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NEWSLETTER

Space Telescope Science Institute

Credit: A portion of the HUDF, which falls within the GOODS CDFS field. (Courtesy of the GOODS team.)

FALL [2003]

The Hubble Ultra Deep Field

Steven Beckwith, *svwb@stsci.edu*, **Rachel Somerville,** *somerville@stsci.edu*, & **Massimo Stiavelli,** *mstiavel@stsci.edu*

Near the beginning of Cycle 12, we will use 412 orbits of director's discretionary time to observe a single field with the Advanced Camera for Surveys (ACS). The result will be the deepest field ever obtained with *Hubble*—about 1.5 magnitudes deeper than the Hubble Deep Field in the *I*-band. In fact, this observation—the Hubble Ultra Deep Field (HUDF)—is likely to be the deepest optical field obtained with any telescope for at least a decade to come. We expect the HUDF to improve our understanding of galaxy formation greatly. We will quickly make the HUDF data and catalogues available to the community.

The HUDF field spans the area of a single ACS tile ($\sim$11.5 sq. arcmin) within the Great Observatories Origins Deep Survey (GOODS) area of the Chandra Deep Field South (CDFS). The HUDF contains a galaxy at a redshift $z = 5.8$.

The HUDF observations will consist of 56 orbits in each of the F435W (*B*-band) and F606W (*V*-band) filters and 150 orbits in each of the F775W (*i*-band) and F850LP (*z*-band) filters. (These are the same filters used in the GOODS observations.) The depth in F775W and F850LP is optimal to search for very red objects at the detection limit of the F850LP image. *Hubble* will also make observations with the Near Infrared Camera and Multi-Object Spectrometer (NICMOS; F110W and F160W), Space Telescope Imaging Spectrograph (STIS; slitless G750L) and Wide Field Planetary Camera 2 (WFPC2; F300W) in parallel with observations of the main field. This will result in three additional rich data sets. At a depth of 100 orbits per filter, the NICMOS parallel observations will set new records for depth in the *J*-band and *H*-band bands, surpassing the deepest existing NICMOS observations.

The HUDF will expand our understanding of galaxy formation in several ways. It will pick up the extreme faint end of the luminosity function for low surface brightness galaxies at moderate redshifts, and it will push out to redshifts greater than $z \sim 6$.

Continued page 3

How much of a good thing is enough?

Steven Beckwith, *svwb@stsci.edu*

During the last decade, the *Hubble Space Telescope* created much of NASA's good news. *Hubble* has already produced nearly three times the number of discoveries as the two *Voyager* spacecraft, NASA's second most productive science mission overall. Another indicator, the demand for *Hubble* time continues to outstrip the supply by more than a factor of six. Meanwhile, *Hubble's* observational capabilities improve with the installation of each new instrument; they are now ten to one hundred times more powerful than they were at launch, and their capability will increase by another factor of ten after the next servicing mission, following the installation of the Cosmic Origins Spectrograph and Wide Field Camera 3.

For NASA, astronomers, and the public, *Hubble* has been a very good thing. The question is: How much of a good thing is enough?

Hubble's long run of great performance cannot last forever. Even champions eventually lose their edge, as younger competitors overtake the old masters. When will *Hubble*'s time have come? This question sparks strong emotions—and some oversimplification—on both sides of the debate. One side compares *Hubble* to an old jalopy, ready to fall apart at the next bump in the road; it says NASA should end the *Hubble* mission, freeing-up money to pay for new projects. The other side likens *Hubble* to a classic car; it can continue to perform at a high level indefinitely, if kept up by regular servicing.

Neither analogy captures the complexity of the issue facing NASA. Far from an old jalopy, *Hubble* is at the peak of its performance, continuing to outpace everything else in NASA's lineup. It is still unsurpassed in its ability to produce new scientific discoveries and should remain so for many years to come. Competitive new telescopes will eventually overtake even *Hubble*'s great power, and then we should stop paying the bills to keep it running. The only telescope on the horizon that can come close to *Hubble*'s capabilities is the *James Webb Space Telescope*, not scheduled for launch until late 2011.

One difficulty for NASA is that when *Hubble* is no longer able to compete, they cannot just leave it floating in space. They will have to remove it from orbit, an undertaking nearly as expensive as launching it in the first place. This need to de-orbit *Hubble* suggests that there will be at least one more opportunity to visit and upgrade *Hubble*, effectively a final servicing mission, after the last one currently planned, which for now is still booked in 2004. The mission to prepare *Hubble* for controlled de-orbiting is an important chance to keep *Hubble* productive beyond its currently planned lifetime. The opportunity cost of the shuttle launch might be paid for largely from the shuttle program, but the money to cover the costs of maintaining the telescope may have to come from somewhere else in NASA's ambitious program.

Understanding the difficulty of setting science priorities, the stewards of our space science program acted in NASA's best tradition and put the issue to a panel of experts who would provide unimpeachable advice: John Bahcall (chair), Barry Barrish, Jacqueline Hewitt, Christopher McKee, Martin Rees, and Charles Townes. The panel quickly achieved consensus and gave NASA its recommendations in August, six weeks ahead of schedule. The panel stated that NASA's first priority should be to keep *Hubble* in service after 2010 if shuttle servicing is possible (which the *Columbia* accident calls into question).

In the preparation of *Hubble* for its 'final tow'—a mission in 2010, say, to install rockets that can take it safely out of low earth orbit—the panel discerned the important science opportunity. Because this final mission is imperative—but the final de-orbit can be delayed—it could be scientifically advantageous and cost-beneficial to service *Hubble* and even upgrade its science capabilities, to add several more years to its wonderfully productive life. To assess the scientific benefits against the programmatic costs, the panel recommended that the proposal to extend *Hubble's* life should compete in a scientific peer review panel against proposals for other NASA projects seeking the same money.

The panel left to the Office of Space Science the difficult task of deciding which program elements should compete against Hubble and on what terms. They may consider *Hubble*'s value to the overall space enterprise and how *Hubble* helps justify space exploration. Because *Hubble*'s value cuts across programmatic boundaries, the competition could be across those boundaries as well.

The *Hubble* project uniquely marries superlative science with human spaceflight, providing one of today's best reasons to send humans into space. Servicing *Hubble* demands a blend of dexterity and decision-making that no robots possess. The four *Hubble* servicing missions to date demonstrate the enormous returns possible from repairing, maintaining, and improving an expensive scientific facility. As NASA continues to launch people into space for scientific discovery, its top managers should not overlook *Hubble*'s great popularity and value as a showcase of human spaceflight success.

The cost of maintenance, upgrades, and five additional years of *Hubble* operation is about three quarters of a billion dollars, exclusive of launch costs. The cost of visiting *Hubble* simply to install rockets for a controlled de-orbit might cost a similar amount but offer no science benefit. These are, indeed, large sums, yet the two costs combined represent only a few percent of NASA's total budget for five years. By comparison, the returns in science and public acclaim that we can expect from five extra years of *Hubble* will far exceed those from any other few percent of everything else NASA does. According to Greg Davidson's 'Science News metric,' which is often cited by NASA officials and known to be of interest to Congress and the Office of Management and Budget, *Hubble* returned one third of NASA's 'good news' in 2002. That high return should continue for years to come.

Astronomy does not feed people, cure disease, provide military security, or contribute directly to the material well-being of the nation. Its benefits lie elsewhere. Astronomy inspires us to think about our origins and destiny and to find our place in a larger cosmos. It helps educate new generations of young thinkers and gives meaning to life. In these ways, astronomy shares with the whole space program the purpose of exploring the universe. *Hubble* plays a central role in astronomical exploration. It is appropriate to judge *Hubble's* continued operation against other reasons we send people into space. Only then will we really find out how much of a good thing is enough. Ω

***Hubble* UDF from page 1**

Investigators will be able to use the Lyman-break color selection technique to pick out objects in a desired redshift range, such as *B*-band dropouts at $z \sim 3$ to 4 or V-band dropouts at $z \sim 4.4$ to 6. They will be able to select very high redshift candidates, at $z > 6$ based on their *i*-band – *z*-band colors to probe the end of the epoch of reionization. The HUDF observations will constrain the contribution to the global star formation history from low luminosity and low surface brightness galaxies that may have been missed in previous surveys. Finally, we expect the HUDF will bring the morphologies of objects that were barely detectable as faint fuzz in previous surveys.

As with the GOODS observations, investigators will use difference images at different epochs to discover supernovae at high redshifts. The chance of finding a supernova at a redshift greater than $z = 2$ is better than 50% even in the small HUDF field. As it pushes into new regions of observational parameter space, the chances of serendipitous discovery with the HUDF are good.

We set the location and observing strategy of the HUDF following extensive discussions between an Institute-based team and an external scientific advisory committee. The field location is accessible to ground-based telescopes in both hemispheres, in particular to the Atacama Large Millimeter Array and Expanded Very Large Array. Also, it takes advantage of the considerable investment of *Chandra* time in the CDFS. The field has low background, which is desirable for deep observations with the *Space Infrared Telescope Facility* at longer wavelengths.

Hubble will execute the HUDF observations in two 40-day epochs, starting September 24 and December 4, 2003. The last observation is scheduled for January 16, 2004. We will release reduced ACS and NICMOS images and preliminary source catalogs to the public by mid-February at the latest. Sometime after January 16, the HUDF web page will inform the community of the actual release date. We will archive STIS and WFPC2 parallel observations and make them available to the public immediately. To facilitate spectroscopic follow-up from the ground during the winter 2004 observing season, by November 1, 2003, we will release the coordinates of sources selected by *i*-band – *z*-band color. These sources come from the first epoch of observations and will be based on data expected to be about 30% of the final depth.

For more details, see **http://www.stsci.edu/science/udf**. Phase II information is available on the web (DD proposal 9978). Ω

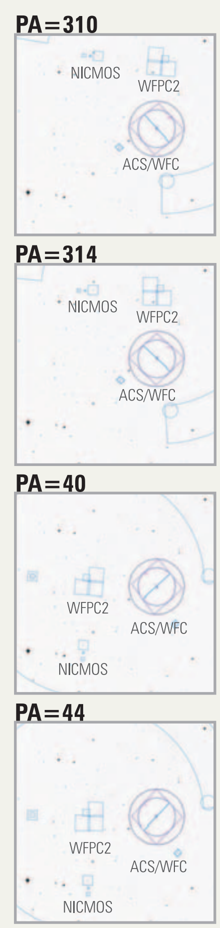

Figure 1

Figure 1: The HUDF data will be obtained at four different orientations. The figure shows the location of the ACS, NICMOS and WFPC2 fields at each orientation. The WFCENTER pointing of ACS is kept constant to minimize the change in the ACS Wide Field Camera field of view.

