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Newsletter

Highlights of this Issue:

Morphology of Magellanic Cloud Planetary Nebulae: Probing stellar populations and evolution

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The Importance of Planetary Nebula Morphology

Planetary Nebula (PN) morphology has been used extensively to gain insight into the evolution of intermediate- and low-mass stars. In recent years, the most impressive advances in this field have been achieved by using the wealth of new data on Galactic PN morphology together with stellar and nebular spectroscopy, and in combination with hydrodynamic modeling (Calvet and Peimbert 1983, Stanghellini et al. 1993, Zhang and Kwok 1998). It is now widely accepted that PNe are the ejecta of ~1 to 8 $M_{\odot}$ progenitor stars, expelled toward the end of their lives, specifically, during the thermally pulsating, Mira-like phase on the Asymptotic Giant Branch (AGB). These ejecta travel at a low velocity, and carry most of the envelope mass. It has been observed that the remnant central stars suffer a post-AGB fast, low-mass wind, shaping the PN shells of a variety of morphological types. Data and analysis suggest a morphological sequence that threads the three major PN classes — round, elliptical, and bipolar — from low- to high-mass progenitors. Planetary Nebulae in this sequence have increasing optical thickness, and show variations in their chemical content. The mean Galactic latitude for each morphological class seems to decrease within the sequence.

Although some insight has been derived from studies of Galactic PN morphology, there remain several fundamental unanswered questions. For instance, what is the exact amount of the mass lost in the PN formation process? This is of fundamental importance for deriving the initial mass versus final mass relation, as well as the PN contribution to the chemical enrichment of the interstellar medium. Furthermore, why would some AGB winds produce asymmetric shells? What is the mechanism of bipolar PN formation? Are bipolars generated via binary evolution, or do some originate from stellar rotation, unseen planets, or a combination of these and other factors? Why do bipolar PNe seem to originate from higher-mass, chemically enriched progenitors?

Interestingly, bipolar PNe are located preferentially in the Galactic plane, i.e. their spatial distribution is similar to that of massive (Population I) stars, whereas other types of PNe are found at high and low altitudes above and below the Galactic plane. This suggests that bipolar nebulae are formed from more massive than average progenitors (Greig 1972). If so, then bipolar PNe may originate from stars with a different evolutionary history, i.e., stars that form dense tori as a normal part of their evolution. This result, if confirmed, provides

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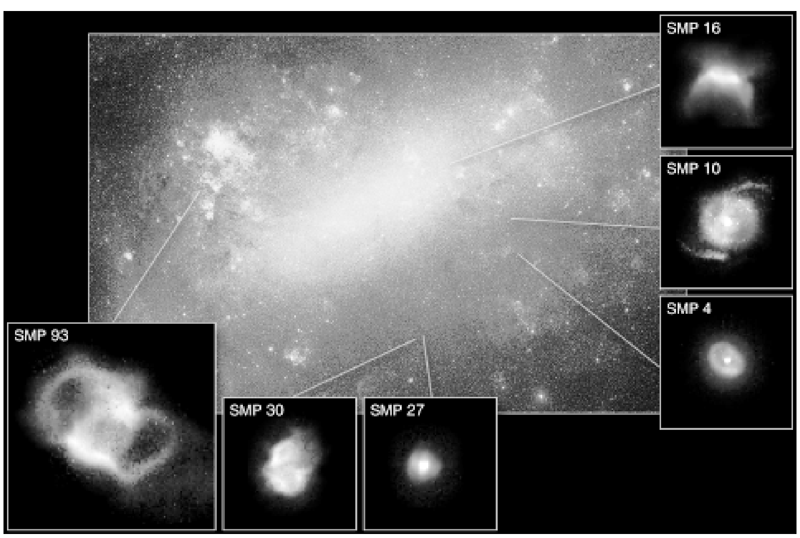

Large Magellanic Cloud PNe observed with STIS/HST: a variety of morphological types among the extra-galactic PNe observed by us in Cycle 8. Also shown is their location within the host galaxy.

DIRECTOR'S PERSPECTIVE

Steven Beckwith

With exquisite grace and remarkable stamina, seven astronauts restored Hubble to full working condition last December. Actually, they left it in better condition than it was even before the fourth gyro failed in November. By jostling the spacecraft, or maybe by simply cycling the power, they fixed a nagging problem with a power control unit that was not delivering full power to the satellite because of a resistance that developed in the circuit path. That was not in the carefully choreographed flight plan, but hey, who are we to complain? The human factor worked in our favor.

It was a big kick to see the whole thing live on television. The broadcast piqued public interest in the mission, too. It was one of NASA's few visible successes last year. After a couple of failed Mars missions, the success of the astronauts in repairing astronomy's most famous research tool was a big boost for the agency and the manned space program. It was a big boost for astronomy, too. Hubble's success helps all astronomers by maintaining public interest in what we do.

Each servicing mission has become more complex. Servicing mission number 3a (SM3a) bumped up against several records for the duration of the space walks. Fixing the gyros, upgrading the computer, installing voltage improvement kits, and inspecting the satellite all took a bit longer than planned. Photographs of the solar arrays revealed that some critical hinge pins had worked their way loose, threatening the long-term viability of the satellite. In a series of dramatic meetings reminiscent of scenes from the movie, Apollo 13, engineers from ESA and NASA concluded that no fix was necessary, thus relieving the astronauts from a potentially difficult, unplanned duty.

Not everyone cheers NASA when they mount repair missions to space satellites. The cost to the Hubble project of SM3a was about $30 M. The cost of training and getting the astronauts to orbit and returning them safely is several hundred million dollars, depending on how one amortizes the cost of the manned space program over the number of shuttle missions each year. Not cheap. Is it worth several hundred million dollars to fix a two-billion-dollar spacecraft?

Many of us would say yes, especially when the object of the fix is already firmly part of the taxpayer's positive image of Hubble. Look what the first servicing mission did for us. Hubble is an example of how manned space flight can be a good value for science.

On the other hand, it costs more to build satellites that can be serviced. There is more engineering involved in making all units modular and accessible and in making the structures strong enough to be grappled, jostled, opened and closed. Servicing certainly increases the total cost of a science project by more than the incremental cost of servicing. When is the cost of servicing a good investment for a field?

The answer may lie in the speed of improvement of the telescope technology compared to the rate of advance in instruments. For many years, the power of telescopes has improved slowly, whereas the advance of instruments, driven mainly by improvements in detectors, has occurred rapidly. Even the giant 10m Keck telescope only increased light gathering power by a factor of four over its predecessor, the Palomar 5m, despite nearly 50 years between the two. The size of detector arrays increases by factors of four every few years, and each generation of detectors has demonstrably better quality and sensitivity. In this environment, it makes sense to upgrade existing telescopes with better instruments, since a modest investment pays a rich reward.

But the future of space telescopes may be different. The Next Generation Space Telescope project confidently predicts that they can increase the light gathering power of *NGST* over Hubble by a factor of 10 for less than half of Hubble's cost. In their current budget, the instruments cost only a bit less than the telescope itself, though some of us think the instrument costs are seriously underestimated. If the estimates are correct, it would be cost effective to simply build new telescopes rather than service the old ones, especially since it would be expensive to make the telescope serviceable in the first place. We would be better off building a backup *NGST* to buy down the risks rather than making it serviceable.

Of course, if it turns out that making an 8 m space telescope is harder than we think, these arguments may be wrong. Under current projections, *NGST* will be launched two decades after Hubble. *NGST*'s instrumentation budget is clearly inadequate to equip it with the most capable instruments possible even with today is technology, let alone that of 2010, say. If it takes another two decades to improve upon *NGST* by even a modest factor, we may look back fondly on the days of manned visits to our great telescopes and wish we could find some way to send our best and brightest into space to keep our observatories at the state of the art, the way we have with Hubble.

Steven Beckwith
Baltimore, March 31, 2000

A decade of science: HST observations of pulsars

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While neutron stars are the brightest sources in the γ-ray sky, in the optical domain they are very faint and the search for their counterparts is a difficult task relying upon the most powerful telescopes. Indeed, after the identification of Baade's star (V=16.5) as the optical counterpart of the Crab pulsar (Cocke et al. 1969), about ten years were necessary to achieve the identification of the 700 times fainter (V=23.6) Vela pulsar (Lasker 1976).

The chase for optical emitting neutron stars was boosted in the 1980s with the advent of a new generation of CCD detectors which offered both higher sensitivity and better angular resolution. A few new identifications were secured, including the first extragalactic pulsar in the LMC supernova remnant SNR0540-69. The total number of isolated neutron stars with likely or secured optical counterparts amounts now to 9 (see Mignani 1998 for a recent summary). To these, we can add two neutron star candidates (RXJ 1856-3754 and RXJ 0720.4-3125) selected from the ROSAT catalogue on the basis of their high x-ray to optical flux ratios (see Caraveo, Bignami & Trumper 1996).

After the seminal work carried out with ESO telescopes (see Mignani et al. 2000a for a review), *HST* has made a major contribution in the field of pulsar astronomy. Indeed, the majority of the recent identifications have been the result of *HST* observations. This was made possible by the high blue and ultraviolet sensitivity of the FOC, particularly well suited for the detection of objects intrinsically brighter at short wavelengths, such as neutron stars. Likely counterparts were proposed for two nearby (d<300 pc) pulsars, PSR B0950+08, PSR B1929+10 (Pavlov et al. 1996), and for PSR B1055-52 (Mignani et al. 1997). In addition, a viable counterpart for the ROSAT source RXJ1856-3754 was found with WFPC2 (Walter & Matthews 1997).

