

NEWSLETTER

Space Telescope Science Institute



Image Credit: Taken on board Servicing Mission 3B spacecraft.

Overview of Servicing Mission 4

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Shuttle astronauts will make one final “house call” to NASA’s *Hubble Space Telescope* as part of a mission to extend and improve the observatory’s capabilities through 2013. NASA Administrator Michael Griffin announced plans for a fifth servicing mission to *Hubble* on Tuesday, October 31, 2006, during a meeting with agency employees at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Over the course of the last three shuttle missions we have conducted a detailed analysis of the performance and procedures necessary to carry out a successful *Hubble* repair mission. What we have learned has convinced us that we are able to conduct a safe and effective servicing mission to *Hubble*,” Griffin said. “While there is an inherent risk in all spaceflight activities, the desire to preserve a truly international asset like the *Hubble Space Telescope* makes doing the mission the right course of action.”

Griffin stated that the flight was tentatively targeted for launch during the spring to fall of 2008. Mission planners have now settled on a launch-readiness date of September 11, 2008, for space shuttle *Atlantis*. The flight has been designated STS-125. The astronaut crew has been announced as the veteran astronaut Scott D. Altman, commander; Gregory C. Johnson, pilot; with mission specialists including veteran space walkers John M. Grunsfeld and Michael J. Massimino, and first-time space fliers Andrew J. Feustel,

Michael T. Good, and K. Megan McArthur. Scott Altman is no stranger to *Hubble*—he commanded *Columbia* in 2002 for STS-109, the last servicing mission. The crew is already undergoing rigorous training for the mission.

The *Hubble* servicing mission, SM4, is planned to be an 11-day flight. On its third day following launch, the shuttle will rendezvous with the telescope. Five separate space walks will be needed to accomplish all of the mission objectives.

This will be the fifth visit to *Hubble* since its launch in April 1990. SM1 took place in December 1993, SM2 in February 1997, SM3A in December 1999, and SM3B in March 2002. (SM3 was split due to a critical need to replace gyroscopes in 1999.) SM4 was originally planned for 2004, but the *Columbia* tragedy on February 1, 2003, led to its postponement and eventual cancellation due to safety concerns. Following three successful flights, significant improvements in the shuttle, and a re-examination of servicing mission risks, NASA considers it safe to fly the shuttle back to *Hubble*.

The mission will be the heaviest servicing mission to date. *Atlantis* will be carrying about 22,000 pounds of hardware. Four carriers inside the shuttle cargo bay will carry the new science instruments, replacement hardware, tools for the astronauts, and the rig to attach *Hubble*

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NASA Commits to return to the Hubble Space Telescope

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In the November 3, 2006, the American Astronomical Society, the largest professional organization for research astronomers in the United States, released the following statement on the approval of a servicing mission for the *Hubble Space Telescope*.

"The American Astronomical Society applauds NASA Administrator Michael Griffin for approving the servicing of the Hubble Space Telescope. By orbiting above the Earth's atmosphere, HST has the best site for astronomical observation and has used that unique advantage to uncover more about our Universe than any previous telescope. From planets in our Solar System to the furthest reaches of the Universe, HST has peered deeper and seen farther. Approving the use of the space shuttle to provide new instruments and repair aging equipment on the HST shows that NASA understands the value of scientific research to the public. We thank the Administrator and the talented astronauts who will perform this servicing mission. They will enhance this national resource and extend its life."

Upon releasing the statement, President J. Craig Wheeler said, "We owe a debt of gratitude to Administrator Griffin for making this critical decision, and to the astronauts, whose personal skills, training, and courage will get the job done."

A successful servicing mission will add the Cosmic Origins Spectrograph and the highly capable near-ultraviolet-to-infrared Wide Field Camera 3, and repair the Space Telescope Imaging Spectrograph. We are also exploring whether there is any way we can repair the Advanced Camera for Surveys, which we so catastrophically lost in January this year. These repairs depend on the ingenuity and skills of the *Hubble* project and astronaut team—and I have learned in the last 18 months never to underestimate the creativity and determination of that partnership. SM4 will rejuvenate *Hubble* and enable our community to tackle some of the most exciting topics in astrophysics. These will range from the acceleration of the universe under the influence of dark energy, to the development of structure under the influence of dark matter, the



Figure 1: The astronauts selected for the final shuttle mission to perform work on the *Hubble Space Telescope* pose for a group photo. From left to right are astronauts Megan McArthur, Michael Good, Gregory C. Johnson, Scott Altman, John Grunsfeld, Michael Massimino, and Andrew Feustel.

creation of the first galaxies after the Big Bang, and the physical properties of extrasolar planetary systems.

Not until the launch of the *James Webb Space Telescope* in 2013 will the astronomical community have access to such a large and capable space-based telescope as the 2.4-m *Hubble*. Even after *Webb* is launched, *Hubble* will retain its unique advantage in the ultraviolet and optical wavelength range. The bravery, skills, and commitment of the astronauts promise to make the next decade of *Hubble* science as exciting as the previous 16 years. What an incredible and privileged time it is to be an astronomer! Ω

to the shuttle. One of the carriers incorporates an advanced design and composite materials to save weight, allowing more material to be carried to orbit.

On SM4, four astronauts will undertake extravehicular activities (EVAs) in pairs on alternating days. They will fit *Hubble* with two new instruments, the Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS). They will replace all six of the telescope's gyroscopes, a fine guidance sensor, and all six batteries. The crews will add new thermal coverings to *Hubble*'s exterior and, in preparation for the de-orbit mission at the end of *Hubble*'s life, they will attach a capture mechanism to the aft bulkhead. Astronauts will also attempt to repair the Space Telescope Imaging Spectrograph (STIS), which was installed on *Hubble* in 1997, but ceased operations in August 2004 due to an electronics failure.

The improvements of SM4 are expected to keep *Hubble* operational until at least 2013. They will also greatly enhance the discovery power of the observatory. For example, both COS and WFC3 contain advanced technology that far surpasses what has been available on *Hubble* to date, and key performance factors are expected to improve by 10 to 70 times.

COS is designed to perform high-sensitivity, medium- and low-resolution spectroscopy of astronomical objects in the 1150–3200 Å wavelength range. COS will significantly enhance the spectroscopic capabilities of *Hubble* at ultraviolet wavelengths, and will provide observers with unparalleled opportunities for observing faint sources of ultraviolet light. It is not meant to be a replacement for STIS, which will remain in *Hubble* after the servicing mission—each spectrograph has unique capabilities.

COS has a simple, two-channel optical design. It minimizes the number of reflections involved in dispersing and detecting ultraviolet light, and is particularly designed to provide high throughput in the far ultraviolet, below about 2050 Å. Designed for high-throughput spectroscopy of point sources, COS may also be used to observe extended objects, but with limited spatial information and degraded spectral resolution. It will be located in the bay currently occupied by the Corrective Optics Space Telescope Axial Replacement, which was installed on SM1 to correct spherical aberration for first-generation *Hubble* instruments.

WFC3 is designed to replace Wide Field Planetary Camera 2. Using two CCD detectors in the ultraviolet-optical wavelength range and a HgCdTe detector in the near infrared, it will provide imaging from 2000 to 17000 Å. Equipped with a comprehensive set of wide-, intermediate-, and narrow-band filters, WFC3 is intended to ensure that *Hubble* will continue to have superb imaging capabilities during its lifetime.

The gyros that astronauts will replace on SM4 are used to control the pointing of the telescope during science observations. The original telescope design called for three of the six gyros to be operating at a time. To conserve the use of the three gyros currently remaining, a new attitude-control system was devised requiring only two operating gyros. This enabled one to be turned off in August 2005, and *Hubble* has been observing successfully since that time. While the image quality has not been degraded, observations with either orientation or timing constraints are now more difficult to schedule, and only about half the sky is observable at any one time (compared greater than 80% of the sky in three-gyro mode.) We anticipate returning to three-gyro mode after SM4.

Astronauts will replace all six of *Hubble*'s original nickel-hydrogen batteries, which have provided electrical power during approximately one-third of the time *Hubble* spends in the Earth's shadow when the solar arrays do not function. Sixteen years into the mission, these 125-pound batteries have lasted more than 11 years longer than their design lifetime, longer than the batteries in any other spacecraft in low Earth orbit. In addition to the stability of nickel-hydrogen chemistry, this durability attests to the robust design of these batteries and their careful on-orbit management by NASA engineers.

The new batteries are made using a process called wet slurry, which makes them physically stronger and better performing. Each new battery has an added safety feature: a battery isolation switch that ensures no electrical power is present at the connectors while the switch is in the off position.

Astronauts will add stainless steel sheets at various locations on *Hubble*'s exterior to help control the telescope's internal temperature. These sheets will cover portions of the existing multi-layer insulation that have degraded over time due to exposure to the harsh environment of space.

When *Hubble* reaches the end of its life, NASA plans to de-orbit it safely into the open ocean by firing a rocket that will be attached on a future *robotic* visit to the observatory. To prepare for this mission, engineers developed the Soft Capture Mechanism (SCM) and the Rendezvous Navigator Sensor (RNS). The SCM is a ring-like device that will be attached to *Hubble*'s aft bulkhead. It will provide a mating interface and navigational targets for future rendezvous, capture, and docking operations. The RNS system consists of optical and navigation sensors, as well as supporting avionics and processors. However, it will not be installed on *Hubble*—its role during SM4 is to collect data during the capture and deployment of the telescope. This information will be used for developing the navigation systems of the future spacecraft that will de-orbit *Hubble* at the end of its useful life. Ω

The View of SM4 from NASA Headquarters

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At Goddard Space Flight Center on October 31, 2006, Administrator Griffin, accompanied by Senator Barbara Mikulski of Maryland, announced that NASA would mount a shuttle-based Servicing Mission 4 (SM4) to the *Hubble Space Telescope*. The mission is scheduled for September 2008. A successful SM4 mission will ensure *Hubble* can continue its exciting exploration of the universe until at least 2013.

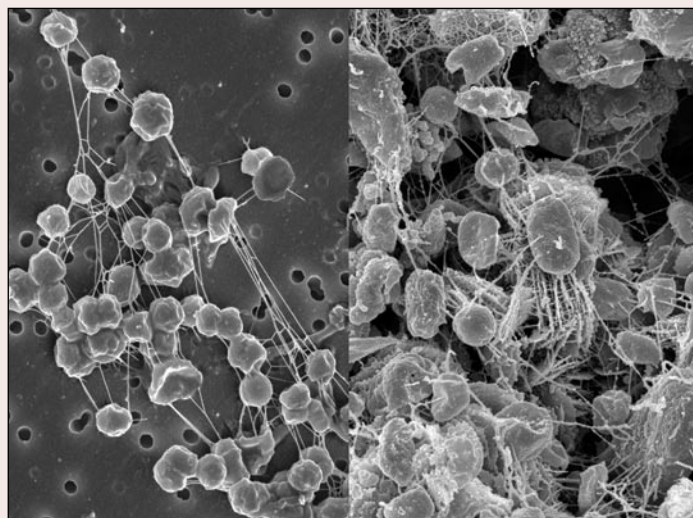
SM4 will allow the installation of two new scientific instruments, the Wide Field Camera 3 and the Cosmic Origins Spectrograph, which are eagerly awaited by the astronomical community. Also, astronauts will replace the batteries, gyros, and one fine-guidance sensor. Perhaps the most ambitious undertaking will be an attempt to repair the Space Telescope Imaging Spectrograph, which failed in 2004. Because of its accommodating design, astronauts have a good chance of recovering the instrument.

This fifth and final servicing mission to *Hubble* will be very full, with five extravehicular activities to perform all the desired work. SM4 will ensure *Hubble* remains the world's premiere space-based observatory operating at ultraviolet, optical, and near-infrared wavelengths, and will ensure the continued synergy of coordinated science investigations with the *Chandra X-ray Observatory* and the infrared *Spitzer Space Telescope*.

The Science Mission Directorate at NASA Headquarters is working closely with the Space Operations Mission Directorate (the shuttle folks) to make sure that the science priorities of SM4 can be carried out on a safe shuttle mission.

The past couple of months have certainly been exciting for NASA's *Hubble* program at NASA Headquarters. In addition to helping secure SM4, we have had some changes in staff. Jennifer Wiseman left Headquarters to accept a position as Chief of the Laboratory for Exoplanet and Stellar Astrophysics at Goddard, and Jeffrey Hayes, the Program Executive for Operations, was appointed Program Scientist to replace her. We all wish Jennifer the best of success in her new position. Michael Moore continues on as the Program Executive for SM4.