ACS Calibration and Science News

Roeland P. van der Marel, *marel@stsci.edu*

The advent of the Advanced Camera for Surveys (ACS) has significantly enhanced the survey capabilities of *Hubble*. The Great Observatories Origins Deep Survey (GOODS) has been the first big survey with ACS. The GOODS/ACS team, led by M. Giavalisco, announced its results in a recent press release **(http://hubble.stsci.edu/newscenter/archive/2003/18/)**. The data include images of thousands of galaxies in a broad swath of sky. The images provide constraints on galaxy formation and evolution over a wide range of distances and ages. Preliminary results are consistent with hierarchical growth of galaxies through mergers and accretion, with the major epoch of galaxy building trailing off when the universe was about half its current age. Comparison with *Chandra* data provides additional insight into the presence of active galactic nuclei and the growth of black holes, while comparison with forthcoming data from the *Space Infrared Telescope Facility* will further elucidate the star formation processes in galaxies. The GOODS data spectacularly underscore the potential for deep imaging with ACS and make us all wait with excitement for the forthcoming data from other deep imaging projects, such as the UDF (Ultra Deep Field) and COSMOS (Cosmic Evolution Survey).

In other press releases, the Hubble Heritage team released ACS images of the majestic dusty spiral NGC 3370 **(http://hubble.stsci.edu/newscenter/archive/2003/24)** and the Pencil Nebula NGC 2736 **(http://hubble.stsci.edu/newscenter/archive/2003/16)**, which is shown in Figure 1. Although resembling an abstract painting to the untrained eye, the nebula is, in fact, part of the Vela supernova remnant. The nebula's shape suggests that it is part of the supernova shock wave that recently encountered a region of dense gas. It is this interaction that causes the nebula to glow and appear like a rippled sheet.

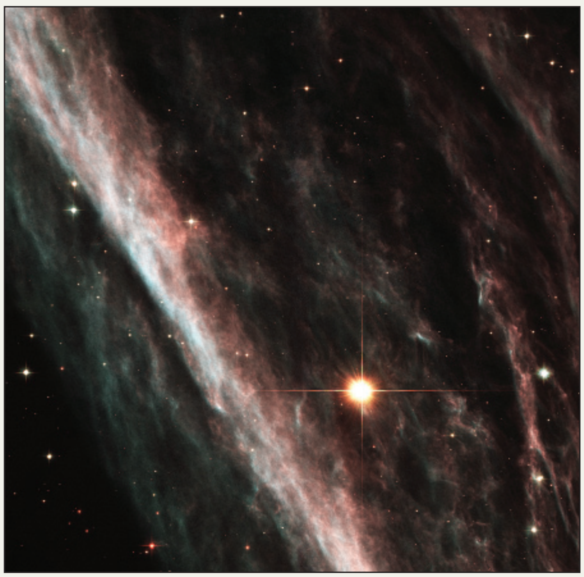

Figure 1: The Pencil Nebula (NGC 2736), part of the Vela supernova remnant, as imaged by ACS. The supernova shock wave recently encountered a region of dense gas, causing the nebula to glow like a rippled sheet.

As ACS continues to obtain high quality science data for the astronomical community, we at the Institute continue to work on improving the calibration and our understanding of the instrument.

R. Gilliland and G. Hartig used calibration observations to quantify precise exposure-time values, stability, and shading effects down to the shortest exposures allowed (0.1 sec on the High Resolution Channel, HRC, and 0.5 sec on the Wide Field Channel, WFC). In general, they found the actual exposure times to be consistent with the commanded values. However, they did discover differences of up to 4% for some of the shortest exposure times. We are working to include these results in the calibration pipeline. Gilliland and Hartig found no significant shutter shading effects (exposure time variations over the field of view) for either channel. (See ACS ISR 03-03, available from **http://www.stsci.edu/hst/acs/**).

A group led by J. Biretta obtained observations of blank fields at various angles from the bright earth limb to measure the amount of scattered light in ACS data. No strong scattered light component was found at angles in excess of 20 degrees. More scattered light may be present at smaller angles, which are never used to obtain science data. (See ACS ISR 03-05.)

J. Krist finished a study of the ACS point spread function (PSF) on both the WFC and the HRC. The PSF is much more stable over the field of view than those of the Wide Field Planetary Camera 2 (WFPC2) or the Space Telescope Imaging Spectrograph (STIS). However, variations of the core width and ellipticity of the ACS/WFC PSF are large enough to be of concern to observers performing photometry with very small apertures or measuring the ellipticities of small galaxies with bright nuclei. CCD charge diffusion, which sets the lower limit to the PSF width, is field dependent due to variations in the thickness of the detectors. The upper limit is set by elongation of the PSF, which is due to the combination of astigmatism (field-dependent) and defocus (field- and time-dependent). We have implemented the measured ACS aberrations and charge diffusion variations in the Tiny Tim PSF modeling software (version 6.1 and later; **http://www.stsci.edu/software/tinytim/**). (See ACS ISR 03-06.)

A. Pasquali and her collaborators used observations of Wolf-Rayet stars for the wavelength calibration of the G800L grism on the HRC. They derived dispersion solutions, which they have incorporated into the extraction software 'aXe' (**http://www.stecf.org/software/aXe/**), which the Space Telescope European Coordinating Facility maintains. (See ACS ISR 03-07.)

New exposure time calculators (ETCs) for ACS are available through the ACS web site, at **http://www.stsci.edu/hst/acs/software/etcs/ETC_page.html**. We developed them as part of the Astronomer's Proposal Tool (APT). Nevertheless, the web interface through which they are accessible has the same look and feel as the ETCs that were previously available. The report of a study led by F. Boffi describes the improvements and performance tests of the new ETCs. (See ACS ISR 03-08.) We recommend that users switch to the new ETCs, and we welcome feedback on the performance of the new software.

A. Riess obtained the first on-orbit calibration of photometric losses due to imperfect charge-transfer efficiency (CTE). The size of the photometric losses appears to have a strong power-law dependence on the stellar flux, as seen for other CCDs flown on *Hubble*. For WFC, photometric losses are apparent for stellar images undergoing numerous parallel transfers. The losses are approximately 2% for typical observing parameters, but rise to 10% in worst cases (e.g., faint stars on low background). Losses due to serial transfer are much smaller. Qualitatively similar results apply for the HRC, although the losses are smaller due to the smaller chip size and smaller number of charge transfers compared to the WFC. Riess developed formulae to correct photometric losses as a function of position, flux, background, time, and aperture size. Future data will better constrain the time-dependent term, which seems approximately linear from measurements of the charge-deferred tails of cosmic rays in dark images. (See ACS ISR 03-09.)

Monthly 'anneals'—periods during which the detectors are heated and cooled down again—repair hot pixels on *Hubble* CCD detectors. The success rate for annealing hot pixels in WFC is ~63%, well below the values of ~85% for the CCDs on STIS, WFPC2, and ACS/HRC. Even after multiple anneals on ACS/WFC some 30 percent of hot pixels remain, producing a linear increase of the number of hot pixels on the CCD with time. Projections suggest that 6% of all WFC pixels will be hot by 2010. Although proper dithering strategies can minimize the scientific impact, we still strive to understand the origin of the annealing behavior of the WFC CCDs.

During the August 2003 meeting of the SPIE (International Society for Optical Engineering), a 'tiger team' met to discuss the hot-pixel annealing properties of the WFC CCDs. The team consisted of detector experts and representatives from the Institute and the ACS Instrument Definition Team. The team identified two main differences between the WFC CCDs and the other CCDs on *Hubble* as the possible sources for the different annealing behaviors: integration and read-out methods and shielding. The shielding difference might mean that neutrons produce a higher percentage of WFC's hot pixels than is the case for other *Hubble* CCDs. Neutron damage requires higher temperatures to anneal than proton damage. However, because we have no good understanding of the annealing process at the relatively low temperatures at which we anneal the *Hubble* CCDs (room temperature), an unambiguous interpretation of the data is not possible. Unfortunately, we cannot increase the annealing temperatures on *Hubble*, so there is no straightforward way to improve the WFC annealing properties in orbit.

C. Cox and collaborators investigated the dark count rate of the WFC CCDs, in both normal and hot pixels, as a function of detector operating temperature. The dominant effect of a change in temperature is a simple scaling of the dark rate in each pixel. There is a ~20% increase in dark rate for every degree of temperature elevation. Therefore, the best way to decrease both the number and impact of hot pixels is to decrease the detector operating temperature. We expect this to be possible after the installation of the Aft Shroud Cooling System during the next *Hubble* servicing mission. We expect CTE losses to be smaller at lower temperatures as well—an added advantage. (See ACS ISR 03-04.)

Regular calibration observations of the bright earth have shown that the long-term position of the coronagraphic spot in the HRC continues to be unstable at the level of approximately 5 pixels. Procedures are now in place to measure the actual position of the coronagraphic spot in the days before a coronagraphic science observation and to uplink the measured spot position to the telescope before the actual science observations.

We have received and reviewed all Phase II programs for Cycle 12 science observations, and another cycle of exciting ACS imaging is now underway. Also, we have completed the plan for Cycle 12 ACS calibrations, including continued routine monitoring of darks, biases, flat fields, and sensitivity. There are also programs to refine the calibration of the photometric zero points, polarizer and ramp filter characteristics, the photometric degradation due to CTE losses, and low spatial frequency variations in flat fields. Throughout Cycle 12 we will also continue our efforts to improve the MULTIDRIZZLE software for simultaneous co-addition and geometrical rectification of dithered images.

The deadline for Cycle 13 proposals is January 23, 2004. A new *ACS Instrument Handbook* is available for proposal planning. We are also working on a new *ACS Data Handbook*, which will contain updated advice on how to analyze and interpret ACS data. As always, consult the ACS web page at **http://www.stsci.edu/hst/acs/** for the latest information. Ω

COS Update

Tony Keyes, *keyes@stsci.edu*

The Cosmic Origins Spectrograph (COS), which will be installed during Hubble Servicing Mission 4 (SM4), is optimized for low-background, far-ultraviolet (FUV) spectroscopy in the range 1150 to 1775 Å with resolving powers R ~ 20,000 and R ~ 2000 for point-sources. COS will be the most sensitive FUV spectrograph ever flown on *Hubble*. Its large FUV detector format and low background combine to increase discovery efficiency by an order of magnitude over equivalent Space Telescope Imaging Spectrograph (STIS) modes.

In the near-ultraviolet, 1700 to 3100 Å, COS will also include R ~ 16,000 to 20,000 and R ~ 2000 modes, similar to the STIS low and medium resolution modes but with a lower detector background anticipated.

Normally, COS operation will be in time-tag mode and FUV observations will include pulse-height information.

Principal Investigator James Green of the University of Colorado leads the COS Instrument Development Team (IDT), and Ball Aerospace in Boulder, Colorado, is building the instrument.

