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NEWSLETTER

Space Telescope Science Institute

Image Caption: A color figure zoomed on a region of the GOODS. The exquisite resolution of ACS makes it possible to clearly distinguish the morphological features and internal color structure of even the smallest and faintest galaxies detected by the survey.

First Science Results from GOODS

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On August 29, 2003, the Great Observatories Origins Deep Survey (GOODS) team reached a major milestone with the release of the version v1.0 of the reduced, multiband imaging data taken as part of the GOODS Treasury project using the Advanced Camera for Surveys (ACS). This program is part of the greater GOODS project, which includes matched imaging observations with the *Space Infrared Telescope Facility (SIRTF)*, the *Chandra* X-ray observatory, and *Hubble*—plus systematic follow-up spectroscopic observations from the Keck and Very Large Telescope (VLT) observatories. The *Hubble* GOODS project includes 398 orbits with ACS, covering a total area of ~0.1 square degree in two fields, Hubble Deep Field North (HDF-N) and Chandra Deep Field South (CDF-S), in four bands, B_{435}, V_{606}, i_{775}, and z_{850}. The primary scientific goals of the survey are fivefold: first, to identify a sample of ~12 Type Ia Sne (supernovae) at $z > 1$ to provide an unambiguous detection of the presence of 'dark energy' in the kinematics of the Hubble expansion; second, to measure the evolution of stellar mass and star formation activity in galaxies over the redshift range $0.5 < z < 6$; third, to investigate the assembly of the Hubble sequence; fourth, to measure the evolution of dark-matter structure on galaxy scales at $0.5 < z < 2$ with weak lensing measures; and fifth, to provide a census of obscured and unobscured active galactic nuclei (AGN) up to $z \sim 6$ and investigate the relationship between galaxy and AGN evolution.

The *Hubble* GOODS observations, which started in August 2002 and were completed in May 2003, were carried out in eight 'epochs' (four in each field) separated by approximately 45 days to enable sensitivity to the supernovae. Two months after the completion of each epoch, the team released an initial, best effort version of the reduced data (v0.5). The hugely improved v1.0 release includes the full stack of all five epochs of ACS observations. The team recalibrated the data using improved reference files—dark, bias, and flat-field—and better corrections of geometrical distortions and distortions due to velocity aberration. It also derived and implemented an improved astrometrical solution, which is accurate to better than 0.09 pixel, and re-sampled the images

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Director's Perspective: Judging Ourselves

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One of the less appealing aspects of managing an organization is dealing with complaints. Few of us enjoy listening to other people complain, and we are exceedingly clever at devising strategies for putting distance between ourselves and the complaint: countering incorrect assertions, penning witty replies, and avoiding them altogether through judicious delegation. Rarely do we admit the virtue of using complaints as a window into our organizations and their impacts on the world around us. Yet it is precisely this revelation that is most useful about listening to people's disaffection with our work, and the process sometimes provides insight into larger forces at work in the culture of science.

The vast majority of the complaints I receive are related to failed proposals for time on the *Hubble Space Telescope*, a commodity that I—at least in principle—have sole authority to grant. My sympathies usually lie with the authors of such letters, since a large fraction of the proposals we turn down are truly excellent (see my column of March 2002). There is really little I can do to increase the amount of time available, and this kind of complaint just goes with the job. But increasingly there is a trend about these complaints best highlighted by one particular letter that made two assertions about our process: first, that the peer review panel consisted of intellects far inferior to the author's, and therefore incapable of appreciating the proposal (this was actually a plausible if arrogant assertion, since the author is an accomplished scientist), and, second, that the author would never agree to participate in one of our peer reviews. The juxtaposition of these two statements looked like excellent grist for a Director's Perspective.

Our peer review systems depend on the good will of eminent scientists to sit on our peer panels and judge the work of their colleagues. Most are incredibly busy and might have better things to do. If the above-cited author expressed feelings widespread among our colleagues, we would be unable to recruit people for the hard job of peer review, and that would cause a crisis. We would have to devise compulsory mechanisms for service, just as we have for jury duty, or we would revert to the system whereby directors made the decisions with inadequate input. I for one would hate to be in that position.

Indeed, we began to have real problems recruiting people to participate in the Cycle 13 time allocation panels. Normally, the majority of people we ask to serve respond positively. This year, the majority turned us down. We work hard to recruit good people, and I am confident that our panels will be excellent, but I worry that we will have an increasingly difficult time in future cycles. In addition to the review of *Hubble* proposals, the community now has to review *Chandra* proposals and, shortly, *SIRTF* proposals as well. Add these to the large number of new ground-based facilities that demand reviewers' time—the ESO VLTs, the Gemini telescopes, the public part of the Keck telescopes, and eventually new radio facilities such as ALMA—and it becomes clear that astronomers will spend half their time writing proposals and the other half judging the proposals of their colleagues. Only the first task serves their self-interest.

In the case of *Hubble*, this worry is currently confined to a few people at the Institute with the responsibility to fill the *Hubble* panels with experts over the whole range of astrophysics. It will soon become your worry, too. We must preserve our system of peer review to keep our observatories healthy, to ensure that we filter ideas in the best way we can, given the vagaries of human judgment in the first place. It is important that we make the task of serving on peer panels desirable enough to make sure that the author I cited earlier is simply wrong in the assertion that our panels cannot judge the best ideas.

I would welcome your ideas on how we can avoid a crisis in our peer system. We have been talking about creative ways to improve the acceptance rate, many of them obvious and most controversial. I would like to know what you think.

Please take the time to send me an e-mail with your thoughts about peer review and how we can ensure it continues to function well. I promise to extract some of the better ideas and publish them in this column to stimulate open discussion; perhaps we'll mount a debate using the Internet.

Of course, I reserve the right not to respond to the overly witty, cynical, or even outrageous comments, although I hope you send them to me anyway. Those may provide material for my next after-hours get together with fellow managers as we hone our public relations skills and practice using complaints as a window to the world. Ω from the original CCD pixel size of 0.05 arcsec/pixel into a finer, 0.03 arcsec/pixel scale, which optimizes the sampling of the point-spread function. Finally, the team has now combined individual ACS pointings into a seamless mosaic covering the full field of view in both GOODS fields. Figure 1 shows a color image of a portion of the GOODS CDF-S field obtained from the v1.0 data. The image has been made using images in all four passbands used in the survey. The depth and angular resolution of the ACS images can be appreciated even by simply looking at this spectacular picture.

The quality of the reduced data is excellent. The 10-sigma limiting flux (for point sources) is 27.3, 27.5, 27.3 and 27.0 AB magnitude in the B_{435}, V_{606}, i_{775} and z_{850} band, respectively, which is only $\sim$0.6 mag shallower than the sensitivity of the HDF. The v1.0 data are available from the *Hubble* archive as well as from the CADC and ESO/ST-EFC mirror sites. (Links are available in the *Hubble* archive web page.)

The *Hubble* GOODS team released source catalogs in December 2003 and plans a v2.0 release of the data during the summer of 2004. This will include cosmetic improvements and new data sets that will become available in 2004, including 4 additional epochs of observations (*i* and *z* bands only). The new data, carried out as part of a new search for high-redshift Sne by A. Riess and S. Perlmutter, continue the GOODS cadence in the northern field.

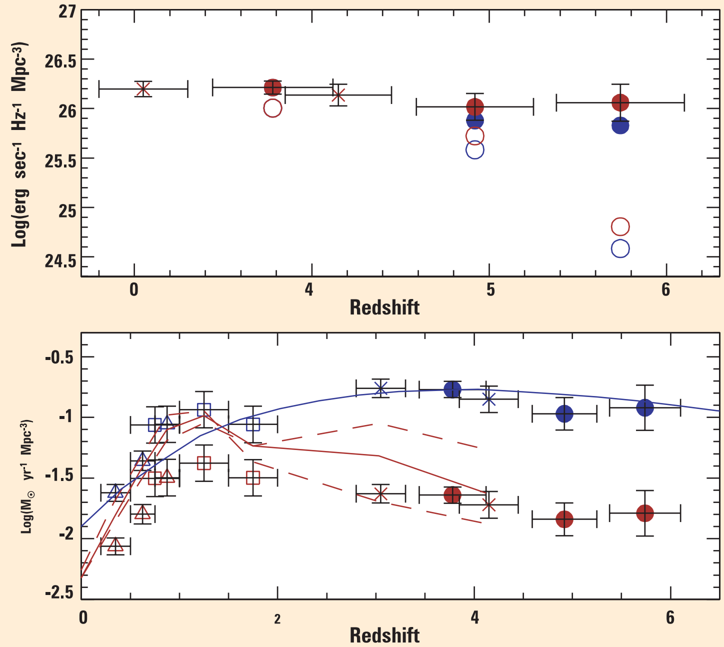

Figure 2: The top panel shows the evolution with redshift of the rest-frame UV luminosity density of Lyman-break galaxies, namely starburst galaxies with relatively bright UV emission. The bottom panel shows the evolution with redshift of the cosmic star formation density as traced by Lyman-break galaxies. The circles represent the GOODS measures at $z \sim 4$, 5 and 6. The blue symbols are the point 'as observed,' the red ones include corrections for luminosity function incompleteness down to $L_{UV} = 0.2 \times L^*$. The error bars reflect the 68% confidence level of fits to the luminosity function. The other points are from literature.[1,2,3] The red points do not include any correction for dust obscuration; the blue points include the correction proposed by Adelberger & Steidel.[4] The red curve is derived from the evolution of cosmic neutral hydrogen density as traced by damped Lyman-alpha absorbers[5]; the blue curve is from semi-analytical models.[6]

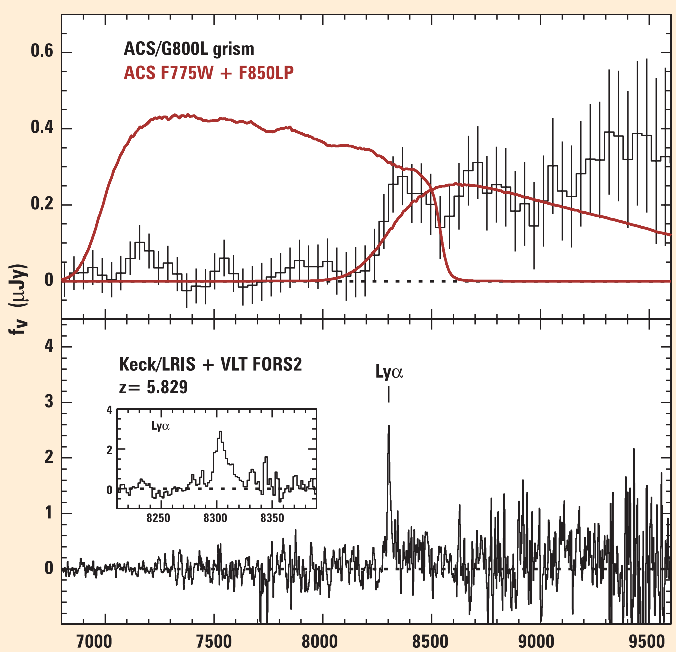

Figure 3: The ACS and Keck spectra of a star-forming galaxy at redshift $z = 5.83$ discovered during the GOODS survey. The top panel shows the ACS grism spectrum superimposed with the I_{775} and z_{850} passband. The spectrum clearly shows the break at the redshifted wavelength of the Lyman-alpha emission due to the blanketing by discrete neutral hydrogen clouds (Lyman-alpha forest). The bottom panel shows the Keck spectrum, where the Lyman-alpha line is clearly visible (it is diluted in the continuum because of the very low spectral resolution in the ACS grism spectrum). The insert panel shows a magnified, unsmoothed view of the Lyman-alpha emission line.