The next 18 months or so will be hectic, challenging, exciting, and rewarding times for everyone involved with *Hubble* at the Institute, Goddard, and Headquarters. We are all committed to ensuring that SM4 turns the page to the start of a glorious final chapter of *Hubble's* already remarkable story of discovery. Ω



Mars May Be Cozy Place for Hardy Microbes

A class of especially hardy microbes that live in some of the harshest Earthly environments could flourish on cold Mars and other chilly planets, according to a research team of astronomers and microbiologists. In a two-year laboratory study, the researchers discovered that some cold-adapted microorganisms not only survived but reproduced at 30 degrees Fahrenheit, just below the freezing point of water. The microbes also developed a defense mechanism that protected them from cold temperatures. These close-up images, taken by an electron microscope, reveal the tiny one-cell organisms, called halophiles and methanogens, that were used in the study.

<http://hubblesite.org/newscenter/archive/releases/2006/2006/48/>

Image Credit: Maryland Astrobiology Consortium, NASA and STScI

SM4: Perspectives of a Scientist

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In 2000, *Time Magazine* chose Albert Einstein as the “Person of the Century.” Some people were surprised that a scientist was chosen over world political leaders, authors, artists, and economists. I wasn’t. Einstein’s achievements have crossed the boundaries between science and culture, and have penetrated into every area of human intellectual endeavor. Just enter “Albert Einstein” at the Amazon.com webpage and you’ll find more than 25,000 results. Einstein changed our view of the universe in a fundamental way. The *Hubble Space Telescope* has shown us Einstein’s universe. And when I say “us” I don’t mean just the scientists. *Hubble* has literally brought the wonders of the cosmos into homes worldwide. You now find *Hubble* images not only in astronomy textbooks, but also on the covers, variously, of a book of music for the trumpet, a German art magazine, a book that teaches English to Japanese children, and an album of a rock group. And here comes the best part. After almost seventeen years of operation, Servicing Mission 4 will bring *Hubble* to the richest moment in its life in terms of scientific capability! Sometimes people ask me if I don’t feel depressed by the apparently diminishing role of humans in the universe. After all, we are not at the center of the cosmos, or even the center of the Milky Way Galaxy. Even the stuff of which we are made is only four percent of the matter in the universe, and everything we can observe is but a speck of all there is. But notice that the apparent decrease in our physical presence is only a consequence of the tremendous *increase* of our knowledge. And *Hubble* played a crucial role in that expansion of our horizons of understanding.

I am truly proud to have been a part of this incredible scientific adventure called the *Hubble Space Telescope*, and I am looking forward to an even brighter future. Ω

SM4: Perspectives of an Astronaut

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For astronauts, and for me on a personal level, the opportunity to leave planet Earth and fly in the space shuttle on any mission is an incredible privilege. It is nevertheless important to remember that this activity carries with it more than a significant risk, as the tragic loss of the *Columbia* and the STS-107 crew patently demonstrated. As a crew, we go forward with the *Hubble* Servicing Mission 4 with the knowledge that we are participating in an activity that is much bigger than all of us and worth the risk to ourselves and our families. We recognize that this mission reaches beyond the teams of astronomers who will directly benefit from the new and exciting observations enabled by the Wide Field Camera 3 or the Cosmic Origins Spectrograph, and beyond the extended *Hubble* lifetime on orbit.

The work that we do on orbit—with the efforts of the big team including Goddard Space Flight Center, the Institute, scientists around the world, and many others—has become an integral part of our culture. When we go to *Hubble* in 2008, we will not just write another chapter in the *Hubble* story, but will extend a work that is already a major mark in human history.

The day-to-day efforts to train and prepare for the flight have already started, with training in the Neutral Buoyancy Laboratory (big swimming pool), robotic-arm training, and long planning meetings. Our commander Scott Altman, and space-walkers Mike Massimino and I are certified “Hubble Huggers,” and we know how special it is to be part of the *Hubble* team. The new space flyers on this flight—pilot Greg (Ray J) Johnson, flight engineer Megan McArthur, space-walkers Drew Feustel and Mike Good—regard their assignment as being incredibly special, and they’re right! There is an enormous amount of hard work for all us to do, but in the background is the thought that the greatest discovery from *Hubble* may well be enabled by our labors on Servicing Mission 4. Ω

Reflections on HST Servicing Mission 4

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For three days in February, it was our pleasure to welcome to Goddard the entire seven-person astronaut crew assigned to the SM4 mission for the first of many crew familiarization sessions—better known as “Crew Fams.” It’s an extraordinary group. Commander Scott (Scooter) Altman also served as mission commander on SM3B in 2002. The lead EVA astronaut, John Grunsfeld, has flown to *Hubble* twice before in SM3A (1999) and SM3B. Mike (Mass) Massimino is also a veteran spacewalking “Hubble Hugger,” having serviced the observatory in SM3B. SM4 is the first space shuttle flight assignment for EVA astronauts Andrew (Drew) Feustel and Mike Good, but both have greatly impressed *Hubble* Program “oldtimers” who have worked with them during three EVA practice runs in the Neutral Buoyancy Laboratory at the Johnson Space Center. The delicate task of operating the shuttle’s remote arm during the five EVAs of SM4 has been assigned to Megan McArthur. Piloting the shuttle will be Greg (Ray-J) Johnson. Interestingly, we have three Ph.D. scientists on this crew—astrophysicist Grunsfeld, geophysicist Feustel and oceanographer McArthur.

As I sat with some of the astronauts during a meeting this week, I reflected on how exciting it feels to be back in the business of planning a real mission to service our observatory once again. We began serious planning for SM4 during the mid-1990s. When the Cosmic Origins Spectrograph was selected for flight on SM4 by NASA in 1997, the mission was scheduled for 2002. A “torrent of water” has “flowed over the dam” since then. Most devastating of course was the tragic loss of the space shuttle *Columbia* on February 1, 2003. NASA’s recovery to the point where the shuttle fleet could safely be returned to flight was slow and painful. On *Hubble*, our own pain was compounded by the cancellation of SM4 on January 16, 2004.

On so many occasions the *Hubble* Team has demonstrated resiliency and technical creativity, and the time after the cancellation was no exception. There followed a visionary, but ultimately futile, attempt to design a mission that would service *Hubble* with robots, monitored and controlled by engineers on the ground. Prior to his appointment as NASA’s new Administrator in April, 2005, Mike Griffin served as Chair of one of the technical review panels assessing the feasibility of a robotic servicing mission to *Hubble*. His conclusion at the time was that such an approach was ill-advised. However, as Administrator he offered us an alternative. If the safety of shuttle missions could be demonstrated with at least two successful missions, and if the safety of a mission to *Hubble* could be convincingly established, he would consider reinstating SM4.

Mike set the bar very high and the Shuttle Program cleared it with room to spare. The shuttle successfully returned to flight with missions STS-114, 121 and 115 in 2005 and 2006. The astronaut crews demonstrated the ability to inspect and repair the thermal protection systems on the shuttle craft. A plan was also developed to have a backup rescue mission waiting on the launch pad, if needed, during the *Hubble* mission. All of Mike Griffin’s conditions were met. On October 31, 2006, here at Goddard he gave SM4 a “go.” In that same announcement he named the astronaut crew for the mission and stated that SM4 would fly no earlier than May, 2008.

Plans are firmer today. SM4 is slated to fly on shuttle mission STS-125 in mid-September of 2008. Once again we’re doing what we’ve done so successfully four times before, testing real-flight scientific instruments and other components, wrestling with new technical problems seemingly every week (business as usual), helping to choreograph spacewalks, designing tools to help make the astronauts’ EVA tasks simpler, and thinking through myriad details of how to operate *Hubble* while it’s attached to the shuttle. And life on *Hubble* is fun once again. Ω

Status of Wide Field Camera 3

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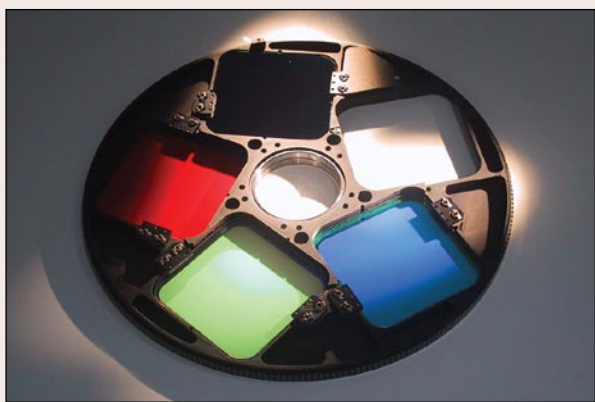


Figure 1: Filter wheel 6 for WFC3's ultraviolet-visible channel. This wheel, originally flown in *Hubble's* original Wide Field and Planetary Camera, now contains newly fabricated filters F475W, F606W, F600LP, and F845M filters.

In the past year, the Wide Field Camera 3 (WFC3) instrument was partially disassembled to inspect, repair, and re-test various components, but it is now re-assembled and progressing toward its system-level thermal-vacuum acceptance testing in spring 2007.

Several problems discovered during testing in 2004 have been corrected. Of greatest significance for scientific performance, the ghost images of bright stars have been essentially eliminated by replacing most of the ultraviolet broad-band filters and several other key filters. As a bonus, the new filters offer better throughput and superior out-of-band rejection. Due to structural defects, the F588N filter was replaced with a F200LP (i.e., clear) filter. The

infrared filter set has been improved with the addition of F140W in place of the F093W, which was designed to aid in the ground alignment of the optics. With the improved short-wavelength performance of the infrared detector, the WFC3 Science Oversight Committee judged F093W to be less useful than F140W.

The most exciting WFC3 news is about the infrared detector. The current infrared detector meets the instrument specification, but we have a concern that protons in space may cause its CdZnTe substrate to glow, which would reduce the detector's performance. We have fabricated additional detectors with this substrate removed. Furthermore, due to continued improvements by our detector vendor (Teledyne, formerly Rockwell Scientific), these new devices exhibit considerably improved quantum efficiency and reduced dark current. We are in the process of packaging two of these detectors, and we intend to install the best one in WFC3 in fall 2007.

Observers interested in planning programs with WFC3 should note that the "mini-handbook" has been updated as part of the Cycle 16 *Call for Proposals* (http://www.stsci.edu/hst/wfc3/documents/handbook/cycle16/wfc3_cyc16TOC.html). The full *WFC3 Instrument Handbook* is now in preparation and will be available, along with the WFC3 exposure time calculator, for Cycle 17. Ω

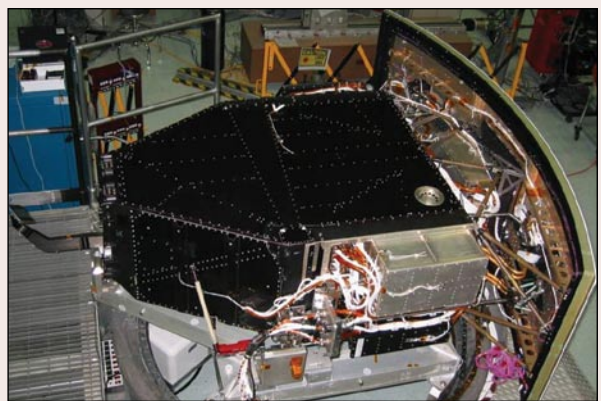


Figure 2: The fully assembled WFC3 in the cleanroom at the Goddard Space Flight Center. The pickoff mirror is seen on the left.

Status of the Cosmic Origins Spectrograph

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Recently, the Cosmic Origins Spectrograph (COS) successfully completed its second round of thermal vacuum testing and instrument calibrations in the space-environment simulator at Goddard Space Flight Center. Many people, including the COS instrument development team, led by Principal Investigator Dr. James Green of the University of Colorado, the Institute's COS team, and engineers from GSFC and Ball Aerospace, participated in these intensive activities. Prior to these tests in late 2006, COS had last been calibrated under vacuum conditions in October 2003, at Ball's facilities in Boulder, Colorado. In addition to confirming nominal instrument performance, the most recent tests exercised new instrumental modes and capabilities.

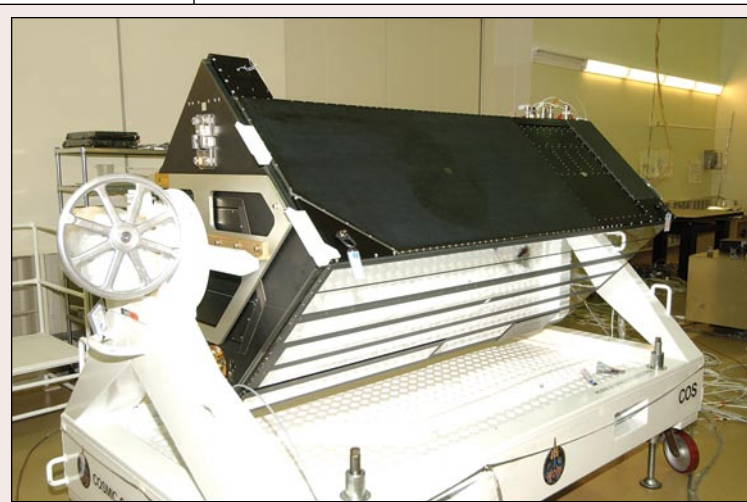


Figure 1: The Cosmic Origins Spectrograph.

