performance of these capabilities from proposal specification through to command-load generation, including all basic science and alignment capabilities for both the far- and near-ultraviolet channels.

For the WFC3, we coordinate 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. The WFC3 project made substantial progress in 2001, acquiring key components and subsystems, which are being installed into the instrument optical bench at Ball Aerospace. Institute scientists and data analysts played a key role procuring and characterizing all flight filters. The Institute leads the planning for operations, flight and ground software development, and ground calibration of the instrument. We have also been active informing the community about WFC3 at scientific meetings.

WFC3 capabilities in the Hubble scheduling systems are on track to support the WFC3 SMGT in the fall of 2003. We have completed all command database definitions and the instrument-reconfiguration command instructions. We have implemented one-third 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 the instrument. We are developing WFC3 science data processing software on an accelerated schedule to support thermal vacuum tests of the instrument. Pipeline software will be used to process and store thermal vacuum test data.

Goal 2 | Develop Best Possible **Next Generation Space Telescope**

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

The Next Generation Space Telescope (NGST) 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 the mission of NGST. We have posed questions based in science that need to be answered in technical terms: How sensitive must the telescope and instruments be to see a supernova at redshift z~8, an epoch less than one billion years after the Big Bang? How will astronomers detect 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? What optical quality must the NGST possess 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~1-3)? How will astronomers plan such observations? How large will the NGST archive be? During 2001, the answers to such questions—developed by NASA, the Institute, and the community—have signaled the transition of the NGST project into the phase of detailed design.

During 2001, NASA initiated the major procurements that will define the observatory and the development partners. The first, the selection of the prime contractor, will have the greatest technical impact on the mission. Although the Institute could not be part of the formal procurement process, we played a major supporting role in the definition of requirements and in reviewing the Request for Proposal (RFP). Acting on behalf of the astronomers who will use the telescope, the Institute recommended to NASA high- level requirements for the end-to-end sensitivity, imaging quality, and other scientifically important characteristics of the observatory. Acting as the future operators of the observatory, we identified characteristics that would make NGST more efficient and easier to operate. By reviewing these recommendations with the Interim Science Working Group, we ensured that our recommendations captured both our own experience operating Hubble and the needs of the community.

To support the prime contractor procurement, the Institute developed and published a concept for the end-to-end operations of NGST. Using experience gained from Hubble and an in-depth understanding of the NGST mission and science goals, a multi-discipline team analyzed the steps needed to convert science goals into spacecraft commands and ultimately into calibrated data from the archive.

The team found that NGST operations will be simpler than those for Hubble because of NGST's orbit about the Lagrange point L2. Astronomers will be able to take long observations without concern for occultations by the earth or passages through the South Atlantic Anomaly, which can disrupt Hubble operations in its low-earth orbit. Although L2 is 1.5 million kilometers from earth, NGST can transmit daily science data back to a single ground station using a one-meter spacecraft antenna. With the L2 orbit, the natural time scales are long. Small releases of gas will unload the angular momentum accumulated in the reaction wheels on a daily basis. Every month or two, longer releases will make small adjustments to the L2 orbit as required.

Making the most efficient use of the L2 orbit requires the development of flight computers to manage the mission autonomously, from a list of uplinked science observations with flexible timing constraints. The Institute provided guidelines for communicating with these computers and for the observation management software. Using a modified version of the Hubble Astronomer's Planning Tools, the NGST proposer will be able to visualize and create detailed observing plans to meet his or her specific scientific objectives. Without the need to synchronize these programs with an ever-changing orbital ephemeris, as with Hubble, the Institute can implement such plans in a matter of weeks, reducing the time between proposal submission and data receipt by up to 6 months.

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The NGST Announcement of Opportunity (AO) will lead to selection of the Flight Science Working Group, the team responsible for the Near Infrared Camera (NIRCam), and the lead and team membership of the Mid Infrared Instrument (MIRI). The European and Canadian Space Agencies have similar activities for selecting ESA and CSA science leadership. Institute staff used their experience with 10 Hubble instruments to support the NASA team responsible for the NGST AO. In parallel, the Institute investigated the use of an independent infrared guidance unit to share the focal plan, thus removing that responsibility from the NIRCam.