Scientifically, GOODS is already having an impact. A special issue of *The Astrophysical Journal Letters*, scheduled to appear in January 2004, presents 20 papers by the GOODS team presenting preliminary results mostly based on the *Hubble* data. One remarkable result is the identification of 15 Type Ia supernovae at $z > 1$, which was achieved through the combined efforts of the GOODS team and the High-*z* SNe team. The former provided the detected optical transients that it identified as Type Ia candidates on the basis of color criteria (made possible by the multi-band observations). The latter provided follow-up ACS and NICMOS imaging to measure the light curves of the SNe and ACS grism spectroscopy to measure their redshifts. The collaborating teams will use this unique sample to constrain the cosmological

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parameters Ω_{matter} and Ω_{lamda} as well as an accurate estimate of SNe rates and their relation to star formation rate.

The exquisite sensitivity and the large area covered by the GOODS data—0.1 square degree, 33 times larger than the two HDFs—has provided the best samples to date of Lyman-break galaxies at $z \sim 4$, 5, and 6 (the dropouts in the B_{450}, V_{606} and i_{775} band, respectively). The GOODS team estimated incompleteness and selection bias by inserting artificial galaxies of known properties into the real data and retrieving them as if they were real. On this basis, the team estimated with good confidence the ultraviolet luminosity density—and thus the star formation density—of Lyman-break galaxies from $z \sim 3$ to $z \sim 6$ (see Figure 2). The team found evidence that intense 'cosmic' star formation (traced by the star-formation density of Lyman-break galaxies) occurred early in cosmic evolution, at $z \sim 6$ (less than 7% of the cosmic age) and continued with similar intensity to $z \sim 1$ (about 43% of the cosmic age). The large fraction of the current stellar mass density—possibly as much as 50%—that formed early in the cosmic history (e.g., $z > 3$) shows that these early galaxies produced the bulk of the stars that today are being observed in spheroids. When complete, GOODS will provide measures of how much merging has been necessary to assemble today's bulges and ellipticals from their progenitors at high redshift.

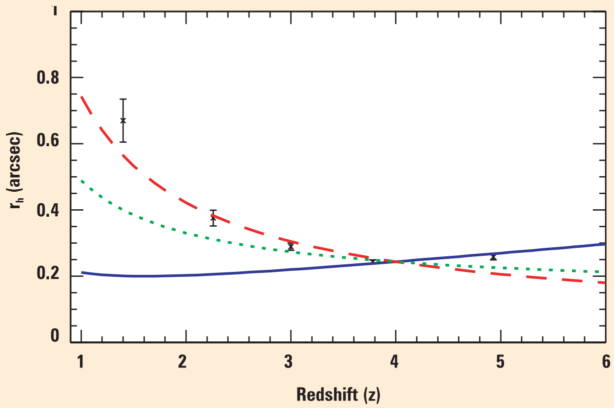


Figure 4: The evolution of the size of galaxies as a function of redshift. The solid blue line is the expected evolution of a 'ruler', namely an object whose physical size does not change. The red line shows the trend predicted by the hierarchical cosmology theory for galaxies with given fixed virial velocity, while the green one is for galaxies with given mass. Of course, we cannot select galaxies either by mass or by velocity, and thus the observed trend will be similar but not identical to these two ideal cases, if hierarchical evolution takes place.

The identification of a large sample of galaxies at $z \sim 6$ is important in itself. Figure 3 illustrates one such galaxy selected by the Lyman-break technique and followed up by spectroscopy with the ACS grism and a Keck spectrograph. These observations show a strong continuum break and asymmetric line emission identified as Lyman alpha at $z = 5.83$. Possibly, we are observing these galaxies towards the end of the epoch of cosmic reionization and can use their properties to better understand the physical processes that characterize that epoch.

The high angular resolution of ACS has allowed the first accurate measurement of the evolution of galaxy sizes from $z \sim 6$ to $z \sim 1.5$, which constrains cosmological models. Figure 4 shows that the observed relationship between galaxy size and redshift is consistent with the main prediction of hierarchical cosmology that accretion and merging of smaller galaxies into larger ones are major drivers of galaxy evolution.

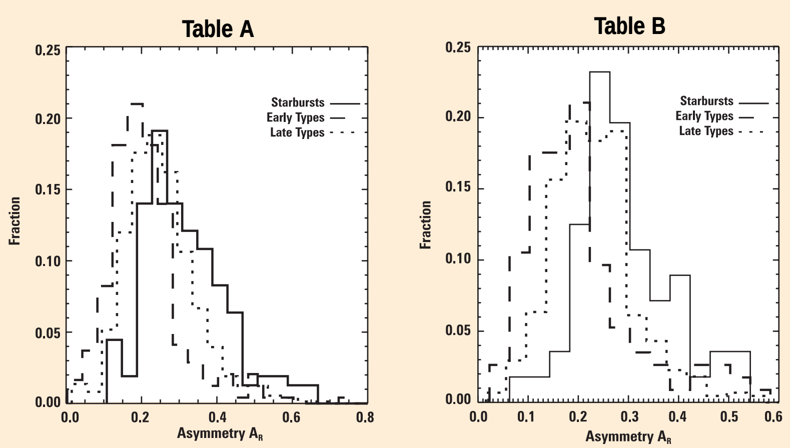
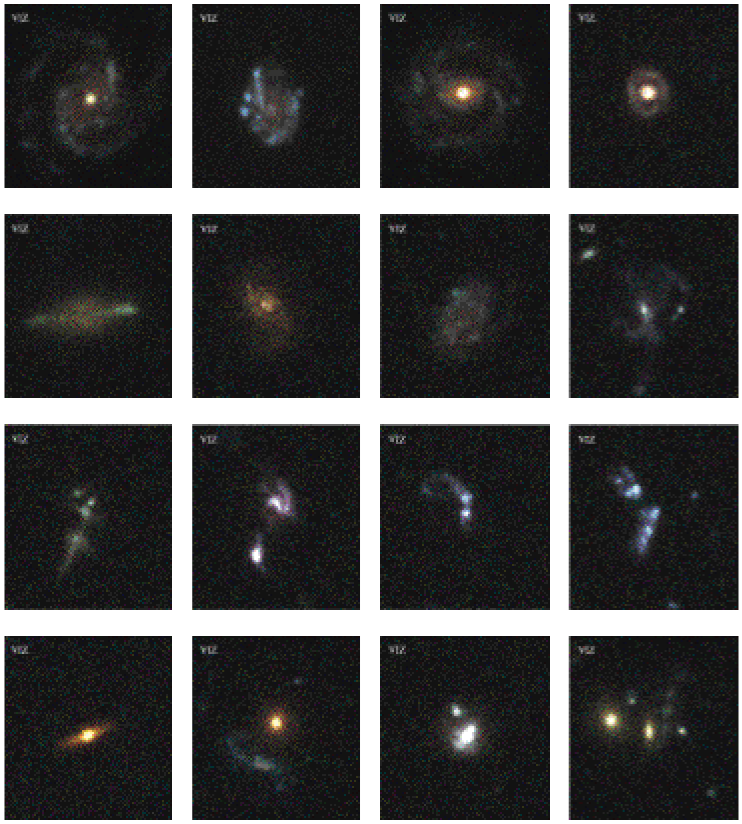


Figure 5: Distribution of the asymmetry indices in rest-frame *B* and *R* bands for three spectral types of galaxies; starbursts, late, and early types. The asymmetry index is obtained by rotating a galaxy image by 180°, subtracting it from its pre-rotated image, summing the intensities of the absolute value residuals and normalizing the sum to the original galaxy flux. The comparison shows that the star-forming galaxies (starbursts and late types) are more asymmetric in both rest-frame *B* and *R* bands. The fact that the asymmetry is also observed in rest-frame *R* band at a statistically significant level indicates that this is not due to contribution from star-forming regions in disks of galaxies, as measured from *B*-band images, but due to galaxy interaction and mergers. This result implies that starburst activity is likely triggered as a result of close interactions.

The wavelength coverage and high angular resolution of the *Hubble* GOODS observations allow detailed study of the rest-frame morphology of galaxies. The team finds that optically selected starburst galaxies (i.e., the bluest objects in the survey) have, on average, larger asymmetries than normal galaxies in both rest-frame *B* and *R* bands. This suggests that a significant fraction of the starburst activity may be tidally triggered by close interactions (see Figure 5).

An important goal of the *Hubble* GOODS program is to understand better the origin and evolution of galaxy morphology. The unmatched angular resolution of *Hubble* enables us to distinguish various types of galaxies, quantify their features—bulge and disk, asymmetry and concentration, and color dispersion—and statistically track their evolution as a function of time. Figure 6 shows representative galaxies of different morphologies at $1 < z < 2$. Ω



Disk Dominated

Low Surface Brightness

Mergers/Irregulars

Bulge Dominated

Figure 6: ACS images of galaxies of various types detected in the GOODS. The unparalleled spatial resolution obtained in the GOODS—0.03 arcsec—allows clear determination of the morphology of galaxies.