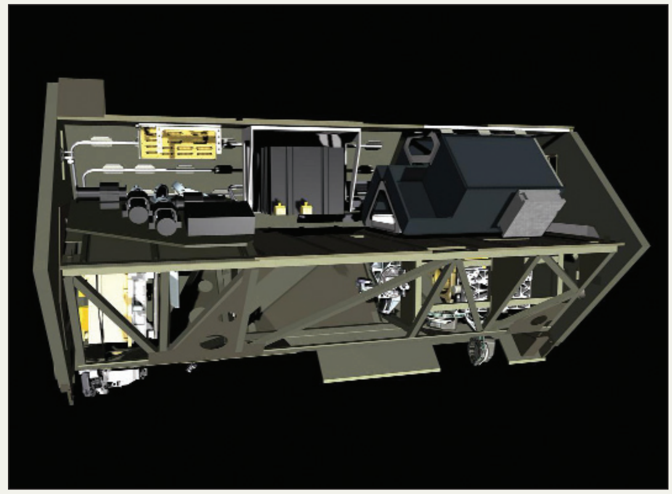

Figure 1: Design view of the COS optical bench and calibration platform. (Courtesy Ball Aerospace)

After completion of instrument assembly in March 2003, COS went through a series of acoustic, vibration, and electromagnetic tests. In June and July, the IDT, assisted by Institute instrument scientists and Ball Aerospace engineers, completed *in vacuo* optical alignment and initial performance verification testing. These tests verified that the instrument meets or exceeds design specifications for spectral resolution and sensitivity.

Figure 2: Integrated COS instrument on transporter in clean room. (Courtesy Ball Aerospace)

Baseline versions of the COS data-processing pipeline and archival procedures are in place at the Institute. As a result, for the first time in the development of any *Hubble* instrument, the Institute pipeline will process all ground calibration data, convert the raw instrument-formatted data files to standard FITS-format files, and store all data for routine, permanent retrieval from the *Hubble* data archive. (We have already processed and stored the initial alignment and verification test data.)

The full, thermal-vacuum science calibration of the instrument is presently scheduled for a four-week period in September and October 2003. After that, the instrument will be delivered to Goddard Space Flight Center (GSFC) for ground system testing and storage until SM4.

At the Institute, we have completed testing of the scheduling and commanding system for all science, calibration, and alignment modes of the instrument. We are preparing for the comprehensive Servicing Mission Ground Test, which will be held after delivery of the instrument to GSFC. The COS Group at the Institute has prepared an updated COS mini-handbook (version 2), which will be distributed with the Cycle 13 *Call for Proposals*. Instrument scientists will be present in the Institute booth at future AAS meetings to answer questions about our preparations and the operational characteristics planned for this exciting new spectrograph. Ω

WFC3 Update

John MacKenty, *mackenty@stsci.edu*

The Wide Field Camera 3 (WFC3) continues to make good progress during its integration and testing phase. Ball Aerospace delivered the completed optical assembly to Goddard Space Flight Center (GSFC) in December 2002, following optical testing. There, the WFC3 team performed the second and third (after vibration) rounds of optical testing, using the refurbished illumination system originally used to test WF/PC-1 and WFPC2 at the Jet Propulsion Laboratory. The optical performance of WFC3 is excellent, exceeding both the 'required' and 'goal' specifications over the entire field of view.

The WFC3 team at GSFC integrated the optical assembly into the instrument enclosure and installed nearly all of its electronics' boxes and cables. (The enclosure and the recently repainted radiator are reworked parts of the WF/PC-1 instrument, which was retrieved from *Hubble* during the first servicing mission, in 1993.) The team completed and tested all major elements of the flight and ground software systems. The system-level testing program will start with ambient environment testing and partial science calibration in November and December 2003, and the full thermal vacuum testing is scheduled for spring 2004.

An important innovation in the WFC3 program is provision for rapid swap-out of the ultraviolet-visible (UVIS) and infrared (IR) detector assemblies. This feature permitted the detector development and characterization program to proceed in parallel with the instrument development, allowing the selection of the best available detectors later than usual. Also, it will allow us to respond to detector problems found during testing, nearly up to launch. We have seen the benefits in both detector programs. For example, the UVIS CCD detector package suffered a bond failure in a two-stage thermal electric cooler on its inner radiation shield in spring 2003. Nevertheless, instrument alignment and optical testing proceeded without interruption, using the engineering detector assembly. Meanwhile, the flight unit was repaired and requalified for flight.

With the infrared detectors for WFC3, Rockwell Scientific took a large step forward from the NICMOS-3 detectors it provided for the Near Infrared and Multi-Object Spectrograph. The WFC3 detectors have 16 times the pixel count, higher quantum efficiency, lower noise, and much improved uniformity and stability. With these detectors, the infrared channel meets the ambitious requirements established at the start of the WFC3 program. As a result, WFC3 promises greater survey efficiency by a factor of ten compared with NICMOS. M. Robberto discusses these detectors in detail in a recent report, available at **http://www.stsci.edu/instruments/wfc3/PAPERS/SPIE_MR.pdf**.

We have updated the WFC3 mini-handbook to include performance projections with the flight infrared detectors. It will be available as part of the Cycle 13 *Call for Proposals*. Ω

Too Close for Comfort

This Hubble Space Telescope view of the core of one of the nearest globular star clusters, called NGC 6397, resembles a treasure chest of glittering jewels. The cluster is located 8,200 light-years away in the constellation Ara. Here, the stars are jam-packed together. The stellar density is about a million times greater than in our Sun's stellar neighborhood. The stars in NGC 6397 are also in constant motion, like a swarm of angry bees. The ancient stars are so crowded together that a few of them inevitably collide with each other once in a while. Near misses are even more common.

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

A NICMOS Drama: Bit Flips, Safe Modes, and Recovery

Keith Noll, *noll@stsci.edu*

In the early morning hours of Saturday, August 2, a voltage sensor in the NICMOS cryocooler system (NCS) recorded a 0.97-volt jump in circulator inverter voltage from a nominal 6.2 volts. After eight consecutive half-second intervals showed the same out-of-range voltage, automatic safe-mode procedures shut down the NCS. This was the first time the NCS had stopped since its successful debut in April 2002. Within hours, the *Hubble* project called in engineering and science teams to work on the problem. By midday they decided not to attempt to restart the NCS immediately. Because the temperature in NICMOS would climb out of the usable range within hours, we sent commands to put NICMOS into safe mode, with the filter wheels blanked off to minimize further particulate contamination on the detectors.

By Monday, the engineering teams began to make sense of the data gathered from the engineering telemetry. The voltage increase was a step function, which is uncharacteristic of a mechanical failure. Furthermore, the voltage increase was almost exactly 256 times the smallest voltage adjustment, which was a strong indication of a 'bit flip,' also known as a 'single-event upset,' or SEU, in the buffer that stores the voltage set-point for the circulator inverter, which powers the pump that circulates the neon refrigerant from the cooler to NICMOS. With a plausible failure scenario in hand, the project decided to attempt a restart of the NCS, which proceeded without a hitch on August 7.

During the time that NICMOS was in safe mode, it was gradually warming, and we were without any direct information about the temperature inside the vapor-cooled shield where the key systems of the instrument reside. We did analyze the science data obtained during the few hours NICMOS was operating without NCS and found that NICMOS warmed at about the same rate as was observed at the exhaustion of the cryogen, at the end of Cycle 7. Based on previously observed warm-up and cool-down rates, we estimated that every day of warm-up would require two days of cool-down. However, NICMOS and the NCS proved—and not for the first time—that one makes such predictions only at risk to one's self-esteem.

Thermal sensors showed an immediate, rapid cooling of the neon gas in the circulator loop, which reached its temperature control point within an amazingly short 48 hours! NICMOS would be ready to operate again after only a couple more days to stabilize. How had the cool-down proceeded so rapidly? We do not know for sure, but speculate that we eliminated the only internal source of heat by putting NICMOS into safe mode promptly. That is, the thermos bottle of the vapor-cooled shield prevented the key systems from warming as fast as if NICMOS had remained on. This lesson learned may be useful in rapidly reviving NICMOS after the next servicing mission.

While the engineers worked to revive the NCS, the NICMOS team at the Institute developed the plan to restart and recalibrate NICMOS. To quickly return the instrument to science operations while minimally disturbing other science activities on the spacecraft, we planned an abbreviated version of the filter test from the last servicing mission and a duplication of the calibration focus test. On August 14, we recovered NICMOS from safe mode and began implementation of our verification plan. It was immediately clear that NICMOS had returned to its pre-safing state, the ideal outcome for calibration continuity and science effectiveness. Ironically, the only change that was necessary after reviving NICMOS was to tweak the temperature set point; NICMOS was running a bit too cold. Somehow, the cooling had become a little more efficient after the safing!

Science operations with NICMOS have resumed in full. We will reschedule all the science disrupted by the safing event. Other than some lost sleep and cancelled vacations, it must be said that this event was as benign as we could have hoped. And next time, if a next time comes, we will be even better prepared. Ω

JWST Moves into New Phase

Roelof de Jong *dejong@stsci.edu*, **David Hunter,** *dhunter@stsci.edu*
& **Peter Stockman,** *stockman@stsci.edu*

On June 17–19, 2003, the *James Webb Space Telescope (JWST)* team presented its plans for the development of the observatory, science instruments, and ground system to two review teams: the Goddard Space Flight Center Mission Definition Review Board, led by Dennis Dillman, and the NASA Headquarters (HQ) chartered Independent Review Board, chaired by Jean Olivier (*Chandra* Deputy Project Manager and former *Hubble* Chief Engineer). Successful passage of this review, dubbed the 'delta-MDR,' was the key criterion for NASA's approval for *JWST* to proceed to Phase B, during which detailed designs and budgets are developed.

During the three days, NASA, the European Space Agency (ESA), the Canadian Space Agency (CSA), and the key scientific and corporate partners described the capabilities of the *JWST* mission and how they intended to implement them. NASA and Northrop Grumman Space Technology (NGST) presented the organizational details, schedules, and verification plans that will govern the future of the project through launch, which NASA now plans for August 2011. Each of the three science instrument teams and the Fine Guidance System (FGS) team described the status of their instrument designs and technologies. As mentioned in the summer *Newsletter*, the Canadian FGS now includes a set of near infrared, tunable-filter cameras. Langley Research Center provided an independent cost estimate for the *JWST* development that was consistent with the Project budget plan.

Both review teams were pleased with the progress over the last year and recommended that the *JWST* Project move into Phase B. Each review team provided a short list of issues that should be closed during the next phase of design and planning. NASA HQ approved the transition to Phase B on July 30.

A number of important project milestones will occur in Phase B, such as the decision in September by an expert review team that the primary mirror will be made of beryllium. In December 2003, the project will hold a System Requirements Review, and it will decide whether to employ a micro electro-mechanical shutter assembly in the multi-object spectrograph. Ω

Image Credit: *NASA, The Hubble Heritage Team, and A. Riess (STScI)*

Celestial Composition

Amid a backdrop of far-off galaxies, the majestic dusty spiral, NGC 3370, looms in the foreground in this NASA *Hubble Space Telescope* image. Recent observations taken with the Advanced Camera for Surveys show intricate spiral arm structure spotted with hot areas of new star formation. But this galaxy is more than just a pretty face. Nearly 10 years earlier NGC 3370, in the constellation Leo, hosted a bright exploding star.