In July 2001, NASA announced that it would contract with the Institute to be the Science and Operations Center (S&OC) for NGST. The S&OC will be responsible for the development of all aspects of the ground system operations, communications to NGST, support to the NASA Project and all development partners, and managing the NGST science mission. NASA deemed the Institute uniquely capable of bringing Hubble experience and heritage infrastructure to the NGST project, resulting in significant savings and lower risk. Following this notice and the subsequent S&OC request for proposals, all divisions in the Institute participated in preparing the proposal, which was submitted at the end of November. The Institute proposed that all systems affecting the astronomical user (proposal, planning, archive, and grants) should have the same 'look and feel' as those for Hubble. Over 66% of the code needed for the NGST science operations system can be reused from the Hubble Astronomer's Planning Tools, Spike (for scheduling), the MAST data archive system, PyRAF, and the Space Telescope Grants Management System. With NGST launch planned for 2008, the Institute proposed taking advantage of future improvements in these Hubble systems to make them applicable to NGST. Although the observing constraints and instrument capabilities are significantly different for the two missions, Hubble observers will find the transition to NGST a natural one. A beneficial side product of the sharing between the missions is a significantly lower cost for developing the NGST ground systems compared to that for Hubble.

Throughout 2001, the Institute has supported the NGST Project in public outreach. NGST exhibits at the semi-annual American Astronomical Society meetings have encouraged hundreds of interested astronomers to learn about the phasing of the NGST mirror segments, infrared detectors, and other technology development. In the fall, the Institute unveiled the public NGST website, http://nextgen.stsci.edu, which complements the technical and scientific websites maintained by NASA and the Institute.

Goal **3** | Operate 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 12 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, today's astronomer uses 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 2001, we undertook to expand access to important astrophysics data holdings, increase the productivity of our user community, and enhance the scientific value of our data.

We provided the primary gateway for public access to the early release of data from the Sloan Digital Sky Survey (SDSS), which includes 5-band photometry and moderate resolution spectra for half of the north Galactic cap. This SDSS database is having a revolutionary impact on fundamental investigations ranging from the origin of the solar system to the re-ionization of the early universe. Working closely with SDSS participants, we designed the web-based documentation, search tools, and data descriptions to search the SDSS object catalog and retrieve SDSS data products.

A key development in enhancing archive operations was the completion of migration of Hubble data to magneto-optical (MO) disks. The MO technology provides significantly higher input/output rates, more reliable long-term performance, higher total storage capacity, and lower costs than our previous storage infrastructure. This technology will handle new Hubble data on-line for several years to come, including the user-supplied, high-level science products we expect from the Hubble Treasury programs initiated in Cycle 11. Another major infrastructure improvement was the installation of a 750 gigabyte storage system for our data-retrieval staging area, a 20-fold increase in capacity, which will meet the demands of ACS data volumes and enhance OTFR operations.

We implemented two new services in 2001 to expand the scientific utility of the archive. The MAST Data Scrapbook tool allows users to browse through representative data from all of our missions for targets of interest. Viewing these images and spectra, users can expedite decisions on what data will best serve research needs. The Unique Pointings Tool—a derivative of the scrapbook project—allows users to find data based on scientifically motivated criteria such as the number of passbands available, the ecliptic and/or galactic coordinates, or the time gap between observations. In one application, researchers can use this tool to help build new archival or observational programs—at any observatory or archive—based on the existing data within MAST.

We continue to work actively with our colleagues at other NASA data centers to improve the 'inter-operability' 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, Chandra, and VLA 20 cm FIRST data—that are relevant to interpreting our current holdings.

We are preparing to host data from the GALEX mission, which is scheduled for launch in July 2002. GALEX, the Galaxy Evolution Explorer, 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 is 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 also 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.

We are working with other data centers to define the data standards and models for the 'virtual observatory' concepts being developed nationally and across the world. (See the related News article on the National Virtual Observatory, page 6.)

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 Institute created the Office of Public Outreach (OPO) to share the amazing discoveries of the Hubble Space Telescope with the public. OPO programs are the focal point of public attention for a NASA/ESA space science mission to which thousands of engineers, programmers, technicians, administrators, and scientists have devoted their professional gifts. In the last several years, OPO has produced diverse products and programs capitalizing on the intense interest in Hubble and using it to inform and inspire people in every part of our country. Supporting our production efforts, a corps of 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 product development and support.

In 2001, the arrival of a new Head and changes in the management team provided an opportunity to re-examine the future directions of the OPO program. We developed a new strategic plan, which states freshly OPO's mission, vision, goals, and objectives. The plan defines a broad path for future development. It aims at taking the best elements of our existing outreach efforts, expanding their scope, and making our entire program more innovative, effective, and efficient.