1 Lilly, S., Le Fevre, O., Hammer, F., & Crampton, D. 1996, *ApJ* 460, L1

2 Connolly, A. J., Szalay, A. S., Dickinson, M., Subbarao, M. U., & Brunner, R. J. 1997, *ApJ*, 486, L11

3 Steidel, C. C., Adelberger, K. L., Giavalisco, M., & Pettini, M. 1999, *ApJ*, 519, 1

4 Adelberger, K. L. & Steidel C.C. 2000, *ApJ*, 544, 218

5 Pei Y. C., Fall, S. M., & Hauser, M. G. 1999, *ApJ*, 522, 604

6 Somerville R., Primack, J. R., & Fabel, S.M. 2001, *MNRAS*, 320, 289

Science with Two-Gyro Pointing

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Hubble points at science targets with jitter less than five milliseconds of arc (mas). That is a remarkably small angle—about the size of a silver dollar (remember those?) in Chicago as viewed from New York. This exquisite stability allows astronomers to benefit from the diffraction limit of *Hubble's* optics across the spectrum, from the ultraviolet to the near infrared.

To achieve such superb pointing, *Hubble*'s pointing control system uses an inertial reference frame defined by gyroscopes. The axes of six on-board gyros are aligned in fixed directions that are equally distributed in spherical coordinates. Thus, any combination of three gyros defines a suitable three-dimensional Cartesian reference frame for pointing. The other three gyros serve as backups.

Earlier in the mission, *Hubble* operated with four gyros running, using the redundant information to improve pointing stability and to avoid disruptions to observations when a gyro failed. With the installation of new solar arrays, which substantially reduce jitter disturbances, and to maximize gyro lifetime, *Hubble* has been operating lately with only three gyros turned on at a time.

Hubble now has four operational gyros; two have failed. The life expectancy of a gyro depends mainly on how much it has been used. Engineers say the chance is even that two more gyros will fail by the end of 2005. Because the next servicing mission is scheduled for March 2006—and may slip beyond that date—the Institute is studying the performance of two-gyro pointing and how to adjust *Hubble*'s science program, if necessary. If viable, such a strategy would permit science operations to continue for three to fifteen additional months, after which time a fifth gyro would likely have failed, and science operations would cease.

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Gryo Pointing
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During science observations, *Hubble*'s pointing control system uses error signals from the gyros forty times per second for fine adjustments, and it uses error signals from the Fine Guidance Sensors (FGSs) once per second to compensate drifts. Only two working gyros would mean drifting during one-second intervals about the unconstrained axis of the missing gyro. Currently, engineers estimate the magnitude of this drift will be about 25 mas. It would cause blurring along the associated direction on the plane of the sky, the magnitude and orientation of which would depend on which two gyros were still operating. The closer the unconstrained axis is aligned with the optical axis of the telescope the better, for then the drift would be more in roll, 25 mas of which would be tolerable. If the unconstrained axis lies close to the focal plane, the full 25 mas would tilt the telescope, and the Hubble point-spread function (PSF) could resemble a 25-by-5 mas ellipse. The remaining gyros allow either scenario.

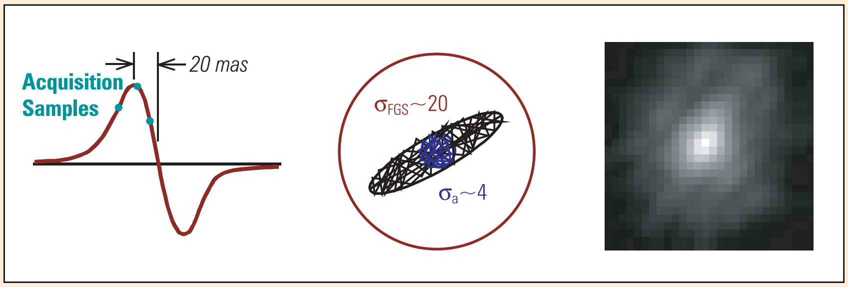

Figure 1: To the left, the S-curve is the FGS interferometer's response to a star. To acquire a star, the FGS samples points, determines the position, and locks into the center null. In the middle, the jitter ellipse under two-gyro pointing as described in the text. To the right, John Krist's simulation of the ACS/HRC PSF in the ultraviolet with a pointing-error ellipse of 7.5 by 20 mas. The diffraction rings are washed out owing to the high jitter. A corresponding simulation for the ACS/WFC in the red would show a PSF only slightly different from that currently achieved with three-gyro control.

Figure 1 shows a simulation of the PSF in the ultraviolet with the High Resolution Channel (HRC) on the Advanced Camera for Surveys (ACS) for two-gyro pointing.

Hubble also relies on the gyros to slew between targets, acquire new guide stars, and recover guide stars when an observation is interrupted by an earth occultation. These operations will become more challenging with only two gyros working. Targets near the pole of the *Hubble* orbit may become favored. The Institute is currently studying these issues and will report on them in the future.

Mode	PSF now: % central pixel	PSF now: width (mas)	PSF two-gyro: % central pixel	PSF two-gyro: width (mas)
Small Resolution	20	55	11	83
Large Resolution	18	145	15	153

Table 1: Impact of two-gyro guiding for 'small resolution' (e.g., ACS/HRC F220W) and 'large resolution' (e.g., ACS/WFC F814W) modes based on simulations by John Krist with an assumed jitter ellipse of 20-by-7.5 mas under two gyros. The '% central pixel' is the enclosed energy of the central pixel. The changes in enclosed energy and PSF width for two-gyro guiding are strong functions of observing mode.

For many observations, a larger jitter ellipse may be acceptable to accomplish the science. Table 1 shows an analysis of the impact on various observing modes. For short wavelengths and high angular resolution, the projected two-gyro stability significantly degrades the observations, so much so that it would sometimes be hard to recover the science. For long wavelengths and lower angular resolution, typical of the wide field cameras in the Advanced Camera for Surveys (ACS), the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), and the Space Telescope Imaging Spectrometer (STIS), the jitter ellipse may have a minor impact on the data, permitting a robust scientific program under two-gyro pointing.

Instrument	Aperture	% Time
ACS	Small	5.1
	Large	49.8
Nicmos	Small	3.4
	Large	17.6
STIS	Small	0.4
	Large	16.4
WFPC2	Large	2.3
FGS	Small	5.0
Total	**Small**	**13.9**
	Large	**86.1**

Table 2: Percentage of program allocated to different observing modes: 'Small' means high spatial resolution, which is difficult under two-gyro pointing, 'Large' means lower spatial resolution, relatively unaffected under two-gyro pointing.

Hubble's Cycle 12 science concentrates heavily on surveys with the wide-field cameras. Table 2 shows the distribution of programs among instruments and high- or low-resolution mode. More than 85% of the programs use low-resolution cameras, which would be little affected by two-gyro pointing if the long dimension of the jitter ellipse is less than 20 mas. The high priority given to survey science by the Cycle 12 Time Allocation Committee testifies that the science of *Hubble* under two-gyro pointing can be outstanding—if we can solve the acquisition problems inherent with two-gyro use and achieve the level of jitter engineers currently predict. Nevertheless, the very high resolution of *Hubble*, especially at ultraviolet wavelengths, sets it apart most strongly from other telescopes. A two-gyro mode is clearly an inadequate basis for the long-term health of *Hubble*'s future science program. It is an excellent stopgap—but only a stopgap—to continue *Hubble*'s contributions at the cutting edge of science in the event that two more gyros fail before the next servicing mission. And it could serve as a way to extend the useful observations at the end of *Hubble*'s life. Ω

Advanced Camera for Surveys News

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

The Advanced Camera for Surveys (ACS) is not only obtaining stunning views of the far depths of the universe; it is also providing new insights into our own backyard, the solar system. M. Showalter and J. Lissauer used the ACS High Resolution Channel (HRC) to discover two of the smallest known moons around Uranus (**http://hubble.stsci.edu/newscenter/archive/2003/29**). The new moons are only eight to ten miles across and so faint that they eluded detection by the Voyager 2 spacecraft, which discovered ten other small moons when it flew by the gas giant planet in 1986. The *Hubble* observations also confirmed the discovery of a tiny moon that had been spotted in Voyager pictures but had not been seen since. At 25th magnitude, compared to 6th magnitude for nearby Uranus, the detection of these moons is another clear demonstration of the power of the ACS.

G. Bernstein and his team set their sights a little further out in the solar system. They targeted the Kuiper Belt, a ring-shaped region that houses leftover building blocks from the Solar System's creation. The team pointed the ACS Wide Field Channel (WFC) at a region in the constellation Virgo over a 15-day period in January and February 2003. A network of 10 computers spent six months searching the resulting images for faint, moving spots, signaling new Kuiper Belt Objects (KBOs). *Hubble's* sensitivity can detect KBOs smaller and fainter than is possible from ground-based telescopes. The team discovered three objects, each thought to be a lump of ice and rock approximately 10 miles across (**http://hubble.stsci.edu/newscenter/archive/2003/25**). The big surprise was that this search found so few objects—some 60 were expected. The result challenges the usual explanation of the Kuiper Belt as the source of short-period comets.

In another press release (**http://hubble.stsci.edu/newscenter/archive/2003/28**), the Hubble Heritage Team released an ACS image of NGC 4594. This is an early-type spiral galaxy seen almost edge-on. Shown in Figure 1, the image makes it clear why this galaxy is affectionately known among astronomers as the 'Sombrero Galaxy.' NGC 4594 is also cataloged as Messier 104, although Charles Messier never actually saw it. He recorded the final (103rd) entry in his catalog in 1781, and number 104 was added after his death. Had Messier seen the remarkable detail in the ACS image, he might have been more appreciative of galaxies; as it was, he cataloged them merely to avoid confusing his search for comets.

Figure 1: Hubble Heritage ACS image of NGC 4594, known as the 'Sombrero Galaxy.' *Hubble's* high resolution provides a detailed view of the dust disk in this early-type spiral galaxy, viewed nearly edge-on.