NASA and AURA Sign JWST S&OC Contract

Roelof de Jong *dejong@stsci.edu*, **David Hunter,** *dhunter@stsci.edu*
& **Peter Stockman,** *stockman@stsci.edu*

In 1998 Senator Barbara Mikulski and then NASA Administrator, Dan Goldin, visited the Space Telescope Science Institute to announce that NASA had selected it as the Science and Operations Center (S&OC) for the *Next Generation Space Telescope*. Ed Weiler had recommended this decision on the basis of the Institute's experience with *Hubble* and early involvement in the new mission. At the Institute we looked forward to extending the services and the relationships developed for *Hubble* to the science community of its successor. Little did we know that several years would pass before NASA and the governing body of the Institute, the Association of Universities for Research in Astronomy (AURA), would establish a contract to turn the 1998 announcement into reality.

The first major step in the process was completed in 2001. NASA approved a 'JOFOC' or Justification for Other than Full and Open Competition. The JOFOC permitted NASA to issue a sole-source contract for the *NGST* S&OC. Nevertheless, much work still lay ahead. NASA issued a *Request for Proposal* in October 2001, and AURA responded within two months. On June 6, 2003, following extensive negotiations, NASA and AURA signed the S&OC contract for the newly named *James Webb Space Telescope (JWST)*.

The new contract defines for the Institute a role in *JWST* similar to that for *Hubble*. The Institute will develop the science operations systems for *JWST*, provide scientific and engineering support to NASA and the science instrument teams, and support the commissioning of the observatory. The Institute is responsible for the systems and facilities that will control the day-to-day flight operations of *JWST*. Following launch, the Institute will operate the observatory from the planning phase through the archive and distribution of scientific data. In its management of the science program, the Institute will develop the *Call for Proposals* and instructions for potential observers, organize international peer reviews, select the science programs, support the development of detailed observing plans, maintain instrument calibrations, and manage grant funding to U.S. observers. As for *Hubble*, the Institute will be responsible for education and public outreach and will assist those astronomers who wish to publicize their results. The contract will fund these efforts until one year after launch, a period that will include commissioning, early *JWST* science team observations and, very likely, a number of large community Legacy programs. Ω

Superb Detectors for JWST

Don Figer, *figer@stsci.edu*, & **Roelof de Jong,** *dejong@stsci.edu*

After a challenging and highly successful detector development and testing programs, the *James Webb Space Telescope (JWST)* is poised to benefit from the best infrared array detectors ever made. The University of Arizona chose HgCdTe detectors made by Rockwell Scientific Company (Figure 1) for use in the Near-Infrared Camera (NIRCam). NASA/JPL chose Si:As detectors made by Raytheon Vision Systems (Figure 2) for use in the Mid Infrared Instrument (MIRI). Three 1024 x 1024 Si:As detectors will be needed in the current MIRI design. The Near-Infrared Spectrograph (NIRSpec) and the Fine Guidance Sensors (FGS) teams are expected to announce their final selections soon.

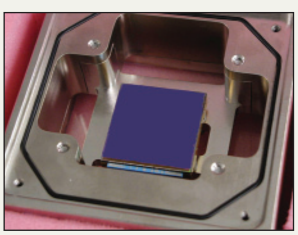

Figure 1: The Rockwell H2RG Sensor-Chip Array (SCA).

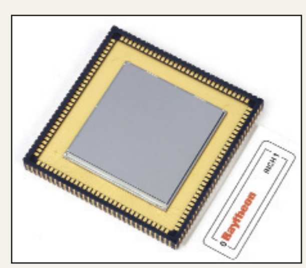

Figure 2: Raytheon multiplexer for the mid-infrared detector.

The *JWST* Project has funded both Raytheon and Rockwell to produce near-infrared array detectors for evaluation against the challenging requirements of the NIRCam, NIRSpec, and FGS. These instruments require ten, two, and four 2048 x 2048 (2K2) array detectors, respectively. Craig McCreight

(NASA/Ames Research Center) led the NASA development program that provided the vendors with the resources to build a series of progressively more capable devices, culminating in the deliveries of 2K2 'home run' devices for comparative testing. Given the original goal of developing working technology by September 2003, this program has been a great success.

Institution	Principal Investigator	Technology
University of Hawaii (UH)	Dr. Donald N. B. Hall	HgCdTe
University of Rochester (UR)	Dr. William J. Forrest	InSb
Space Telescope Science Institute (STScI)	Dr. Donald F. Figer	HgCdTe & InSb

Table 1: The near-infrared detector-testing laboratories.

In parallel with the detector development program, NASA funded a detector-testing program, which was also led by Craig McCreight. Three laboratories, selected through a competitive proposal process, evaluated the products of the development program under the ultra-low background conditions expected for *JWST*. NASA announced the test groups in January 2001, as listed in Table 1. The NASA/Ames Research Center (R. McMurray, M. McKelvey, and C. McCreight) was also a member of the *JWST* test network, with primary responsibilities for testing the mid-infrared technology and performing radiation testing of the near-infrared devices. In both the development and characterization aspects of this work, Matt Greenhouse, the *JWST* ISIM Project Scientist, played a key role in defining and clarifying requirements and approaches.

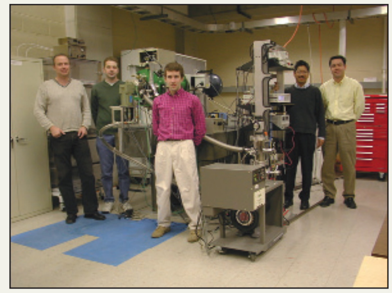

Figure 3: The IDTL test team in front of the test system. Left to right: Bernie Rauscher (Project Scientist), Ernie Morse (Data Analyst), Eddie Bergeron (Data Analyst), Sito Balleza (Project Engineer), and Don Figer (PI). Not pictured: Mike Regan (Project System Scientist).

In order to perform the challenging test program, the Institute and the Johns Hopkins University set up the Independent Detector Testing Laboratory (IDTL) with a general vision "to provide world class testing and development facilities for astronomical detectors and associated technology." NASA selected the IDTL to fulfill the unique role amongst test labs of comparatively characterizing both the Raytheon and Rockwell detectors. This involved measuring first-order detector properties (read noise, dark current, persistence, quantum efficiency, etc.) as functions of environmental parameters (radiation exposure, thermal conditions, operating modes) for both detector types, using the same procedures, setups, dewars, light sources, targets, electronics, acquisition software, analysis software, and staff.

Parameter	Requirement	Goal	Rockwell H2RG
Sensor-Chip Array (SCA) Format	Minimum of 2048x2048 pixels, with reference pixels located within or outside of the 2048x2048 field.		2048X2048
Pixel Pitch	18 – 25 μm		18
Total Noise (Quadrature sum of all sources) per pixel in 1000 s*	≤ 9 e^- rms	≤ 2.5 e^- rms	< 10 e^-
Read noise for a single read	≤ 15 e^- rms	≤ 7 e^- rms	12 e^-*
Dark current	< 0.01 $e^- s^{-1}$		0.001 $e^- s^{-1}$
Well Capacity	6 x 10^4 e^-	2 x 10^5 e^-	10% non-lin: 1.04 x 10^5 e^- saturation: 1.30 x 10^5 e^-
Electrical crosstalk between adjacent pixels	≤ 5%	≤ 2%	1.64%
Latent or Residual Images, when measured at the same integration time as was used for the near saturation image.	< 0.1% after the 2nd read following an exposure of ≥ 80% of full well	< 0.01% after the 2nd read following an exposure of ≥ 80% of full well	0.02%
Frame Read-out Time	12 s	< 12 s	10.7 s
SCA pixel readout rate	100kHz rate, 10ms/ pixel.	> 100kHz rate	100 kHz

* Estimated using digitally filtered data.

Table 2: Performance requirements, goals and measurements of the *JWST* near-infrared detectors.

In May of 2003, the IDTL test team (Figure 3) successfully completed the *JWST* detector characterization project, after obtaining two terabytes of data over two years from a half dozen prototype detectors during 25 cool-downs. Table 2 provides a summary of the measurements for the selected detector types.

The measured performance of the Rockwell detector is impressive,

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with dark currents as low as 1.3 electrons per thousand seconds per pixel, the lowest ever measured for an array having a long wavelength sensitivity cutoff at 5 mm. A typical data set is shown in the left panel of Figure 4. Equally impressive, the read noise for both vendors' devices was low, < 10 e^- per frame averaged over eight non-destructive reads. All imaging devices trap charge that can appear later while imaging another object. We measured a very low 'persistence' for the Rockwell devices of ~ 0.03% total integrated charge over 2000 seconds after a saturating exposure to light (see the right panel of Figure 4). Further details are described in Figer et al. (2003).

The future looks 'dark' for *JWST*, thanks to the superb detectors produced in an excellent development program and characterized in a successful test program. The next major task is to produce the many devices needed over the next few years to support the successful integration of the instruments into *JWST*. Ω

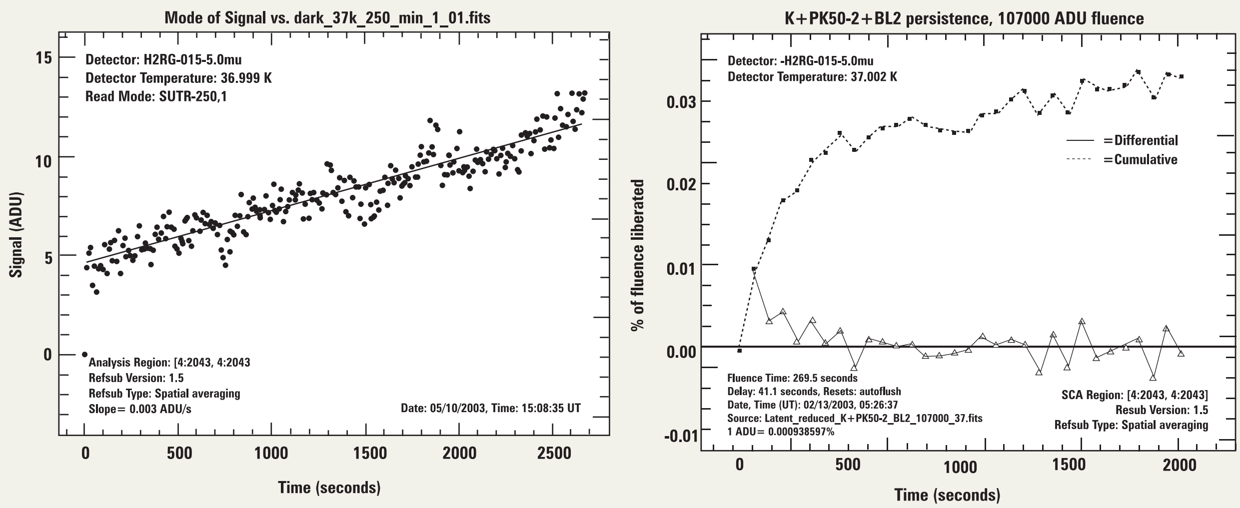

Figure 4: The diagram on the left shows IDTL measurements of accumulating charge versus time for the H2RG detector; after applying the appropriate gain, and after accounting for read-induced signal, the dark current is as low as 1 electron/1000 seconds/pixel, or a factor of ten better than the requirement. The diagram on the right shows the IDTL measurements of integrated persistent charge (top) and differential persistent charge (bottom) after exposure to saturating fluence; the performance is at least a factor of 3 better than the requirement.

