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NEWSLETTER

Space Telescope Science Institute

Winter 2003

An artist's concept of a gas giant planet orbiting the cool, red dwarf star Gliese 876. *Illustration Credit:* NASA and G. Bacon, STScI. (See page 24.)

Interview: Bill Workman & Ian Jordan

Bill Workman, *workman@stsci.edu,* and **Ian Jordan,** *jordan@stsci.edu*

Bill and Ian, you are working on the Hubble long-range observing plan (LRP). Please explain the role of the LRP in Hubble operations and the work that creating it entails.

BILL: Well, it's not clear we can describe what we do in less than 'Hubble Time', but we'll try!

BILL & IAN: Primarily the Long Range Planning Group (LRPG) and the LRP exist to help the Institute and user community maximize the science output of the Hubble Space Telescope (HST). Observers see the LRP as a set of plan windows that represent times when a particular set of exposures are likely to be observed by the telescope, similar to scheduling observing runs at a ground-based observatory. Rather than getting a specific night, however, most HST observations are assigned a 5-8 week window of opportunity. The assignment of these windows prior to the start of the observing cycle allows observers to plan ahead in anticipation of data receipt, and Program Coordinators (PCs) and Instrument Scientists plan their individual workloads to prepare observations for execution.

On the other hand, we (LRPG) use the LRP as a tool to visualize how well we are using HST and to provide candidates to the Short Term Schedulers for building the weekly flight schedules. We use a toolset comprised of the SPIKE planning software and a multitude of user scripts to build, evaluate, and maintain the LRP. These tools help us see when a visit can be observed by HST, based on its physical constraints, such as target viewing and Sun and Moon avoidance. We also have to worry about how HST orbit and data-volume resources are being consumed. If you are a user of HST, you've no doubt heard of the South Atlantic Anomaly (SAA), which basically defines the two main types of orbit resources we must consider: SAA-impacted and SAA-free. Also, because visits come in all shapes and sizes, we have to worry about fitting the right combination of pieces in each resource. The bottom line is that our job is to match the user's requested observing (constraint) window with available telescope orbit resources. Since we don't actually schedule the telescope, the task is—by definition—statistical in nature. Like any good science project, the 'fun' part is dealing with the uncertainties in the system. In this case, this means predicting HST behavior and what the whole General Observer (GO) observing program will look like for the cycle.

How do you know when you are done with the LRP?

IAN: Well, the long range plan is never done! Perhaps the LRP logo should be a yin-yang symbol?

BILL: That's because we continuously operate in one of two modes: the HST plan build mode and the maintenance mode. The build mode occurs prior to the start of each observing cycle when the Phase II proposals are ingested and processed in bulk by the PCs. Their work provides the inputs necessary for SPIKE (our major planning software component) to do its thing. We run SPIKE in a sequence of steps designed to assign plan windows that satisfy the individual science requirements within the available orbit and data-volume resources. It takes several iterations to make sure the visits are distributed in a way that maximizes the productivity of the telescope.

IAN: Yet, when we published the Cycle 11 component of the LRP on April Fools' Day this year, it appeared barely half full. Or was it half empty? But now—listen up, observers—it's full!

BILL: We spend the rest of the year maintaining the LRP, due to impacts from instrument and spacecraft anomalies, and the 15 to 25% of activities that are not available during the build process, such as Targets of Opportunity, Director's Discretionary time, and other GO visits that cannot be planned far in advance.

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Hidden Treasure

Steven Beckwith, *swvb@stsci.edu*

Ideas are the motive force that keeps us in the business of science. They are individual moments of revelation, created by one mind and experienced by one person. We are taught that they *belong* to the creative individual. All the heroes of science are admired for the impact of their own ideas, often with little recognition of the many contributing advances creating a context for those ideas.

It was against this backdrop that we hosted the Hubble Treasury Program Workshop in November. The workshop concept was that scientists would come together and discuss their ideas for large programs with the Hubble Space Telescope, sharing their thoughts, discussing the practical details, and creating teams to write proposals for large projects. More than a few of our users were skeptical of this notion that proposals—*ideas,* after all—could thrive in the communal atmosphere of such a gathering. The relatively low attendance of only 70 users reflected this skepticism, as did the large number of people who declined invitations to speak, to share their ideas for the stated purpose of spawning teams.