Recent calibration work at the Institute has addressed several issues related to ACS flat fields. R. Bohlin and his collaborators characterized the effect of filter wheel repeatability on ACS flat fields (see ACS ISR 03-11, available from **http://www.stsci.edu/hst/acs/documents/isrs**). The ACS filter wheel movements are accurate to one motor step, which is not a problem except for those filters that have small blemishes. A blemish produces an out-of-focus feature in the flat field, which changes position if the filter wheel does not rotate to its nominal position. For a few filter combinations, this leads to flat-fielding errors that can exceed one percent over a small part of the field of view. For seven of these filter combinations on the WFC and six on HRC, flat fields are now available as a function of filter wheel offset step. The pipeline data processing automatically selects the flat field corresponding to the offset step of each observation.

Only on-orbit science data—not ground-based calibration data or internal lamp exposures—can determine the structure of ACS flat fields at low spatial frequencies accurately. R. van der Marel devised a method for

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determining these 'L-flat' corrections using photometry of a stellar field imaged multiple times with different pointings or rolls. ACS ISR 03-11 discusses the method and presents a numerical implementation of the algorithm, which was already used previously to analyze early ACS WFC and HRC data of the globular cluster 47 Tuc. Tests with artificially generated data demonstrate the accuracy of the method. In late 2002, the Institute implemented fourth-order polynomial L-flat corrections, thus calculated, to the ground-based calibration flats in the ACS pipeline. The resulting flat fields are accurate to approximately one percent. In the future, a more general (non-parametric) characterization with the same algorithms will further improve the accuracy.

The improved *ACS Data Handbook* released in December 2003 provides a detailed description of how to work with ACS data. It explains when it is appropriate or necessary to recalibrate ACS data obtained from the *Hubble* archive. The user needs pipeline tasks, such as 'calacs' and 'pydrizzle', to recalibrate data. To run these tasks, the Institute strongly recommends that the user download and install the latest versions of STSDAS/TABLES (v.3.1) and PYRAF (v.1.1), which the Science Software Branch recently released (**http://www.stsci.edu/resources/software_hardware/**). MULTIDRIZZLE, which provides important additional functionality for processing and co-adding geometrically distorted data, is available in a beta-test version at **http://stsdas.stsci.edu/pydrizzle/multidrizzle/**. (If you have previously installed MULTIDRIZZLE, you will need to reinstall it after installing STSDAS v3.1 and PYRAF 1.1.)

As always, consult the ACS web page at **http://www.stsci.edu/hst/acs/** for the latest information or send email to the Institute Help Desk at *help@stsci.edu*. Ω

STIS Update

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Data from the Space Telescope Imaging Spectrograph (STIS) continue to produce copious scientific results. Between August 1 and October 31, 2003, alone, refereed astronomical journals published more than thirty papers in which STIS data played a critical role. These papers covered a broad range of astronomical topics, ranging from Jupiter's moon Io[1] to merging galaxies at high redshifts.[2]

Several of these papers[3,4,5,6] used the unique ability of STIS to obtain long-slit spectra with extraordinarily high spatial resolution to study the kinematics of gas in the inner regions of nearby galaxies. Results include an atlas of STIS G750M spectra and associated *Hubble* images (see Figure 1) and improved understanding of the relationship between the mass of central black holes and the characteristics of their host galaxies. Studies like these are critical for our understanding of the evolution of galactic nuclei and the massive black holes at the centers of many galaxies.

The Institute implemented several significant enhancements to STIS calibration during the summer and fall of 2003. It released a new version of CALSTIS (2.15b) and a number of updated STIS-package utility tasks within STSDAS 3.1, which was released on October 20, 2003. CALSTIS v2.15b was also implemented into the On-The-Fly-Reprocessing (OTFR) pipeline (which delivers calibrated data from the MAST archive) on December 16, 2003.

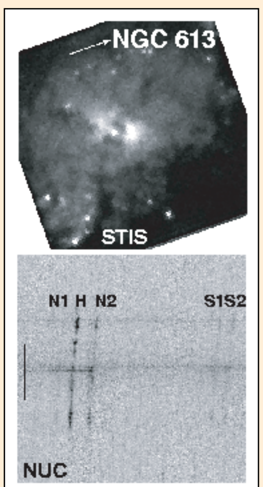

Figure 1: An example of the data used for "An Atlas of *Hubble Space Telescope* Spectra and Images of Nearby Spiral Galaxies."[4] On the left, the 5 x 5 arcsec STIS target acquisition CCD image of NGC 613. The arrow is one arcsec long and shows the orientation, but not the position of the spectrographic slit. On the right, the long-slit STIS G750M spectrum, centered on the nucleus of this galaxy. The wavelength scale runs from 6482 to 7054 Å from left to right, and the vertical bar marks a distance of five arcsec along the slit.

The most important improvement in CALSTIS 2.15b corrects CCD one-dimensional spectra for the effects of increasing charge transfer inefficiency (CTI). The algorithm, which is described in detail in STIS ISR 2003-03R (**http://www.stsci.edu/hst/stis/documents/isrs/0303R.pdf**) corrects for the loss of charge during the CCD readout process. The magnitude of the correction depends on the time elapsed since STIS was put on orbit, the location of the target on the detector, the signal level of the target, and the background level. This CTI correction can be quite significant, especially for faint targets. For example, a typical spectrum taken in August 2003 with an extracted signal level of 300 electrons per column on a background of 2 electrons per pixel suffers from a CTI-related flux loss of 12% when observed at the nominal (central) position on the CCD. The newly implemented algorithm corrects the impact of CTI on the flux calibration to about 1%. This is the first on-the-fly CTI correction for any *Hubble* instrument.

The October 2003 issue of the *Space Telescope Analysis Newsletter* describes other changes to STIS calibrations and associated utility tasks (**http://www.stsci.edu/hst/stis/documents/newsletters/stan0310.html**).

The Institute's Spectrographs Branch delivered new reference files to the archive. The new files correct first-order CCD spectra for the effects of time-dependent sensitivity (TDS) in STIS's optical sensitivity. These changes can amount to nearly 2% per year at UV wavelengths and must be handled separately from CTI effects. The Institute implemented the TDS correction in the OTFR pipeline on November 11, 2003. (Similar corrections for first-order MAMA spectra were implemented in 1999.)

Figure 2 illustrates the benefits for fluxes measured from STIS data of the corrections for CTI and TDS effects.

On October 31, 2003, the Spectrographs Branch implemented a new geometric-distortion solution for STIS NUV-MAMA imaging in the OTFR pipeline. This new solution was obtained using fields in the stellar clusters NGC 4214 and NGC 604, which were imaged with both the STIS NUV-MAMA and the PC chip of the WFPC2. Typical median errors between the predicted and the real positions were found to be in the range of 0.28 to 0.53 MAMA pixels (7–13 mas). For comparison, the older geometric distortion table produced median errors of a few MAMA pixels. Over the next few months we plan to also derive improved geometric-distortion solutions for the FUV MAMA and the CCD detectors.

The Spectrographs Branch implemented three new families of 'pseudo-apertures' in the Astronomer's Proposal Tool to help STIS users preparing Phase-II proposals. Pseudo-apertures refer to existing, physical STIS apertures, but locate the target on the detector to allow the user to easily make use of certain important benefits. Table 1 describes the pseudo-apertures and their intended use. The x1d tool and the CALSTIS pipeline have also been updated to automatically recognize when the new positions are used, selecting appropriate rows from the reference tables for calibration of the data. These x1d and CALSTIS changes require CALSTIS 2.15b.

As always, the Spectrographs Branch reports significant updates to STIS performance through the STIS website, **http://www.stsci.edu/hst/stis**. Ω

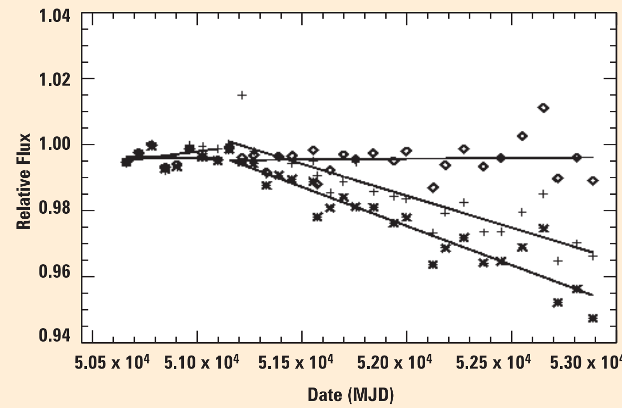

Figure 2: The flux measured as a function of time at 2850 Å in individual G230LB sensitivity-monitoring observations of a standard star. The lower points show the measured flux without CTI or TDS corrections. The middle points show the improvement due to CTI corrections. The top points show the further improvements when both CTI and TDS corrections are applied.

New Pseudo-Aperture Name(s)	Detector	Optical Element(s)	Location	Intended Use
52x0.05D1 52x2D1 52x0.1D1 25MAMAD1 52x0.2D1 F25QTZD1 52x0.5D1 F25SRFD1	FUV-MAMA	ALL	2 arcsec above bottom edge of FUV-MAMA detector	Reduces dark current by factor of ~5 relative to nominal, central positions. Very beneficial for observations of faint targets.
2x0.2E2 52x0.5E2 52x2E2	CCD	G750L G750M	Near E1 positions at row 900,slightly offset along dispersion direction	To yield best alignment with fringe flats performed with 52x0.1 aperture
WEDGE0.6	CCD	50CORON	Where wedge "A" of coronagraphic mask is 0.6 arcsec wide	Smallest coronagraphic aperture on *Hubble Space Telescope*

Table 1: Description of the newly defined STIS 'pseudo-apertures.'