In 2006, GSFC and Ball personnel removed all 22 electronics boards for inspection and replacement of some components. As a precautionary action in response to the failures—after several years of on-orbit operation—of low-voltage power converters in both the Space Telescope Imaging Spectrograph and the Advanced Camera for Surveys, all 18 similar devices in COS were replaced with improved components. The updated electronics boards were thoroughly tested and qualified prior to the recent thermal vacuum tests.

The COS team at the Institute has completed all the standard science, calibration, and target-acquisition modes for operating COS. In 2006 we developed the

new TAGFLASH time-tag observing mode, in which the internal wavelength-calibration lamps are flashed at intervals during science exposures. Pipeline processing of this calibration information—which is recorded adjacent to the science data on the detector format—compensates for any movement of the optical components, improves spectroscopic resolution and wavelength accuracy, and eliminates the need for separate wavelength-calibration exposures. TAGFLASH was thoroughly tested in the recent thermal vacuum activities, and will be used as the default observing mode on-orbit.

The COS mini-handbook version 3 was distributed with the October 2006 Cycle 16 *Call for Proposals* (http://www.stsci.edu/hst/cos/documents/handbooks/current/cos_cover.html). The forthcoming *COS Instrument Handbook* version 1 will be distributed with the Cycle 17 *Call* in Fall 2007. In 2007 we will also release the COS exposure time calculators and the tool for evaluating the field of view for bright objects. Ω

FGS3r Status

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Astronauts will install a refurbished Fine Guidance Sensor (FGS3r) on Servicing Mission 4 (SM4). The original FGS2 was returned from orbit in January 2000, as part of SM3A. Since then, Goodrich, its manufacturer, has upgraded the instrument's motor encoders with new balls, races, bearings, coarse and fine light-emitting diodes, and lubricant. They also installed an Actuated Mirror Assembly (AMA) to provide for on-orbit alignment, as with the previously refurbished FGSs, FGS1r and FGS2r.

Aligning the FGS optical elements relative to its Koester prisms is critical to avoid losing sensitivity due to the spherical aberration on *Hubble's* primary mirror. For FGS3r, this alignment was achieved using a new tool called the "full field-of-view test set," which could simulate the interference fringes of a star anywhere in the FGS field of view during ground testing. (In the past, fringes could be sampled at only one place in the field of view.) Using the new tool to align the FGS3r's optics for all rotation angles of the star-selector servos, Goodrich engineers were able to achieve near-perfect interferometric performance across the entire FGS3r field of view. The alignment remained after vibration testing (to simulate launch loads) and the first thermal vacuum test, which gives high confidence that the unit will remain aligned through launch and on-orbit desorption of water from the graphite epoxy structure. The AMA will be used on orbit to correct any gross change in the alignment of the Koester prisms with respect to the well-aligned upstream optics.

After SM4, we expect *Hubble* to use fainter guide stars than ever before. It is interesting to note that during its first ten years on orbit, this particular unit was the least capable of *Hubble's* three FGSs. Now, it may well turn out to be *Hubble's* best pilot ever. Ω

STIS On-Orbit Repair

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The Space Telescope Imaging Spectrograph (STIS) was originally installed into *Hubble* on February 14, 1997, during Servicing Mission 2 (SM2). Seven and a half years later, on August 3, 2004, a failure occurred in the Side-2 electronics of STIS. This failure was traced to a component in a power supply for STIS's mechanisms, including the aperture wheel, selector for gratings and mirrors, and the CCD shutter. As the Side-1 electronics had already failed in 2001, the Side-2 failure rendered STIS unusable for scientific operations.

The survival heaters in the instrument continue to function, and the detectors themselves should not have suffered any damage.

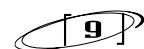
The Side-1 electronics cannot be accessed without removing STIS from *Hubble*, which means they cannot be repaired. However, astronauts can access the electronics box containing the failed component on Side 2 after the axial-bay doors in the aft shroud are opened. NASA has decided to attempt the replacement of the circuit card containing the failed component during SM4. This repair should restore STIS to a fully functional state.

One of the most challenging aspects of the STIS repair will be removing and safely securing the 111 fasteners that hold the electronics box cover in place. NASA has designed a special tool—a "fastener capture plate," or FCP—which will be attached to the existing cover. An astronaut will use a hand-held electric driver to unscrew each fastener through a matching hole in the FCP, which will then trap the loosened fasteners. The FCP and the electronics box cover can be removed together, along with all the trapped fasteners.

Once the cover plate is removed, the astronaut will use other specially designed tools to remove the circuit card with the failed component and insert its replacement. A new cover plate will be installed and secured using two clamp-like latches instead of the 111 fasteners. A brief functional and aliveness test will verify the functioning of the new circuit card and its electrical connections. A backup replacement will be available in case there is a problem with the first circuit card.

After the circuit card is replaced, a new passive radiator panel will be attached to STIS. Without this new cooling system, the additional heat

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generated in the *Hubble* aft shroud by the new Cosmic Origins Spectrograph would raise the temperature in the STIS Multi-Anode Microchannel Array (MAMA) detectors by a few degrees. With the new radiator, the MAMA detectors are expected to be slightly cooler than they had been during the latter period of STIS operations. This cooling should significantly reduce the MAMA detector dark currents.

The STIS repair as currently envisioned will require a full-day extra-vehicular activity (EVA), and this task is a lower priority than are the installations of the Cosmic Origins Spectrograph (COS), Wide Field Camera 3, and new gyros and batteries. Should anything happen to reduce the number of EVAs available for *Hubble* servicing, or should any of the higher-priority tasks require significantly more time than planned, it may not be possible to attempt the STIS repair.

At the time of its failure in 2004, STIS was still highly productive scientifically, accounting for about 30% of the *Hubble* observing program. COS will replace or supersede some of the STIS's capabilities, while others will remain unique. These include the ability to take long-slit spectra with high spatial resolution, slitless first-order spectra in the optical and ultraviolet wavelength ranges, and echelle spectra with spectral resolution about 100,000. STIS can also observe targets that are too bright for COS to observe effectively.

While COS will be the instrument of choice for faint point-source targets where a spectral resolution of 24,000 or less is adequate, a number of scientific problems will still require STIS. These include studies of black hole dynamics, galaxy rotation curves, and observations of the interstellar medium at high spectral resolution. We expect the unique capabilities of a repaired STIS to ensure it will be used for a substantial part of the *Hubble* observing program after SM4. Ω

Failure of the Advanced Camera for Surveys

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On Saturday, January 27, 2007, the Advanced Camera for Surveys (ACS) suffered a serious failure in the electronics supplying power to its three observing channels and other subsystems. The failure is under investigation by an anomaly review board. The most likely cause of the failure is a short circuit in the side-2 low-voltage power supply or the auxiliary power box.

ACS has two redundant sets of electronics. A short in the side-1 electronics in June 2006 rendered the two CCD channels—the Wide Field Channel and the High Resolution Channel—unusable on that side. With the recent failure on side 2, it appears that future use of these channels will not be available on either side.

The circuitry of the Solar Blind Channel was unaffected by the June 2006 anomaly. The SBC was returned to service on side 1 on February 19.

The ACS failure has prompted several initiatives related to Cycle 15 and 16 observing programs. The Cycle 16 *Hubble* observing proposal deadline was extended from January 26 to February 9, 2007, to give observers a chance to resubmit their proposals using one of the other *Hubble* instruments. The *Spitzer* observatory accommodated this change by moving its deadline to February 16, 2007. In addition, the Institute director has activated a set of six contingency programs using the Wide Field Planetary Camera 2 and Near Infrared Camera and Multi-Object Spectrometer. These programs were designed for just such an emergency, to ensure that *Hubble* continues obtaining valuable scientific data. A description of those programs can be found at <http://www.stsci.edu/hst/proposing/docs/acs-backup-proposals>.

The Institute has been evaluating the feasibility of converting pending Cycle 15 and earlier ACS observations over to the other *Hubble* cameras.

More information on the status of the ACS and *Hubble* observing programs can be found at <http://www.stsci.edu/hst/> and on the Cycle 16 announcement page, at <http://www.stsci.edu/hst/proposing/docs/cycle16announce>. Ω

ACS Backup Programs

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Following its installation in Servicing Mission 3B, the Advanced Camera for Surveys (ACS) was the workhorse instrument on the *Hubble Space Telescope*, accounting for more than 75% of the scheduled programs. ACS suffered two anomalies during 2006, leading to a switch to operations on side-2 electronics and a reconfiguration of the use of the three ACS cameras (Wide Field Channel, Solar Blind Channel, and High Resolution Channel). Given its dominance in the schedule, we recognized that if ACS failed, *Hubble* would quickly exhaust the available observations waiting to use the Near Infra-Red Camera and Multi-Object Spectrometer (NICMOS), Wide Field Planetary Camera 2, and Fine Guidance Sensor. To mitigate the potential science impacts of that eventuality, the Institute issued a call for additional, large backup programs using those three instruments. The programs were to be held in reserve, and inserted into the observing schedule only in the event of a future ACS anomaly.

A total of 35 proposals were submitted by the deadline of November 3, 2006, including 9 with ESA scientists as principal investigator. The proposals were reviewed and graded by members of the Cycle 15 Time Assignment Committee, and the technical feasibility of highly ranked proposals assessed by members of the relevant instrument teams at the Institute. Based on the TAC rankings and the feasibility analysis, the Institute director selected the following proposals for further development:

Selected Proposals

G. Clementini (Bologna, Italy):	RR Lyrae stars in M31 globular clusters
D. Zucker (IoA, Cambridge, UK):	Probing the least luminous galaxies in the local universe
P. Côté (Herzberg Inst., Canada):	The structure, formation and evolution of galactic cores and nuclei
D. Calzetti (STScI/Univ. Mass):	Exploring the scaling laws of star formation
L. Bianchi (Johns Hopkins Univ.):	Imaging of star forming regions throughout the Local Group
C. Conselice (Univ. Nottingham, UK):	NICMOS imaging of GOODS

Together, these programs provide 300–400 orbits of science observations at any time of the year. Our intention had been to develop these proposals to Phase II status by February 15, 2007. However, the failure of the ACS side-2 electronics on January 27, 2007, demanded a more rapid schedule. All of the proposals were activated on January 29, converted to Phase II status by February 5, and observations of selected targets were implemented during the week of February 12–18. Ω

ACS Report

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September 2006 anomaly in HRC

On September 23, 2006, an anomaly in the High Resolution Channel (HRC) caused the instrument to autonomously enter a “suspend” state. An ARB concluded that the most likely cause of the problem was a bit of non-conductive debris between the contacts of a relay on a signal-processing board in the HRC CCD detector electronics. The contacts had to meet to make a proper electrical connection. The ARB recommended that the problematic relay be toggled open and closed to clear the debris, which worked on October 9, restoring the low voltage power for the CCDs. The HRC resumed service on October 16. New commanding procedures were implemented that left the relay in its working position to avoid using it in the future. As a consequence, the HRC and Wide Field Channel (WFC) would always be powered during routine operations, except when monthly anneals were performed.

This new configuration required changes to the instrument commanding to operate the Solar Blind Channel (SBC), which was not directly affected by the relay problem. Previously, SBC use was tied to a set of commands that toggled the HRC relay, to help ensure that the HRC and SBC did not operate simultaneously. A new study of the electrical and thermal implications of simultaneous operations retired those concerns, and approval was given to operate SBC with both HRC and SBC CCDs powered.

*Continued
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SBC was brought back into service on November 27. The SBC observing capabilities were the same as those that had been available in the past. As earlier, the SBC was powered only when it was being used for science or calibration and was not used in parallel with the other ACS channels.

ACS calibration

The ACS team at the Institute is working to improve the calibration of ACS data obtained after the July 2006 switchover to the side-2 electronics and the concurrent lowering of the temperature set-point of the WFC CCD from -77°C to -81°C . We are updating the ACS data pipeline as these analyses are completed.

Long-exposure dark frames were taken almost daily to provide calibration reference files, monitor dark current, and catalogue hot pixels in the ACS CCDs. Since launch, the dark current had been increasing linearly with time (as with other *Hubble* CCDs), and the measured dark rate after four years in orbit was twice the value at launch (Figure 1).

Even so, the dark current was very low and only a small percentage of the science performed with ACS was impacted by the increase in its mean level. The *non-uniformity* of dark current—“hot pixels”—was a bigger concern. Some pixels showed very high dark current, even orders of magnitude times the mean dark rate. Hot pixels accumulated with time in orbit (Figures 2 & 3).

For practical purposes, we define as “hot” those pixels with a dark rate greater than $0.08\text{ e}^-/\text{sec}$, and as “warm” those more than five standard deviations above the mean dark rate but below $0.08\text{ e}^-/\text{sec}$.