In addition to developing the new strategic plan, we conducted education and public outreach activities in five areas corresponding to the communities we serve.

News **Program**

We produce press release packages, which often include text, photo, illustration, animation, video, and other supplemental information. We design these packages to heighten press and public interest and to make science news from Hubble more accessible. These materials are also widely used in textbooks.

In 2001, three out of seven NASA Space Science Updates (SSUs) featured Hubble content, and all achieved significant press coverage. In April, the release entitled "Farthest supernova ever seen sheds light on dark universe" showcased the intriguing story behind Hubble observations of a high redshift supernova. (See related Science article on SNaZ, page 18.) In October, "Hubble tracks the perfect storm" featured Hubble observations of a global dust storm on Mars. In November, "Hubble makes first direct measurements of atmosphere on world around another star" described fascinating observations of the planetary companion of HD 209458 (See related Science article on Transits of HD 209458.) To improve our support of SSUs in the future, we have revisited with NASA the process of selecting newsworthy topics.

We supported documentaries and program segments produced by the BBC Horizon, NHK, and CBC TV that aired internationally during 2001. We received significant local TV exposure in April, when the local Fox affiliate ran a series of interviews with Institute staff, telling the 'behind the scenes' stories of the people who keep Hubble working.

NASA's science news metric study for 2001 showed that Hubble led all other NASA science programs in news coverage. In all, we issued 39 separate news releases, which generated almost 500 newsprint/magazine/wire articles about Hubble. These articles reached an estimated 40 million science-attentive and science-interested people in the United States alone. At the American Association for the Advancement of Science meeting in San Francisco, the Institute was recognized as being among the top five sources for science news in the United States.

The Hubble Minute, which is a TV program with the style of a news report, has achieved increasingly popular support among news media. Two major new portals on the Internet— NYTimes.com and MSNBC.com, both reaching millions per month—have picked up the Hubble Minute. It was also picked up by APTN (Associated Press Television News), which reaches 15,000 media outlets worldwide and provides information management systems to more than 3300 broadcasters in over 50 countries. With these connections, we now have the potential of reaching every local station in the country and dozens more worldwide. NASA has expressed interest in using the Hubble Minute in a program called "Destination Tomorrow," which distributes video products to schools around the country.

We have established the Science Public Information Network (SPIN) to facilitate interactions and resource sharing within the astronomy public information community. This community is responsible for publicizing science results from major observatories. We will host a website to help our colleagues share ideas and discuss improving astronomy communication. The SPIN website will also disseminate space art and share other useful resources among missions.

We are preparing to support the February 2002 servicing mission with early release observations from ACS and NICMOS. The new cameras promise to reinvigorate public interest in Hubble.

Online **Outreach**

We develop Internet-accessible web content ranging from optimally formatted news releases to more timeless background resources on Hubble and the Next Generation Space Telescope (NGST). In 2001, we debuted the new NGST public web portal and released interactive segments for *HubbleSite*, including an introduction to the color and shape of Hubble images called "Behind the Pictures." This year, our suite of websites attracted over 18 million individual sessions.

"Behind the Pictures" is an informational tour of Hubble's image factory, offering a look at how our color images are actually constructed. While Hubble is well known for providing beautiful and often bizarre pictures of galaxies, planets, and nebulae, few people realize Hubble 'sees' the universe only in black and white and that we add color by hand to enhance an image's scientific value. We point out that the colors are not necessarily those the eye would see if we could visit it in a spacecraft.

We worked with the producer of the New York Times Online science section to create a permanent *HubbleSite* callout on their website. The callout has an image of the latest Hubble release, which we update as a service. In the future, we hope to enrich this callout by including the title and some of the text from the latest release.

Formal **Education**

We develop both online and hard copy curriculum-support products for the K-12 formal education community. We formulate these products in strict compliance with national educational standards and subject them to a rigorous evaluation program before and after their release. In 2001, we debuted online several *Amazing Space* modules, including "Galaxy Hunters," a high school statistics lesson. At an education products workshop, NASA showcased an older module on the Hubble Deep Field and rated it 'exemplary.' As a result, teachers nationwide requested over 5000 copies of this resource.

We manage two NASA grant programs. The education and public outreach (E/PO) grants are associated with awards of Hubble observing time and the IDEAS (Initiative to Develop Education through Astronomy and Space science) are intended to stimulate innovative educational programs in space science. In Hubble Cycle 10, 17 E/PO grant proposals—representing 10 states—and 43 GO/AR/SNAP programs requested $414,105 for education and public outreach. We awarded $285,365 to 13 of these proposals—representing 8 states—and 30 GO/AR/SNAP programs. For the 2001 IDEAS review, which took place in December, 12 external and 4 internal reviewers provided comments and recommendations for 52 proposals.