1 Retherford, K. D., Moos, H. W., & Strobel, D. F. 2003, "Io's auroral limb glow: Hubble Space Telescope FUV observations," *JGR*, 108, SIA 7

2 Conselice, C. J., Chapman, S. C., & Windhorst, R. A. 2003, "Evidence for a Major Merger Origin of High-Redshift Submillimeter Galaxies," *ApJ*, 596, L5

3 Pinkney, J., Gebhardt, K., Bender, R., Bower, G., Dressler, A., Faber, S. M., Filippenko, A. V., Green, R., Ho, L. C., Kormendy, J., Lauer, T. R., Magorrian, J., Richstone, D., & Tremaine, S. 2003, "Kinematics of 10 Early-Type Galaxies from Hubble SpaceTelescope and Ground-based Spectroscopy," *ApJ*, 596, 903

4 Hughes, M. A., Alonso-Herrero, A., Axon, D., Scarlata, C., Atkinson, J., Batcheldor, D., Binney, J., Capetti, A., Carollo, C. M., Dressel, L., Gerssen, J., Machetto, D., Maciejewski, W., Marconi, A., Merrifield, M., Ruiz, M., Sparks, W., Stiavelli, M., Tsvetanov, Z., & van der Marel, R. 2003, "An Atlas of Hubble Space Telescope Spectra and Images of Nearby Spiral Galaxies," *AJ*, 126, 742

5 Noel-Storr, J., Baum, S. A., Verdoes Kleijn, G., van der Marel, R. P., O'Dea, C. P., de Zeeuw, P. T., & Carollo, C. M. 2003, "Space Telescope Imaging Spectrograph Spectroscopy of the Emission-Line Gas in the Nuclei of Nearby FR-I Galaxies," *ApJS*, 148, 419

6 Tadhunter, C., Marconi, A., Axon, D., Wills, K., Robinson, T. G., & Jackson, N. 2003, "Spectroscopy of the near-nuclear regions of Cygnus A: estimating the mass of the supermassive black hole," *MNRAS*, 342, 861

WFPC2 Update

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

Even after the installation of the Advanced Camera for Surveys (ACS), observers continue to use the Wide Field Planetary Camera 2 (WFPC2) for a number of specialized ultraviolet and optical imaging applications. Programs include continued astrometric monitoring, ultraviolet imaging over wide fields (for which WFPC2 is especially suitable), observations suited to the extensive WFPC2 narrow-band filter set, and parallel observing.

To support continuing WFPC2 observing programs, as well as ongoing analyses of WFPC2 data in the *Hubble* archive, the Institute released a revised *WFPC2 Instrument Handbook* for Cycle 13 and continues to improve WFPC2 calibrations.

V. Kozhurina-Platais and her collaborators completed a study of the wavelength dependence of the geometric distortion of WFPC2 (see WFPC2 ISR 03-02, available at **http://www.stsci.edu/instruments/wfpc2/wfpc2_bib.html**). This work is the first empirical, on-orbit measurement of the distortion using the F300W and F814W filters; formerly, distortion measurements existed only for F555W, most recently made by Anderson and King.[1] The new results indicate that the distortion with the F300W filter is about three percent higher than with F555W, while with F814W it is about one percent smaller than with the F555W. The Institute will make the new distortion coefficients available in a format that can be used by existing software tools for the analysis of WFPC2 data.

Analysis of the large database of WFPC2 data is continuing to provide important new scientific results. R. A. E. Fosbury and his team reported that a red arc seen in WFPC2 images behind a distant galaxy cluster is the gravitationally magnified image of the biggest, brightest, and hottest star-forming region ever observed (**http://hubble.stsci.edu/newscenter/newsdesk/archive/releases/2003/32/**). The so-called 'Lynx arc' is one million times brighter than the well-known Orion Nebula. The newly identified star-forming complex contains a million blue-white stars that are twice as hot as similar stars in our Milky Way galaxy. At a redshift of 3.36, the Lynx arc provides a rare glimpse of violent star formation in the early universe.

P. Lamy and his collaborators obtained WFPC2 images of the comet 67P/Churyumov-Gerasimenko (67P/C-G). These images have played a role in preparing ESA's ambitious *Rosetta* mission. *Rosetta* plans to make the first landing of a probe on a comet to study its origin. The *Hubble* observations revealed that comet 67P/C-G is approximately a three-by-two mile, football-shaped object, on which ESA has determined it is possible to land (**http://hubble.stsci.edu/newscenter/newsdesk/archive/releases/2003/26/**). Mission scientists were concerned that the nucleus could have higher gravity, making a soft landing more difficult. The comet 67P/C-G is roughly three times larger than the original *Rosetta* target, which had to be abandoned because of a slip in launch date. With the *Hubble* measurements, the lander package can be adapted to the new configuration before next year's launch.

WFPC2 continues to be the source of some of the most stunning astronomical images ever. Visit the website of the award-winning Hubble Heritage team (**http://heritage.stsci.edu/**) for their monthly portraits of the universe.

As always, consult the WFPC2 web page at **http://www.stsci.edu/instruments/wfpc2/** for the latest information, or if you have a specific question, send email to the Institute Help Desk at *help@stsci.edu*. Ω

[1] Anderson, J., & King, I. R. 2003, *PASP*, 115, 113

FGS Astrometry Update

Ed Nelan, *nelan@stsci.edu*

FGS1r continues to gather high quality astrometry data for a variety of astrophysically interesting objects. In Cycle 12 two programs were initiated to determine distances accurate to better than 10% for ten Galactic Cepheids. Two other programs are using FGS1r in an effort to detect the mass of extrasolar planets by measuring the tiny wobble they induce upon their host stars. Other programs are determining the orbital parameters—and eventually the masses—of stars in binary systems, ranging from nearby M dwarfs to distant O stars.

Currently, the most challenging programs for FGS1r are three that observe white dwarfs. The faintness of these targets approaches the limiting magnitude of FGS1r, where the signal from the star is barely above the dark noise of the instrument. Proposal 9406 (PI Patterson) intends to measure the parallax of GD552, which appears to FGS1r as $V=16.7$. Another (9882, PI O'Brien) observes PG0122+200, which is even fainter, at $V=16.8$. The faint-limit prize goes to the $V=17$ secondary of the binary white dwarf WD1818+126 (9881, PI Nelan). Amazingly, in all three cases, the astrometry being obtained with FGS1r appears to be as accurate as what is routinely obtained for much brighter objects. Ω

NICMOS Update

Daniela Calzetti, *calzetti@stsci.edu*, **and the NICMOS Group**

After more than one and a half years of on-orbit operations, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) and its refrigerating unit, the NICMOS Cooling System (NCS), have demonstrated a high level of stability.

Previously, during Cycle 7 and 7N, temperature variations of the NICMOS detectors had been the main culprit causing difficulty in calibrating science data. The variations led to secular variations in the calibration reference files, notably dark frames and flat-fields. The relaxation of the stresses inside the dewar also produced variations of the focus position, which had to be constantly chased.

By contrast, the NCS, installed during the last servicing mission, has imposed a high level of temperature stability on both the NICMOS detectors and optical bench, as demonstrated by the Cycle 11 and half of Cycle 12 baseline of experience. The NICMOS detectors are actively maintained at an average temperature of 77.15 K; excursions from the average value are typically 0.15 K peak-to-peak, caused by orbital and telescope attitude variations. On top of these, there is a secular temperature variation of about 0.05 K due to seasonal changes; this is actively corrected by changing the NCS control temperature twice a year (lowered in November–December for the warm season, and increased in April–May for the cold season). Thus, the temperature at the detectors is maintained as closely as possible to the nominal 77.15 K value over the course of the year. Dark, flat-field, photometric, and focus monitoring over the last 1.5 years confirms the instrument's stability. The NICMOS focus has not needed any tweaking since spring 2002, following switch-on after the last servicing mission.

The NCS safing event of August 2003 (K. Noll, Newsletter, fall 2003 issue) has provided an unexpected repeatability experiment for the NCS/NICMOS system. The NCS safing happened in the early hours of August 2, and the system was restarted after about five days. Despite the warming up during those days, NCS/NICMOS came back to pre-safing temperature at record speed, after about 48 hours. Subsequent on-orbit checks showed that NICMOS had recovered stable, pre-safing conditions quickly, within a few weeks. Science operations resumed on August 21, in time to support the Mars campaign at closest approach (GO-9738, PI: J. Bell). The first epoch of the NICMOS observations of the Ultra Deep Field (Treasury program GO-9803, PI: R. Thompson) was also performed shortly after the recovery from the NCS safing.

Astronomers are using NICMOS for an array of other exciting science, including searches for giant planets around white dwarfs (GO-9737, PI: Zinnecker, and GO-9834, PI: Debes) and for faint companions of cool brown dwarf stars (GO-9833, PI: Burgasser); narrow-band imaging of brown dwarfs to study their formation processes (GO-9867, PI: Megeath); imaging of merging galaxies, to search for dust-hidden young stellar clusters (GO-9735, PI: Whitmore) and to establish whether they are the progenitors of giant elliptical galaxies (GO-9875, PI: Veilleux); observations of gravitational lenses to study cosmology and the dark matter (GO-9744, PI: Kochanek); observations of the high-redshift starburst and active galaxies identified by SCUBA in the submillimeter, to investigate their nature (GO-9856, PI: Chapman). Also, NICMOS is being used in parallel to the Advanced Camera for Surveys during the Ultra Deep Field observations (GO-9979, PI: Beckwith); this program is likely to provide the deepest NICMOS images ever taken.

Because NICMOS has shown repeatable performance, the Cycle 12 calibration program centers on a less intense monitoring of darks, flat-fields, photometric stability, and focus than during Cycle 11. The only specific calibration programs are the Photometric Recalibration (ID: 9997), aimed at pinning down the last two to three percent uncertainty in the NICMOS photometry, and the Grism Recalibration (ID: 9998), aimed at securing an improved absolute and relative calibration of the blue (G096) and intermediate (G141) wavelength grisms.

The Institute has made progress on the calibration/analysis software front. Recently, it made available an IDL tool that allows users to mitigate the effects of post-SAA (South Atlantic Anomaly) cosmic ray persistence in their NICMOS science observations (**http://www.stsci.edu/hst/nicmos/tools/post_SAA_tools.html**). Historically, the persistence of these cosmic-ray effects has affected between one-half and two-thirds of NICMOS science data. The extra 'noise' produced by the persistence is coherent, non-gaussian, and decaying, with a standard deviation as much as two to three times the typical NICMOS noise. In deep images, this extra noise is evident up to 85 minutes after the passage through the SAA. The IDL software can drastically reduce the extra noise, in some cases reducing it by a factor of three or four, bringing the worst images to within 22% of the equivalent normal noise. In the future, the Institute will offer this tool as an IRAF/STSDAS stand-alone tool.

Proposers for Cycle 13 will also have access to an updated NICMOS exposure time calculator, with improved functionality, including the ability to choose the reference aperture for the signal-to-noise calculation.