Standard data-reduction procedures do not adequately correct hot pixels, whose signal can fluctuate, which produces a significant noise term when the mean value is subtracted. The best approach to reducing the effects of hot pixels on science observations is to divide them into multiple exposures dithered by one or more pixels. During image combination, the information in a hot pixel is discarded.

Like other CCDs on *Hubble*, the ACS detectors underwent a monthly annealing process. The CCDs were warmed up to $\sim 19^{\circ}\text{C}$ for few hours, which healed the majority of the new hot pixels. The annealing rate depended strongly on the level of the dark current: very hot pixels showed a higher annealing rate (up to 87%) than warm pixels. Annealing had no impact on the average dark current level.

Most hot pixels were transient, but some were permanent. New hot pixels appeared daily on the CCD. Most of these were “cooled” by the following

annealing, but the minority of pixels that were permanently hot increased at a non-uniform rate of a few to several hundred per day depending on the signal level.

Dark current and hot pixels depended strongly on the operating temperature. The reduction of the operating temperature of the WFC CCDs reduced them by almost 50%. Their trends in Figures 1 and 4 show a clear drop on July 4, 2006, when the temperature was changed, and Figures 5 and 6 illustrate the before-and-after effect directly. The new operating temperature brought the dark current and the hot pixels in the WFC back to the level eighteen months after the launch.

The change in the WFC operating temperature produced two further benefits. First, at the colder temperature, hot pixels were created at a lower rate. The second benefit was subtler, due to a

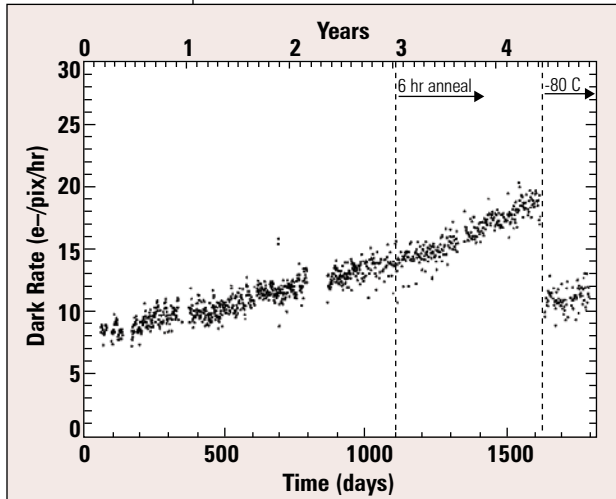


Figure 1: Dark current as a function of time for one of the WFC CCDs. The first dashed line indicates the change in the anneal procedure from twelve to six hours for the duration of the warm-up period. The shorter anneal slightly increased the rate of growth of the dark current. The second dashed line indicates the change in temperature set point for the CCDs. As expected, the dark current dropped drastically at the new temperature.

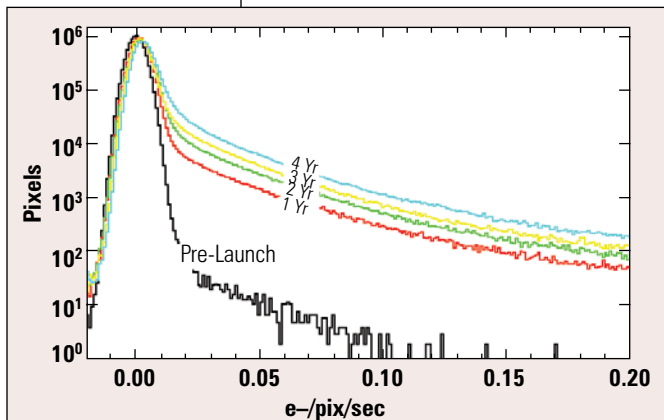


Figure 2: Time evolution of the distribution of hot pixels for one WFC CCD. Pixels with dark current greater than $0.08\text{ e}^-/\text{sec}$ /pixel are flagged as “hot.” The first four years of on-orbit operation are shown. As the radiation damage accumulated, both the mean dark current (the peak of the distribution) and hot pixels population (the tail of the histogram) increase.

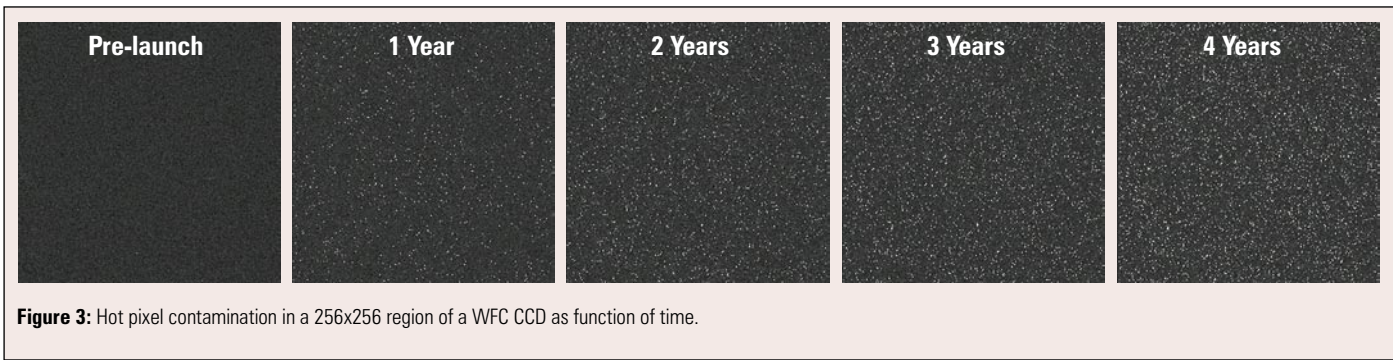


Figure 3: Hot pixel contamination in a 256x256 region of a WFC CCD as function of time.

combination of the reduced number of hot pixels and the effect of the change in temperature on the charge transfer efficiency (CTE), which is the fraction of electrons successfully transferred from one pixel to the next in the process of reading out a CCD detector. The degradation of CTE by radiation damage is the worst aspect of operating CCDs in space.

CTE degradation is due to some electrons being trapped in defects within the pixel and being released on a time scale that depends on the nature of the defect and the operating temperature. The quickly released trapped electrons produced the “tails” on imaged objects oriented transverse to the readout direction. The other trapped electrons (the majority) were released on much longer time scales, and they were not visible in the image as artifacts.

The ACS team is still characterizing the impact of the change of the WFC temperature on the CTE performance. The first indication is that only the CTE tails were affected. While the signal that goes into the tail has not changed, the tails became longer and therefore fainter. The net effect of the number of hot pixels being drastically reduced and the CTE tail of each hot pixel becoming fainter was a significant decrease in the amount of noise in an image. This improvement benefited survey programs in particular.

The ACS team is characterizing other changes in performance associated with the changes in electronics and operating temperature. The WFC flat fields changed by amounts ranging from ~0.6% in the blue to ~0.15% at F814W. New flat fields for filters between F435W and F814W were delivered in early November (ACS/ISR 2006-06). We will update the WFC zeropoints to take into account the variations in the sensitivity of the WFC detectors, ranging from -2.5% at F435W to about -1% for redder filters.

ACS bulletin board

The Institute has established an online ACS bulletin board to facilitate communications between staff and *Hubble* observers on ACS-related topics. (<http://forums.stsci.edu/phpbb/index.php>) The bulletin board is an efficient means of disseminating news and responding more openly to common questions received by the e-mail help desk. With several threads already started, and the number of contacts mounting to several hundred, the early success of this new form of communication with ACS users is encouraging.

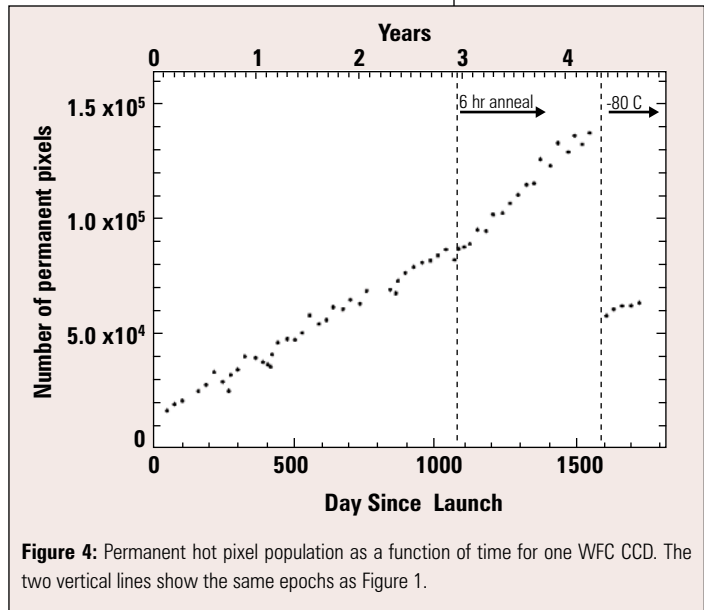


Figure 4: Permanent hot pixel population as a function of time for one WFC CCD. The two vertical lines show the same epochs as Figure 1.

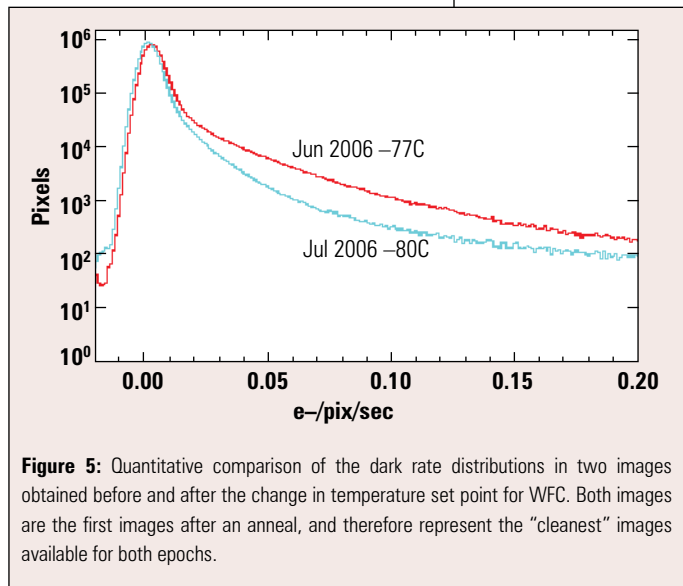


Figure 5: Quantitative comparison of the dark rate distributions in two images obtained before and after the change in temperature set point for WFC. Both images are the first images after an anneal, and therefore represent the “cleanest” images available for both epochs.

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After leading the ACS team for almost two years, Ken Sembach has accepted a position as project scientist in the Institute's *Hubble* mission office. We thank Ken on behalf of the ACS team, the Institute, and the user community for the expert guidance that he provided for the past years.

For answers to any questions about ACS, please consult the bulletin board or send email to help@stsci.edu. Ω

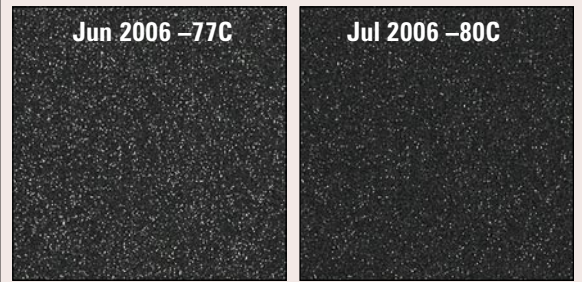


Figure 6: Hot pixel contamination in the same two images as described in Fig. 5.

Profile: Kenneth Sembach



Figure 1: Ken Sembach

Kenneth Sembach has been appointed as the Institute's Project Scientist for the *Hubble* mission. Ken is a tenured astronomer who has been working at the Institute for more than five years, serving as an Instrument Scientist for the Cosmic Origins Spectrograph (COS), as the Instruments Division's Two-Gyro Project Scientist, and most recently, as the Team Lead for the Advanced Camera for Surveys. In these previous positions, he has developed productive working relationships with the engineers, scientists, programmers, and planners who operate *Hubble* and are responsible for the health and maintenance of its various subsystems. In his new role, Ken will serve as a science champion for *Hubble*, working closely with the *Hubble* teams at the Institute and the Goddard Space Flight Center. His duties will include exploring potential science-driven enhancements to *Hubble* based on scientific, technical, and resource considerations; providing the *Hubble* operations teams with scientific guidance related to implementing

observations; and acting as a liaison with the science community.

Ken says, "I enjoy working with teams of people to maximize the quality of science we get from *Hubble* and to solve challenges of all kinds, whether they are scientific or technical in nature. With *Hubble*, they are almost always a wonderful combination of both."