The *HST* contribution to the optical study of isolated neutron stars is summarized in Table 1, where, for each source, the observations available are listed. Not surprisingly, also in view of the faintness of the targets, the imaging instruments were the ones most often used. The imaging data in Table 1 were used to study different aspects of the physics of isolated neutron stars such as (i) pulsar kinematics and distances (through accurate astrometry), (ii) interactions of the neutron star with its surroundings (high resolution imaging) and (iii) pulsars spectral shapes (multi-color photometry). In particular, while the FOC provided the first detections of neutron stars in the near-UV, explorative observations in the near-IR domain were performed by NICMOS. The main achievements provided by *HST* observations in this decade are reviewed by topic in the following sections.

Timing

Table 1 shows that pulsar timing with the *HST* has been pursued for the two brightest objects only: the Crab

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Name	Mag.	Tim	Spec	IR	I	R	V	B	U	UV
Crab	m_V=16.6	HSP	STIS							
			FOS							
B0540-69	m_V=22.1	HSP	FOS				WFPC2			
Vela	m_V=23.6				WFPC2	WFPC2	WFPC2			
B0656+14	m_V=25			NICMOS			WFPC2	FOC	FOC	FOC
Geminga	m_V=25.5			NICMOS		WFPC2	WFPC2	FOC	FOC	FOC
B1055-52	m_{342W}=24.9								FOC	
B1929+10	m_{130LP}=25.7							FOC		FOC
B0950+08	m_{130LP}=27.1									FOC
RXJ 1856-3754	m_V=26						WFPC2		WFPC2	

Summary of HST observations of neutron stars with a confirmed or tentative optical counterpart. Rotation-powered neutron stars are listed in rows 1 to 8. The objects (first column) are sorted according to their spin-down age, with the shade intensity identifying young (~1,000 yrs), middle-aged (~100,000 yrs) and old (~1,000,000 yrs) objects. The isolated and presumably very old (> 10,000,000 yrs) neutron star candidate RXJ 1856-3754 is listed in row 9. The object flux (either in V or in one of the HST passbands) is listed in column 2. Timing, spectroscopy and time integrated near-UV to near-IR photometry observations are listed in the remaining columns. In each case, we list the HST instrument used. Bold corresponds to identifications and measurements first obtained with the HST.

Morphology *from page 1*

important insight into the shortcomings of present models for AGB envelope ejection. The suggested morphological sequence that goes from round, through ellipticals, to bipolar PNe, would be consistent with the higher mass, younger stellar Population of asymmetric PNe. But are we really observing round PNe at all latitudes vs. bipolar in the Galactic plane, or are we sampling different space volumes for the two classes? The resulting space distribution across morphological types could be an artifact of extinction within the Galaxy, and of Malmquist bias.

Magellanic Cloud PNe, and the Morphology-Abundance Connection

The great weaknesses in studying Galactic PNe are the uncertainty in the distances to individual nebulae, and in the selection effects related to interstellar absorption. For these reasons, we are examining Large Magellanic Cloud (LMC) PNe. Given that LMC PNe are typically a half arcsec across, *HST* is needed to resolve them spatially with the necessary detail for morphological classification.

In Cycle 8 we were successful in proposing a SNAP program to observe 50 LMC PNe. Observations have been completed for 27 of these, and the images are outstanding. Our observing technique is based on STIS slitless spectroscopy combined with broad-band imaging. In this way we can study both the total optical emission, which typically includes the central star continuum, and also the detailed, energy-dependent morphology. With our observing strategy, we detected PNe morphology in the following recombination and forbidden lines: [O III] λ4959 and λ5007, Hα, Hβ; in some cases we can also detect [O I], [S III], [S II], [N II], and He I. Examples of the observed PNe are shown in Fig. 1, together with their location within the host galaxy (to fully appreciate the amount of information contained in the images, please refer to the true-color press release image STScI-PRC00-09).

By using these images, and increasing the sample size with the 17 LMC PNe previously observed by *HST* (Stanghellini et al. 1999), we obtain a sizable database of LMC PNe. Our working plan for this sample includes the morphological classification, the search for relations between morphology and nebular abundances, and between morphology and central star physics. All LMC PNe examined so far look like Galactic PNe, and it is always possible to find a Galactic 'identical twin' for each of our observed PNe. We found round, elliptical (Fig. 1: SMP 4), bipolar (SMP 16), quadrupolar (SMP 27) and point-symmetric (SMP 10) PNe in the LMC. The notable difference between the PN population in the Milky Way and in the LMC is the frequency of asymmetric PNe: asymmetry is much more common in the LMC than in the Galaxy.

The chemical content of PNe is essential to understand the evolutionary paths and Population type of the progenitor star. Stars that go through the AGB phase do not modify the original abundance of the so-called alpha elements (S, Ne, Ar), while they are major contributors to the carbon and nitrogen gradients in the ISM. Correlations are sought between the chemical content of the LMC PNe, their morphology, and their projected location within the LMC, to infer possible links to the age of the nebular Populations in the LMC. To this end, we have used abundances available in the literature, but we plan to produce a homogeneous spectrophotometric

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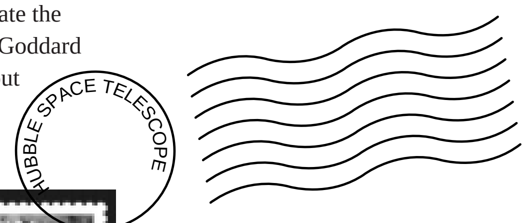
Hubble Stamps

The United States Postal Service recently issued stamps to commemorate the tenth anniversary of HST's launch. The first day of issue took place at Goddard Space Flight Center. The stamps come on a sheet with information about Edwin Hubble and about the objects depicted. For more information, go to: *http://new.usps.gov* and search on "hubble."



Morphology *from page 4*

database for our LMC PNe with the NTT telescope at ESO. In Fig. 2 (from Stanghellini et al. 2000) we show the relation between S and Ne abundances in LMC PNe of different morphology. The segregation of morphological type with respect to S and to Ne is striking; evidently, PN morphology is a good indicator of progenitor Population in the LMC. Figure 3 shows the relation between C and N abundances, from which we can infer the evolutionary paths of the progenitor stars (Iben & Renzini 1983, van den Hoek & Groenewegen 1997). The segregation of morphological types is notable, except for a few PNe that have asymmetric shapes and high carbon abundances.

We could interpret our results as follows: low-mass stars (~1 to 4 $M_{\odot}$) go through the carbon star phase, and do not produce asymmetric PNe. On the other hand, higher mass stars (4 to $8_{\odot}$) do not go through the carbon star phase, and they produce asymmetric PNe. This conclusion is strongly supported by stellar evolution theory, and by the fact that higher mass stars are expected to undergo the hot-bottom burning phase, converting carbon into nitrogen. Some of the low-mass stars producing carbon stars also end up as asymmetric PNe, perhaps through the common envelope phase. If asymmetry in PNe were due uniquely to common envelope evolution, or binary evolution in general, we would not expect to find any of the separations among morphological classes that we show in Figures 2 or 3. On the other hand, there may be a small fraction of asymmetric PNe that are developed as a consequence of close binary evolution, and this is also supported by observations.

Future endeavors

Cycle 9 will be busy for us. In fact, we have an approved WFPC2 snapshot program to observe the fainter central stars of our LMC PNe sample. This program was proposed after examining the Cycle 8 images as the central star was not visible in some PNe. The determination of the stellar magnitudes will allow us to understand the PN morphology-central star evolutionary connections much better that ever before.

Furthermore, we will extend the scope of our scientific program by observing PN morphology in the Small Magellanic Cloud (SMC), with a snapshot program similar to our Cycle 8 LMC PN program. The importance of observing the correlations between morphology, nebular abundances, and stellar physics in SMC PNe is multifold. First, we will determine the late evolutionary paths of the most common stars in a galaxy that, in its chemical content, mimics a young galaxy: the SMC is an ideal laboratory to test our knowledge of stellar and nebular evolution in a different environment. Second, by observing a sizable sample of SMC PNe with *HST* (i.e., resolving their morphology and size) we will add the missing link to the metallicity-stellar evolution connection. Carbon star formation rates are strongly dependent on the progenitor's metallicity, and mass-loss is related to metallicity as well, but how are they related to morphology? Third, we found that the percentages of round, elliptical, and bipolar PNe in the Galaxy differ from those of the LMC in that more asymmetric PNe are found in the LMC (i.e., in a low metallicity environment). Should PN asymmetry really correlate to the metallicity of the environment, we will clearly see a difference in the SMC data set.

We would like to thank our MC PN collaborators: Max Mutchler, Bruce Balick, Chris Blades, and Laura Cawley.