Informal **Science Education**

A recent study reports that over 60% of Americans visit an 'informal science education venue' annually. We utilize this opportunity by creating links with science centers, planetaria, natural history museums, and other forums where people broaden their understanding of science and nature. We provide a range of products and services, including both 'raw materials' for institution-based content developers and final products, such as the multimedia display called "ViewSpace."

In 2001, we brought several important (and fun!) projects to fruition. Particularly memorable was a joint project with the Baltimore Symphony Orchestra, which had the Meyerhoff Symphony Hall in Baltimore bedecked in Hubble images for a performance of Gustav Holst's "The Planets."

Over one hundred museums and planetaria around the country requested copies of our multimedia "ViewSpace" programs to display the latest Hubble information in their lobbies. Some, such as the North Museum of Science and Nature in Lancaster, Pennsylvania, have built special theaters to showcase "ViewSpace." During the year, the number of "ViewSpace" presentations increased to include new topics, such as "Pillars" and "Colliding Galaxies."

We partnered with the Smithsonian Air and Space Museum to produce new animations for their renovated planetarium. When finished, this animation will then be made available to the entire planetarium community.

The large and small travelling exhibits on Hubble, produced in association with the Smithsonian Institution, continued their tour around the country. In 2001, the large exhibition visited Texas, Nebraska, North Carolina, and Florida, and the smaller version went to Massachusetts, Iowa, California, and Connecticut. In total, almost a million visitors have experienced the wonders of Hubble through these exhibits.

Origins **Forum**

We host the NASA Origins Education Forum, which is charged with coordinating the education and public outreach activities of space science missions under NASA's Origins theme. We facilitate monthly teleconferences, listserves, informal gatherings at meetings of the American Astronomical Society, and an annual retreat for the mission leads in education and public outreach, which in 2001 was held at the SETI Institute in Mountain View, California.

We foster collaboration among the missions and provide information on recommended practices. In 2001, Montana State University developed a distance-learning course for in-service teachers based on a collaboration we fostered between the Space Infrared Telescope Facility (SIRTF) and the Stratospheric Observatory for Infrared Astronomy (SOFIA).

We provide an extensive product evaluation service. Any Origins mission may submit a product in development for our independent review. In 2001, we evaluated a full-year astrobiology curriculum for high schools, which had been developed by NASA's Astrobiology Institute. They were delighted with the quality and depth of the review and made many improvements to the product as a result.

We maintain the online Space Science Education Resources Directory for NASA's Office of Space Science. In 2001, NASA awarded this effort a Group Achievement Award.

We connected with the nascent STARTEC (State of the Art Telescopes Educational Collaboration) organization as one of the founding members. It will foster collaboration on education and public outreach between some of the world's foremost observatories.

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.

We recognize that the technical innovations we develop to support our missions in many cases set the standard for performance in their functional area. They also represent sizable investments of resources—our time and creative talents as well as NASA funding. For these reasons and to conform with NASA policy, our goal is to encourage the reuse of these innovative products, first on other NASA or astronomy missions and then also in other applications in the broader scientific or commercial world. In many cases, we have evolved the architecture of the technical products in such a manner that they are more readily adaptable to other uses.

In 2001, our efforts to showcase our products and skills led two commercial concerns to begin using our innovations to solve problems they faced.

The Wilmer Eye Institute of the Johns Hopkins Hospital sought help designing and building a prototype instrument for effective early screening of infants and young children for abnormalities in binocular focusing. The requirements for the instrument presented difficult design challenges, which the Wilmer Eye Institute had been unsuccessful at solving adequately. The instrument had to be small enough to be handheld and to make accurate measurements in a fraction of a second, so that it could be used on infants and young children. Using experience gained from the design and fabrication of astronomical science instruments, Robert Winsor, a member of our technical staff, created a novel optical design for the instrument. It could fit into a compact enclosure and reduce stray light sufficiently to allow rapid detection of the signal returning from the eye. The design also included a mechanical system for the rotating mirror in the instrument that solved problems of vibration and mobility with which the Wilmer Eye Institute had been struggling for some time. This important medical project has successfully moved into the next phase as a result of our expertise in optical and mechanical engineering.