Ken has longstanding scientific interests in the physical properties, chemical evolution, and large-scale distribution of the intergalactic medium. In recent years, his research has focused on the relationship between the intergalactic medium and galaxies. Ken is a strong advocate for current and future ultraviolet/optical observatories in space, and has a keen interest in ensuring that the two new *Hubble* instruments to be installed during Servicing Mission 4—COS and Wide Field Camera 3—are the best they can possibly be. Ω

NICMOS Status and Enhanced Calibration Program

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Following the shutdown of *Hubble* caused by the anomaly in the Advanced Camera for Surveys (ACS) on January 27, 2007, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) was quickly recovered and restored to routine science operations. Because NICMOS is now one of only two primary science instruments still operating, we expect its utilization to greatly increase. Therefore, the NICMOS team at the Institute is taking steps to ensure that the instrument is as well calibrated as possible. To that end, we are applying the experience and insights achieved during the past several years of successful NICMOS operations to improve the observing programs and software on which calibration depends. Many of the artifacts that appear in NICMOS data are due to the effects of temperature, charge persistence, and nonlinearities, all of which are amenable to characterization and calibration.

Starting in Cycle 15, and continuing in Cycle 16, the NICMOS calibration programs will encompass much more than the routine monitoring programs carried out in previous cycles. The new programs will address flat fielding, count-rate-dependent nonlinearity, temperature effects, plate scales, and geometric distortion. The planned observations will also improve the reliability of both the bright and faint photometric standards used for direct imaging and slitless spectroscopy.

The new flat-field calibration program (ID 11016) uses every filter available on all three NICMOS cameras. The goal is a flat-fielding accuracy of about 0.1%, more than an order of magnitude improvement over the current 2–3%. These new flat fields will be the first complete set obtained since Cycle 7—when NICMOS was originally installed on *Hubble*—and will significantly increase the pool of data available for investigating the effects of time and temperature on NICMOS flat fields.

One special calibration program (ID 11062) will further characterize the rate-dependent nonlinearity in the NIC3 camera (NICMOS ISRs 2006-001 and 2006-002). Another (ID 11067) will re-derive the NICMOS plate scale and geometric distortion in all three cameras. Our aim is to update the distortion model with an accuracy of about 1/4 of a NIC2 pixel (i.e., at the level of about 18–19 milliarcsec).

We will obtain new observations of primary and secondary standards for grism spectroscopy and direct imaging (ID 11064). The goal is to obtain up-to-date sensitivity curves for all three grism modes. In addition to improving calibrations, this data will allow us to study the variations in NICMOS sensitivity over a baseline of about three to four years, and will also help to improve the wavelength-dependent model of the NIC3 count-rate-dependent nonlinearity.

The results of directly imaging a large set of infrared standard stars will be used to verify the spectroscopic calibration of the grism (ID 11061). Observations of the primary standards will calibrate the relative brightness of stars over a wide range of luminosities, which will afford more accurate calibrations than the spectroscopic observations, directly and independently establishing faint infrared standards. In the future, the *James Webb Space Telescope*, as well as other current and future infrared observatories, will benefit from these improved photometric standards.

The software and procedures that remove or attempt to correct instrumental effects in NICMOS data are being upgraded. For example, several effects are strong functions of detector temperature, which in the past has been estimated by proxies such the mounting cup sensor—which does not directly measure the detector temperature. In the future, we hope to determine this temperature more accurately, directly from measurements of the detector bias.

We developed software to correct a number of effects in NICMOS data related to persistence. One of the most serious of these is the persistence of the cosmic-ray signals that accumulate in the detectors during passage through the South Atlantic Anomaly (SAA), where *Hubble* spends between 30–50% of its time. These signals, which can persist for several orbits after a passage, can dramatically raise the noise level in science exposures. We have now tested and released a new software routine, SAACLEAN, which uses an accurate model of the persistence to remove the excess signal.

Another new software routine, PUFTCORR, removes the faint ghost images caused by a bright object in a detector quadrant. The ghosts are located at mirrored locations in the other quadrants, and are due to electronic crosstalk. PUFTCORR corrects the problem.

SAACLEAN and PUFTCORR significantly reduce spurious signals at low levels in NICMOS images.

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We are working to more accurately characterize of the temperature-dependent structure in NICMOS flat fields, and we want to better understand the dark current in NICMOS images. The ability to estimate the detector temperature from the bias levels will facilitate these investigations.

The NICMOS team expects that the scientific research based on the increasing flow of data from NICMOS will benefit greatly from our efforts to improve the calibrations and the software that implements them. Ω

Update on the James Webb Space Telescope

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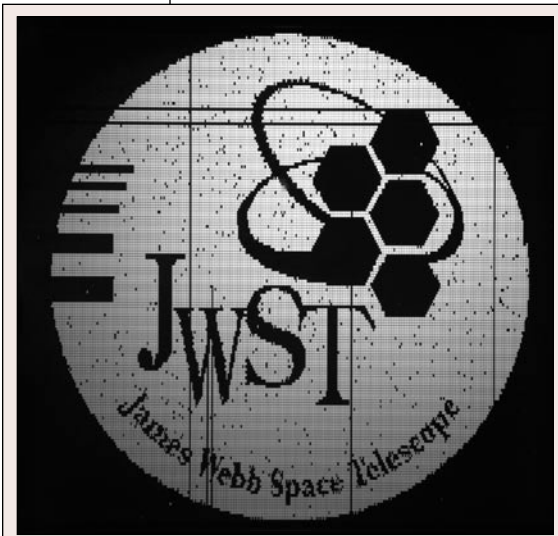


Figure 1: Micro-shutter array (MSA) programmed with the *Webb* symbol. Four MSAs will be used for the three-by-three arcminute field of the Near-Infrared Spectrometer. Although a small fraction of the apertures are dark and appear to be stuck shut, very few apertures are unintentionally white—i.e., stuck open—and those are the main concern for science operations, as a potential source of light contamination.

The *Webb* project remains on track for a launch in June 2013. The science instrument teams are developing engineering units for delivery in late 2008, and have begun construction of flight parts.

The team for the Mid Infrared Instrument (MIRI) successfully completed the critical design review of the optical bench in February 2007. The development of the MIRI cryo-cooler has lagged due to funding constraints, but will be ready before observatory-level integration and testing.

The machining of the beryllium mirrors—the segments of the primary mirror and the secondary and tertiary mirrors—has been completed, and the parts have been sent to Tinsley for grinding and polishing.

Northrop Grumman hosted a “Meet JWST” reception at the Seattle meeting of the American Astronomical Society. Following the reception, several speakers, including John Mather, described the recent progress and remaining challenges of the *Webb* development. John Stoke from the Institute premiered a popular video about *Webb* to good reviews. The DVD will be available at the Honolulu meeting, or you may direct a request to the author of this article.

Webb Technology Readiness

NASA Administrator Mike Griffin has stated that the maturity of enabling technologies is one of the top

three indicators of a project’s technical and financial health. Based upon a recent independent review of its technologies, the prognosis for *Webb* is excellent. While refinements are needed before the preliminary design review and non-advocate review in winter and spring 2008, all the enabling technologies for *Webb* have been shown to meet their performance goals after surviving launch-like loads and the environment at the second Lagrange point, L2, which will be the site of *Webb*’s science operations for the ten-year mission.

On January 30–31, 2007, the non-advocate review team (NRT), chartered by NASA Headquarters, grilled the teams representing the ten new technologies needed for a successful *Webb* science mission. Jean Olivier—former *Hubble* chief engineer and deputy *Chandra* project manager—led the NRT’s close assessment of the briefing packages. Occasionally, a single chart prompted a fifteen-minute discussion. A typical question was whether a “flight-like” part had been through all the various environmental tests, and in what order. Such are the trials of readying a new technology for a long-duration, deep-space missions. *Webb* components must work for ten years after a dose of radiation ten times that lethal to humans. Tests to verify their reliable performance usually involve many repetitions of a part’s function, and sometimes operating the part at an elevated temperature.

All but one of *Webb*'s ten enabling technologies met its performance and environmental goals. Only the MIRI cryo-cooler—which is based on parts proven on over a dozen civilian and military missions—ran into problems. The cryo-cooler achieved its cooling performance goals at 6 K and 18 K, but at a 20% higher power level than was specified. The cooler also induced more vibration than allowed, but this was without active control. While the *Webb* project indicated that the current performance could be accommodated, the Northrop Grumman development team will continue to refine the cooler design and add active vibration control. They are confident that they can produce an engineering unit meeting the power and vibration requirements with margin.

For the other technologies, no further engineering or design effort will be needed before flight units are built. In one case, the NASA team responsible for the programmable aperture assembly in the Near Infrared Spectrograph solved the problems of apertures sticking open by improving contamination control and adjusting the mechanical tolerances on the tiny windows and flaps (see Fig.1). Ω

Technology	Performance meets Requirements	Environmental Tests	Technology Transfer (Corp./dev. status)
Sunshield Coatings	yes	Life/radiation/ micrometeorites	Sheldal/Flight
HgCdTe Detectors	yes	Rad./vibration	Teledyne/Flight
Primary mirror segments	yes	Vibration/acoustics/ thermal cycling	Tinsley/Flight
Si:As Detectors	yes	Rad./vibration	Raytheon/Potential Flight detectors made
Microshutter Array	yes	Rad./vib/acoustics	GSFC/Eng. Unit
Cryo readouts	yes	Life/thermal/vib/rad	Teledyne/Flight
Cryo-heat switch	yes	Thermal/vac./vib.	SDL/Eng. unit
Wavefront sensing	yes	Thermal/vibration of optical elements	Ball/Continued worst case testing
Backplane stability	yes	Thermal cycling/thermal stability	ATK/Flight design-CDR
MIRI cryo-cooler	Cooling passed but excessive power and "exported" vibration w/o active control	Vibration successful (no leaks from field joints or assembly)	NGST/Pulse-tube cooler refined based upon test data and other programs

Table 1: Status of *Webb*'s enabling technologies. Only representative environmental tests are listed.



Celestial Greetings from Hubble

Swirls of gas and dust reside in this ethereal-looking region of star formation imaged by NASA's *Hubble Space Telescope*. This majestic view of LH 95, located in the Large Magellanic Cloud, reveals a region where low-mass, infant stars and their much more massive stellar neighbors reside. A shroud of blue haze gently lingers amid the stars. The image was taken in March 2006 with *Hubble*'s Advanced Camera for Surveys.

<http://hubblesite.org/newscenter/archive/releases/2006/2006/55/>

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

Webb Science Meeting

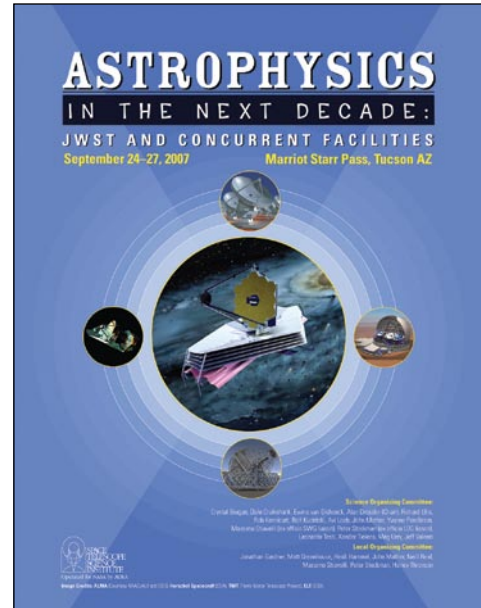
P. Stockman, stockman@stsci.edu

NASA's *Webb* project and the Institute will co-host an international scientific meeting entitled "Astrophysics in the Next Decade: *JWST* and Concurrent Facilities." The meeting will be at the Starr Pass Marriott in Tucson, AZ on September 24–27, 2007. The goals of the meeting are to discuss the astrophysics to be enabled by *JWST* and facilities that will operate at the same time in the next decade, like Atacama Large Millimeter Array, *Herschel*, and second-generation 8-m class instruments.

We intend for this meeting to interest and benefit the broad astronomical community. In addition to preparing for observations, we hope to stimulate the theoretical foundations that will be needed to interpret the observations. We plan to produce a record of the talks and discussions to ensure their lasting value.

The science organizing committee will invite speakers and moderators for approximately twenty topical areas, from the earliest stars and galaxies to present-day star and planet formation. We welcome contributed posters on relevant scientific topics or new observing facilities.