We sponsored the workshop because the largest programs have had disproportionately more scientific impact than the smaller ones per orbit of telescope time. The primary strategic objective of the Space Telescope Science Institute is to maximize the scientific impact of our missions, mainly Hubble at the current time. We were willing to challenge the prevailing sentiment that committees cannot create good programs even if they hope to germinate truly great ideas.

Although we can not know how successful the workshop was until proposals have been submitted and ranked, we did see seeds of creation come forth from this workshop. A few people, stimulated no doubt by a number of insightful talks, started to discuss teaming arrangements for proposing ideas that, indeed, seemed inspired by the need to think big about Hubble programs. During lunchtimes, at dinner, and through a number of informal conversations I had with participants, scientists were excited about areas where Hubble could make a big impact that had been overlooked. Perhaps the daunting time requirements discourage people from thinking big until they have the support of their peers. It seemed to me that the workshop fulfilled its purpose by bringing together talented people expressly to consider what they could do with a lot of telescope time.

Cosmology, the study of distant young galaxies, and the study of nearby galaxies seemed to get the most attention. Planetary astronomers decided there was insufficient interest to justify even one splinter session to think about large proposals for solar system studies. The interstellar medium crowd had a number of interesting ideas, but they also had angst about whether people who studied astronomical *objects* would find their ideas interesting enough to recommend telescope time. At the end of the three-day workshop, almost every participant I encountered felt it had been worthwhile and wished that more people could attend and share in the collective experience.

The Treasury Workshop stimulated much of the discussion that the Second Decade committee envisioned in its recommendation several years ago. The only apparent flaw in its execution was the failure to attract more people to think about what best to do with a few hundred or even a few thousand orbits of time on the Hubble Space Telescope. We will sponsor this workshop again next year. I encourage you to attend. If you did not attend for practical reasons—perhaps you could not leave the classroom mid-semester—please send me an e-mail so that we can minimize the logistical barriers that kept you away. You are the key to keeping Hubble at the forefront of science. Ω

IAN: Beyond those factors, the mere scheduling of observations on flight calendars changes the landscape in the LRP, because we don't know up front exactly where an observation will schedule within the tolerance of its timing links.

BILL: Any of these can cause disruptions in our otherwise optimum LRP. That's when we hear from our LRP users!

Speaking of disruptions, what were the special challenges of implementing the Hubble Treasury and other large observing programs in Cycle 11? What innovations have you made to accommodate them? Do these improvements have other applications?

IAN: Perhaps the most significant challenge is dealing with Murphy's Law—it is remarkable how these programs all wanted to congregate in the fall and winter months! 'Time' is supposed to be Nature's way of keeping everything from happening at once, but that doesn't seem to be the way the universe treats HST.

BILL: Since we did not have the complete set of large and Treasury programs available during the build phase of the LRP for Cycle 11, we needed to estimate much of their resource requirements during the planning process. Despite meetings with the observing teams prior to the LRP build phase, our initial estimates were just not adequate. Without actual visit descriptions in hand, it is difficult to determine the duration of the constraint windows (target-viewing times of year) for all of the requested observing time (orbits).

When all the activity descriptions did become available, we found that there was a great deal of overlap in the times during which the programs wanted to execute—rather than their being distributed uniformly throughout the cycle. The resultant pile of the large, Treasury, and time-restricted GO activities in the fall and early winter led to what has been dubbed 'The Great Train Wreck' period (Halloween to Valentines Day). When there are so many activities that want the same time of year, even being off only a day or two in your resource prediction has a huge effect on the LRP. By the way, we have to give credit to Alison Vick for that apropos phrase. She is our resident Cycle 11 Large and Treasury planning expert, and she has done a great job keeping on top of this unique planning challenge.

IAN: The planning team extends beyond just Bill and myself. Alison, Tricia Royle, and Beth Periello have played particularly important roles in recent years by combing through the plan looking for weaknesses, reviewing the assumptions made in building the plans, and facilitating inter-observatory coordination. Nearly everyone in Hubble Operations contributes to planning in some fashion.