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NICMOS
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The stability and repeatability of the NCS/NICMOS is extremely good news for Cycle 12 GOs and Cycle 13 proposers. NICMOS, which continues to be the only infrared instrument on board *Hubble*, offers unique imaging, coronagraphic, grism, and polarimetric capabilities in the wavelength range 0.8 to 2.5 micron. NICMOS offers continuous coverage in the infrared window, together with high angular resolution over 100% of the sky, low sky background, photometric stability, uniform and repeatable point-spread function, and high Strehl ratio.

Detailed information on NICMOS performance is available in the *NICMOS Instrument Handbook* (**http://www.stsci.edu/hst/nicmos/documents/handbooks/**). Ω

JWST Status

M. Stiavelli, *stiavelli@stsci.edu*, **B. Saif,** *saif@stsci.edu,* **and P. Stockman,** *stockman@stsci.edu*

With the transition to Phase B, the *James Web Space Telescope (JWST)* project has entered a phase of heightened activity. Two important milestones were reached: the selection of the mirror technology and the release of the Science Requirements Document. The next step is the consolidation of instrument designs in preparation for a series of requirement reviews.

Figure 1: A 1.2-m Advanced Mirror System Demonstrator beryllium mirror. NASA selected this technology for the *JWST* primary mirror. The segments will have low areal density, and actuators will control their shapes.

Mirror Technology

The Mirror Recommendation Board (MRB) has recommended using beryllium (Be) for the segments of *JWST*'s cryogenic 6.5-meter telescope. To provide a basis for this decision, the *JWST* project had funded two teams over the past few years to study the design and fabrication of mirror segments. (*JWST* will have 18 hexagonal segments, each about 1.3 meter in diameter (flat to flat), with an areal density of 13.2 kg m^{-2}.) Kodak and Corning constituted the ultra-low expansion (ULE) glass mirror team, and Ball, Brush Wellman, Tinsley, and Axsys made up the Be team. Both teams designed and fabricated off-axis parabolic mirrors 1.2 meter in diameter with areal density of about 10 kg m^{-2}. The wavefront errors of the two mirrors were measured through temperature changes from room temperature to 30 K. The main result of these tests is that the Be mirror shows better performance and stability.

The superiority of Be was expected because the coefficient of thermal expansion (CTE) of beryllium at cryogenic temperatures is smaller than that of ULE glass. Moreover, Be has high thermal conductivity at those temperatures, so that Be mirrors minimize temperature gradients on each segment and between segments on the primary mirror. The absence of thermal gradients is important because some segments are closer to the sunshield and at higher temperatures by 5 to 10 K than ones further away. In contrast, the conductivity of ULE glass is poor at cryogenic temperatures, and its CTE is high. The resulting higher temperature gradients and lower stability would degrade the observatory performance below the level-two requirement on the encircled energy (74% within a radius of 150 milliarcsecond).

The Mirror Recommendation Board, comprising 18 managers and engineers from government, consultants, and prime contractors, favored the technical aspects of Be mirror by a three-to-one margin. Besides technical performance, they evaluated three programmatic criteria: schedule, contractor facilities and staffing, and cost. The ULE mirror scored higher in these categories. However, the high weight assigned to technical performance resulted in the Be mirror reaching a higher overall score.

Science Requirements Document

The Senior Project Scientist, John Mather, supported by the Science Working Group, prepared the Science Requirements Document (SRD), which describes the science driving the *JWST* observatory requirements. The SRD encompasses four main science areas with goals as follows:

- First Light. *JWST* must be able to find and understand the first-light objects. This requires exceptional imaging capabilities and sensitivity in the mid-infrared.

- Assembly of Galaxies. *JWST* must be able to observe the earliest precursor of present-day galaxies in order to understand their growth and evolution. This requires imaging and spectroscopy in the near and mid infrared.

- Birth of Stars and Proto-planetary Systems. *JWST*'s objective is to unravel the birth of stars and their early evolution, from infall, through dust-enshrouding, to the genesis of planetary systems. This objective requires near- and mid-infrared imaging and spectroscopy.

- Planetary Systems and the Origins of Life. *JWST*'s objective is to determine the physical and chemical properties of planetary systems (including our own) and investigate the potential for life arising in those systems. This also requires near- and mid-infrared imaging and spectroscopy.

JWST scientists presented more details on these science objectives at a special session on *JWST* science at the January 2004 meeting of the American Astronomical Society in Atlanta.

NASA used the science goals described in the SRD to set the level-one science requirements, which define the terms of scientific success for the *JWST* mission. These requirements are:

- Measure the space density of galaxies to a 2 micron flux density limit of 1.0×10^{-34} W m^{-2} Hz^{-1} via imagery within the 0.6-to 27-micron spectral band to enable the determination of how this density varies as a function of their age and evolutionary state.

- Measure the spectra of at least 2500 galaxies with spectral resolutions of approximately 100 (over 0.6-to 5-micron) and 1000 (over 1-to 5-micron) and to a 2-micron emission line flux limit of 5.2×10^{-22} W m^{-2} to enable determination of their redshift, metallicity, star formation rate, and the ionization state of the intergalactic medium.

- Measure the physical and chemical properties of young stellar objects, circumstellar debris disks, extrasolar giant planets, and solar system objects via spectroscopy and imagery within the 0.6-to 27-micron spectral band to enable determination of how planetary systems form and evolve.

Instrument Progress

As the *JWST* science objectives solidified, the instrument teams tuned the designs of the four science instruments. At present, the integrated science instrument module (ISIM) includes four science instruments: the Arizona-Lockheed Martin near-infrared camera NIRCam (see Newsletter v. 19, n. 4, p. 7), the European Space Agency near-infrared multiobject spectrograph NIRSpec (Newsletter v. 19, n. 2, p. 13), the multinational mid-infrared camera and spectrograph MIRI (Newsletter v. 20, n. 2, p. 10), and the Canadian near-infrared tunable filters FGS/TF. Institute staff members have worked with the instrument teams to develop descriptions of the instrument operations. These operations concepts are part of the materials presented in a series of instrument-requirements reviews that started in November and will be concluded this winter. Ω

News from MAST

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

At the end of October 2003, MAST holdings comprised 16.2 terabytes of data. During the month of October, new data were archived at a median rate of 16.8 Gb/day, and the median retrieval rate was 72.3 Gb/day. The end of September 2003 saw a welcome decrease in the median retrieval time, which was under 20 hours by early November.

DADS and Server Upgrade Status

Work is progressing well on the major software and hardware upgrades described in the fall Newsletter. We moved a large volume of data to the new EMC storage array and moved on-the-fly-reprocessing to the new SunFire server. We have already seen a significant decrease in retrieval times as a result. Users internal and external to the Institute beta-tested the new Data Archiving and Distribution System (DADS) software, which was installed in early December.

New Archive Branch Head

MAST welcomes Rick White as the new head of the Institute's Archive Branch. Rick replaces Marc Postman, who will remain the principal investigator of the grant that funds the non-*Hubble* archive components of MAST. Marc is now serving as deputy head of the Institute's Community Missions Office.

User Survey

In September 2003, we conducted a user survey to help determine our users' priorities for future developments at MAST. The response to the survey was excellent, with over 300 responses, and we thank all the users who took the time to send in the survey. A clear message from the survey was that decreasing retrieval times and downtime takes highest priority for many of our users. This is also our highest priority at MAST, and we are working hard to implement hardware and software upgrades to accomplish this goal. Some other interesting highlights from the survey are:

- 50% of users access MAST at least once a month
- 61% felt it would be extremely useful to be able to search MAST holdings based on object class
- 80% of our users prefer the WWW interface over StarView
- The highest-ranked ways to expand and improve MAST services were improved support for multi-wavelength data cross correlation and techniques to perform efficient queries on terabyte-scale object catalogs.

To browse the full results of the survey, go to **http://archive.stsci.edu/s/survey.html**.

WWW Interface News

Users can employ the cross-correlation search form (**http://archive.stsci.edu/search/**) to cross correlate a user-supplied or other available catalog with MAST's holdings. A new version of the cross-correlation routine is now available, both at the url above and from the 'Quick Search' form on the main MAST page. The new version offers output in various formats (including VOTable) and allows target names to be specified individually, in comma-separated lists or uploaded ASCII files. Another improvement is that users can now access the WFPC2 associations (see **http://archive.stsci.edu/hst/wfpc2/**) by the cross-correlation search.

New High-Level Science Products at MAST

The Great Observatories Origins Deep Survey (GOODS)

On September 10, 2003, we completed public release of version 1.0 of the high-level science products from the GOODS observations using *Hubble*'s Advanced Camera for Surveys (ACS). The release consists of mosaics of stacks that combine all five epochs of observations. The data may be obtained from MAST or from mirror sites at Canadian Astronomy Data Centre (CADC) and Space Telescope European Coordinating Facility (STECF). (See **http://www.stsci.edu/science/goods/** for details and updates.) We also plan to distribute the GOODS v1.0 data on DVD.

The Ultra-Deep Field (UDF)

The UDF will consist of a single ultra-deep field (412 orbits in total) located within the GOODS area of the *Chandra* Deep Field South. Beginning in September 2003 and continuing to January 2004, the Advanced Camera for Surveys is obtaining the images. In November, the UDF observations were more than half completed in all four bands (F435W, F606W, F775W, F850LP), surpassing the depth of the Hubble Deep Field in the F775 (*i*-band) filter. The Institute director used his discretionary time to make the UDF observations, and we will make the data public soon after the observations are completed. We will make both the raw and reduced data available to users in the following ways:

Reduced data. We will make the reduced and combined UDF images available for ftp retrieval from MAST as well as from mirrors at the STECF and the CADC. The tentative release date is mid-February 2004, depending on details of observations and data reduction.

Raw data. The raw data comprise approximately 0.5 terabytes and will be of interest mainly to those users looking for time-variable sources. As electronic retrieval of these data is impractical, we are considering delivery using hard media, such as DVDs. To assess the demand, we ask those users who intend to request the raw data to sign up on the preliminary UDF-raw-data signup list at **http://www-int.stsci.edu/science/udf/dvd_form.html** as soon as possible. Shortly thereafter, we will announce the raw data release policy and provide a final sign-up list.

For updates on the status of the UDF observations and data release, see **http://www.stsci.edu/hst/udf/**.