The meeting will be open to all astronomers, but the attendance will be limited to approximately 250. A meeting website will be available in March for early registrations and will provide an updated meeting agenda. Meanwhile, questions and indications of interest can be sent to the author of this article or another members of the local organizing committee. Ω



Science Organizing Committee

Crystal Brogan
Dale Cruikshank
Ewine van Dishoeck
Alan Dressler (Chair)
Richard Ellis
Rob Kennicutt
Rolf Kudritzki
Avi Loeb
John Mather
Yvonne Pendleton
Massimo Stiavelli (ex officio SWG liason)
Peter Stockman (ex officio LOC liason)
Leonardo Testi
Xander Tielens
Meg Urry
Jeff Valenti

Local Organizing Committee

Jonathan Gardner
Matt Greenhouse
Heidi Hammel
John Mather
Neill Reid
Massimo Stiavelli
Peter Stockman
Harley Thronson

Searching MAST by Cross-Correlation with VizieR and NED

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It is possible to search for classes of objects in the Multimission Archive at Space Telescope (MAST) using the descriptors provided by the principal investigator (PI). However, this information is often crude, and sometimes even meaningless, as in the case of parallel exposures. Cross-correlating the positions of objects in published catalogs with MAST data positions is an alternative approach. Positional cross-correlation is proving powerful for finding objects of interest in *Hubble* observations, and it is opening exciting new opportunities for research that the PI on the original observations likely never envisioned.

There are currently two major sources of object catalogs, VizieR and NED. VizieR provides catalogs related to stars, galaxies, and other galactic and extragalactic objects. (<http://vizier.u-strasbg.fr/>). NED (NASA/IPAC Extragalactic Database) maintains a master list of extragalactic objects with positions, redshifts, photometry, cross-identification of names, and bibliographic references (<http://nedwww.ipac.caltech.edu/>).

MAST now provides cross-correlation services for both VizieR and NED based on epoch 2000 equatorial coordinates.

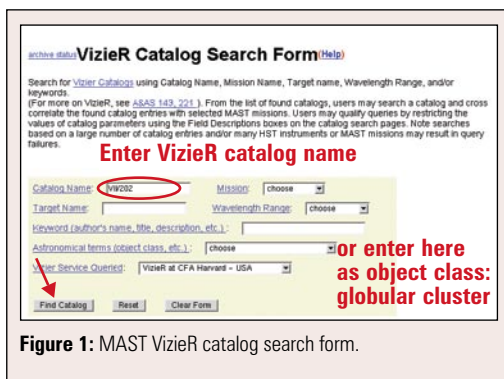


Figure 1: MAST VizieR catalog search form.

We illustrate the power of cross-correlation with two basic tasks: (1) finding *Hubble* observations of objects in a VizieR source catalog and (2) searching MAST for observations of objects of a particular class as listed in NED.

VizieR cross correlation with the *Hubble* archive

Figure 1 shows the MAST search interface for VizieR catalogs. You can either enter your favorite catalog name—in this case, the Milky Way Globular Cluster Catalog from Harris (1997), VII/202—or use other information, such as wavelength range or object class to shop among VizieR catalogs. Once you select your catalog, you decide to search the catalog (S) or to perform a cross-correlation (CC) with MAST data, which would bring you to the screen for selecting MAST missions and search criteria (Fig. 2).

As an example, let's check how many globular clusters in the catalog have WFPC2 association images—combined images from the Wide Field Planetary Camera 2. We set the maximum records to 100, which means that for each catalog entry a maximum of 100 images will be returned. We find that 105 out of the 147 catalog entries have WFPC2 association data.

You can select between various formats for the returned search results—HTML table, an Excel spreadsheet, comma-separated values, or a VOTable/XML file.

In the case of HTML, you can download the FITS preview file by clicking on the association name.

WFPC2 association data is available online and can be retrieved without delay. The same holds true for most other non-*Hubble* MAST missions, such as *International Ultraviolet Observer* and *X-ray Multi-Mirror Telescope* and *Optical Monitor*, but not the *Far Ultraviolet Spectroscopic Explorer* (*FUSE*). Most *Hubble* data and *FUSE* data are not online, but have to be retrieved through the Data Archive and Distribution System. As an example, Figure 3 shows the steps to retrieve data from the Advanced Camera for Surveys (ACS). The calibrated data is typically delivered in an hour.

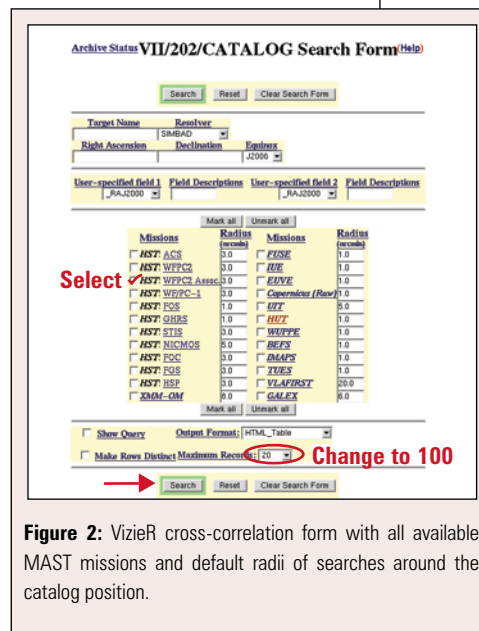


Figure 2: VizieR cross-correlation form with all available MAST missions and default radii of searches around the catalog position.

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MAST
from page 19

MAST offers an option to include only objects that match constraints provided in two user-specified fields on the cross-correlation form. The user builds the constraints using a pull-down menu of all the columns in the VizieR catalog. (Clicking on a column name brings up an explanation of its meaning.)

The screenshot shows the 'Cross Correlation Search Results' page. It includes a search form at the top with fields for Target Name, Right Ascension, and Declination. Below the search form is a table of results with columns for RA2000, DEJ2000, Name, RA2000, DEJ2000, GLON, GLAT, and Size. A table of 'Missions' is also visible, with checkboxes for various Hubble Space Telescope instruments like ACS, WFPC2, STIS, etc. Annotations are present: '1' points to the Search button, '2' points to the 'Mark datasets for retrieval' checkbox, '3' points to the 'Send retrieval request to ST-DADS' button, '4' points to the 'Retrieval Options' section, and '5' points to the 'Data Quality' dropdown menu.

Figure 3: Five steps to get the data from a cross-correlation of the VizieR globular cluster catalog with Hubble ACS data.

The screenshot shows the 'NED Search Form' interface. It has a search form with fields for Target Name, Right Ascension, and Declination. A 'Redshift Constraints' section is highlighted with a red circle and the text 'Larger than 6.0'. Below this are sections for 'INCLUDE objects with following types' and 'EXCLUDE objects with following types', each with a list of object types and checkboxes. At the bottom, there is a 'Cross Correlate found NED objects with following missions' section with a table of missions and checkboxes. A red arrow points to the 'Search NED & Cross Correlate' button.

Figure 4: MAST NED cross-correlation interface.

Using this capability, we could look for extremely metal-poor globular clusters in the VII/202 catalog that have WFPC2 data and can be observed from Gemini North. In the first user-specified field, we select [Fe/H] and enter " < -2.0 " as the constraint. Knowing that Gemini North on Mauna Kea is located at about 20° north latitude, we choose _DEJ2000 for the second user-specified field and enter " > -30 " as the constraint. Selecting WFPC2 with a search radius of 3 arcmin brings back ten catalog entries meeting the criteria. Eight of these entries have multiple WFPC2 observations. One of them even contains a planetary nebula, Kustner 648.

NED cross-correlation with MAST

Figure 4 shows the MAST NED cross-correlation interface. Suppose you are interested in quasars at redshift $z > 6$ that have ACS observations. Use the redshift pull-down menu to select "larger than" and enter 6.0 in the first numeric field. Further down, select "QSOs" from the list of extragalactic objects. At the bottom of the form you find a list of MAST missions. You select ACS and hit "Search NED and cross-correlate" to execute the NED search to find objects and the subsequent search for ACS data at those sky positions.

Your query returns ten high-redshift quasars, five of which have one or more ACS observations taken within a radius of 3 arcmin. Clicking on "See results from NED" brings up a new screen with NED's summary of its catalog metadata on all ten quasars. Clicking on a dataset name on the HTML table provides a preview image, if available. Additional functionality is available when the preview is loaded into the Aladin sky atlas (<http://aladin.u-strasbg.fr/>), including overlaying catalogs (e.g. NED, Simbad or other VizieR catalogs), loading additional images from other archives or from disk, as well as image manipulation.

We can perform more complex queries from the MAST NED cross-correlation interface. Suppose you are interested in the availability of Hubble image data for H II regions in the galaxy M61. We would set the Target Name field to M61 and select "H II" from the galaxy components table in the "include objects with following types" section. Under MAST missions, we check ACS, WFPC2, WF/PC1 (Wide Field Planetary Camera 1), and FOC (Faint Object Camera), and hit the "search NED and cross-correlate" button. The query returns 298 H II regions in this galaxy. By clicking on the dataset

name in the HTML table, a preview is brought up. At the bottom of that preview page, there is a link to bring up the preview image in Aladin. (Fig. 5.)

Data retrieval from NED and VizieR cross-correlations is essentially the same.

Closing thoughts

Users can build more complicated research tasks by additional steps before or after a cross-correlation task.

MAST, VizieR, and NED are evolving systems with changing content. As a result, query and cross-correlation results are subject to change with time.

The MAST team is aware that scientific interests and research styles vary widely, and that our current tools for cross-correlation may not have the functionality you need for your own work, or you may find them too cumbersome to get to your desired results. If you encounter any problems, feel free to contact us (archive@stsci.edu). We are grateful for constructive feedback, which helps us improve and extend our services. Ω

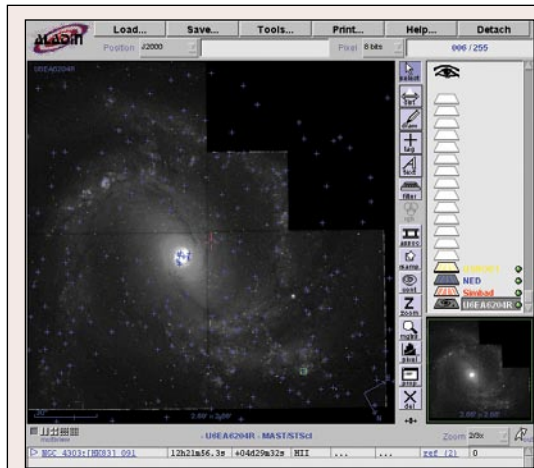
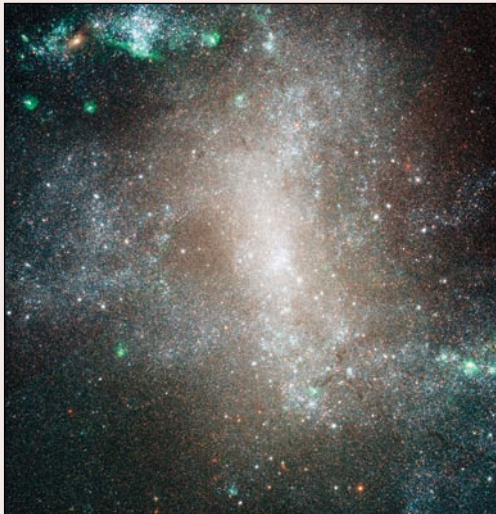


Figure 5: WFC2 preview of data on the H II region [HK83] 091 in the galaxy M61. All NED objects are overlaid as blue crosses. The green square denotes the respective H II region within the galaxy. Detailed NED catalog information is displayed at the bottom of the Aladin window.



Hubble Sees Star Cluster “Infant Mortality”

Astronomers using NASA’s *Hubble Space Telescope* have found that young stellar nurseries, called open star clusters, have very short lives.

This is gleaned from new observations by *Hubble*’s Advanced Camera for Surveys that were used to do a “Where’s Waldo” search for blue stars tossed out of their open cluster “nest” in the nearby galaxy known as NGC 1313.

<http://hubblesite.org/newscenter/archive/releases/2007/05>

Image Credit: NASA, ESA, and A. Pellerin (STScI)

A Nobel Experience

M. Hauser, hauser@stsci.edu



Figure 1: John Mather (left) and George Smoot (right), co-recipients of the 2006 Nobel Prize in Physics (All photos from Mike Hauser).



Figure 2: *COBE* Science Working Group, ca. 1980s (left to right: 1st row—Nancy Boggess (NASA Program Scientist), Sam Gulkis, Phil Lubin, Rai Weiss (SWG Chair); 2nd row—David Wilkinson, Tom Murdock, Chuck Bennett (DMR Deputy PI), Bob Silverberg, Harvey Moseley, Mike Hauser (DIRBE PI), Tom Kelsall (DIRBE Deputy PI); 3rd row—Ed Cheng, Rick Shafer (FIRAS Deputy PI), Steve Meyer, Mike Janssen, John Mather (NASA Project Scientist and FIRAS PI), Ned Wright, George Smoot (DMR PI). Absent: Eli Dwek.



Figure 3: Mike and Deanna Hauser settling in for the trip to Stockholm.

The announcements of the Nobel Prizes in the early fall are familiar to all. The subsequent events in Stockholm, where the prizes are awarded annually on December 10—the anniversary of the death of Alfred Nobel—are less widely known. I had the good fortune to witness the breadth and grandeur of these activities in 2006. This remarkable experience arose because John Mather and George Smoot, my colleagues on NASA's *Cosmic Background Explorer (COBE)* mission, received the 2006 Nobel Prize in Physics "for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation." To extend and expand the celebrations, I offer this personal account of the *COBE* team's rendezvous in Stockholm, which started over 32 years ago.