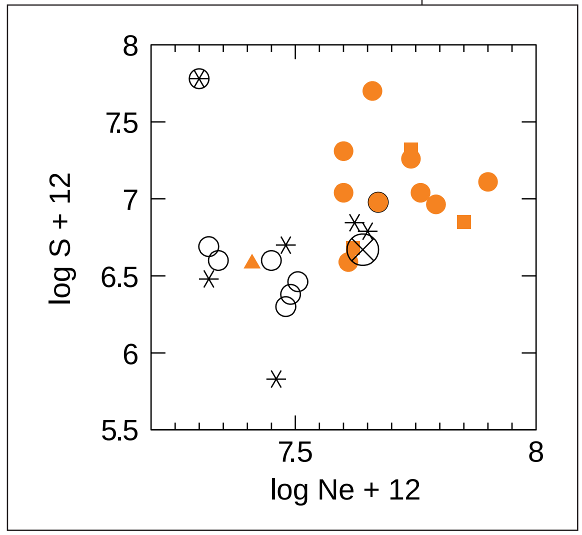


Fig. 2: Sulfur versus neon abundances in LMC PNe. Open circles: round, asterisks: elliptical, triangles: quadrupolar, filled circles: bipolar, filled squares: extremely bipolar PNe. The large crossed circle indicates the average abundances of the LMC H II regions.

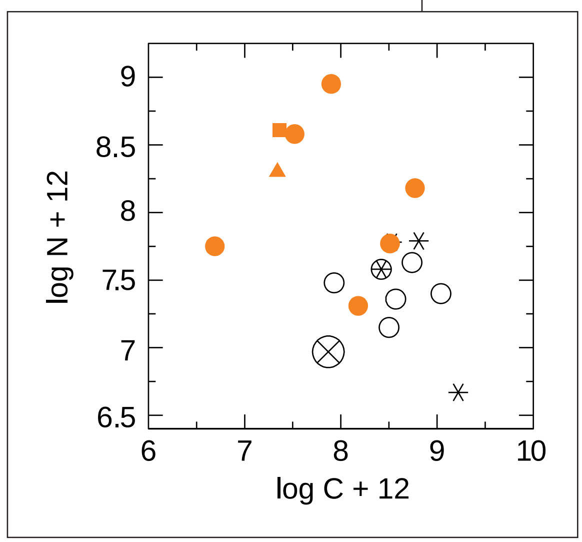


Fig. 3: Nitrogen versus carbon abundances in LMC PNe. Symbols as in Figure 2.

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Pulsars *from page 3*

pulsar (*V*=16.6) and PSR B0540-69 (*V*=22.5), both observed using the High Speed Photometer. Since its removal in 1993, no other instrument suitable for timing observations was available aboard *HST* until the installation of STIS during SM-2.

HSP observations of the Crab pulsar were performed by Percival et al. (1993) both in the visible and in the near-UV. They revealed tiny-but-significant differences between the light curves at the two wavelengths, with the relative widths of the two peaks and the peak separation slightly larger in the visible compared to the near-UV. Such a trend for a larger peak separation with the increasing wavelength was later confirmed by Eikenberry et al. (1997). PSR B0540-9 was observed between 1600 and 7000 Å (Boyd et al. 1995), yielding a light curve very similar to the optical and X-ray ones, thus confirming the common nature of the emission mechanisms.

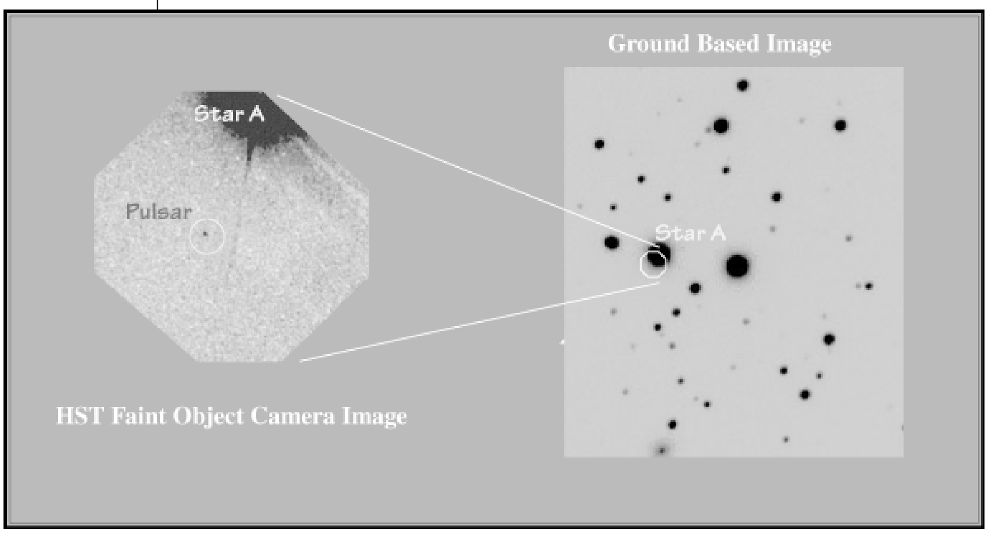

Figure 1. The last pulsar identified by the HST is PSR B1055-52 (Mignani et al. 1997). Since the pulsar position falls very close to a nearby and relatively bright (V=14.7) field star, its optical counterpart was undetectable from the ground (left) even under the most favorable seeing conditions. Only the sharp resolution of the UV-sensitive FOC (right) was able to resolve the faint emission from the pulsar (m_{342W} = 24.9).

Spectroscopy and photometry

Among the optically emitting neutron stars, only the Crab and PSR B0540-69 were within reach of *HST* spectroscopy. Time-resolved spectroscopy of the Crab was performed with the STIS/MAMA operated in time-tag mode (Gull et al. 1998) and provided the first near-UV spectrum of the pulsar after the IUE one, obtained back in the 1970s (Benvenuti et al. 1980). After correction for the interstellar reddening, the spectral distribution was found to follow a flat power law, consistent with the findings of Percival et al. (1993) in the near-UV/visible and in the visible. No obvious correlation between the spectral shape and the pulsar phase emerged from the STIS data. While the Crab has been repeatedly observed with the FOS (unpublished data), only one observation is available for PSR B0540-69 (Hill et al. 1997), which produced the first, and so far, the only spectrum of this pulsar in the near UV/visible region. As in the case of the Crab, the de-reddened spectrum of PSR B0540-69 shows a flat featureless continuum, which, however, is characterized by a spectral slope significantly steeper than the Crab one. For definitely fainter objects, optical spectral studies could be pursued only through multicolor photometry.

In the case of Vela, multicolor photometry revealed a spectrum significantly different from the one of the other two young pulsars. While the general spectral shape is consistent with a flat power law, very recent WFPC2 675W/814W photometry clearly resolved an absorption dip around 6500 Å, which is probably due to synchrotron self-absorption (in preparation). PSR B0656+14 and Geminga were studied in the visible and near-UV by the WFPC2 and the FOC while in the near-IR, NICMOS observations have been performed but only preliminary results have been reported so far (Harlow et al. 1998). In both cases, the available multicolor flux measurements turned out to be clearly inconsistent with a single spectral model, thus implying that both non-thermal and thermal emission processes probably contribute to the optical luminosity. Although these two objects are very similar in both their intrinsic properties (age, period, magnetic field) and X/γ-ray phenomenology (Goldoni et al. 1995), their spectra in the visible/near-UV are markedly different.

In the case of PSR B0656+14, the optical flux distribution can be fit by the combination of a non-thermal magnetospheric component and a thermal one, originated from the hot neutron star surface (Pavlov et al. 1997). On the other hand, for the slightly older Geminga, the optical continuum seems to be thermal, with a broad emission feature at 6000 Å (Mignani et al. 1998). This has been interpreted as a hydrogen cyclotron emission line originating in the neutron star's atmosphere (Jacchia et al. 1999). From the wavelength of the feature, one can thus infer directly, for the first time, the value of the magnetic field of

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an isolated neutron star. The value obtained by Jacchia et al. for Geminga is in good agreement with the value obtained from the pulsar timing. For the older pulsars (PSR B1055-52, PSR B1929+10 and PSR B0950+08), only one FOC detection is available and very little can be said about the nature of the optical emission apart from noting that the measured fluxes appear compatible with thermal emission produced from the cooling of the neutron star surface (Mignani et al. 1997; Pavlov et al. 1996).

Astrometry

WFPC2 images has allowed a major step forward in the field of pulsar astrometry. By exploiting the sharp angular resolution of the PC, WFPC2 observations allowed to perform very precise astrometric studies, yielding relative proper motions and parallax measurements. Although in a few cases optical proper motions had been already measured from the ground (see e.g. Mignani et al. 2000a), WFPC2 observations provided measurements of equal, or even higher, accuracy in a much shorter time span.

Geminga is the first neutron star for which a WFPC2 proper motion was obtained together with the measurement of its parallactic displacement (Caraveo et al. 1996). While the proper motion reassessment significantly improved the values obtained from the ground (Bignami et al. 1993; Mignani et al. 1994), the measurement of the parallactic displacement, the only one ever obtained in the optical domain for a neutron star, provided the value of the source distance (157 pc). The same data were also used by Caraveo et al. (1998) in a multi-step astrometric chain aimed to link the very accurate WFPC2 relative position of Geminga to the Tycho/Hipparcos absolute reference frame. This procedure yielded the source absolute coordinates with a precision of 40 mas and made it possible to phase together gamma-ray observations obtained years apart (Mattox et al. 1998). A further demonstration of the superior capabilities of the WFPC2 for very accurate astrometry measurements came with the new measurement of the proper motion of the Crab pulsar which was obtained in less than two years of observations, to be compared with the time span of 70 years originally required by Wyckoff & Murray (1977). Moreover, the confirmation of the proper motion direction, found to be aligned with the axis of symmetry of the Crab Nebula torus and to the jet/counter-jet vector, suggested possible connections between the pulsar kinematics and its observed morphology.