You are somewhat famous as a team for your complementary styles and inventive approaches. How do you interact, plan your work together, and operate as a team? Do you have any lessons about collaborative work that others might learn from your experiences?

IAN: Famous or infamous? Seriously though, when you work with people who clearly have in their mind that the ultimate goal is to get the job done and who like what they are doing, most of the associated problems seem to fall into place like the remaining pieces in a nearly completed puzzle. Wayne Kinzel was the LRP group's manager when I joined it five years ago. He created a very positive atmosphere that encouraged us to throw our efforts at problems and involve ourselves at least peripherally in those at which we were not experts. Denise Taylor helped keep the same atmosphere when Wayne moved on to the James Webb Space Telescope (JWST). If I had to pick one single lesson, I would say that a bottom-up management approach works best in a branch like ours.

Figure 1: *Ian Jordan, the eternal optimist and Bill Workman, the eternal pessimist?*

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Interview from page 3

BILL: Ian is too modest! It's hard to put Ian and my styles into words. He is absolutely correct about the management styles that have shaped the tenor of the LRPG over the years. We've both tried to continue that fostering of the continuous process improvement mentality in the group. It's our individual interpretations of what that means that makes us a unique pair! I think Ian will agree that he is the eternal skeptic while I am the eternal optimist! I guess between the two of us, we are the eternal pragmatist! Ian and I have individual unique ways of viewing the LRP problem and communicating our ideas to each other and the rest of the team. One of us will come up with a great idea one day and then spend the next two years convincing the other that it needs to be implemented! Then one day the idea man will present the case in a slightly different way, and flash, the light bulb comes on in the other person's mind! It's not really that extreme, but we each see different aspects of an actual problem. Because of that, it's kind of like we are thinking to ourselves, "Since the problem and solution are so obvious to me, then of course you know what I mean!" So it can take awhile for us to articulate our views to the other person. However, once we do, watch out! The bottom line is that we complement each other extremely well. I just didn't realize we had become famous for it!

IAN: Infamous! But Bill has one thing wrong—I'm not a skeptic, just a realist!

BILL: I guess if there's any lesson to be learned it's that you as an individual don't necessarily have the whole (or even the right) answer all the time. If the LRPG is successful as a team, and I think it is, it's because we make every effort to allow each member to share and discuss their ideas about a problem and its solution. The final problem definition and solution will always be better because it is the culmination of multiple perspectives and a lot of hard work.

Bill, last year you finished building a house for yourself, your wife, and five children. What did this entail? Do you have another major home project in mind?

I began thinking about building when my wife Maria and I started talking seriously about getting a new house about five years ago. I'm a country boy at heart, so I wasn't interested in a new home in a subdivision. I was interested in making our next house as unique as possible given our limited budget. So we started looking into buying a building lot with dark skies (as dark as you can get near Baltimore!) near our current home. After a year-long search we finally settled on a lot and then waited another two years while we saved up money for construction. The decision to be my own project manager was partly financial and partly for the challenge. I was able to save a great deal in overhead costs by managing the project myself. Of course we spent that on upgrades! The project management itself was fairly straightforward. It probably helped that my previous house was an old fixer-upper, so I had some experience taking bids and working with subcontractors; just not on such a large scale. The hardest part was keeping everyone on schedule, including myself since I was my own sub on much of the interior finish work. The job took about six months from ground breaking to occupancy. This was on par with the subdivision builders, but much faster than custom builders can do. That's because the house itself is a modular (not to be confused with 'manufactured') built in a factory. They trucked it up as four 'boxes' from Front Royal, Virginia, and lifted the sections into position with a crane. That was amazing to witness!

The new house really is a work in progress even after a year of living there. So our 'next' project is really a continuation of what we started five years ago. We still need a garage, a front porch, landscaping, and we need to finish the master bath. By then it will be time to redecorate!

Ian, you are an avid amateur astronomer. What are your involvements with other amateurs, and what are your particular observing interests.