The *COBE* mission

Within days of joining NASA in 1974, I received a phone call from John Mather, a young post-doc at the Goddard Institute for Space Studies (GISS). He invited me to participate in a meeting to consider responding to a NASA Announcement of Opportunity by proposing a mission to study the cosmic microwave background (CMB) radiation. At the meeting at GISS on September 27, 1974, John Mather, Patrick Thaddeus, David Wilkinson, Rai Weiss, and I discussed the state of measurements of the spectrum and anisotropy of the CMB, and the desirability of searching for the cosmic infrared background (CIB). We discussed the likely limitations of future measurements from sub-orbital platforms and the case for a space mission. We agreed to propose a mission—"Cosmological Background Radiation Satellite"—to measure the CMB and search for the CIB.

NASA received other proposals to measure the CMB anisotropy from a team at JPL led by Sam Gulkis, and a team from UC Berkeley led by Louis Alvarez and including George Smoot. At first, NASA did not respond to these proposals, because a study of the IRAS mission was underway and a second infrared astronomy mission seemed unnecessary. Nevertheless, Nancy Boggess, the Program Scientist for Infrared Astronomy at NASA Headquarters, understood the importance of the science of the CMB and CIB, and invited me to NASA Headquarters to help explain the opportunity to other managers. I recall pointing out during those discussions that this mission could produce Nobel Prize science. Would that I could always be that prescient (or at least bold)!

NASA proceeded to approve a mission definition study, and eventually developed and carried out the *COBE* mission. Books by John Mather and John Boslough (*The Very First Light*) and George Smoot and Keay Davidson (*Wrinkles in Time*), as well as an article by Bertram Swarzschild in *Physics Today* (December 2006, pp. 18–22), chronicle the intervening years of toil, the tragedy of the *Challenger* disaster, and the ultimate triumph of the *COBE* mission.

The three instruments on *COBE* strongly resembled the 1974 suite sketched by the Mather team: Far Infrared Absolute Spectrophotometer (FIRAS) to measure the CMB spectrum, Differential Microwave Radiometers (DMR) to search for CMB anisotropy, and Diffuse Infrared Background Experiment (DIRBE) to search for the CIB. These instruments exceeded all of our scientific aspirations.

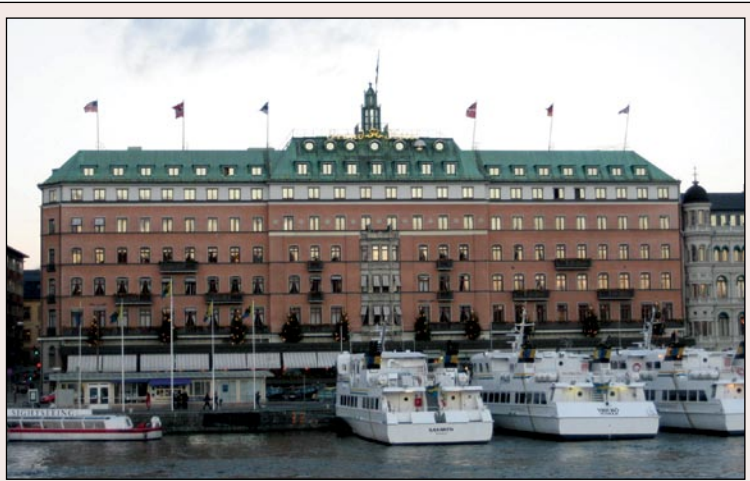


Figure 4: Grand Hotel Stockholm, located on a channel of the Baltic Sea.



Figure 5: Volvo limousine with Nobel logo for each Laureate.



Figure 6: John Mather with attendant, Olof Hultgren.

The definition team for the *COBE* mission initially included Mather, Weiss, Wilkinson, Smoot, Gulkis, and myself. Over the course of time, the *COBE* Science Working Group (SWG) grew to 19 members, comprising the co-investigators for all three instruments. The SWG was a cohesive and congenial group, collectively responsible for the scientific success of the *COBE* mission. One of my great pleasures in participating in the mission was laboring shoulder to shoulder with such extraordinarily talented individuals.

As listed in the Mather and Boslough book, some 1500 people contributed to the *COBE* success.

On to Stockholm

I was delighted by the announcement from Stockholm on the morning of October 3, 2006, that John Mather and George Smoot had been awarded the Nobel Prize in Physics. They were being honored for the *COBE* determination that the CMB has a precise blackbody spectrum,¹ dramatic confirmation of the Big Bang scenario of cosmic evolution, and the discovery of its anisotropy,² providing a quantitative measure of primordial inhomogeneities in density which led to the growth of the cosmic structures seen in the universe today. I was particularly excited, because in 1976 I had recruited John to come to GSFC to pursue the *COBE* mission, and now he was the first NASA employee to receive a Nobel Prize.

Each Nobel laureate received a quota of 16 tickets to the ceremonies, and thanks to the generosity of John and George, all members of the *COBE* SWG and many of their spouses were able to attend, including my wife Deanna and myself. We departed Baltimore on Monday, December 4, equipped with cameras and arrangements for the requisite formal wear, to reach Stockholm in time for the full experience. Starting December 6, a series of receptions, lectures, luncheons, dinners, and a concert led up to the prize ceremony itself (Table 1).

**Continued
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¹ 1990, Mather et al. *ApJ* 354, L37

² 1992, Smoot et al. *ApJ* 396, L1

Upon arriving at the Grand Hotel Stockholm on Tuesday, we were immediately impressed with the elegance and orderliness of the arrangements. In the lobby of this five-star hotel was a Nobel desk, staffed throughout the week by the Nobel Foundation, offering ready assistance to all participants. We were given a booklet containing John Mather's schedule and a bus schedule, so

Date	Morning	Afternoon	Evening
12/6	Informal reception, Nobel Museum	Formal wear fitting	
12/7	Press conference for physics, chemistry, economics prizes, Royal Swedish Acad. of Sciences	Nobel lecture in literature (in Turkish), Royal Swedish Academy of Sciences	
12/8	Nobel lectures in physics, chemistry, Stockholm University		Nobel Prize concert, Stockholm Concert Hall Buffet dinner, Grand Hotel
12/9	Filming of "Nobel Minds" TV Show, Royal Palace Library	Luncheon, American Embassy Nobel Foundation reception, Nordic Museum	COBE team private party, Wedholms Fisk restaurant
12/10		COBE team picture session at Grand Hotel Nobel Prize award ceremony Stockholm Concert Hall	Nobel banquet and dance, Stockholm City Hall Nobel nightcap event, Stockholm School of Economics
12/11	Bus tour of Stockholm	Visit to Vasa Museum	

Table 1: Stockholm itinerary for Mike and Deanna Hauser



Figure 7: Typical Nobel banquet place setting in display case at the Nobel Museum (hence the reflection from the rear of the case).



Figure 8: Press conference including (left to right) John Mather and George Smoot (physics), Roger Kornberg (chemistry) and Edmund Phelps (economics).

we would know when to be ready to travel to each event to which we were invited. Meanwhile, each laureate had a personal attendant and a limousine to transport them and their families.

The first organized event was an informal reception at the Nobel Museum on Wednesday, December 6. Here, laureates and guests were briefed on the importance of the Nobel Prizes to Sweden and its students. We heard a brief account of Alfred Nobel's life, and were shown a movie of past award ceremonies so we would know what to expect on December 10. The formalities are unchanged from year to year. The Museum exhibits include a rotating display of pictures of each of the preceding 703 Nobel laureates, and a display of typical place settings for the Nobel banquet.

Taking advantage of the unscheduled afternoon after a light lunch at the Nobel Museum visit, I went to check the fitting of the formal wear I had rented by e-mail. The conversion of my measurements to metric units had been a success, and all was in good order. White tie and tails were required attire for men at the formal events. National medals were encouraged. For women, it was ball gowns, with tiaras "appreciated."

At a press conference Thursday morning at the Royal Swedish Academy of Sciences, the laureates in physics and chemistry, and the winner of the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel, were queried about their research, about their advice to students, and particularly about why Americans win so many Nobel Prizes. (Responses to the latter question

mentioned the quality of our educational system, the level of funding available, and the flexibility to form collaborations within and between institutions, even worldwide, to address research problems.)

Each Nobel laureate delivers a lecture prior to the award ceremony. The first of these was the literature lecture given Thursday afternoon by the Turkish writer Orhan Pamuk. We were fortunate to be able to obtain tickets, since the ornate room in the Royal Swedish Academy of Sciences where it was held is only modest in size. As we were about to board the bus, we learned that the lecture would be delivered in Turkish! Fortunately, printed copies were available in English and several other languages. In his lecture, Pamuk provided a moving account of why and how he writes. Though photographs were not permitted during the lecture (nor during any of the major events), I captured the setting prior to the talk.

The physics lectures were delivered on Friday morning in an auditorium at Stockholm University, which enabled a large audience to attend, including many students. John Mather gave a review of the *COBE* project, showing pictures of the scientists involved, and describing the purpose and results of measuring the CMB spectrum. George Smoot focused on the CMB anisotropy. In contrast to the literature lecture, which was read, the science laureates used PowerPoint presentations. All the Nobel lectures can be viewed from the web (http://nobelprize.org/award_ceremonies/lectures.html).

The Nobel concert Friday evening was a magnificent event held at the Stockholm Concert Hall, attended by the Swedish royal family and enjoyed by a full house. The renowned American opera star Renée Fleming was the featured performer. With the Royal Stockholm Philharmonic Orchestra, she performed a largely operatic program, but ended with lighter fare from Gershwin and the musical theater. The audience demanded five encores and more, but Ms. Fleming stopped after five, commenting that she had been told to expect that Swedish audiences would be reserved! Later, she came back to the Grand Hotel and attended a buffet dinner for concert attendees. Some of the *COBE* group had the pleasure of meeting and talking with her.

On Saturday morning I had the privilege of accompanying the laureates to the library in the royal palace for the taping of the "Nobel Minds" TV program, which was to be broadcast on the BBC network later in December. Participants included the Nobel laureates in physics, chemistry, physiology or medicine, and the economics prize winner. After an introduction to the royal library, the guests were taken on a tour of many beautiful rooms in the palace while preparations were made for the



Figure 9: Preparing for the Nobel lecture for literature.



Figure 10: Professor Per Carlson, Chairman of the Nobel Committee for Physics of the Royal Swedish Academy of Sciences, congratulates George Smoot and John Mather following their Nobel Lectures.



Figure 11: Entrance to the Stockholm Concert Hall for the Nobel Prize Concert.

Continued
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taping—which we then watched in a separate room via closed-circuit TV. The interviewer engaged the laureates in lively discussion in response to questions posed from around the world.

Following the taping, the American laureates, accompanied by their guests, attended a luncheon

at the residence of the U.S. Embassy. Since almost all of the laureates of 2006 were American, this was quite a large gathering, requiring tables in three rooms. The recently arrived ambassador, Michael Wood, toasted the laureates, quoting President Bush, who said on the occasion of the 100th anniversary of the Nobel Prizes in 2001, "...many awards recognize excellence. The Nobel Foundation recognizes greatness. The annual selection of laureates expresses a profound optimism about humanity and our prospects for improvement."

Later that afternoon, all of the laureates and their guests attended a reception hosted by the Nobel Foundation in the great central hall of the Nordic Museum. The mood was enhanced by the presence of live background music, light refreshments, and champagne.

Prior to going to Stockholm, the *COBE* team had agreed that we would find a time to get together to celebrate privately. Saturday evening was the only opportunity when no other event was scheduled and all attendees would be in Stockholm. Following the reception at the Nordic Museum, 34 of us gathered in a room at the Wedholms Fisk restaurant, a few blocks from our hotel, for coffee, dessert, more champagne, and a lot of reminiscing.

At this gathering, we agreed that we should meet again on Sunday at the hotel, prior to departure for the Nobel Prize ceremony, to take group pictures in our formal attire. We attempted to arrange ourselves as we had been in our picture from the 1980s—a result imperfectly achieved. Nevertheless, we could take a group picture of our spouses, a first in any garb.

The scheduled events on Sunday were the highlights of the week. First was the Nobel Prize ceremony itself, held at the Stockholm concert hall. At this traditional, elegant ceremony, the work of each laureate in turn was described in Swedish, with translations in the programs. The laureate was then called to the center of the stage, where King Carl XVI Gustaf presented the Nobel medal and shook his hand. Then, the laureate stepped back, bowed to the king, turned and bowed to the members of the Royal Swedish Academy of Sciences, turned again and bowed to the audience, all while accompanied by a trumpet fanfare. Between prize categories, the Royal Swedish Philharmonic Orchestra provided a symphonic interlude. The physics prize being the first awarded, John Mather was the first to receive his prize, followed by George Smoot—dramatic moments for their many colleagues assembled there. This moving ceremony was televised and web cast live, and can be viewed



Figure 12: Interior of the Stockholm Concert Hall as the audience arrived.