Initial Public Release of GALEX Data Coming Soon

As announced in the fall Newsletter, MAST will soon host the initial data release ('DR0') of near-ultraviolet and far-ultraviolet images and spectra for selected regions of the sky obtained by the *Galaxy Evolution Explorer (GALEX)* mission. The release date will be approximately one month after MAST obtains the data from the project. These data will be available—and news about the development of website tools and project milestones is available now—through the website **http://galex.stsci.edu** (or click the *GALEX* link on the MAST home page). The website will support basic queries on a MAST-style form as well as via direct queries in the SQL server-language. The website provides a tutorial and is now available for use with simulated data. We encourage interested users to familiarize themselves with these tools to prepare for the release of real data and for proposing to the *GALEX* guest investigator program. Ω

Hubble's True First Light

G. Fritz Benedict, University of Texas, *fritz@astro.as.utexas.edu*

Just after midnight on 1 May 1990, only a week after *Hubble* was launched, everybody in the Mission Operations Center at Goddard Space Flight Center (GSFC) was an astrometrist. They were engaged in *Hubble*'s 'first-light' observation, although it was not called that at the time. The first-light observation is a rite of passage for any major telescope, demonstrating that light passes through the entire optical system, that the telescope tracks reasonably well, and that, with a little tweaking, scientific results will surely flood forth. The 'official' first-light observation of *Hubble* was a snapshot of a small piece of the star cluster NGC 3532 taken on 20 May 1990 by the Wide Field and Planetary Camera. Nevertheless, an observation three weeks earlier, of an otherwise undistinguished star in Lyra—GSC 26661602—by one of the three Fine Guidance Sensors (FGSs), arguably deserves the prize.

All *Hubble* science observations require two of the three FGSs to be locked on stars for stable pointing. The FGSs are white-light Koester's prism interferometers operating with a baseline of the primary mirror diameter, 2.4 meters. With two FGSs locked, other science instruments can take long exposures without blurring or smearing. Meanwhile, the third FGS can move around within its accessible field of view (called a 'pickle' because of its shape) to perform astrometric measurements. The 'astrometer' FGS can either measure relative positions of stars or concentrate on one source, using its fringe to probe the target's structure.

NASA's pre-launch goal for relative astrometry using an FGS was a precision of three-milliseconds of arc, superior to ground-based astrometry for comparable observing programs. (The diameter of United States 25-cent piece viewed from a distance of 1500 miles or 2414 km is one millisecond of arc.)

To ensure the scientific potential of the FGSs for astrometry, NASA formed the Space Telescope Astrometry Team (STAT) in late 1977. Unlike other instrument teams, the STAT built no instrument. Rather, it mother-henned

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The Space Telescope Astrometry Team

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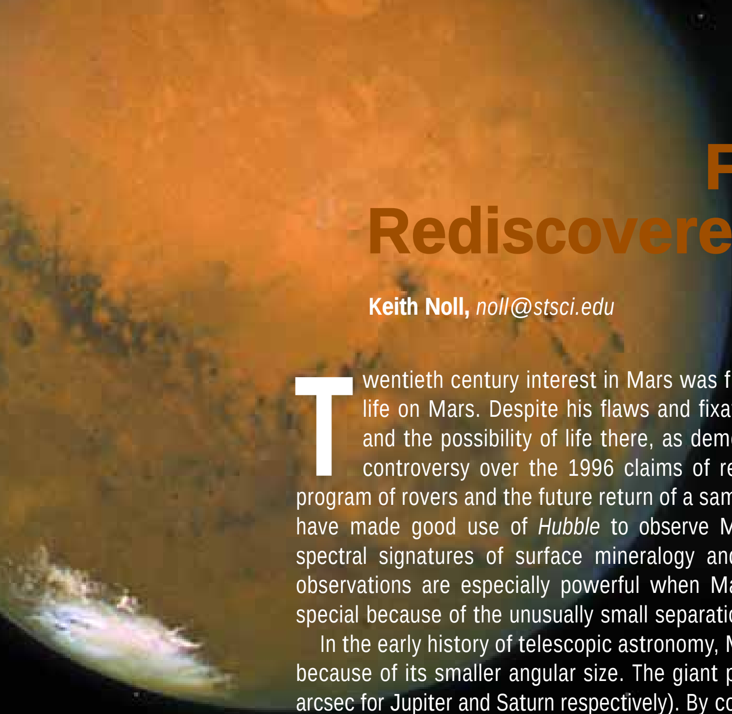
Darrell Story
Bill van Altena
Larry Wasserman
Art Whipple



Fascination with Mars, Rediscovered at Opposition 2003

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Image Caption: Portrait of a dry, cloud-free Mars at perihelic opposition in August 2003, changed dramatically from the relatively cold and cloudy oppositions near aphelion.

Twentieth century interest in Mars was fired by Percival Lowell's popularization of the notion of canal-building life on Mars. Despite his flaws and fixation,* we still pursue the legacy of Lowell's enthusiasm about Mars and the possibility of life there, as demonstrated by the Viking missions to Mars in the 1970s, the storm of controversy over the 1996 claims of remnant life in martian meteorite ALH84001, and NASA's ambitious program of rovers and the future return of a sample from the surface of Mars. Not surprisingly, planetary astronomers have made good use of *Hubble* to observe Mars, including searches for nascent dust storms, map-making using spectral signatures of surface mineralogy and chemical composition, and studies of atmospheric ozone. Such observations are especially powerful when Mars is viewed at opposition, and the August 2003 opportunity was special because of the unusually small separation between Earth and Mars.

In the early history of telescopic astronomy, Mars received less attention than imperial Jupiter and majestic Saturn because of its smaller angular size. The giant planets present relatively large disks throughout the year (~50 and 20 arcsec for Jupiter and Saturn respectively). By contrast, Mars—at half the size of the Earth and with its distance from Earth varying significantly—has an apparent angular diameter usually well under 10 arcsec. Nevertheless, about every 26 months, when Earth catches up to the slower Mars, and they line up with the Sun, Mars appears larger because it is closer. Because Mars's orbit is quite eccentric, the very closest approaches occur at oppositions when Mars is near perihelion, as happens every 15 to 17 years. At these 'perihelic' oppositions, such as occurred last August, Mars grows as large as 25 arcsec across, offering a spectacular view.

During the 13-year life of *Hubble*, Mars has been in opposition seven times. After the 1993 servicing mission, the separation at each successive opposition has decreased, from 101 million km in 1995 to only 56 million km in 2003. This year's special opportunity for *Hubble* to observe Mars at 20% better resolution than ever before produced two accepted Mars proposals in Cycle 12: 9738 (J. Bell, Cornell) and 9975 (P. James, U. Toledo). The Institute scheduled the observations throughout August and September 2003, according to the scientific requirements of the programs. At midsummer, all appeared calm and settled with the *Hubble* plan for Mars in 2003. Visions of wonderful Mars images danced in our heads like early Christmas sugarplums.

As August arrived, the first rumbles of an unexpected media earthquake reached the Institute. Because the eccentricity of Mars changes slowly, it emerged that the 2003 opposition would not only be the closest during *Hubble*'s lifetime—and not only the closest in the lifetime of everyone now alive—but the closest in 60,000 years, since the time when Neanderthals thrived. While the separation in 2003 was not different in any practical way from other perihelic oppositions, the record-smashing event caught the fancy of the media and public. People began to ask, "What will *Hubble* see at closest approach?" The answer, unfortunately, was, "Not Mars!" Even though *Hubble* was scheduled to observe Mars a few days before and after the time of closest approach, it was not scheduled to observe Mars *at the very time*, on August 27, 2003. While the planned observations would be equivalent scientifically to ones taken anytime near then, that was not the point as far as the public and media were concerned. Recognizing the deficiency, the Institute director readily allocated two orbits of his discretionary time to address it.

Institute astronomers worked closely with J. Bell and co-investigator M. Wolff to plan and schedule observations on the night of closest approach. When the time arrived, a team consisting of Bell, Wolff, and Institute staff assembled to shepherd the data into the archive and quickly create color images for the press. The observations and data transfer went well, and the team worked into the wee hours assembling the first of two images to be released that day. At about 4 a.m., the team noticed that file transfers that took only seconds to complete earlier in the night were now taking minutes. This slowdown signaled the start of what was to be a record-breaking demand on the Institute web site: 43 million hits in the next three days.

While astronomers interviewed in the press pointed out that Mars was equally edifying in the weeks before and after the closest approach, the public knew what it wanted, which was signification of an astronomical event. The long lines that snaked out of public observatories on the night of the 27th had all but disappeared on the days that followed. Apparently, the dynamics of such cultural phenomena are more intricate and less predictable than planetary orbits!

Hubble played a star role with aplomb in the Mars mania of 2003, and with luck it will be called back on stage when Mars next comes close to the Earth, in November 2005. Ω

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*While Percival Lowell is now regarded as a failure as a scientist of Mars, he did much to popularize astronomy and promote its practice. For, example, he advocated locating telescopes on remote mountains to improve seeing and weather. While professional astronomers had long recognized the value of this step, it was not widely practiced. Indeed, Asaph Hall discovered the two tiny moons of Mars in 1877 using what was then the world's largest telescope at the Naval Observatory site at Foggy Bottom in Washington, DC!

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the FGSs, working with the builders (originally Perkin-Elmer, by launch Hughes Danbury Optical Systems, and now Goodrich). It transacted its responsibilities via Linda Abramowicz-Reed, the primary contact to the builder, and Art Bradley, the liaison at GSFC with the Pointing Control System, which includes the FGSs as well as star trackers and rate gyros.

The STAT worked out of Building 98 on the GSFC campus, which was a mark of the high esteem in which astrometry was held. The STAT had its own building! It mattered not to STAT members that it was the smallest, oldest, most decrepit building at GSFC or that it was hot in summer and cold in winter. Building 98 was a fine base of operations, a place where the STAT could plan strategy and develop tactics. For six months after launch, team members circulated in and out of GSFC, staying at the nearby 'team condo' for days at a time.

During the week after launch, the STAT helped the *Hubble* project check the functionality of the FGSs and determine where *Hubble* was pointing. The goal was to point *Hubble* at a bright star to collimate the telescope by measuring image quality and adjusting the position and tilt of the secondary mirror. The discovery of spherical aberration was still in the future.