Celera Genomics Group, an Applera Corporation business in Rockville, Maryland, was looking for a cost-effective solution to operate their pipeline processing of data related to the human genome and found a solution to their needs in our Operational Pipeline Unified Systems (OPUS) software package. (See the related News article on OPUS, page 5.)

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.

Our technical staff has embodied excellence throughout the history of the Institute. Its partnership with our world-recognized scientific staff created the success of the Hubble mission, the Multimission Archive at Space Telescope, and our outreach programs. NASA recognized the technical authority and productivity of the Institute's human resources when it selected the Institute as the Science and Operations Center for the Next Generation Space Telescope (NGST). Thus, we foster and enable our technical staff as a cornerstone of the Institute's future.

In 2001, we created an Information Technology Council (ITC) to provide advice, conduct reviews, and promote professional development. The ITC is a permanent, self-governing, independent body with a rotating, honorary membership drawn from the technical staff. The ITC's primary goals are to provide a broad view to management on technical issues and to offer guidance and mentoring to the staff. The ITC will stay abreast of technology directions arising in the astronomy, aerospace, and NASA communities. It will recommend strategies for the Institute to keep pace. The ITC will provide a forum for technical staff to discuss long-term goals and collaborative opportunities across organizational boundaries. It will organize technical symposia and other exchanges of technical knowledge. It will promote participation in our Research Opportunities for Technical Staff program, which was introduced in 2000.

The Engineering and Software Services (ESS) Division fosters a culture of continued learning and improvement to strengthen the Institute's engineering expertise and cutting-edge methodologies. In 2001, we initiated a bi-monthly engineering colloquium series, featuring both internal and external speakers. We published the first four issues of an internal engineering newsletter, The ESSence—Engineering and Software Solutions for Science. We continued our program of enhanced professional training opportunities for technical staff. This program includes 'mini-sabbaticals,' which allow technical staff to devote two weeks to an internal learning project designed to enhance technical capabilities and innovation. Already in the first year, we see the benefits of this program in improved systems engineering and testing techniques; deeper understanding of extreme programming techniques—like pair programming—and their appropriate application; and progress towards an initial test deployment of a new security system for our databases.

In resonance with the Institute's emphasis on the central role of technical contributions in the success of our science missions, AURA instituted a new Award for Technology and Innovation in 2001. This award will be given to an individual at an AURA center who has demonstrated excellence in an area of technology—including but not limited to engineering, design, and software development—and who has made a significant innovative contribution during the past year. This past year, AURA presented the first Award for Technology and Innovation to Perry Greenfield for introducing the Python scripting language to the Institute and for the PyRAF project, which is developing a replacement for the IRAF command language using Python. Additionally, the AURA Service Award was given this year jointly to Institute staff members Elyse Wagner (Lead Grants Administrator) and Lee Hurt (Project Engineer) for their development and successful deployment of the state-of-the-art, electronic Space Telescope Grants Management System. This system has revolutionized the way that astronomers and administrators administer Hubble grants. These two awards exemplify how we honor the contributions of the Institute's technical staff to the success of our missions.

Over the last year, the NGST mission has required an increasing level of support from the technical staff. Managers at all levels of the Institute have grappled with strategies for sharing our technical talent among Hubble, NGST, the archive, and other missions. To ensure that talent is deployed to best effect, we have employed matrixing, cross-training, systems reuse, and cross-mission planning. The Missions Directorate Management Council continues to refine plans and procedures to accommodate our superb technical staff to our new multimission status.

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 2001, we selected 12 new Hubble Fellows and supported approximately 30 Hubble Fellows nationwide. We organize the yearly Hubble Fellowship Symposium, which allows all Fellows to present their latest scientific results.

We also manage 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 2001, we had 2 Institute Fellows and hosted approximately 22 regular postdoctoral fellows. We also hosted 8 graduate students, about half of whom are 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 2001, we hosted 5 Distinguished Visitors, 12 Journal Club Visitors, and 14 Collaborative Visitors.

Each spring, we organize a symposium on an astronomical topic of major interest with important new developments. Usually, 100-200 astronomers attend these symposia, drawn by the offerings of cutting-edge research and invited speakers of the first rank. The 2001 symposium, entitled "The Dark Universe: Matter, Energy, and Gravity," brought together physicists and astronomers working on all aspects of dark matter, theories of gravity, and cosmology.