The measurement of the Vela pulsar proper motion, triggered by the study of its association with the Vela SNR, has been repeatedly tried, both in radio and in the optical, yielding conflicting results. Very recent WFPC2 observations (DeLuca et al. 2000) yielded an accurate determination of the Vela pulsar proper motion, clearly confirming the ground-based results of Nasuti et al. (1997). Exploiting the Geminga experience, an *HST* program aimed to the measurement of the Vela parallax is now in progress with the WFPC2. This could yield a model-independent value of the pulsar distance, so far assumed to be 500 pc, but admittedly affected by a very significant uncertainty.

Finally, using WFPC2 observations taken 4 years apart, it was possible to measure for the first time the optical proper motion of the candidate counterpart to PSR B0656+14 (Mignani et al. 2000b). A value of 43 mas/yr (with a PA of 93 degrees), much more accurate than the radio one (e.g. Pavlov et al. 1996), was thus obtained. For the allowed range of the pulsar radio distance (200 to 800 pc) the measured proper motion would imply a transverse velocity between 50 and 100 km/s. This relatively high velocity, coupled with the unusual colors of this object (Pavlov et al. 1997), certainly leaves no doubt about its neutron star nature, and it provides the last piece of evidence needed to confirm the pulsar identification.

Future prospects

Although *HST* observations gave important contributions in the optical astronomy of neutron stars, much work still remains to be done towards the complete understanding of the emission processes at work and of their dependence on the neutron star age. While detailed spectral studies require spectroscopic facilities that are probably beyond the limits of the current generation of *HST* instruments, timing observations with the STIS should certainly be pursued both to achieve new identifications and to confirm the ones already proposed. Starting from the improved pulsar database, now being built in the radio domain, both Chandra and XMM-Newton observations will certainly single out targets worthy of investigation with the *HST*.

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A New President for AURA

From Bill Smith, AURA's new president.

On February 11 the AURA Board of Directors announced my appointment as President of AURA. I have accepted this appointment with a great appreciation for AURA's past accomplishments and an even greater anticipation for what AURA can be in the future. I am committed to establishing a leadership role for AURA not only within the U.S. community, but internationally.

Bill Smith

Over the past two years, I have made a concerted effort to take stock of AURA's strengths, and also its perceived weaknesses. One of the most consistent views of AURA–from its supporters, critics, funding agencies, and policy makers–is the high quality of its people. This view is uniform and widespread. This fact makes it all the more gratifying that I have been given the opportunity to lead AURA over the coming years.

There is no question that the coming years will be perhaps the most challenging in AURA's history. The Gemini Observatory will be entering its long-awaited operational phase; the Space Telescope Science Institute will take on a new mission with the Next Generation Space Telescope; the National Solar Observatory will work to build community support and prepare for the Advanced Solar Telescope; and NOAO will take on new leadership roles as community needs evolve. I have every confidence that AURA can meet these challenges and even seek new opportunities that fit our mission.

I am particularly proud of my association with the Space Telescope Science Institute. STScI is in every way a success story, and has enabled the *Hubble Space Telescope* to be the most productive scientific facility of our age. Over a relatively few years, STScI has established a tradition and reputation for excellence that now stands as the example for others. STScI was established by AURA to both represent and serve the community and in so doing has carried out a vital part of NASA's mission. We now look forward to an even more exciting future as the Next Generation Space Telescope takes shape.

It was in fact, the anticipation of the Next Generation Space Telescope that motivated me to seek employment with AURA and this remains one of my highest personal priorities. *NGST* represents both an opportunity and a challenge. Our opportunity lies in the role we will play in developing the science mission, participating in the development, and engaging the community in one of NASA's most ambitious missions. Our challenge is to follow through on our commitment to transition from *HST* to *NGST* on a modest budget while we maintain a high quality of service to our user community.

There is no question that through the leadership of Steve Beckwith and the talent of the STScI staff, we will achieve success. I look forward to serving as AURA's President.

Pulsars *from page 7*

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AURA Service Award goes to Glenn Miller

The following is taken from the citation of the award, which is ordinarily given in the year after it is earned.

The 1998 AURA Award for Service at the Space Telescope Science Institute was presented to Dr. Glenn Miller in recognition of his dedication and commitment to improving observatory operations while maximizing science return and reducing operating costs. While Glenn's contributions may not be well-known to many in the general astronomical community, those in the community responsible for managing and operating service-based observatories are well aware of them.

Glenn has become the leader in establishing common ground in managing and operating queue-scheduling astronomical observatories. This is about more than the success of the Spike software system for planning and scheduling. Through his work on numerous committees and working groups, as well as extensive publications, Glenn has led and challenged the observatory operations community to develop innovative ways of sharing expertise, tools and ideas for a broad area of "front end" activities including program solicitation and selection, user support, observation tools and documentation along with planning and scheduling. Glenn has invested his personal time, intellect, enthusiasm and energy to prepare the community for reduced cost operations with payoffs already realized. The models adopted by observatories such as ESO VLT, Gemini, FUSE, AXAF and SIRTF clearly bear Glenn's stamp on them.

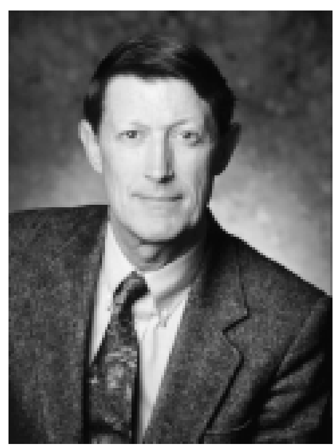
Glenn Miller

Dr. Robert Williams

Bob Williams recently received NASA's Distinguished Public Service medal, the agency's highest award to a civilian.

Dr. Robert Williams served from 1993 to 1998 as the Director of the Space Telescope Science Institute (STScI), which has principal responsibility for the science operations and for the conduct of the science program of the *Hubble Space Telescope* (*HST*). STScI is widely viewed as a major national scientific institution and one of the most successful organizations of any kind affiliated with NASA.

Dr. Williams played a major role in establishing and solidifying its emminence. During his tenure, Dr. Williams accomplished the remarkable management feat of presiding over a reduction in the budget and size of the STScI while at the same time dramatically improving the efficiency and productivity of the *HST's* science program. Moreover, he converted the STScI into a truly "user friendly" organization, accomplishing major simplifications of the systems through which individual astronomers use the *HST* to acquire cutting edge astronomical observations, and substantially improving the Institute's personal responsiveness to its users. At the same time Dr. Williams conceived and led one of the most important scientific initiatives to be undertaken with the *HST* – the Hubble Deep Field (HDF). Using Director's Discretionary Observing Time and broadly involving the scientific community, Dr. Williams and his team acquired the deepest image of the universe ever obtained at optical wavelengths. These observations (which were immediately released as public, non-proprietary data available to all) provided an entirely new and unexpected picture of the deep universe. They have profoundly affected modern studies of the large-scale structure of the universe and the evolution of galaxies. Dr. Williams' contributions to the *HST* Program, to NASA and to astronomical science are of the highest order and fully merit the award of the Distinguished Public Service medal.



Bob Williams

SM3A: What Happened During the Third Servicing Mission

Carl Biagetti, STScI *biagetti@stsci.edu*

HST's third servicing mission (SM3) was originally to be a single mission to upgrade observatory science, including the installation of the Advanced Camera for Surveys and the restoration of infra-red science by installation of a cooling system to revive NICMOS, as well as several other spacecraft refurbishments, including a complete replacement of all six rate-sensing gyros.

These plans were drastically altered when, in early 1999, a fourth gyro began showing signs of imminent failure. Such a failure would reduce *HST*'s complement of working gyros to two, one less than the minimum required for telescope pointing control. The situation prompted the Project and NASA to call up an emergency servicing mission in order to restore the pointing control by performing the gyro swap-out originally planned for SM3.

The gyro did in fact fail on Nov. 13, 1999, forcing *HST* into safemode and rendering the observatory inoperable for science until the gyros were replaced. The emergency mission, now called SM3a, had been originally scheduled for Oct. 1999, but was delayed because of a series of Shuttle problems, until Dec. 19, the very last opportunity to launch in 1999. Meanwhile *HST* had remained in the co-called "zero-gyro" control mode, using only coarse sun sensor and magnetometer information for 2-axis stabilization to maintain sunward orientation of the solar arrays.

The crew of Discovery (STS-103) consisted of Commander Curt Brown, Pilot Scott Kelly, Payload Commander Steve Smith, and Mission Specialists Jean-Francois Clervoy, John Grunsfeld, Mike Foale, and Claude Nicollier.