Determining where *Hubble* was pointed was a cascaded process, starting with the star trackers, accurate to a few minutes of arc, and ending with a pattern of stars observed by the three FGS units that could be matched to the *Guide Star Catalogue*.

With *Hubble* pointed somewhere near Vega, engineers used hand-built command sequences to test the FGSs. An FGS has two tracking modes: 'coarse,' where the FGS behaves like a quadrant detector and circles the centroid of light from a star, and 'fine,' where the interferometer tracks on a star using its fringe. Before an FGS can track a star in either mode, it has to find the star, which involves a spiral search.

At midnight on 30 April/1 May 1990, the sequence commanded FGS1 to perform a spiral search out to a 90 arcsec radius and coarse-lock onto the first star it found, which was also the first star *Hubble* ever 'observed.' Next, FGS3 repeated the same sequence, finding a second star and stabilizing *Hubble*, which now stared at a random piece of sky, a rich star field in the Milky Way. To find out where exactly, additional stars were needed, to obtain a pattern to match. Engineers commanded FGS2 to scan three subfields in its pickle, which located two more stars. The team present then matched the trapazoid formed by the four stars with positions in the *Guide Star Catalogue*, providing a solution with formal errors of 20 arcsec.

The FGSs were remarkably unaffected by the spherical aberration of *Hubble's* primary mirror, which delayed most of the science program until astronauts installed corrective optics on the first servicing mission. The spherical aberration, combined with what would have been slight (and normally unremarkable) misalignments in the FGSs, added bumps and wiggles to the nominal fringe. Nevertheless, the fringe was stable and still had a zero crossing, which ensured the usefulness of the FGSs for both astrometry and telescope pointing.

In October 1992, the *Hubble* project conducted a most important review of the astrometric potential of the FGSs. The STAT report at this review was convincing. It demonstrated relative astrometry with 3-milliarcsec accuracy even using the prelaunch calibration of the FGSs. It showed the ability of an FGS to dissect a binary star with far better precision than anyone had ever obtained. It showed the FGSs were stabilizing satisfactorily and that the STAT had the tools to calibrate them to higher precision.

For almost 14 years, the FGSs have been pointing the *Hubble* telescope with higher stability than the requirement—and they have been producing excellent science. Researchers have published over eighty scientific papers based on FGS results since launch. FGS3 routinely obtained a precision of one milliarcsec per observation in fringe tracking mode. FGS1r, the new astrometer of choice, does slightly better. FGS targets have included: AGN nuclei; asteroids; stars hosting extrasolar planets; cataclysmic variables; high- and low-mass binary stars; novae; and variable stars of use to the cosmic distance scale. Scientific results range from: the mass of an extrasolar planet to more precise absolute magnitudes for distance-scale standards; to asteroid diameters; to precise distances of interesting stars; and to precise binary star orbits, whose dimensions on the sky are smaller than the typical seeing at a good ground-based observing site. Ongoing investigations include: a precise determination of the Cepheid period-luminosity relation; further extrasolar planet mass determinations; tightening up the lower main sequence mass-luminosity relation through astrometry of low mass binaries; and precise distances with which to constrain theories of the star-star interactions evidenced by cataclysmic variables.

To this day, the FGSs remain the only operational astronomical interferometers in space.

They should remain scientifically productive through the end of this decade. Perhaps the last *Hubble* observation will be astrometric—certainly the first was. Ω

The STAT Report of *Hubble*'s First Light

"At 12:01 a.m. EDT 1 May 1990 Fine Guidance Sensor (FGS) number 1 detected the presence of a faint ($V > 12$) star and entered coarse track. This first detection of an astronomical object (other than the Earth, which had been detected by the FGSs a day earlier) occurred during a test called pattern match, a procedure carried out to determine the pointing of *HST* to within a few arc seconds…. It appears that the first star ever observed with the *Hubble Space Telescope* was done during an astrometry activity. The star field, about six degrees from Vega, is quite crowded. However, none of the stars detected have neighbors nearer than 30 arc seconds. If we accept the existing solution, the first star's position and magnitude from the *Guide Star Catalog* are 19H 25M 31.89S + 36D 02M 10.9S (2000.0), $V = 12.45$."

Yet Another Deep Field: The TNO Search Field

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Our search for extremely faint Trans-Neptunian Objects (TNOs) using the Advanced Camera for Surveys (ACS) produced a useful data set as a byproduct: an image of the sky in the F606W filter that is deeper than the Hubble Deep Fields, covers 13 times the area, and offers improved sampling density. The TNO Search Field images and documentation are now available from the MAST archive (**http://archive.stsci.edu/pub/hlsp/tno**).

The Missing Planetesimals

Observations of extrasolar systems are providing extensive information on the beginning state of planetary systems—circumstellar dust rings—and an end state—giant planets, which allows us to test theories. Nevertheless, the intermediate stage of planetary formation, which we believe involves planetesimals of 1 to 1000 km diameter, may remain unobservable around other stars for many decades. In our own solar system, however, some of the planetesimals survive in the relatively quiescent trans-Neptunian region. This is the only available laboratory for testing theories of the accretion and collisional evolution of icy planetesimals. Since 1992, observers have found over 800 TNOs using ground-based telescopes. They evidence a surprisingly complex dynamical distribution, with substantially higher eccentricities and inclinations than had been predicted for a remnant quiescent disk.

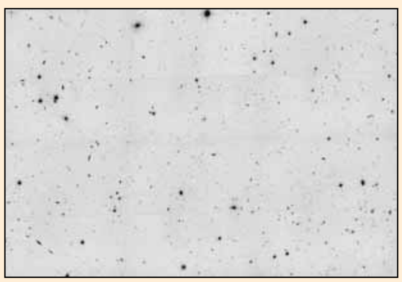

Figure 1: A segment of the TNO Search Field. Point sources at 29.8 mag are detectable at 5 sigma over the full 6 x10 arcmin mosaic.

The goal of the Cycle 11 Large program GO-9433, "Size Distribution of TNOs" (G. Bernstein, PI), was to use the unmatched ability of *Hubble* to detect point sources to find the faintest—and hence smallest—TNOs. The size distribution of TNOs is the primary observable of models for planetesimal accretion, and our goal in this ACS survey was to extend knowledge of the size distribution down to ~15 km diameter by reaching ~29.2 mag, which is ~2 mag fainter than any pulished ground-based survey. We exposed each of six adjacent fields of view of the ACS Wide Field Camera for 38,000 seconds over a 15-day span in January and February 2003. Because the faint TNOs are moving targets, we could not detect them by simply summing the exposures. We had to shift the images to track the motion of a TNO in a specified orbit, then sum the images and then detect point sources—and we had to repeat the process for every possible TNO orbit, which posed a significant computational challenge.

Our search for TNOs was spectacularly unproductive: we discovered only three TNOs— nearly 30 times fewer than expected by extrapolations from brighter surveys. This deficit of small objects in the Kuiper Belt is the first detected feature in the size distribution of these remnant planetesimals. It likely indicates an advanced state of collisional erosion among TNOs. The size distribution is also found to depend strongly on the dynamical properties of the TNOs. Results of the TNO survey are fully reported in astro-ph/0308467, which has been submitted to the *Astronomical Journal.*

One Astronomer's Trash Is Another's Treasure

For the purpose of the TNO survey, stars and galaxies were undesired clutter. To remove them, we created a stack of the 576 ACS exposures registered to the sidereal frame, which we subtracted from each exposure before searching for the moving objects. Recognizing that one astronomer's background noise is another's signal, we have placed the deep sidereal mosaic image in the MAST archive for use in faint-galaxy studies. Figure 1 shows a segment of the image.

The TNO Search Field joins a list of valuable, publicly available data sets from *Hubble* surveys, a list that is expanding rapidly since the advent of the ACS. Figure 2 shows that the TNO Search Field lies between the Ultra Deep Field (UDF) and Great Observatories Origins Deep Survey (GOODS) in the depth-versus-area plane defined by current and planned *Hubble* surveys.

We took advantage of the 96 exposures per pointing to construct a combined image with 25 mas pixels, yet minimal interpolation smoothing, and no correlations between adjacent pixels. This careful attention to sampling issues, along with the large area compared to HDF or UDF, should make the TNO Search Field a useful resource for the study of morphology, number, and clustering of faint galaxies, despite its lack of color information. Another advantage is that, with the assistance of Norbert Zacharias of the United States Naval Observatory, the mosaic has a global astrometric accuracy of 10 mas and relative accuracy better than 5 mas.

We hope that the creativity of the astronomical community in finding unanticipated uses for deep *Hubble* imaging will continue in the case of the TNO Search Field. Ω

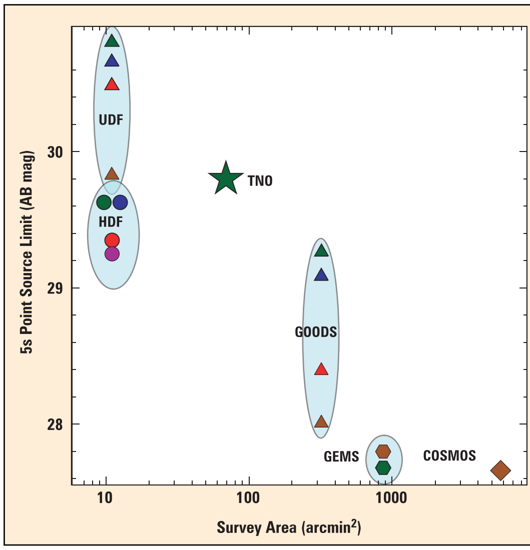

Figure 2: Depth versus area for available and planned *Hubble* survey fields. The approximate limiting stellar magnitude and coverage area of each survey is plotted. The color of each symbol indicates the filter used, violet/blue/green/red/brown spanning the *u* through *z* bands. The ACS survey fields now define a wide envelope in the depth versus area plane.

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IVC Meeting . . . . . 11–12 March, 2004
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STUC Meeting . . . . . 22–23 April, 2004
Cycle 13 GO/AR electronic budget deadline . . . . . 21 May, 2004
JWST SWG Meeting, Broomfield, CO . . . . . 2–3 June, 2004

May Symposium

Planets To Cosmology: Essential Science In *Hubble*'s Final Years: . . . . . . 3–6 May, 2003

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