Figure 13: Library in the Royal Palace, set up for taping "Nobel Minds" program.



Figure 14: Luncheon at the US Embassy.

on the web (http://nobelprize.org/award_ceremonies/ceremony_sthlm/video/2006/index.html).

Following the award ceremony, we were transported to the Blue Room of the Stockholm City Hall for the comparably grand Nobel Prize banquet. The royal family, laureates, their spouses, and other guests of honor sat at a long central table, flanked on both sides by tables seating the remainder of the approximately 1300 guests. Simply finding one's assigned seat—using a booklet akin to a small-town telephone directory—was an adventure.

The evening began with the entrance of the royal family and guests of honor down the grand staircase, led by a group of students. The entire setting was exquisite, especially the beautiful table settings and the formal attire of the guests, most notably the gowns and jewelry of Queen Silvia, Crown Princess Victoria, and Princesses Madeleine and Christina. Prince Carl Philip was also present, but his attire was like that of the other men present. The Director of the Nobel Foundation, Marcus Storch, began with a champagne toast to the King, and the King followed with a toast to Alfred Nobel. Hundreds of white-clad waiters then marched down the grand staircase, dispersed to the tables, and began to serve the guests nearly simultaneously—a stirring performance.

John Mather sat next to the Queen, and his wife Jane sat next to the King. No doubt heady stuff for a civil servant and his wife!

Between courses of the meal there was entertainment: modern dance numbers performed on a landing of the grand staircase. At the end of the meal, several laureates made short statements. John Mather rose to emphasize graciously that the *COBE* achievements were the result of the combined efforts of a large team. At the conclusion of the banquet, all present proceeded up the staircase to a ballroom on the next floor for dancing.

One final event topped off the night for some 500 lucky ticket holders: the Nobel nightcap event, which began at midnight. Not sponsored by the Nobel Foundation, this annual tradition is organized by the students at a local academic institution. This year it was held at the Stockholm School of Economics, and the theme was "light." The students issued invitations that promised "...an unforgettable night of flair, food and fun. Drink, dance and discover our fabulous light as excitement continues throughout the night." The students delivered on their promises, though I cannot personally vouch for the throughout-the-night part. All in all, December 10, 2006 was one of the most memorable days of my life.

Deanna and I dragged ourselves out of bed Monday morning, our last day in Stockholm, for the Nobel Foundation's bus tour of the city and a visit to the famed Vasa Museum. The *Vasa* was a 17th



Figure 15: Heroic statue and musicians at the Nobel Foundation reception at the Nordic Museum.



Figure 16: *COBE* team dressed for the Nobel Prize ceremony. 1st row: Nancy Boggess. 2nd row (left to right): Rai Weiss, Tom Murdock, Bob Silverberg, Harvey Moseley, Mike Hauser, Eli Dwek, Dennis McCarthy (*COBE* Project Manager). 3rd row: Mike Ryschkewitch (cryogenic engineer during the mission, now GSFC Deputy Director), Rick Shafer, Steve Meyer, Mike Janssen, John Mather, Ned Wright, George Smoot, Al Kogut.



Figure 17: *COBE* team spouses. Left to right: Jean Murdock, Sharon Meyer, Sandy Janssen, Beverly Silverberg, Al Boggess, Jane Mather, Sarah Moseley, Deanna Hauser, Gwen Shafer, Terry Kogut, Joan McCarthy, Patricia Wright.

**Continued
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century wooden Swedish warship, intended to be the pride of the fleet, but it proved unstable and sank within minutes of its launching. It was recovered intact following its rediscovery in the 1960s, undamaged by its 300 years in cold water. Following years of clean-up and restoration, the museum was built around it.



Figure 18: Stockholm Concert Hall awaiting entrance of the speakers (blue chairs, right), Royal Family (gold chairs) and Nobel laureates (red chairs) for presentation of the 2006 Nobel Prizes.



Figure 19: Grand staircase in the Stockholm City Hall leading down to the Blue Room from the ballroom (shown at the end of the Banquet).

We joined a group of ten *COBE* colleagues for a traditional Swedish Christmas smorgasbord in the evening, beginning with a choice of 18 ways to prepare herring and ending with a dazzling display of desserts. The laureates had another formal dinner that evening, this time at the palace. Their stay in Sweden extended another several days, with events including visits to various Swedish academic institutions.

Beyond the receptions and hoopla, what are the lasting impressions of my Nobel experience?

First, I feel great admiration for the dignified manner in which the laureates are honored, and for the pride of the Swedish in being the agents of these recognitions. One cannot help but be impressed by the widespread public interest represented by media coverage in newspapers, live TV coverage of the award ceremony and banquet, and recorded coverage of the concert and numerous interviews. Everywhere, the laureates were treated like rock stars, with people lining up to catch a glimpse and even perhaps to get an autograph.

Second, I was impressed by the conscious plan to bring students into close contact with the laureates in celebratory events, at the lectures, and in visits to various academic institutions. The organizers clearly recognize and exploit this golden opportunity for educational stimulation and outreach.

Finally, I am deeply gratified by the dramatic affirmation of the spirit of the *COBE* team in these events. Of the 18 surviving members of the *COBE* Science Working Group (sadly, David Wilkinson is

deceased), 14 attended the ceremonies, most with spouse and some with children. In addition, Dennis McCarthy, the *COBE* Project Manager, Mike Ryschkewitsch, a senior cryogenics engineer during the mission and now Deputy Director of Goddard Space Flight Center, and Al Kogut and Dale Fixsen, participating scientists that had key roles in the mission, attended. The evident mutual pleasure of our all being together again reminded me that the labor of creating the *COBE* mission and bringing it to a successful scientific conclusion was a powerful bonding agent, persisting over decades. John Mather was exactly right when he took every opportunity to stress that *COBE* was a team effort. Stockholm was a magical celebration of teamwork. Ω

At the heart of this star-forming region lies star cluster NGC 602. The high-energy radiation blazing out from the hot young stars is sculpting the inner edge of the outer portions of the nebula, slowly eroding it away and eating into the material beyond. The diffuse outer reaches of the nebula prevent the energetic outflows from streaming away from the cluster.

Ridges of dust and gaseous filaments are seen towards the northwest (in the upper-left part of the image) and towards the southeast (in the lower right-hand corner). Elephant trunk-like dust pillars point towards the hot blue stars and are tell-tale signs of their eroding effect. With *Hubble*, in this region it is possible to trace how studies of star-formation processes started at the center of the cluster and propagated outward, with the youngest stars still forming today along the dust ridges.

The Small Magellanic Cloud, in the constellation Tucana, is roughly 200,000 light-years from the Earth. Its proximity to us makes it an exceptional laboratory to perform in-depth studies of star formation processes and their evolution in an environment slightly different from our own Milky Way.

Dwarf galaxies such as the Small Magellanic Cloud, with significantly fewer stars compared to our own galaxy, are considered to be the primitive building blocks of larger galaxies. The study of star formation within this dwarf galaxy is particularly interesting to astronomers, because its primitive nature means that it lacks a large percentage of the heavier elements that are forged through nuclear fusion in successive generations of stars.

HUBBLE OBSERVES

Infant Stars in Nearby Galaxy

<http://hubblesite.org/newscenter/newsdesk/archive/releases/2007/04>

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





HUBBLE ILLUMINATES

Cluster of Diverse Galaxies

<http://hubblesite.org/newscenter/newsdesk/archive/releases/2007/08>

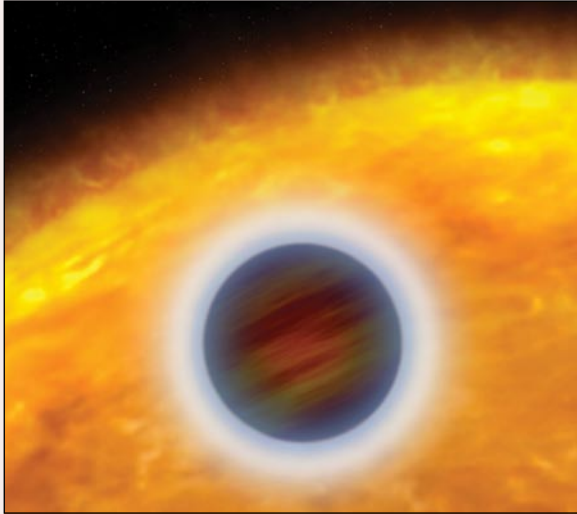
Image Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

This image from NASA's *Hubble Space Telescope* shows the diverse collection of galaxies in the cluster Abell S0740 that is over 450 million light-years away in the direction of the constellation Centaurus.

The giant elliptical ESO 325-G004 looms large at the cluster's center. The galaxy is as massive as 100 billion of our suns. *Hubble* resolves thousands of globular star clusters orbiting ESO 325-G004. Globular clusters are compact groups of hundreds of thousands of stars that are gravitationally bound together. At the galaxy's distance, they appear as pinpoints of light contained within the diffuse halo.

Other fuzzy elliptical galaxies dot the image. Some have evidence of a disk or ring structure that gives them a bow-tie shape. Several spiral galaxies are also present. The starlight in these galaxies is mainly contained in a disk and follows along spiral arms.

This image was created by combining *Hubble* science observations taken in January 2005 with Hubble Heritage observations taken a year later to form a 3-color composite. The filters that isolate blue, red and infrared light were used with the Advanced Camera for Surveys aboard *Hubble*.



Hubble Probes Layer-cake Structure of Alien World's Atmosphere

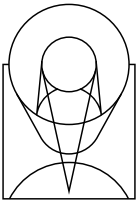
The powerful vision of NASA's *Hubble Space Telescope* has allowed astronomers to study for the first time the layer-cake structure of the atmosphere of a planet orbiting another star. *Hubble* discovered a dense upper layer of hot hydrogen gas where the super-hot planet's atmosphere is bleeding off into space.

This is an artist's illustration of the extrasolar planet, designated HD 209458b, which is unlike any world in our Solar System. It completes an orbit around its host star every 3.5 days. It is about the size of Jupiter. Unlike Jupiter, HD 290458b is so hot that its atmosphere is "puffed up." Starlight is heating the planet's atmosphere, causing hot gas to escape into space. Astronomers used

Hubble to analyze the starlight that filtered through the planet's atmosphere. Imprinted on the starlight is information about the atmosphere's structure and chemical makeup.

<http://hubblesite.org/newscenter/archive/releases/2007/07/>

Image Credit: NASA, ESA, and G. Bacon (STScI)



Contact STScI:

The Institute's website is: <http://www.stsci.edu>
Assistance is available at help@stsci.edu or 800-544-8125.
International callers can use 1-410-338-1082.

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

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Pat McCarthy (chair), Carnegie Observatories, pmc2@ociw.edu

Martin Barstow, U. of Leicester	Phil Nicholson, Cornell U.
Laura Ferrarese, NRC-CNRC	Robert O'Connell, U. of Virginia
Peter Garnavich, U. of Notre Dame	Alvio Renzini, INAF
Jim Green, U. of Colorado	Abi Saha, NOAO
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ST-ECF Newsletter

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

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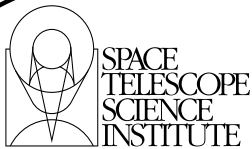
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Calendar

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WFC3 Science Oversight Committee	March 8–9, 2007
Youth Colloquium Talks at the Institute, 9:30 a.m.	March 12 & 13, 2007
Telescope Allocation Committee	March 19–23, 2007
Parent & Son Evening Under the Stars, 6–9 p.m.	March 23, 2007
Hubble Fellows Symposium	April 2–4, 2007
Space Telescope Users Committee	April 12–13, 2007
Spring Symposium, "Black Holes"	April 23–26, 2007
AURA Board of Directors (Tucson, AZ)	April 25 & 28, 2007
National Take Your Child to Work Day	April 26, 2007
AURA Member Representatives (Tucson, AZ)	April 26–27, 2007
<i>Webb</i> full-scale model on Washington Mall	May 9–11, 2007
Women's Science Forum	May 12, 2007
Youth Colloquium Talks at the Institute, 9:30 a.m.	May 21 & 22, 2007
ESA Symposium: The Impact of <i>HST</i> on European Astronomy, at ESTEC, Noordwijk, Netherlands. (D. Macchetto is Chairman of SOC.)	May 29–June 1, 2007
Space Telescope Institute Council	June 11–12, 2007
<i>Webb</i> Science Working Group (Berkeley, CA)	June 26–27, 2007
<i>Webb</i> Science Working Group	October 23–24, 2007
AURA Board of Directors (Ann Arbor, MI)	October 28–30, 2007



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