Astronomy is inherited—my mom was an avid amateur, who lectured at a planetarium on occasion. I guess I've managed to turn a hobby into a profession: two years at the United States Naval Observatory in DC and then a transfer to Black Birch Astrometric Observatory in New Zealand for five years. I did a six-month stint working for the Planetary Data System, archiving various comet data at the University of Maryland before coming to the Institute. My wife Linda has actually been the more active amateur and was a photometric variable star observer for the Canterbury Astronomical Society in New Zealand. (We met through a mutual double star observer/friend). Since the birth of our two sons, astronomy has taken a back seat, but we're hoping for a change as they grow older. Linda has already sketched out plans for a backyard observatory, with room for an aperture larger than I can afford!

Spacecraft and space travel are my passion. Apollo still burns in my brain, yet I was only ten when the last human walked on the Moon. I have had the good fortune to have colleagues and managers who have indulged and cultivated those interests, and I have worked on feasibility studies as well as mission and vehicle architectures for potential space astronomy missions. Perhaps some of the Newsletter's readers even have magnets on their fridges or in their offices from a project I've been associated with!

Looking forward, how will long-range planning be different in the era of JWST?

IAN: Without the SAA and low-Earth occultation to contend with, JWST planning will be simpler, since much of HST's planning activities revolve around accommodating these orbital banes. But circling about the Lagrange Point L2 with a telescope nominally designed without moving parts has new challenges, such as managing schedule changes to cope with solar particle events and finding optimum ways to ensure that individual science programs coexist compatibly with spacecraft activities as well as with all other science programs—and in a wavelength regime different than HST's.

But I think the single most significant challenge will be one that can't yet be defined. It has been encountered with HST, though it is perhaps more evident in the successive encounters by the Voyager spacecraft missions: science capabilities may very well expand as mission software evolves and as the true capabilities of the observatory become realized. HST has seen successive instrument upgrades after launch, which JWST will not experience, yet the science desired from a spacecraft can evolve as more and more data comes down. JWST management and investigators will drive the program in new directions to maximize the amount and expand the kind of science that can be achieved through onboard software improvements. It may or may not be possible to anticipate some of these advancements, but we must be on guard not to make operational decisions that would preclude expanded capabilities.

BILL: Also, operationally, people will no longer build the detailed flight schedules, mission specification, and command loads that are required for HST. Flight schedules will become ordered lists of observations and high-level activity descriptions. This 'scheduling' function will be merged into a LRP/scheduling system that will feed the onboard scheduler directly. Beyond that, many of the same LRP maintenance issues that we have today will continue to exist. It's just that the same person will be doing the long range planning and what we think of today as short term scheduling. And while that person may not communicate directly with the spacecraft, they will get more immediate feedback from it that they will need to respond to.

Any final thoughts?

BILL: I just wanted to add that I continue to be amazed when I take time to reflect on where I am today. I certainly try not to take for granted that I actually get paid by my fellow taxpayers to help support the great work of the Hubble Space Telescope. I also try not to take for granted all of my talented coworkers here at the Institute who make me look good! And who would have ever thought that a good ol' country boy like me from Pennsylvania would ever get to work with a good ol' country boy from Missouri on the Hubble Space Telescope—and that we'd actually become famous for it! Is America great or what?!!

IAN: Infamous! I can't think of anything to add to that! Ω

Riccardo Giacconi Wins Nobel Prize

Riccardo Giacconi receiving the 2002 Nobel Prize in Physics from the King of Sweden on December 10 in Stockholm. Riccardo, the first Director of the Space Telescope Science Institute, received the prize in recognition of his pioneering of the field of X-ray astronomy, discovering compact, variable, X-ray sources including black holes, and leading the development of the current generation of imaging X-ray telescopes. Ω

Photo courtesy of Ethan J. Schreier.

Community Missions Office

Melissa McGrath, *mcgrath@stsci.edu*

The Institute recently created a Community Missions Office (CMO), which has two major purposes. The first is to oversee our involvement in several smaller missions and projects such as the Far Ultraviolet Spectroscopic Explorer, Kepler, National Virtual Observatory, and the Multimission Archive at Space Telescope (Mast). The second is to facilitate Institute support of future community missions with the unique products and services developed over the years to support the Hubble mission. Our strength is direct science staff involvement in mission support, with our primary goal being to maximize the science return of the mission. Software products that may be useful we currently offer to the community for mission support include our planning and scheduling software (SPIKE)—currently used by nine telescopes and observatories, data processing pipeline software (OPUS), data archive services (MAST), and our grants management system (STGMS).