On Dec. 21, approximately 48 hours after lift-off, the Shuttle and its crew rendezvoused with *HST*. The telescope was grappled at 7:34pm (EST) as Clervoy successfully operated the Shuttle's robotic arm following Orbiter maneuvering to match *HST*'s attitude. Berthing in the Shuttle bay was complete a short while later.

The first day of extra-vehicular activity (EVA1) provided *HST* with the 6 new gyros, the highest-priority upgrades of the mission. Installation of the 3 pairs of gyros went fairly smoothly except for a problem in fitting one of the old units into its carrier and closing its lid. Mission managers determined that this was safe since the carrier was to go into another larger box. All three gyros passed their aliveness tests, and several hours after the EVA, the gyro functional tests were successfully completed. *HST* once again had a complete set of working gyros.

The next task, opening the NICMOS coolant valves (for venting in preparation for cooling system installation in the next servicing mission), was the cause of some confusion and delay before, in the end, successful comple-

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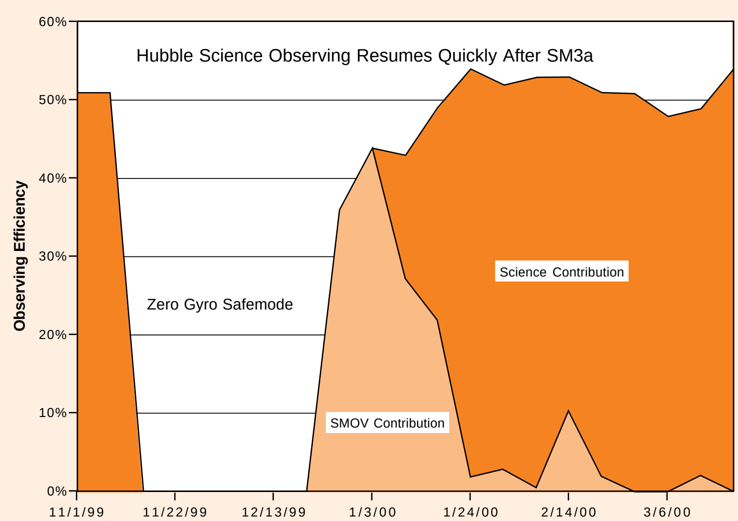
Hubble Science Observing Resumes Quickly After SM3a

Hubble science observing followed closely on the heels of the initial post-servicing mission observatory checkout. The on-target observing efficiency rebounded within a few weeks of resuming science observing with Servicing Mission Observatory Verification (SMOV) activities accomplished in very short order. Congratulations go the SMOV team for designing and accomplishing a program that enabled such quick return to Hubble science mission.

We lost approximately 5 weeks of science observing during the Zero Gyro Safemode period. While some of the lost observations were inserted quite quickly into the observing plan, many of them are constrained (e.g., by orientation or guide star availability) that require waiting a year to try again. The new FGS2R has recently been commissioned to its full operational state that relieves some of the guide star availability issues.



SM3A *from page 10*

tion. By this time, however, the EVA was over 5 hours old.

Next, the six Voltage/temperature Improvement Kits (VIKs) were installed. The VIKs help regulate battery recharge voltages and temperatures, and as a result, were second only to the gyros in mission priority. The work proceeded quickly and all six got installed on this EVA and passed their aliveness tests.

Due in large part to the delays with the NICMOS valve openings, a relatively late (and assumed to be simple) addition to the mission timeline, the EVA lasted 8 hours and 15 minutes, the second longest in history, 14 minutes short of the record.

Although still in excess of 8 hours, the second EVA went considerably more smoothly. The 486 computer was installed, replacing the old DF224. Its Aliveness Test (AT) and, later, Functional Test (FT) were both successful.

The refurbished FGS2R was installed in place of FGS2. The installation ended up taking more time than expected, in part because of FGS balkiness at insertion. There was also a CO_2 leak alarm in Claude Nicollier's suit. It was thought to be a false alarm, because the transducer went instantaneously from a normal reading to off-the-scale high, but the crew then began monitoring Claude who, himself, showed no sign of a problem. The EVA work proceeded without any further delay.

This EVA added up to 8 hours and 10 minutes, only 5 minutes shorter than the previous day's.

EVA 3 was completed shortly after 10pm (EST) on Friday night, Dec 24. The astronauts (Smith and Grunsfeld) installed the Optical Control Electronics (OCE) for the new FGS, the new Single Access Transmitter (SSAT2), a second Solid State Recorder (SSR2) in place of an old reel-to-reel (ESTR3), and MLI refurbishment on Bays 9 & 10.

At the post-EVA press briefing, NASA reported on the results of the photo inspection of the +V3 side of the spacecraft. A few new cracks were seen, along with some further propagation of old cracks. But no new open areas were found. The patches installed on SM2 all appeared in good shape.

The repairs to *HST* were at that point complete.

HST was released from Discovery at 6:03pm, Dec. 25, shortly after the aperture door was opened for the first time in 42 days. *HST* successfully went to Normal Mode under control of the new computer using the new gyros (gyros 3-6 in the control loop).

The astronauts deliberately released the telescope with its V1 axis pointing into the northern Continuous Viewing Zone (CVZ), and this attitude was, by requirement, maintained for the next 12 days. This is now done after every servicing mission as a preventive measure in order to avoid exposure of the telescope optics to UV light reflected from the sunlit portion of the Earth. During this 12-day special attitude, the first portion of the servicing mission observatory verification (SMOV) program was carried out. The pointing control system, including the new computer and the new gyros, were checked out and recommissioned for immediate use in spacecraft attitude control. They have been working continuously and flawlessly ever since.

Also, during the first two weeks, the other spacecraft upgrades, such as the new solid state recorder, and the replacement S-band transmitter, were checked out.

The SMOV program proceeded as planned with WFPC2 and STIS CCD being recommissioned for normal science on Jan. 10. STIS MAMA science was recommissioned on Jan. 17. Early release observations (EROs) were performed using the WFPC2. Images of the Eskimo Nebula (NGC 2392) and the Abell Cluster 2218 were released on Jan. 24.

Meanwhile, the replacement FGS (FGS-2R) was undergoing a more elaborate checkout and commissioning program. Optical adjustment of its actuated mirror was completed by Jan. 18. The instrument has since been calibrated and commissioned; it is now being used routinely as one of *HST*'s complement of three fine-guidance sensors. (FGS-1R, per the plan, remains as the operational astrometer.)

As of this writing, a rather routine FGS-2R stability check, scheduled for the last week of April, is the only SMOV activity remaining from the December 1999 repair and refurbishment mission.

SM3b, now scheduled for June 2001, will produce the planned ACS and NICMOS science upgrades along with installation of new solar arrays and other spacecraft subsystem upgrades.

On behalf of the science community, we would like to thank and congratulate NASA and the Discovery crew on an extremely successful repair mission.

The New Science Division: Focus and Objectives

Antonella Nota and Mario Livio nota@stsci.edu, mlivio@stsci.edu

At STScI, astronomers constitute about 25% of the staff. About 115 are AURA, ESA, or CSC astronomers, 23 are postdocs and 11 are graduate students (part of a collaborative agreement with the Department of Physics and Astronomy at JHU). Staff astronomers spend a fraction of their time (50% for AURA/ESA tenure track and tenured astronomers, 80% for AURA parallel track and fixed-term scientists) in work that supports the *HST* observatory, *NGST* development, the Archives, the Office of Public Outreach and the Computing and Engineering Divisions. The remaining fraction of the scientists' time is spent pursuing independent research. Before the recent STScI reorganization, scientists were associated mainly with their functional duties, and from an organizational point of view, they were distributed among the various functional divisions at STScI.

One of the goals of the recent reorganization has been to enhance the scientific environment at STScI, and this has led to the creation of the Science Division, on January 1st, 2000. All scientists at STScI now reside within the Science Division, for the fraction of time they spend pursuing their independent research. For the remaining fraction of "functional" time, they are matrixed from the Science Division into the functional units they support.

The Science Division has three goals. The first is to establish and maintain an atmosphere of scientific excellence at STScI, by providing a "home" to all scientists. The second is to provide the best possible human resources for the fulfillment of the functional requirements of the other STScI Divisions, by assigning tenure- and parallel-track scientists to the various functional duties. Finally, the Science Division is to provide mentoring and career development opportunities to the staff, especially to junior scientists.

The enhancement of the scientific atmosphere will be accomplished by expanding on the current scientific infrastructure and developing a stimulating scientific environment to foster innovation and scientific initiatives. Towards this goal, we have created five Scientific Interest Groups, expanding on the topics of the Journal Clubs already existing at STScI. Each of these (Solar System and Planets, Stars and ISM/IGM, AGN, Starbursts, Galaxies and Cosmology, and Instrumentation) will have a Science Leader who will be responsible for the coordination of the scientific activities, including the organization of workshops and colloquia.

The other prime mandate of the Science Division is to fulfill the functional requirements of the other STScI Divisions, by assigning tenure and parallel track scientists to the functional duties. The Science Division will be responsible for tracking the functional assignments and ensuring the career development of the staff. The Science Division will also coordinate the procedures for renewal, promotion and evaluation of tenure for the staff scientists, in addition to supervising and coordinating the procedures for hiring new scientists.