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Can JWST See the First Stars?

Nino Panagia, *panagia@stsci.edu*

One of the primary science goals of the *James Webb Space Telescope (JWST)* is to answer the question: "When did galaxies begin to form in the early universe, and how did they form?" Theorists predict that the formation of galaxies is a gradual process in which progressively larger, virialized masses, composed mostly of dark matter, harbor star formation as time elapses. These dark-matter halos containing stellar populations then undergo a process of hierarchical merging and evolution to become the galaxies that make up the local universe. In order to understand what are the earliest building blocks of galaxies like our own, *JWST* must be able to detect and identify 'first light' sources, i.e., the emission from the first objects in the universe to undergo star formation.

The first stars in the universe form in a virtually metal-free environment (the so-called Population III) and, therefore, we expect their properties to be drastically different from those of stars in the local universe. The absence of metals implies a reduced opacity of the star-forming material and, therefore, we expect the temperatures of possible progenitor clouds to be higher than in present-day molecular clouds. Accordingly, we expect the Jeans mass—which is the minimum cloud mass for which gravitational force overcomes pressure and causes the cloud to collapse—to be much higher. As a consequence of these conditions, the formation of massive (and very massive) stars is favored over, say, solar-mass stars. Indeed, primordial stars, because of their lower opacities, may form with masses as high as 1000 $M_{\odot}$, and remain stable over their entire lifetimes.

While it is hard to predict a precise form for the distribution of initial masses (the Initial Mass Function or IMF), it is clear that Population III stars must have an IMF that is much flatter than Salpeter's function (i.e., the one observed in the solar neighborhood and that is valid in the local universe) and may extend up to masses as high as 1000 $M_{\odot}$. Because of their zero metallicities, Population III stars are very hot (about a factor of two higher effective temperatures than their local universe counterparts). Because of their high masses they are very luminous. Typically, a 300 $M_{\odot}$ star has a luminosity of 30 million $L_{\odot}$, an effective temperature of about 100,000 K, and a lifetime of a few million years. (The L/M ratio remains constant above 100 $M_{\odot}$.)

Will *JWST* be able to detect the direct starlight from such massive stars? Although they are very luminous, most of their energy is radiated in the far-UV, short of the Lyman limit ($\lambda <$ 912 Å). Only a modest fraction of their flux occurs at wavelengths longer than the Lyman limit, where neutral hydrogen would not absorb it. As a consequence, *JWST* and other planned observatories operating at longer wavelengths will be unable to detect the direct starlight. On the other hand, such a strong flux of ionizing radiation, in the absence of metals, would efficiently ionize the surrounding gas (if any) and heat it to an electron temperature as high as 20,000 K or even higher, forming bright H II regions. Under these conditions, almost half of the stellar energy output could be transformed and re-radiated by the gas as Lyman-α photons.

This conversion of far-UV photons to Lyman-α photons would be very good news for observations if the intergalactic medium (IGM) were transparent to Lyα radiation, i.e., if the IGM were fully ionized. However, before the epoch of reionization, the damping wings of the Gunn-Peterson forest will absorb or scatter most of the Lyα photons. Panagia et al. (2002a,b, and in preparation) have shown that *JWST* can directly detect only relatively rich groups of massive stars (i.e., containing a total 1,000,000 solar masses in stars more massive than 100 solar masses each) at redshifts as high as 15 to 20. The first WMAP results (Spergel et al. 2003) suggest that the re-ionization process may have started at this epoch. Nevertheless, the formation of big groups of stars was not an efficient process at such high redshifts, and the direct detection of such primordial stars may still elude us.

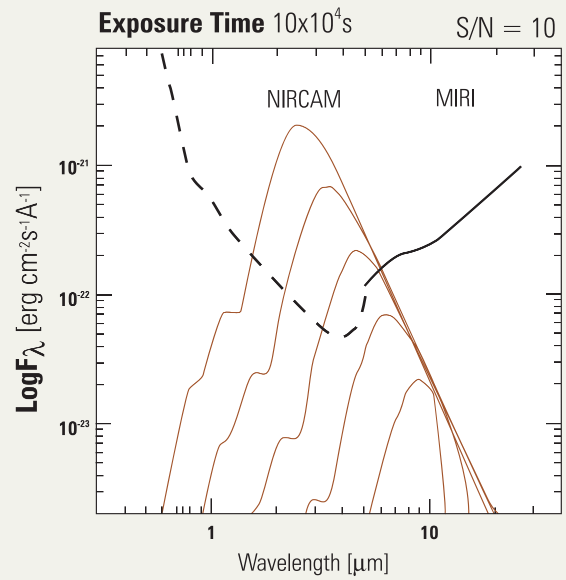

Figure 1: Type Ia supernovae spectral energy distributions (SEDs) at maximum light ($M_B = -19.5$) for various redshifts, calculated adopting $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, and $H_0 = 65$ km s^{-1} Mpc, and degraded to resolution R ~ 4. Top to bottom, the red curves are for redshifts 5, 7, 10, 14, and 20. The *JWST* sensitivity curve, shown in dashed black line for NIRCam and solid black line for Mid Infrared Instrument (MIRI), assumes a 10^5 second exposure, a signal-to-noise ratio of 10, and a resolution of R ~ 4.

Even if *JWST* cannot detect massive Population III stars directly, supernova (SN) explosions may come to the rescue. We know that local-universe supernovae can be as bright as an entire galaxy (e.g., at maximum light type Ia supernovae, or SNIa, have $M_B \sim -19.5$). As a result, they may be detectable up to large distances. Practically, SNIa are efficient emitters only at rest-frame wavelengths longer than 3000 Å, and, therefore, they will be hard to detect at redshifts higher than $z \sim 10$ (see Figure 1). Moreover, the stellar evolution that leads to classical SNIa explosions is believed to take several hundred million years (e.g., Madau et al. 1998) and, therefore, no type Ia is likely to occur at redshifts higher than about $z \sim 8$. Type II are much more efficient UV emitters, but only rarely are they as bright as a SNIa. As a consequence, they will barely be detected at redshifts higher than 10 (see Figure 2). Even if they are exceptionally bright, like SN 1979C or SN 1998S, they could still be quite rare events.

On the other hand, because massive Population III stars are much

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more massive than Pop II or Pop I stars, the resulting supernovae may have properties different from those of local-universe SNe. Heger et al. (2001) have considered the fate of massive stars in conditions of zero metallicity and have found that stars more massive than 260 $M_\odot$ would collapse directly to a black hole without producing an explosion. The same would occur for stars with masses in the approximate range 30–140 $M_\odot$. Below 30 $M_\odot$ the SN explosions would resemble those of SNII ($E_{kin} \sim 10^{51}$ erg). For stellar progenitors with masses in the range 140 to 260 $M_\odot$, Heger et al. find that the explosions would be caused by a pair-production instability and would be 3 to 100 times more powerful than for core-collapse (type II and type Ib/c) SNe. As a consequence, even an individual SN may become bright enough to be detected with *JWST*.

Heger et al. calculate that, near maximum light, the brightest pair-production SNe at $z = 20$ may be observed at a flux level of about 100 nJy at 5 microns, or, correspondingly, be brighter than an AB magnitude of 26. This flux is more than 100 times higher than that of a typical SNII and, therefore, would be well within the reach of *JWST* observations with an integration time of a few hours.

While bright supernovae produced by the explosions of primordial Population III stars may be detectable, do they occur frequently enough to be found in a systematic search? For a standard cosmology ($\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, $H_0 = 65$ km s^{-1} Mpc, $\Omega_b = 0.047$), and assuming that at $z = 20$ a fraction 10^{-6} of all baryons goes into stars of 250 $M_\odot$, Heger et al. (2001) predict an overall rate of 0.16 events per second over the entire sky, or about 3.9 x 10^{-6} events per second per square degree. Since for these primordial SNe the first peak of the light curve lasts for about a month (see Figure 3), about a dozen of these supernovae per square degree should be at the peak of their light curves at any time. Therefore, monitoring about 100 fields of the Near Infrared Camera (NIRCam) with integration times of about 10,000 seconds every few months for a year should lead to the discovery of three of these primordial supernovae.

We conclude that, with a significant investment of observing time (a total of 4,000,000 seconds) and with a little help from Mother Nature (to endorse our theorist's views), *JWST* will be able to detect the very first sources of light in the universe. Ω

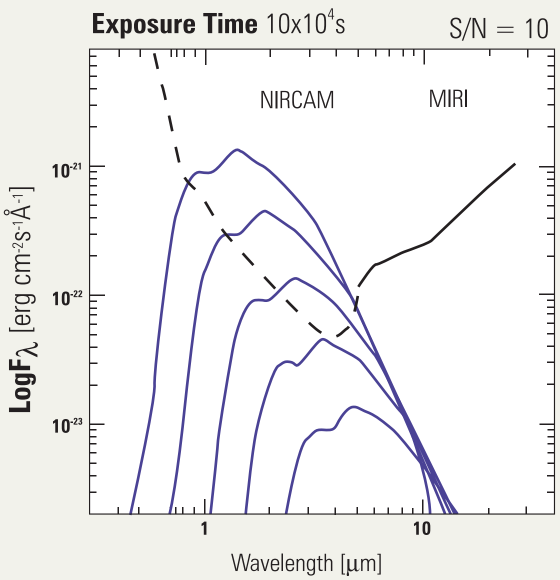

Figure 2: Type II supernovae SEDs at maximum light ($M_B = -17.5$) for various redshifts, calculated adopting $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, and $H_0 = 65$ km s^{-1} Mpc, and degraded to resolution R ~ 4 resolution. Top to bottom, the blue curves are for redshifts 5, 7, 10, 14 and 20. The *JWST* sensitivity curve, shown in dashed black line for NIRCam and solid black line for MIRI, assumes a 10^5 second exposure, a signal-to-noise ratio of 10, and a resolution of R ~ 4.