Institute community-mission support has many potential benefits to both the astronomical community and NASA. We can save considerable mission-development expense by reuse of existing software and expertise. Our support can mitigate risk because of the extensive testing and use our systems have already undergone. Use of common interfaces—for example, for accessing an archive or grants management system—provides convenience and saves time for users, who have one less new system to learn. Reuse of existing Hubble systems can free up creative energy for unique innovations on proven systems or for development in other areas.

If you would like to learn more about our support available for community missions, please contact Melissa McGrath (410-338-4545) or Carol Christian (410-338-4764), send email to our office at **cmo@stsci.edu**, or visit **http://www.stsci.edu/resources/software_hardware**. Ω

The Challenge of the Large and Treasury Programs in Cycle 11

David Soderblom, *drs@stsci.edu*

The Hubble Second Decade committee showed that large programs produce more published science per orbit expended. For this reason, they recommended that the proposal selection process favor large programs, defined as 100 orbits or more. (**http://sso.stsci.edu/second_decade/recommendations/index.html**) The committee also pointed out the particular usefulness of large programs that produce high-quality, 'science-ready' datasets for studies beyond the immediate science goals of the observations.

Guided by the Institute director, the Telescope Allocation Committee (TAC) selected Large and Treasury programs comprising nearly 40% of the total time awarded in Cycle 11. The TAC also increased the number of Target of Opportunity observations by more than 50%. These shifts in the mix of Hubble program sizes and types—documented in Tables 1 and 2—caused considerable changes in the scheduling environment for Hubble.

The first step in Hubble scheduling is the Long Range Plan (LRP), which shows when observations with restricted timing must be scheduled. (See the Interview.) Figure 1 depicts the LRP mix of such observations through summer 2003. Figure 2 shows a closer look at a three-month period of the LRP. An observation appears in the first week it can properly execute, so some of the peaks get smoothed into subsequent weeks. Since we can schedule only about 80 to 90 orbits per week, it is obvious that the Large, Treasury, and observations with constraints demand virtually every available orbit from early November through mid-February, leaving little reserve capacity.

Table 1. The % Breakdown of Hubble Programs by Size and Type

Cycle	1-8	9	10	11
Small (1-30 orbits)	76	50	45	44
Medium (31-99)	19	35	44	18
Large (100+)	4	15	10	38
ToOs (orbits)	289	288	436	

Despite these pressures, we are trying to expedite Hubble scheduling in several ways. We are trying to reduce the number of observations in a cycle that take place after the nominal cycle time period is past. Some carryover is inevitable, of course, like failed observations with constraints forcing them to execute a full 12 months later. We have recently wrapped up Cycles 7 and 8, and we expect to finish Cycle 9 by spring 2003. Then we will have only observations from two cycles executing at once, which has not occurred for a number of years. Ω

Table 2. Large Hubble Programs Over the Last Decade

Cycle	Orbits	PI	Subject
5	100	Mould	Extragalactic distance scale
5	150	Williams	Hubble Deep Field
6	150	Mould	Extragalactic distance scale
7	166	Williams	HDF South
8	120	Gilliland	Planets in 47 Tuc
9	105	Schmidt	Testing the accelerating universe
9	123	Richer	White dwarf cooling sequence in M4
9	157	Kulkarni	GRBs
9	112	Lamy	Origin of short-period comets
10	100	Perlmutter	Type Ia SN at high redshift
10	115	Schmidt	Type Ia SN at high redshift
10	116	Tripp	Survey for missing baryons
11	134	Riess	Deceleration test with high-z SN
11	118	Rao	Survey for damped Ly-alpha lines
11	100	Cote	ACS Virgo cluster survey
11	145	Fruchter	Origins of GRBs
11	398	Giavalisco	GOODS
11	116	Bernstein	KBOs
11	126	Brown	Andromeda halo
11	125	Rix	Evolution of galaxy structure