Third, the Science Division will provide mentoring to the junior scientists and will address career-related issues for the science staff as a whole. Scientific mentoring of the junior staff will be planned through the Science Interest Groups: the Science Leaders will provide the junior scientists with scientific advocacy and opportunities for growth. The Science Division also identified Agenda Groups, representing specific categories from Graduate Students and postdocs to Senior Astronomers. The newly elected representatives of these groups will collect and bring up specific practical career related issues to the attention of the Science Division for fast resolution.

In addition to these new initiatives, the Science Division will carry out all the tasks that have been previously assigned to the Research Program Office. These include the organization of the annual STScI May Symposium, the coordination of the Hubble Fellowship and Institute Fellowship programs, the organization of colloquia, and popular talks. We invite the reader to browse our soon-to-be renovated web pages for future activities and initiatives:

http://www.stsci.edi/isd

STScI Electronic Grants Management System

The Space Telescope Science Institute is pleased to announce the implementation of an electronic web-based grants management system. The System will be used to provide funding for U.S. astronomers associated with General Observer and Archival Research Programs, as well as all other programs administered by STScI.

The main features of the system are the electronic submission of budgets, performance reports, financial reports including payment requests, and all other administrative actions such as no-cost extension and equipment requests. The system will provide electronic notification of grant awards and amendments as well as real-time access to proposal and grant status information.

The system will be implemented in April. The Grants Administration Office will contact the Authorizing Officials (AOs) of each institution to activate institutional accounts. All U.S. Investigators who have an existing grant or are associated with an approved Cycle 9 GO/AR Program will have accounts established in the new system. The AO at each institution will enable all investigator accounts and assign appropriate privileges for various functions within the system.

Cycle 9 General Observers and Archival Researchers are strongly encouraged to submit their budgets via the new electronic system. All accounts for institutions with an approved Cycle 9 U.S. investigator will be activated by Cycle 9. The Cycle 9 budget deadlines for U.S. investigators are as follows:

For electronic submission of budget via the new electronic system: June 1, 2000. For paper submission of budgets via the USPS: May 1, 2000.

Information about the new grants system will be available on our web site in April. If you have any specific questions, please send e-mail to *grantinfo@stsci.edu* or call 410-338-4200.

Multi-Mission Archive at the Space Telescope Science Institute (MAST) News

Paolo Padovani (on behalf of the MAST team) padovani@stsci.edu

Hubble Data Archive Status

The Hubble Data Archive (HDA) contains, as of March 1 2000, 7.3 Tbytes of data. The number of science datasets now totals more than 200,000. Archive ingest has averaged 3.1 Gbytes/day in the past year, while the rate of data retrieval has been about 4 times as large.

Calibrated WFPC2 and STIS data

Because our On-The-Fly-Calibration (OTFC) system has been tested and is working well, we will stop archiving in the near future the calibrated data for WFPC2 and STIS. We will continue to archive the raw data files so users can either retrieve the raw data alone or recalibrate the data with the OTFC system and receive raw and calibrated files. We are also preparing to transfer existing data to new magneto-optical jukeboxes. We will not transfer any of the existing calibrated data from either of these instruments. In order to get calibrated data; users must use the OTFC system. For STIS, calibrated data extensions include FLT, CRJ, SFL, X1D, X2D, SX1 and SX2. For WFPC2, the extensions are C* (COF, C1F, C2F and C3T).

Want a Java Starview demo? Email archive@stsci.edu today!

StarView v6.0 is a Java application for the StarView II archive search interface, which will soon replace StarView. StarView v6.0 will provide all of the essential capabilities of the current version of StarView, and it will be available on any platform that supports Java, including Solaris and Windows. Version 6.0 will also have enhanced capabilities in customizable search forms and a more controlled screen environment. Because of its Java origins, the StarView "look and feel'' is a little different from the current StarView, but the components should be recognizable to our archive users. External testing of the prototype of the release will continue through April and May, with a public downloadable version to be released in June 2000. We are looking for volunteers to demo the prototype. If you are interested, please contact us at *archive@stsci.edu* or *donahue@stsci.edu*.

EUVE Previews

The Extreme Ultraviolet Explorer (EUVE) MAST search script (available at *http://archive/stsci.edu/euve*), which allows users to search the EUVE catalog of observations and download EUVE data from HEASARC, now includes preview images. EUVE 1-D quick-look spectra for most EUVE sources were extracted from the permanent archive 2-D images using the standard EUVE IRAF routines, and written to gif files using IDL plotting routines. Plots include spectra from each spectrometer: the short wavelength spectrometer (SW; 70-190 Å), the medium wavelength spectrometer (MW; 140-380 Å), and the long wavelength spectrometer (LW; 280-760 Å). If there are data from more than one spectrometer, a combined 70-760 Å spectrum is available. Preview spectra are accessible from the result page of the search script, as currently done for IUE and other missions. In addition to the images, users can also download ASCII files of wavelengths and calibrated fluxes, and/or display listings of FITS keywords.

The MAST "Quick Search" Routine

The MAST "quick search" routine performs a search of the MAST archive for a given object based on its name or coordinates. The routine has been recently expanded to search all MAST missions, including some the latest additions: the Berkeley Extreme and Far-UV Spectrometer (BEFS), the Interstellar Medium Absorption Profile Spectrograph (IMAPS), and the Far Ultraviolet Spectroscopic Explorer (FUSE). The result page now includes links to preview spectra and ASCII

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INSTRUMENT NEWS

Fine Guidance Sensors

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HST's current Fine Guidance Sensors are the best we've ever had. Recall that during the Second Servicing Mission (SM2), in March 1997, the original FGS1, which had become mechanically unreliable, was removed from *HST* and replaced by the upgraded spare which we now know as FGS1r. After SM2, the original FGS1 was returned to its manufacturer, Raytheon Optical Systems Inc., and refitted with new star selector shaft bearings to restore its mechanical health. Like FGS1r, it was also fitted with an articulating mirror assembly (AMA). As described in previous issues of this Newsletter, the AMA allows ground controllers to precisely align the FGS with *HST*'s optical axis. This dramatically reduces the degrading effects of *HST*'s spherically aberrated primary mirror on the performance of the FGS interferometers, and that means access to fainter guide stars as well as improved performance as a science instrument.

In the recent Servicing Mission 3a (SM3a), FGS2, which had been showing signs of mechanical deterioration for at least the last 3 years, was finally replaced by the refurbished (original) FGS1. This instrument, redesignated FGS2r since it now resides in bay 2, has been fully commissioned for guiding *HST* beginning in early April. The commissioning process began with the in-flight adjustment of the AMA to optimize FGS2r's interferometric sensitivity. Following this, a 5 orbit long series of observations of stars in an astrometric cluster were made to gather the data needed to calibrate the optical distortions across FGS2r's large field of view. Next, its position relative to FGS1r, FGS3, WFPC2, and STIS was determined from additional observations of astrometric stars. All in all, some 31 orbits of *HST* time have been expended to calibrate and commission FGS2r for guiding the observatory. This is a small price to pay in light of the fact that we expect FGS2r to be called upon to participate as a guider for at least half of *HST*'s ~5800 orbits/year.

From our experience with FGS1r during its first year in orbit, we anticipate appreciable changes to FGS2r's interferograms due to the "desorption" of water from its structures. Accordingly, we plan to monitor the new FGS over the next year or two to verify the continued accuracy of its calibrations and alignment relative to the other FGSs and SIs. If need be, the instrument's AMA can be re-adjusted once the desorption ceases (as was done for FGS1r).

One activity after SM3a activities was an evaluation of the effect, if any, of the servicing mission on FGS1r and FGS3. This was done by comparing baseline data from pre-SM3a observations to that acquired after SM3a. The comparisons have shown that neither the interferograms nor the optical distortions in FGS1r and FGS3 experienced any measurable change. FGS3's potential as a sub-milliarcsec astrometer remains unimpaired, while the FGS1r interferograms continue to be remarkably stable in time. But there has been an impact to the FGS1r science program. We have yet to calibrate FGS1r's optical distortions to the accuracy required for scientific investigations. That test, preempted by the Nov 1999 safing event and the delayed SM3a, had been planned for late Dec, 1999, when *HST* would be in a favorable position to observe the selected star cluster at a variety of spacecraft roll angles. After considering the options, we have deferred the test until December 2000, when *HST*'s roll angle once again becomes unconstrained for the same observations. Meanwhile, we continue to monitor FGS1r's optical distortions to allow for a reliable "back calibration" of science data that has been or will be gathered before then.

Now that *HST* has two FGSs with the AMA, the question emerges as to which, FGS1r or FGS2r, can be expected to offer the best performance as a science instrument. For the time being, FGS1r is clearly the instrument of choice. It has fully stabilized and continues to perform to expectations. Furthermore, its orientation in *HST*'s focal plane is better suited for astrometric measurements of objects at times of maximum parallax factor, an advantage that will always be true. Therefore we expect FGS1r to retain its designation as *HST*'s astrometer for the duration of the mission.