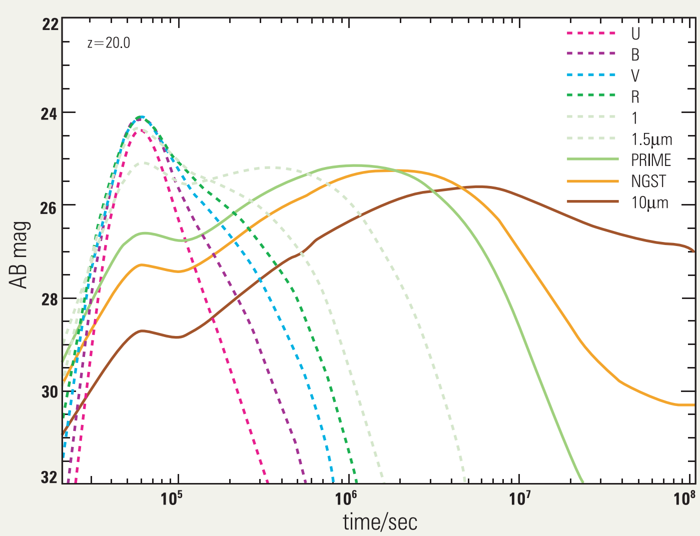

Figure 3: Light curves for a pair-creation supernova from a 250 $M_\odot$ star at $z = 20$ (Heger et al. 2001). Time, wavelengths, and magnitudes are given in the observer's rest-frame. Wavelengths shorter than the IGM Lyα absorption (2.55 microns) are shown as dotted lines. The curves labeled 'PRIME' and 'NGST' correspond to observed wavelengths of 3.5 and 5 microns, respectively.

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News from the Multi-Mission Archive at STScI (MAST)

Rachel Somerville on behalf of the MAST team, *somerville@stsci.edu*

As of early August 2003, MAST contained 14.7 terabytes of data. In July, the mean daily ingest rate (18 gigabytes per day) and the mean daily retrieval rate (50 gigabytes per day) were near-record highs.

As many users noticed, retrieval times were unusually long during July and early August. Hardware problems and an unusually large volume of data requests caused the delays. While we anticipate slightly longer than optimal retrieval times to continue during the process of upgrading the Data Archive and Distribution System (DADS) database, server, and storage system (see below), we do not foresee a repeat occurrence of the extreme delays experienced in July 2003. We understand the inconvenience these delays cause to our users, and we are doing everything we can to get data out as quickly as possible. We encourage users to contact the archive helpdesk (*archive@stsci.edu*) if a data request takes longer than 2 to 3 days.

DADS and Server Upgrades

The large size of Advanced Camera for Surveys (ACS) files poses a challenge to the MAST goal of quick delivery. To meet it, MAST has been implementing major hardware and software enhancements. These changes include the migration of *Hubble* and other MAST data from magneto-optical jukeboxes to a new 32-terabyte EMC 'spinning disk' storage array, which is less subject to mechanical problems and provides more rapid delivery of requested files. Also, we have installed a multi-CPU SunFire 15K server with approximately four times the number of processors and amount of memory of our HP alpha-based server cluster. The new hardware is engineered to be fault-tolerant and highly available, which should increase reliability. The SunFire server will host a redesigned version of DADS, which will provide greater control over the request queue and prevent bottlenecks from forming when the system encounters a problematic retrieval request. The SunFire will also host the latest version of the Operations Pipeline Unified System (OPUS) software. After testing is completed, users can expect faster access to the *Hubble* archive database. In the interim, we have created new 'FastAccess' FTP sites within MAST to distribute high-demand files, such as ACS Early Release Observations and Treasury program data. This prevents multiple requests to DADS for these data from increasing retrieval times. We frequently update these FTP sites, which can be accessed via the MAST home page at **http://archive.stsci.edu**.

ACS and WFPC2 Associations Added to Pointings Table

The MAST 'pointings' search (**http://archive.stsci.edu/cgi-bin/point**) allows users to determine which regions of the sky *Hubble* has observed and to do sophisticated searches based on the number of observations, number of filters, time between observations, and other criteria for a given region. We have added ACS and Wide Field Planetary Camera 2 (WFPC2) to the pointings database, to join imaging from the Space Telescope Imaging Spectrograph, Faint Object Camera, and Near Infrared Camera and Multi-Object Spectrometer. Please see **http://archive.stsci.edu/cgi-bin/point** for details on how we define the pointings for each instrument.

GOODS Observations and High-Level Science Products

All five epochs of observations of the Great Observatories Origins Deep Survey (GOODS) Treasury Program northern (Hubble Deep Field North) and southern (Chandra Deep Field South) fields are now available on anonymous FTP sites. (Links at **http://archive.stsci.edu/hst/**.) The GOODS v1.0 data release of the reduced, co-added five-epoch mosaics began on August 29. The *V*-, *I*-, and *z*-bands for the CDF-S and the *z*-band HDF-N mosaics are available, and other bands will be made available as the processing is completed.

WWW Search Interface News

File upload search option available. Users may now search MAST missions using an uploaded file of target names or coordinates. The uploaded file can be a multi-column table or simply a list of (delimited) target names or coordinates. To find out more, click on the "File Upload Form" link at the top of each MAST mission search page and read the help-page entries for the various form elements. You can specify several output formats, including the standard HTML, CSV (comma separated values), Excel spreadsheet, or VOTable.

Abbreviated names now allowed for FUSE data ID. Users may now specify the *Far Ultraviolet Spectroscopic Explorer (FUSE)* data ID by its eight-character observation name (e.g., A1080303) on the MAST FUSE search form. (Previously, 11 characters were required.

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GALEX Interface News

The *GALEX* satellite (*Galaxy Evolution Explorer*) was launched on April 28, 2003, with the goal of mapping the full sky in the near and far ultraviolet in imaging mode and part of the sky in spectroscopic mode (resolution 125 to 150). Led by the California Institute of Technology, this project is now in operation, surveying stars and galaxies out to large distances. MAST will host *GALEX* data as its newest active mission. In late 2003, we will make the first formal data release ('DR0') available to the public through the website **http://galex.stsci.edu**. (Or click the "*GALEX*" link on the MAST home page.) The website is available now for users to get accustomed to *GALEX* products by means of simulated data. We have provided a tutorial for ease of navigation.

We constructed the *GALEX* website in a MicroSoft .NET Framework environment and integrated it within the SQLServer2000 Database Management System. The latter permits many novel features, such as 'active images' for convenient follow-up queries on nearby neighbors of an initially selected target. Two query forms, one 'MAST-style' and the other an SQL query box, are available to permit searches on individual objects or on objects within ranges of parameter space. We are developing a third query form optimized for searches on individual objects and their closest neighbors. Ω

Reaching for the Stars: Hispanics in Astronomy

Juan P. Madrid, *madrid@stsci.edu*, **Eva Villaver,** *villaver@stsci.edu*,
Gerardo Vàzquez, *vazquez@stsci.edu* & **Jessica Kim Quijano,** *jkim@stsci.edu*

Figure 1: Hispanic children from Baltimore and their counselors in the Institute's auditorium.

Last March the American Astronomical Society's newsletter published an article in which Keivan Stassun, member of the Committee of the Status of Minorities in Astronomy, pointed out a dramatic reality in our field:

"Under-representation in astronomy is an order-of-magnitude issue: The Ph.D. production rate among Hispanic-Americans and African-Americans in astronomy averages 2–3% per year, compared to these groups' 25% representation in the overall population."

In response to this situation, we decided to create an activity for Hispanics following the example set by the activities for women in astronomy led by Megan Donahue. The presence of Hispanics working at the Institute creates a good opportunity to do public outreach targeting the largest minority in the US. In other words, 'have minorities, get minorities.' Future generations of minority astronomers will feel more comfortable knowing that a diverse workplace exists.

The main goal of our activity was to show a group of young Hispanics that it is possible to be both Hispanic and an astronomer, a fact that, given the lack of models in their families, is not evident for many of them.

We contacted Education Based Latino Outreach (EBLO), a non-profit community organization based in the Fells Point area of Baltimore. EBLO offers a summer camp as well as tutoring courses year-round for children between the ages of 6 and 12. We scheduled a visit to the Institute during the second week of August as part of their summer-camp educational activities. Twenty-five young Hispanics—some born in the US, others born in five different Latin-American countries—attended the activity.

All the children spoke Spanish and most of them spoke perfect English. We were able to offer a bilingual activity. Spanish is the language that the children usually speak at home, and the possibility to speak the same language in a stimulating environment encouraged them to participate actively. This created an ideal atmosphere to get our message across.

Juan Madrid gave an introduction to the *Hubble* mission and to solar system astronomy with images taken by *Hubble*. Despite the fact that these young Hispanics come from low socioeconomic backgrounds, many of them were already familiar with *Hubble*. At the very beginning of the talks, one particularly smart girl, Yolanda Vargas, age 11, made an immediate connection with the *Hubble* model displayed at the Air and Space Museum in Washington, D.C.

The students heard a talk about stellar evolution by Eva Villaver and were amazed to learn that earth will be swallowed by the sun at the end of its evolution. One of us, Gerardo Vàzquez, told the young students about the long path he followed in Mexico and in the United States to become a post-doctoral fellow at the Institute. This was meant to stimulate the young students to follow the same road.

The children were very active and never stopped asking clever questions. One of the kids believed he saw a map of Mexico on the Hubble Heritage image of the Keyhole Nebula, part of the Carina Nebula (NGC 3372). Another one claimed that there was a rabbit hidden in the moon.

We were provided with superb material from the Office of Public Outreach. We offered the kids beautiful posters with breathtaking *Hubble* images. All of them left thrilled by these gifts. We feel very happy knowing that *Hubble* images are now on the walls of these students' bedrooms, perhaps inspiring them to become astronomers.

Given the success of this first activity, we are looking forward to bringing another group to the Institute next fall. The continuity of this sort of activity is essential to attract talented Hispanics into astronomy. Outreach with minorities is challenging yet gratifying at the same time. Hispanic schoolgirls and schoolboys rarely have the opportunity to be invited to a research facility like the Institute. We hope that this visit made them wish to be an active part of a future project to explore the universe, as with *Hubble* today.

The website of the AAS Committee on the Status of Minorities in Astronomy (CSMA) is: **http://www.astro.wisc.edu/csma**/. The committee publishes a newsletter available at their website.

A recent NSF report on Women, Minorities and Persons with Disabilities in Science and Engineering can be found at: **http://www.nsf.gov/sbe/srs/nsf99338/frames.htm**. Ω

The Salvation of HST

With apologies to Robert Service who can scan better than I,

Lauretta M. Nagel, *nagel@stsci.edu*

There are strange things done in the noonday sun by the ones who work the stars,
The science trails have their secret tales,
That would make you watch for scars,
The ET lights have seen cool sights,
But the neatest they ever did see,
Was, to NASA's credit, in Low Earth Orbit,
The salvation of *HST*.

Now *HST* was a telescope, see, for to study the universe.
She was big and new, and to her crew, her testing was a curse.
For her primary mirror, to make it all clearer, must be perfectly smooth without flaw.
But a missing widget caused some to fudge it—aberration was what she saw.

On April 24th, we sent her forth to begin her Verification,
But her vision lame caused everyone pain, the joke she was of the nation!
"How can we gauge the universe's age? It's a question we thought was key!"
The observers cried as the engineers sighed and the press laughed at *HST*.