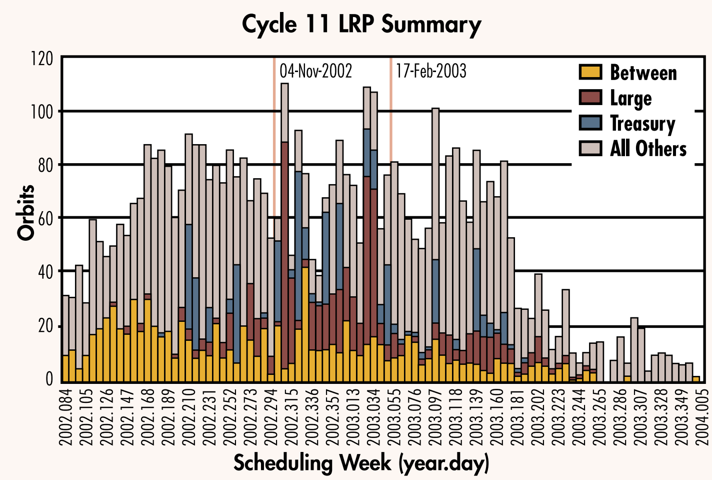

Figure 1: *Mix of programs from the Cycle 11 Long Range Plan. Large and Treasury programs are red and blue, respectively. The cream-colored 'between' observations must schedule between two dates specified by the observer. In many cases, the 'all others' group includes observations with orientation restrictions that are, in effect, timing constraints.*

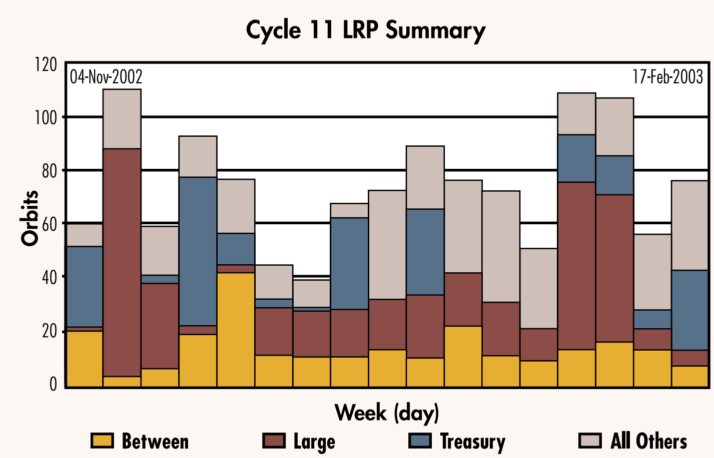

Figure 2: *Close-up look at the Long Range Plan from early November through mid-February. It is fully booked by Large, Treasury, and programs with scheduling constraints.*

STIS Update

Paul Goudfrooij , *goudfroo@stsci.edu*

The Space Telescope Imaging Spectrograph (STIS) has continued to perform very well since it resumed operations using its backup 'side-2' electronics in July 2001. Hubble Servicing Mission 3B had no noticeable negative effect on STIS performance.

During 2002, the Institute implemented three significant enhancements to the STIS calibration pipeline. The first is a new dark-current correction for CCD observations based on the CCD housing temperature, which shows a strong correlation with the dark current. (As explained in the fall 2001 Newsletter, the CCD temperature itself is not monitored on side 2.) We have used the new correction in the STIS On-The-Fly Recalibration (OTFR) pipeline since January 7, 2002. We updated the 'daydark' task in the STIS package for side-2 use in version 3.0 of Space Telescope Science Data Analysis Software (STSDAS), which was released on August 7, 2002.

The second STIS pipeline enhancement is a correction for time dependence in the flux calibration of the Multi-Anode Microchannel Array (MAMA) data. Because contaminants accumulate on the optical surfaces, the sensitivity of the MAMA observing modes degrade with time in a manner that is dependent on wavelength. The flux calibration module in the STIS OTFR pipeline for the MAMA first-order spectroscopic modes has incorporated this correction since September 5, 2002. We will implement the correction for MAMA imaging modes in the next version of the pipeline. Meanwhile, the Exposure Time Calculators on the web already take the time-dependent sensitivity into account in the sense that calculated exposure times or signal-to-noise ratios for MAMA first-order and imaging modes are applicable to the current observing date.