Spectrographs Group

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Following Servicing Mission 3A, STIS returned to normal operations on January 10, 2000. During the Orbital Verification period following the Servicing Mission (SMOV) a number of basic checks were made on the various modes of STIS to ensure that the prolonged safing from November through December of 1999 and the servicing mission itself had not adversely affected the performance of STIS. For the CCD detector system, bias and gain were

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Spectrographs *from page 14*

nominal, but two anomalies were noted. First, the read noise in GAIN 1 was about 10% higher than normal. Also, the number of hot pixels was about 10% higher than expected based on recoveries from prior anneal cycles (during the safing the CCDs were in a warm state analogous to anneal conditions). The latter is probably explained by the cooler temperatures experienced during the zero-gyro safing period, which were 13-14 C colder than during a typical anneal cycle. The read noise started at a value of 4.6 e^- following STIS activation, rose to 4.8 e^- for about 10 days, and then dropped to 4.4 e^- by January 10, where it has remained since. The nominal pre-SM3A value was 4.0 e^-. An anomaly review board with representatives from STScI, the STIS IDT, GSFC, and industry was appointed by John Campbell to investigate the problem, and work is ongoing. No definite cause has yet been identified. The elevated read noise has had little impact on science (typically <5% on expected S/N).

MAMA dark currents are nominal. We note that the NUV-MAMA dark rate started very high (4150 counts per second), but this was almost exactly as expected following the long period at cold temperatures (2 C) during the zero-gyro period. Initial FUV-MAMA G140L spectra acquired on December 30 showed nominal throughput (agreement to within 1.3% with a prior IUE spectrum of a white dwarf) with no evidence for contamination (no loss of UV throughput) of either the instrument or the OTA due to the servicing mission. Contamination monitoring of the other STIS first-order spectroscopic modes also showed no degradation. The largest discrepancy compared to before the servicing mission is a 1.5% difference in G140L; this is less than a 2-sigma difference.

To check the mechanical stability of STIS and its alignment with the FGS system, we obtained images of slits illuminated by the internal tungsten lamp, and we also observed an astrometric star field. Aperture positions in the CCD detector were within 1 pixel of their nominal locations. The STIS-to-FGS alignment was good to within 0.17 arcsec, and the plate scale and orientation were verified to be consistent with currently-quoted values in the Instrument Handbook.

After the *HST* secondary mirror was repositioned to provide better observatory focus, a special series of slit throughput measurements and [O II] filter images were done with STIS to verify the focus of the spectroscopic and imaging modes. After telescope breathing corrections are taken into account, the STIS slit plane is within 1 micron of nominal focus, and it is also within 1 micron of the WFPC2 best-focus position.

For the 12-day bright-earth-avoidance period following Servicing Mission 3A, Paul Goudfrooij of the Spectrographs Group, in collaboration with other STScI scientists, planned a science program using the STIS CCD, to take advantage of time that otherwise would not have been used. In a total of 45 visits, deep images were obtained of the regions surrounding two radio galaxies, two nearby irregular galaxies (reaching ~1 magnitude beyond the tip of the red giant branch), and two interacting galaxies (reaching the turn-over absolute magnitude of globular cluster systems). A moderate-depth slitless G750L spectrum of objects in a selected region of the Hubble Deep Field North was also obtained. All data from these observations are publicly available in the archive under program ID 8530, and all interested observers are encouraged to delve into this unique data set.

WFPC2

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WFPC2 continues to perform effectively after seven years on-orbit. Charge Transfer Efficiency (CTE) issues are an on-going concern, but at this point they primarily impact a small segment of the science program with faint targets observed in UV and narrow band filters; correction algorithms have recently been published (see below). Recent activities include re-commissioning and check-out following the December service mission, a CTE workshop held at STScI, transition to the archive's On-the-Fly-Calibration system, and development of the Cycle 9 observing program.

Numerous tests were performed on WFPC2 following the December 1999 *HST* servicing mission. While WFPC2 itself was not serviced, there is always concern about contamination or other unexpected effects. We are happy to report there were no significant impacts on WFPC2 performance. As expected, we did see a temporary increase in the rate at which molecular contaminants collect on the cold CCD windows. This primarily affects the far-UV throughput, but is a temporary effect, and the contamination is rapidly dissipating. Prior to servicing, contamination for the PC1 CCD (for example) grew at a rate giving a throughput loss of 0.45% per day in the F170W filter. After the service mission higher rates were seen: growth rates in PC1 were 1.38% loss per day for Jan. 3 - 17;

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INSTRUMENT NEWS

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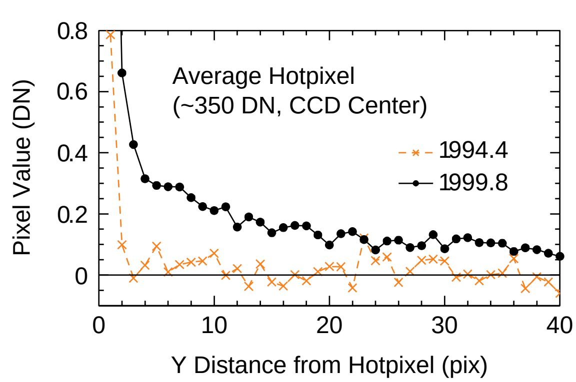
0.97% loss per day for Jan. 17 - 31; and 0.53% loss per day for Feb. 1 - 25. As can be seen, the growth rate has nearly returned to the normal value two months after the service mission. Similar results were seen for the other CCDs. Most importantly, there is no evidence of any permanent contamination; the decontaminations (heatings) of the CCD windows on January 3, 17, 31, and February 25 were all able to restore the far-UV throughput to 100% of its pre-servicing value.

Many other tests were also performed following the service mission. Separate tests were made on the UV throughput at the shortest wavelengths (F122M and F160BW filters); again no permanent changes were seen. A sweep through the entire WFPC2 spectral range (filters F160BW, F170W, F185W, F218W, F255W, F300W, F336W, F439W, F555W, F675W, and F814W) showed no throughput change to about 1% accuracy in the visible, and a few percent accuracy in the UV. In addition, there were no changes seen in the read noise, dark current, a-to-d converter gains, flat fields, point spread function, or other parameters. A report detailing these tests and results will be posted on the WFPC2 WWW site (Casertano, et al. 2000).

STScI hosted a workshop on CCD Charge Transfer Efficiency (CTE) issues in January, and a number of interesting results were presented related to WFPC2. There is now considerable evidence that the loss of counts seen in stellar photometry is caused by trapping and release of electrons during the readout process. This causes images at high Y (and X) pixel locations (i.e., those with more transfers) to appear fainter than those at low pixel locations, especially for faint images in situations with low background counts. Studies have been made using both cosmic rays and hot pixels as probes of charge trapping, and both methods show significant “tails” on images which are caused by



trapping and release of charge on time scales of tens to hundreds of milliseconds during the readout process. Figure 1 illustrates the Y-tail on a single ~350 DN pixel at the center of a CCD both during the first year of operation (1994) and near the current epoch. These tails can contain a significant fraction of the total charge for an image; these counts will be missed by typical stellar photometry performed with small apertures. It is also clear that the effect of these traps has dramatically increased with time since WFPC2 was placed on-orbit, due to on-going radiation damage to the CCD arrays. We emphasize that the photometric effect for typical scenarios (long exposures in broad filters, target at CCD center) remains small (5 to 10%), and that correction algorithms are available (e.g., Whitmore, Heyer, and Casertano 1999, PASP 111, 1559). Additional information and papers from the CTE workshop are available under the “advisories” section of the WFPC2 home page.

We remind observers that the new On-the-fly-calibration system (OTFC) has been operating for some time, and that soon it will be the only source of calibrated WFPC2 data from the *HST* archive. OTFC offers a huge time savings to observers, since it is no longer necessary to manually re-calibrate science data to receive full advantage of updated calibration files and software improvements. We have extensively tested the new system on ~900 WFPC2 images. Some of these were selected to provide a representative sample of nearly all WFPC2 image types, modes, and filters, while other images were selected randomly from new observations taken each day. The test images were calibrated by hand using the best available reference files, and automatically through the new OTFC system and in all cases the results were identical. We plan to continue monitoring OTFC with periodic checks to ensure optimal results.

Preparations for the Cycle 9 GO observing program are well underway. In most aspects Cycle 9 preparations will be identical to previous Cycles, with a few minor changes. Unlike previous Cycles, we will automatically assign a contact scientist at STScI only for large or difficult proposals, though one can still be requested. So far there have been very few requests for a contact scientist, which is consistent with our expectations, given the experienced WFPC2 user community. We will still perform a brief inspection of all GO phase 2 proposals to check for common and obvious errors. Advice given to observers has been similar to past

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Cycles, though we are now suggesting that programs with small targets requiring high photometric accuracy (~1%) might consider target placements closer to the readout register (lower CCD Y positions) to reduce CTE effects. We are currently assembling the Cycle 9 calibration program, and we welcome input from observers with any special concerns.

Near-Infrared Camera and Multi-Object Spectrometer (NICMOS)

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A Brief History of the Instrument

NICMOS, the Near-Infrared Camera and Multi-Object Spectrometer, will be re-activated with an active cooling system (the NCS) during the servicing mission SM3B, currently scheduled for mid-2001. In order to clarify the changes in the instrument's performance as a consequence of the new cooling method, a brief history of the Instrument is presented here.