We said to our crew, "This will never do," and we set up a Strategy Panel.
They talked when they met and their goals were set with an energy

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they could channel.
Solutions, you see, are not all that free when you think of the cost and the risk.
Return her home and she might never roam again above the Earth's disk.
And they thought of re-coating by astronauts floating, but baffles are awfully sharp.
"NASA won't let us," said Bruce McCandless, "they think we'll end playing the harp!"

As they studied and searched, and the telescope lurched along with each terminator crossing,
We worked the control laws with ever more tight jaws until there was very low tossing.
Astronomers toiled with software to foil the effects of the aberration,
Debated and disputed each's merits reputed to show an amelioration.

COSTAR was created and built while we waited for Servicing Mission number one,
A set of spectacles on deploying tentacles was the concept for how it was done.
To achieve its space, it would take the place of the gallant HSP,
But to fix up the vision and enable the mission, it was crucial for *HST*.

And WiffPic2 was developed, too, with contacts in the optical path,
For 'Images true!' we then could coo and deflect all the scientists' wrath.
We waited and watched while the shuttle launched to carry both instruments there.
We watched and we waited with lots of breath bated while they worked with
Extraordin'ry care.

Now gorgeous the view, and out of the stew, we've from our telescope restored
Fewer nail-biting nights and more gorgeous sights. We've seen our instruments' reward.

"Expect the unexpected" as we scope the undetected, and further, we think you'll see,
That nothing will stop her discovering whoppers and marvels, our *HST*.

There are strange things done in the noonday sun by the ones who work the stars,
The science trails have their secret tales,
That would make you watch for scars,
The ET lights have seen cool sights,
But the neatest they ever did see,
Was, to NASA's credit, in Low Earth Orbit,
The salvation of *HST*. Ω

Measuring Stellar Mass Loss Rates at the Femto Level (10^{-15} $M_\odot$ yr^{-1})

Jeffrey L. Linsky, *jlinsky@jila.colorado.edu*, & **Brian E. Wood,** *woodb@casa.colorado.edu*

Stellar mass loss is important for stellar evolution and the chemical enrichment of the interstellar medium, from which new generations of stars are formed. Astronomers have used three types of spectral feature to study it: blue-shifted absorption lines (used by Deutsch [1956] to measure the mass loss rate from the M5 giant Alpha Her), free-free continuum emission in the radio region, and continuum and molecular line emission in the infrared. These techniques can measure mass loss rates in the range 10^{-5} to 10^{-10} solar masses per year ($M_\odot$ yr^{-1}) for hot stars, late-type giants and supergiants, and pre-main sequence stars.

By comparison, the solar mass loss rate of 2 x 10^{-14} $M_\odot$ yr^{-1} is more than 4 orders of magnitude below the sensitivity limits of the three commonly used techniques. Since other main sequence and subgiant stars should also lose mass, a new technique is needed to measure it. While small mass loss rates may not affect the evolution of the stellar core, they are critically important for controlling the angular momentum evolution of a star and for understanding the evolution of planetary atmospheres—and thus, whether or not life can form on planets around other stars. Is it possible to extend the sensitivity of mass loss rate measurements by 4 orders of magnitude? Yes. The high spectral resolution, well characterized instrumental profiles, and excellent wavelength scales of the Goddard High Resolution Spectrograph (GHRS) and Space Telescope Imaging Spectrograph (STIS) instruments make this seemingly impossible task feasible.

One might guess that the most opaque spectral line in the universe, the Lyα line of hydrogen, would contain a weak signal indicating stellar mass loss. Typically GHRS and STIS spectra of nearby main sequence stars show three Lyα features: a hydrogen emission line formed in the stellar chromosphere, a broad interstellar hydrogen absorption line located near line center, and a narrow, unsaturated interstellar deuterium absorption line displaced by –82 km s^{-1} from the interstellar hydrogen absorption line. A careful analysis of this complex suite of lines from some nearby stars reveals subtle features indicating stellar mass loss.

Figure 1 shows the Lyα line profile of Alpha Cen B (K1 V) and its distant companion Proxima Cen (M5.5 Ve) as observed by STIS. One can predict the shape of the interstellar hydrogen absorption feature from the interstellar deuterium and metal lines formed at the same temperature as hydrogen. The predicted interstellar hydrogen absorption (the dashed line in Figure 1) is narrower than the observed absorption, indicating that additional hydrogen absorption is present on both the red and blue sides of the interstellar absorption.

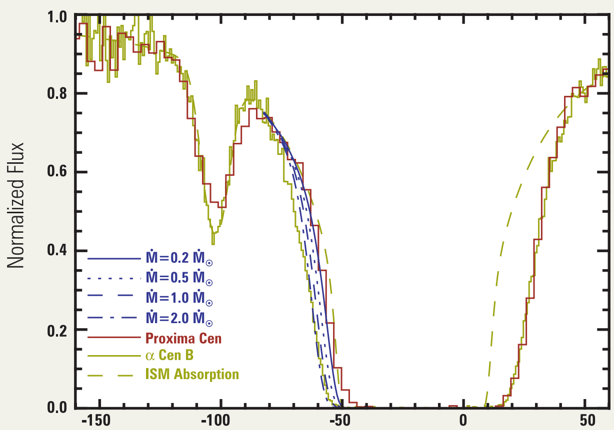

Figure 1: Comparison between the Lyα spectra of Alpha Cen B (green histogram) and Proxima Cen (red histogram). The inferred ISM absorption is shown as a green dashed line. The Alpha Cen/Proxima Cen data agree well on the red side of the HI absorption, but on the blue side the Proxima Cen data do not show the excess Lyα absorption seen toward Alpha Cen B (i.e., the 'astrospheric' absorption). The blue lines show the blue-side excess Lyα absorption predicted by the four models of the Alpha Cen/Proxima Cen astrospheres, assuming four different mass-loss rates. The 2.0 $dM_{\odot}/dt$ model fits the Alpha Cen spectrum reasonably well, and the 0.2 $dM_{\odot}/dt$ model represents an upper limit of 4 x 10^{-15} $M_{\odot}$ yr^{-1} for the mass-loss rate of Proxima Cen.

The key to understanding the extra absorption is realizing that the inflowing, partially ionized interstellar gas interacts with the outflowing ionized solar (or stellar) wind. This interaction defines the large-scale structure of our heliosphere and, for other stars, their 'astrospheres.' The heliospheric interaction has been modeled by Baranov and Malama (1993), Zank et al. (1996), and others. They find that charge-exchange reactions between protons and hydrogen atoms lead to a concentration of hot hydrogen, the so-called 'hydrogen wall,' located at roughly 200 AU in the upwind direction, where the two gas flows interact. The result is extra absorption in the Lyα line that is redshifted relative to the centroid of the interstellar absorption for the line of sight to a star. Redshifts are predicted for nearly all angles relative to the upwind direction of the interstellar gas flow, as the solar wind slows the charge-exchanged atoms in the upwind direction and accelerates them in the downwind direction.

Additional absorption on the red side of the interstellar Lyα line by the heliospheric hydrogen wall is now detected in STIS and GHRS spectra of nearby stars for many lines of sight. If they are embedded in partially ionized interstellar gas, stars with coronal winds like the Sun will have astrospheres analogous to the heliosphere. Since we observe a stellar hydrogen wall from the outside, the additional Lyα absorption will be blue-shifted relative to the interstellar absorption rather than redshifted. This is the observable quantity for measuring mass loss from solar-like stars.

Comparison of the STIS Lyman-α profiles for Proxima Cen and Alpha Cen B (see Figure 1) by Wood et al. (2001) provides an excellent example of heliospheric and astrospheric absorption. Since the two stars are less than 2 degrees apart in the sky and only 1.3 pc distant, the interstellar absorption and the heliospheric hydrogen-wall absorption (on the red side of the interstellar absorption) should be the same. Indeed, this is the case.

On the other hand, the blue side of the Lyα absorption in the spectra of the two stars is different. Since this part of the absorption is due only to the astrospheric hydrogen wall absorption, the stellar winds of the two stars must be different. Comparison of such observations with theoretical models leads

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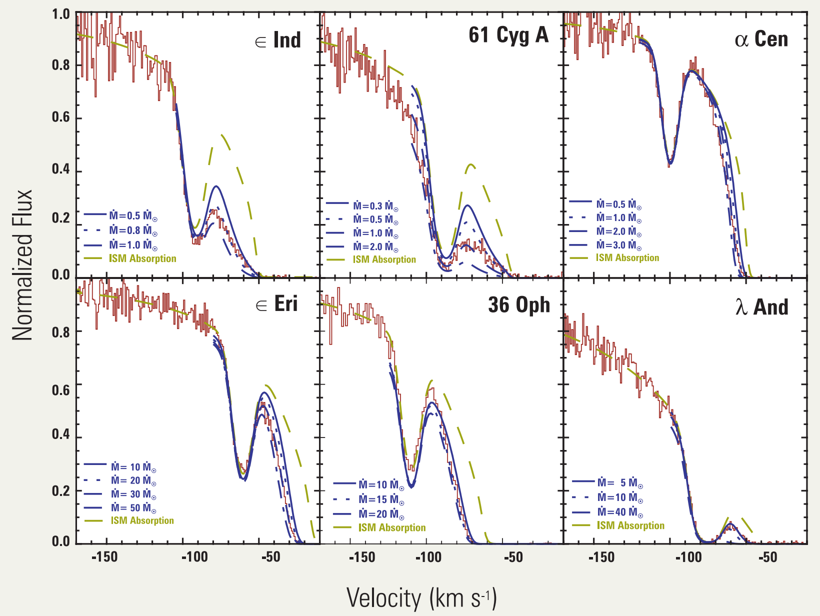

Figure 2: Closeups of the blue side of the HI Lyman-α absorption lines for six stars with detected astrospheric absorption, plotted on a heliocentric velocity scale. Narrow DI ISM absorption is visible in all the spectra just blueward of the saturated HI absorption. Green dashed lines indicate the interstellar absorption alone, and blue lines show the additional astrospheric absorption predicted by hydrodynamic models of astrospheres assuming various mass loss rates.

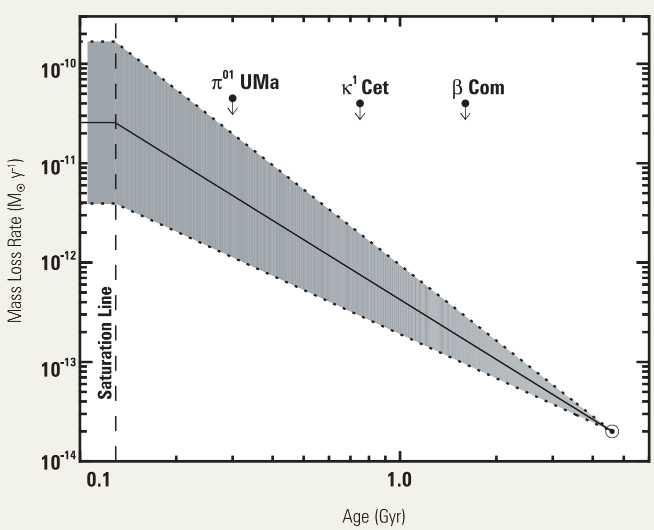

Figure 3: The mass loss history of the Sun. The upper limits are based on radio nondetections of three solar-like stars (Gaidos et al. 2000).

to estimates of the stellar mass loss rates. Wood et al. (2002) have modeled the astrospheric absorption for eight stars. Figure 2 shows a comparison of theoretical models with the blue side of the observed Lyα absorption for the lines of sight to six of these stars.