The third pipeline enhancement is a 'blaze-shift' correction in the flux calibration of STIS echelle spectra. This corrects an unanticipated problem from the so-called 'monthly offsets' of the Mode Select Mechanism in STIS, which, beginning on January 5, 1998, caused the accumulated charge in MAMA spectroscopic observations to be spread out over the detector, rather than to allow it to concentrate in one area. However, the monthly offsets also produce wavelength shifts in the sensitivity curve used to convert net count rate into flux. The sensitivity in an echelle order is not a linear function of wavelength; there is a more rapidly varying component due to the echelle blaze function, which depends on incidence angle. We determined the blaze shifts that produce self-consistent fluxes at wavelengths where echelle orders overlap and fitted the shifts as functions of the monthly offset and the time since STIS was installed in Hubble. The blaze-shift correction for the primary central wavelengths was implemented into the OTFR pipeline on September 5, 2002.

Finally, we remind STIS users that current, side-2 CCD observations suffer from a higher effective read noise than those taken prior to June 2001 on side 1. The increase in read noise is approximately 1 e^- per pixel for gain = 1 and 0.2 e^- per pixel for gain = 4. The STIS Exposure Time Calculators on the web take this higher read noise into account.

The increased read noise shows a herring-bone pattern easily seen in short-exposure images. When one converts CCD images to 1-D time series and takes the Fourier transform, one sees that the read-noise patterns are temporally correlated. Simple filtering of the data can sometimes mitigate the pattern noise, but to avoid artifacts in the data one must carefully tune the filter within a narrow frequency range (tens of Hz) centered at the precise frequency of the pattern. The STIS web pages provide code to analyze and filter the pattern noise in STIS CCD data. We encourage STIS observers dealing with read-noise-limited CCD observations to consider using this code.

We will always report updates to STIS performance on the STIS instrument website, **http://www.stsci.edu/hst/stis**. Ω

Report on Cycle 10 Operations

David Soderblom, *drs@stsci.edu*

For the first time, the Institute has prepared a report summarizing Hubble telescope operations over a year. The Hubble Space Telescope in Cycle 10 is available as a PDF document at **http://www.stsci.edu/hst/HST_overview/documents**. (Look under 'User Information Reports.') It provides a synopsis of Hubble operations during Cycle 10, which ran from July 2, 2001, through June 30, 2002.

The report contains a variety of information, including the numbers of programs of various types, when they were executed, how efficiently the telescope was used, observation failure rates, and the work of the Telescope Time Review Board. Ω

WFPC2 Close-Out Programs

Anton Koekemoer, *koekemoer@stsci.edu*

The Wide Field and Planetary Camera 2 (WFPC2) has been the principal imaging camera on board the Hubble Space Telescope for the past nine years, having been installed during the first Servicing Mission in December 1993. Its comprehensive suite of 48 filters, spanning wavelengths from the far ultraviolet to one micron, and including wide, medium and narrow-band as well as polarimetric and linear ramp filters, have facilitated an exceptionally wide range of scientific projects, with over 125,000 science exposures obtained to date.

Cycle 12 is currently planned to be the last full cycle for WFPC2 operation, since it will be removed in 2005 during Servicing Mission 4 and replaced with the Wide Field Camera 3 (WFC3). Therefore we are currently planning the final cycle of special 'close-out' calibration programs and related activities, aimed at maximizing the scientific value of the wealth of archival WFPC2 data. In addition to our normal calibration plan for WFPC2, performed during every cycle, we are soliciting general input from the community as to whether there are any additional calibration programs that should be carried out with WFPC2 during this final cycle in order to improve or augment our current calibration accuracies or explore new types of calibration.

In conjunction with the recent Calibration Workshop, in October 2002, a special splinter session was devoted to the topic of WFPC2 close out. Participants identified a number of possible programs.

Special calibration programs already in our calibration plan include:

- Photometric cross-calibration between WFPC2, the Advanced Camera for Surveys, and ground-based filter systems. This involves observing in common a number of standard star fields, including the primary standard used for the Sloan Digital Sky Survey.
- Improved astrometric characterization by observing Omega Centauri in a range of filters, orientation angles, and positional offsets.
- Additional characterization of Charge Transfer Efficiency (CTE) problems, including effects on extended targets and a test of whether 2 x 2 binning may reduce CTE, which is relevant to newer instruments.