Each year, we also organize one or two smaller scale workshops focused on 'journal club' themes, and approximately 50 participants attend. In 2001, the workshop entitled "ACS High Latitude Surveys" attracted 60 participants, who discussed suggestions for large observing programs using the Advanced Camera for Surveys.

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We organize discussion sessions on 'hot topics' in astronomy. Here, vigorous debate follows short presentations on a new, possibly controversial result from Hubble or other observatories. The objectives of this format are a better understanding of the topic and the incubation of new ideas and collaborations. In 2001, we organized three stimulating discussion sessions, entitled "Planets in Clusters," "Astrobiology," and "The Re-ionization of the Universe."

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 2001, the DDRF supported about 50 scientific projects and allocated approximately $330,000 in funding to 18 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 conduct a mentoring program for junior tenure-track and parallel-track scientists. In 2001, we reviewed the nature of the mentoring program and rearticulated the expectations in a mentor-'mentee' relationship. We reviewed the existing relationships and encouraged all scientists to involve themselves in this important program.

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, the Science Personnel Committee Chair, and a rotating member evaluates the summaries and selects 1/6 of the tenure and parallel track scientists to receive merit increases in salary.

In order to encourage high scientific productivity, we monitor the fraction of time that AURA scientists spend performing independent research each year, based on bi-weekly time cards. We have found that, on average, tenure track astronomers spend about 42% of their time doing research, compared with 50% expected. For parallel track astronomers, we found the fraction was about 18%, with 20% expected. Both fractions increased after our special efforts to encourage functional managers to protect staff science time.

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 2001, most practical issues were resolved successfully.

Scientists Serving **Our Missions**

We are committed to provide optimal scientist resources to all divisions in support of the Institute's missions. We are committed to provide positive and challenging functional opportunities to our scientists. To achieve these goals, we coordinate with division managers and individual scientists to make the best assignments for both parties. We assign all tenure-track, parallel-track, and ESA scientists to their functional duties. When issues arise in the assignment process, we facilitate their resolution.

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.

New mission concepts pace the advance of astronomy. They provide the means to answer scientific questions that current missions raise but cannot address, and they increase the opportunities for serendipitous discoveries. Ideas for new missions can arise from the collective wisdom of community-based studies or from the creativity of individual scientists. For multiple reasons, the Institute has a special responsibility to foster new mission ideas—due to our leadership role on behalf of the community, to our technical assets of systems and skills, and to our basic obligations to encourage the talents and curiosities of our staff.

The Institute pursues this goal in a variety of ways. In the case of the Advanced Camera for Surveys (ACS), about to be installed on Hubble, the Institute conducted a community-based study called "The Future of Space Imaging," which recommended to NASA the basic requirements for the next-generation Hubble camera. A NASA competition selected Holland Ford of Johns Hopkins University to be the Principal Investigator (PI) to develop ACS, and several Institute scientists are on the ACS team. In the case of the National Virtual Observatory (NVO), the idea gained momentum from another Institute-led, community-based study called "HST Second Decade," which drew upon experience with the Hubble archive. Later, the Institute was partner in a Johns Hopkins-led proposal to the NSF to study enabling information technology for an NVO. This proposal was selected in 2001, and today we are helping to develop the infrastructure for NVO in collaboration with many other astronomy organizations. (See the related News article on NVO, page 6.)

The HST Second Decade committee also recommended that a near-infrared channel be included on the Wide Field Camera 3 (WFC3). The near-infrared capability is now an important part of this instrument. Institute staff members are part of a team led by the Goddard Space Flight Center to develop the WFC3 for installation on a future servicing mission.

In the case of the Kepler mission, being developed as part of NASA's Discovery Program, the PI—William Borucki of NASA Ames Research Center—approached the Institute through an interested astronomer, Ronald Gilliland, asking us to provide certain mission services as well as science-team participation. Because this mission was both a science opportunity and a chance to derive extra benefit from our technical assets, we participated in the Kepler proposal, which was selected in 2001. The Institute will support Kepler by providing both science participation and data services.

We encourage our scientific staff to participate as individuals in new mission plans. Such activities support their scientific research and benefit the nation's program of astronomical exploration and discovery. During the last year, our scientists participated in many workshops, science teams, and working groups, as well as mission and program reviews at the request of NASA. In most cases, these involvements will never produce 'new business' opportunities for the Institute. Nevertheless, we believe that such involvements are important contributions to the long-range course of science.

science
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Cosmology is a very useful **science**, and they are **benefactors** of mankind who help us to read this book of the visible **heavens**.

— Thomas Vivian, 1792

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