During its first operational period, which lasted from February 1997 (date of installation on *HST*) to January 1999, NICMOS was passively cooled by sublimating N2 ice. Science observations were obtained from the beginning of June 1997 until mid-November 1998, during which period the cryogen kept the detectors' temperature around 60 K, with a slow upward trend, from 59.5 K to ~62 K, as the N2 was sublimating. On January 3, 1999, the cryogen was completely exhausted, marking the end of NICMOS operations under this cooling regime. NICMOS offers infrared capabilities in three cameras, NIC1, NIC2, and NIC3. The three cameras have different magnification factors, with Field of Views of 11"x11", 19.4"x19.4", and 51.2"x51.2", and pixel sizes of 0.043", 0.076", and 0.20", respectively. The three cameras had been built to be parfocal and to operate simultaneously.

A few months before launch, however, the NICMOS dewar underwent thermal stresses which made the three cameras no longer parfocal (although they still retain the capability to operate simultaneously). Even worse, shortly after installation on *HST* the NICMOS dewar developed a thermal short that had two consequences: 1. It pushed the NIC3 focus outside the range of the Pupil Alignment Mechanism (PAM); 2. It created a "heat sink", which caused the nitrogen ice to sublimate at a quicker pace, thus shortening the lifetime of the instrument (from the expected 4 to 5 years down to about 2 years). A couple of months after the start of the short, the instrument stabilized at the operating configuration which remained during the duration of its cryogenic lifetime: NIC1 and NIC2 in focus and practically parfocal, and NIC3 out of focus relative to the other two cameras and with its best focus slightly outside the PAM range. During Cycle 7 and Cycle 7N, two observing campaigns, one in January 1998 and the other in June 1998, were organized to obtain in-focus NIC3 observations by moving the *HST* secondary mirror.

After the end of NICMOS science operations, the warm-up of the instrument was monitored up to a temperature of ~100 K, with the goal of estimating performance in the operating temperature range of the NCS (see next section). The monitoring was performed via daily collection of multiple dark and flat-field data, and bi-weekly measurements of the Cameras' focus (see the January 1999 STScI Newsletter). Analysis of the data yielded the predictions on the performance described below, but also unveiled a 'dark current anomaly' (see the June 1999 STScI Newsletter). In the temperature range ~75-85 K the dark current strongly deviated from the expected exponential profile by showing a transient enhancement (a 'bump') centered around 82 K. The physical nature of the bump is still largely unexplained. The most plausible theory, i.e. that the bump was caused by electrons trapped in low-energy states within the detector material, could not be confirmed by laboratory tests. Thus, whether the bump will or will not be present when NICMOS is cooled down by the NCS is unknown at the time of this writing.

The Future

After installation of the NCS on-board *HST* during SM3B, NICMOS detectors are expected to operate at a temperature in the range 72-77 K. The different operating temperature implies a number of changes in the detector's performance for Cycle 10 and beyond. We summarize here those aspects that are expected to change and those that are not.

- The dark current is expected to increase from <0.05 e^-/s to ~1.0 e^-/s (if the 'bump' is present) or to ~0.4 e^-/s (if the 'bump' is not present). The longest exposures at wavelengths below ~1.7 micron will be slightly affected by the increased dark current.

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- The DQE is expected to increase by ~40-45% at 1 micron, ~30-35% at 1.6 micron, and ~20-25% at 2 micron.
- The read-out noise is not expected to change and will still be ~30 e^-.
- The filters, which are viewed by the entire wavelength response of the detectors, are expected to be cooled to less than 160 K. This is closer to their original design temperature than the ~100 K they were cooled at during Cycle 7 and 7N (because of the thermal short). Therefore, the filters will still be cold enough for their background to remain undetectable.
- The dewar deformation that resulted in the thermal short was most likely plastic. The expectation is that under NCS cooling the NICMOS optical configuration will be the same as in Cycle 7 and 7N: NIC1/NIC2 close to being parfocal and in focus, NIC3 non-parfocal with the other two cameras. For NIC3, the optimal focus will be slightly out of the PAM range, but still usable with the best achievable focus.
- Image quality is expected to be equivalent to that obtained during Cycle 7N.

Advanced Camera for Surveys

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The Advanced Camera for Surveys is to be installed in *HST* during Servicing Mission 3B (SM3B), currently scheduled for launch in June 2001. ACS is designed to replace WFPC2 as the primary imaging instrument on *HST* and will be installed in the axial bay location currently occupied by the FOC. ACS will be available to the GO community for the first time in Cycle 10. Information in support of the Call for Proposals can be found at the STScI web site, and includes an Instrument Handbook which summarizes our current understanding of the instrument's performance, and an exposure time calculator for ACS. STScI has been preparing for ACS science operations and already has the baseline pipeline, CALACS, in place and tested. The core commanding for ACS is also in place and development work is currently focused primarily on operations with the Aft Shroud Cooling System (ASCS), which will provide cooling of the ACS and STIS detector systems via an external radiator panel which will be mounted on *HST* during SM3b.

The ACS features three cameras designed for wide field, high resolution and solar blind, FUV imaging. The Wide Field Channel (WFC) comprises a 4096 × 4096 CCD mosaic, optimized for near-IR imaging, and a three mirror optical chain with silver coated mirrors. The High Resolution Channel (HRC) has a 1024 × 1024 CCD optimized for high near-UV quantum efficiency and a three mirror optical chain with MgF_2 /Al coated mirrors. The WFC and HRC share two filter wheels. The Solar Blind Channel (SBC) employs a STIS flight spare FUV MAMA detector and shares two mirrors in its optical chain with the HRC. Specific details of these channels are summarized below in Table 1. The HRC channel also offers an aberrated beam coronographic capability which is implemented as a component of the HRC. The coronograph comprises a focal plane mask, with spots of diameter 1.8" and 3", and a Lyot stop. It is expected to provide a factor of 10 suppression of the point spread function at distances >2.5" from the center of the occulted object. The primary design goal for the WFC is to achieve a factor of 10 improvement in discovery efficiency compared to WFPC2, defined as the product of field of view and total throughput at 800 nm.

ACS is currently undergoing integration at Ball Aerospace and is due to be delivered to GSFC in Summer 2000 for final testing and ground calibration of the instrument. It is anticipated that the instrument will be delivered to the Kennedy Space Flight Center for launch around March 2001.

ACS Camera Specifications

Camera	*WFC*	*HRC*	*SBC*
Field of view	*202" x 202"*	*29" x 26"*	*35" x 31"*
Plate scale	*0.05"/pixel*	*0.027"/pixel*	*0.032"/pixel*
Spectral response	*380 nm - 1100nm*	*200 nm - 1100 nm*	*115 - 170 nm*

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files of wavelengths and fluxes for the International Ultraviolet Explorer (IUE), the Hopkins Ultraviolet Telescope (HUT), the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), BEFS, and EUVE. The "quick search" page is available at *http://archive.stsci.edu/quick_search.html*. To use, just enter a SIMBAD-friendly target name or the target coordinates as RA and Dec. The search results page will show up to 10 entries for each mission having observations of the requested target, with a link to each mission search script for displaying additional entries.

The MAST Prepared Datasets

MAST provides access to a set of highly processed datasets from missions supported by MAST at *http://archive.stsci.edu/prep_ds.html*. These datasets have undergone special processing by their authors and are likely to have interest for several purposes such as spectral atlases obtained from GHRS and IUE data. In all cases these data are provided both as ASCII tables and as figures. The latest additions include: (1) a nearly continuous time series of spectra in the wavelength region including the Si IV 1394, 1403 Å doublet for the B0.5e star γ Cas over nearly 22 hours and (2) an IUE atlas of stellar spectra by Wu, Mo, and Crenshaw. The gamma Cas data were obtained through the GHRS Large Science Aperture and with the G160M grating and read down in rapid mode. Thus, the spectra may be co-binned in wavelength in order to construct a light curve (so-called "GIMP" artifacts have been removed). The data are a unique time series on a hot star for the GHRS. The Wu et al. atlas comprises low dispersion spectra of 476 "normal" stars and 38 subdwarf and white dwarf stars reduced through NEWSIPS processing. We now have quite a complement of digitized UV atlases of bright stars, and these can be used for a variety of purposes.

We invite you to take a look!

Calendar

Cycle 10

Call for Proposals issued	*June, 2000 (tentative)*
Phase I proposals due	*September 8, 2000 (firm)*
Proposers notified	*December, 2000 (tentative)*
Phase II Proposals Due	*February, 2001 (tentative)*
Routine Observing Begins	*July, 2001 (tentative)*

The Institute recently reorganized in order to be better prepared for the development and support of NGST. To learn more about how we are structured and about some of the people here, take a look at our annual report: http://sco.stsci.edu/annual_reports/

ST-ECF Newsletter

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

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How to contact us:

First, we recommend trying our Web site: *http://www.stsci.edu* You will find there further information on many of the topics mentioned in this issue.

Second, if you need assistance on any matter send e-mail to *help@stsci.edu* or call 800-544-8125. International callers may use 1-410-338-1082.

Third, the following address is for the *HST* Data Archive:
archive@stsci.edu

Fourth, if you are a current *HST* user you may wish to address questions to your Program Coordinator or Contact Scientist; their names are given in the letter of notification you received from the Director, or they may be found on the Presto Web page *http://presto.stsci.edu/public/propinfo.html*.

Finally, you may wish to communicate with members of the Space Telescope Users Committee (STUC). They are:

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