Since the winds of cool dwarf stars originate in coronae, we expect, and indeed find, that the measured mass loss rates (per unit stellar surface area) are correlated with the X-ray surface fluxes derived from data from the Position Sensitive Proportional Counter on the *Roentgen Satellite* (*ROSAT* PSPC). As stars age, their rotation rates decrease due to magnetic braking, and the X-ray fluxes decrease. There are many empirical relations describing this evolution of stellar activity. We adopt the empirical relations of Ayres (1997), combine them with our empirical mass loss/activity relation, and find a simple relation between mass loss rate and stellar age, $dM/dt \sim t^{-2.00 +/- 0.52}$. This relation, plotted in Figure 3, predicts that the mass loss rate of the young Sun ($t \sim 10^8$ years) was 200 to 10,000 times larger than at present. The cumulative mass loss from age 10^8 years to the present is $< 0.03\ M_\odot$.

This new result provides the first quantitative estimate of the solar wind flux that planets received during the early solar system. This is important for addressing such questions as (i) why the young Earth had running water when the Sun was 25% fainter than today, and (ii) whether solar wind erosion removed water and other molecules from the atmosphere of the young Mars.

Stellar winds can erode planetary atmospheres, and the higher mass-loss rates suggested for the young Sun and young stars with high X-ray fluxes would exacerbate these effects. Solar-wind sputtering processes have been proposed to have important effects on the atmospheres of Venus and Titan, but the atmosphere of Mars may be the most interesting case of solar wind erosion because of the questions whether water, and perhaps even life, once existed on the surface.

Unlike the Earth's, the atmosphere of Mars is not currently protected from the solar wind by a strong magnetosphere. There is evidence that Mars once had a magnetic field, which disappeared at least 3.9 Gyr ago (Acuña 1999). At that time, the martian atmosphere would have been exposed to a solar wind about 40 times stronger than the current wind, which would have had a dramatic effect on its atmosphere. Mars appears to have had running water on its surface in the distant past and a thicker atmosphere that could have supported a climate consistent with surface water (e.g., Jakosky & Phillips 2001). Solar wind erosion is a leading candidate for the thinness of Mars' present atmosphere and the lack of surface water (e.g., Lundin 2001). Planets around other stars could have similar histories. Ω

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Reflected Glory: Hubble Observes the Spectacular Light Echo around V838 Monocerotis

Howard E. Bond, *bond@stsci.edu*

One of the most spectacular stellar phenomena of recent years has been the appearance of light echoes around the unique variable star V838 Monocerotis. Observations of the echoes with *Hubble* and its new Advanced Camera for Surveys (ACS) have played a key role in unraveling some of the mysteries of this remarkable object.

Australian amateur astronomer N. J. Brown discovered the outburst of the previously unknown variable V838 Mon in early January 2002, when the star rose from 15^{th} to 10^{th} magnitude. Remarkably, it abruptly rose another 4 magnitudes in early February 2002. Several weeks later, Arne Henden of the U.S. Naval Observatory, Flagstaff, discovered the surrounding, rapidly expanding light echo.

A light echo is created when light from a stellar outburst propagates into and illuminates nearby interstellar dust. Because of the extra path length, the light scattered from the dust arrives at the Earth weeks, months, or years after the light from the outburst itself. Light echoes require a sudden stellar outburst and pre-existing nearby dust, and moreover the outburst must be of high intrinsic luminosity in order to illuminate the dust adequately. Satisfying the combination of all three requirements is extremely rare, and only two previous occurrences of light echoes are well known, around Nova Persei 1901 and SN 1987A in the Large Magellanic Cloud.

A team led by the author proposed for *Hubble* director's discretionary time to obtain imaging polarimetry with the ACS, which fortunately had just been installed into *Hubble* by the *Columbia* astronauts in March 2002. Other team members are Arne Henden; Zolt Levay, Nino Panagia, and William B. Sparks (STScI); Sumner Starrfield (Arizona State University); R. Mark Wagner (University of Arizona); Romano Corradi (Isaac Newton Group of Telescopes); and Ulisse Munari (Padua Observatory).

In April 2002, the team made ACS observations in the *B* filter only. The images revealed a wealth of sub-arcsecond detail in the echoes. They made *B*-, *V*-, and *I*-filter observations in May, September, October, and December 2002. Figure 1 shows color renditions of these images.

The geometry of a light echo is simple: at any given time, the illuminated dust lies on a surface of constant light travel-time delay, which is a paraboloid with the star at its focus and its open end pointing toward the Earth. Since these paraboloids expand with time, the echoes will initially appear to

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expand—in fact, at an apparent speed several times the speed of light.

The detailed light curve of the V838 Mon outburst is known from ground-based photometry: after the initial rise in January, there was a sharp, blue peak in early February, followed by a decline and then a rebrightening to a much redder plateau, culminating in a rapid drop back to its original optical brightness, which occurred in late April 2002. (This sharp decline was due to dust formation around the star, which remains luminous in the infrared up to the present time.) Detailed examination of the ACS color images reveals a multitude of precise replicas of the light curve propagating away from the star in the form of sharp outer blue rims, dips, and inner red plateaus.

Light echoes have at least two important scientific applications. First, they permit the direct geometric determination of the distance to the star. Bond's team has carried out the distance measurement using two independent methods—both for the first time in astronomical history. One method relies on the apparent angular expansion rates, which, for simple dust geometries, are functions of the distance. Unfortunately, at present this method provides only a lower limit to the distance (~2 kpc). At later times, this method will produce much more precise results, especially at the epoch where the apparent expansion reverses and becomes an apparent contraction.

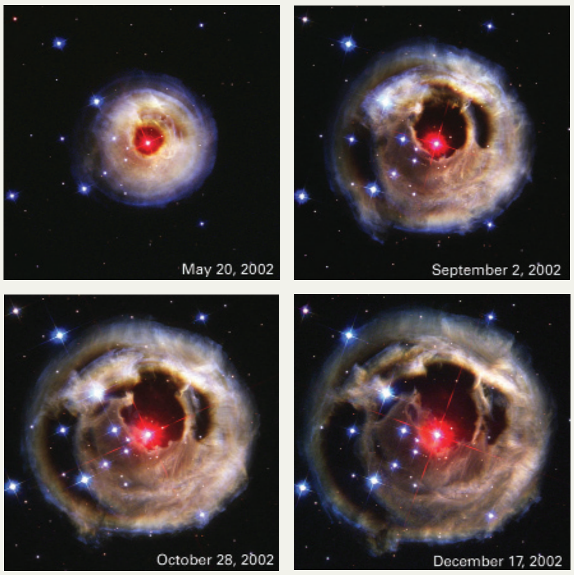

Figure 1: Color renditions of the ACS images of the V838 Mon light echoes in May, September, October, and December 2002. As light from the outburst of the central star propagates out into surrounding stationary dust, the echoes appear to expand at several times the speed of light. Aside from the beauty of their complex structure, the echoes provide a means for direct geometric determination of the distance to the star and for unambiguous three-dimensional mapping of the circumstellar dust.

The second method, first proposed by Sparks in 1994, is based on polarimetry. Here the principle is that maximum linear polarization occurs for light scattering at right angles. As a result, the location of maximum linear polarization in the echoes marks material that is in the plane of the sky, and is thus located a distance *ct* from the star, where *t* is the time since the outburst. This method, applied to the December 2002 images taken with the ACS's polarizing filters, yields a distance of 6 kpc.

This large distance means the outburst of V838 Mon was extremely luminous, reaching $M_V \approx -9.6$ at its maximum in February 2002. The energy release was thus comparable to that of a classical nova, except that V838 Mon was definitely not a classical nova of any previously recognized type. Unlike a classical nova, which quickly expels its outer layers and exposes an extremely hot source, V838 Mon has remained a cool supergiant throughout its outburst. Whether V838 Mon indeed represents a thermonuclear runaway on a white dwarf in a new region of parameter space, or instead signifies some wholly new type of stellar outburst mechanism, remains to be seen. One possibly relevant clue is that an early B-type main-sequence companion star has emerged in ground-based spectra, but whether the B star is simply an uninvolved bystander is as yet unknown.

The second application of light echoes is three-dimensional mapping of the surrounding dust. The location of each illuminated dust element in three-dimensional space is uniquely determined, knowing the time since light from the outburst reached the Earth. This is the only such method for 3-dimensional mapping available in astronomy. Observations to date, however, only provide mapping in a narrow cone whose axis points toward the Earth. Nevertheless, it is already clear that the dust distribution is highly non-spherical and complex, with numerous, large-scale voids and smaller-scale 'cirrus-like' structures. Also, there is a small, elongated cavity centered on the variable star. Since the dust clouds are roughly centered on the star at a radius of about 2 pc, it seems likely that the dust was ejected in a previous outburst of V838 Mon several tens of thousands of years ago.

The reverberations of these spectacular light echoes should continue for the rest of this decade, providing astronomers—if they can persuade future Hubble Time Allocation Committees of the value of such observations—with a unique opportunity for circumstellar mapping and the application of two new methods for determining astronomical distances. Ω

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

Sombrero Galaxy

The picturesque Sombrero galaxy is one of the largest *Hubble* mosaics ever assembled, this magnificent galaxy is nearly one-fifth the diameter of the full moon. The Hubble Heritage team used *Hubble*'s Advanced Camera for Surveys to take six pictures of the galaxy and then stitched them together to create the final composite image. The photo reveals a myriad of stars in a pancake-shaped disk as well as a glowing central bulge of stars.

Contact STScI:

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Lisa Storrie-Lombardi, Caltech

The Space Telescope Science Institute Newsletter is edited by Robert Brown, *rbrown@stsci.edu,* who invites comments and suggestions.

Technical Lead: Christian Lallo, *clallo@stsci.edu*
Contents Manager: Sharon Toolan, *toolan@stsci.edu*
Design: Krista Wildt, *wildt@stsci.edu*

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SPACE TELESCOPE European Coordinating Facility

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.

Richard Hook *(Editor)*

Space Telescope -
European Coordinating Facility
Karl Schwarzschild Str. 2
D-85748 Garching bei München
Germany
E-Mail: *rhook@eso.org*

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Notification of PIs	2 April 2004
Phase II deadline	7 May 2004
Cycle 13 observations begin	1 July 2004
MAST Users Group meeting at STScI	20 October 2003
May Symposium at STScI	3-6 May 2004
Space Telescope Users Group meeting at STScI	6-7 November 2003

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