Additional topics identified during the WFPC2 close-out session include:

- Reducing the errors in photometric zero points between the filters in use on WFPC2.
- Measuring the extended wings of the point-spread function on large scales across the chips.
- Characterizing the photometric effects of intra-pixel variations resulting from focus changes due to telescope 'breathing'.
- Measuring possible changes in the central wavelengths of some of the narrow-band filters.
- Improved measuring of filter red leaks, including characterization of their spatial dependence.
- Improved characterizing of the efficiency of some filters, for example the z-band F785LP and 1042M filters.

While these topics cover a broad range of aspects of WFPC2 calibration, there may still be additional topics that we should consider. Therefore, we invite any interested members of the community to contact us with suggestions for Cycle 12 calibration observations to complement and enhance our current programs. We will be finalizing our Cycle 12 calibration proposals in spring of 2003, and we will gladly consider incorporating any suggestions we receive before then. Suggestions for special programs may fall in the previously mentioned categories or address other issues to improve the scientific value of archived WFPC2 data.

We also remind observers of the opportunity to submit their own 'calibration outsourcing' proposals in Cycle 12. These proposals may be observational, archival, or both. A few examples of potential topics for calibration outsourcing programs are listed at this website: **http://www.stsci.edu/instruments/wfpc2/wfpc2_out.html**

The WFPC2 group at the Institute welcomes your comments or suggestions as we shepherd this highly productive instrument through its final observations. Just send email to **help@stsci.edu** with the subject line "WFPC2 Close-Out Calibration Programs." We strongly encourage members of the community to take the initiative in proposing any close-out programs that would enhance the quality of a particular aspect of WFPC2 science. We will be happy to provide advice or collaborative input. In this way, we hope to maximize the archival legacy of WFPC2 and ensure a rich resource for the community long after the instrument has been returned to Earth. Ω

ACS News and Highlights

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

Mark Clampin is taking a well-deserved sabbatical leave, and I am now leading the Advanced Camera for Surveys (ACS) Group. It is a pleasure to thank Mark on behalf of the Institute and the whole community for the expert guidance that he has provided for the past several years.

The ACS continues to perform very well, and the first exciting science results are starting to come out. For example, Michael Brown and Chad Trujillo used ACS to image a newly discovered Kuiper Belt Object, dubbed 'Quaoar'. ACS resolved the object's angular size of 40 milliarcseconds, which corresponds to a diameter of about 1300 kilometers. This result makes Quaoar approximately half the size of Pluto and the largest object in the Solar System found since the discovery of Pluto seventy-two years ago (**http://oposite.stsci.edu/pubinfo/pr/2002/17/pr.html**).

As a second example, several teams are using ACS to discover high redshift supernovae and have already reported more than a dozen (IAU Circulars 7912, 7981 and 8012). The Great Observatories Origins Deep Survey (GOODS) Treasury program (described in the spring 2002 Newsletter) is particularly well suited for this task. The GOODS team quickly reports any newly discovered supernovae to the community (**http://www.stsci.edu/ftp/science/goods/transients.html**), and another General Observer (GO) program subsequently follows up. The ACS grism mode yields low-resolution spectra that are ideally suited to determine the supernovae redshifts (IAU Circular 7908).

As a last example of first ACS science, Howard Bond and collaborators used ACS to study a spectacular light echo of the peculiar outburst star V838 Mon. Among other things, this research demonstrated the powerful polarimetric capabilities of ACS (IAU Circulars 7892 and 7943).

ACS observations make up 60% of the Hubble science program in Cycle 11, and many exciting observing programs are now in progress. The oversubscription in Cycle 11 was large, but there is good news even for those of you who were not successful. Many state-of-the-art datasets are already available for public use from the data archive. They include the data from the ACS Early Release Observations and the first few epochs of GOODS data.

During the annual Leonid meteor shower in November, Hubble pointed as usual in the anti-radiant direction to minimize the potential for damage. This direction happened to be towards the Helix nebula. Margaret Meixner led a team that used this opportunity to acquire non-proprietary ACS imaging data in various filters.

The Institute director is considering the possibility of non-proprietary ACS imaging of an 'Ultra-Deep Field' using Director's Discretionary time, in the same spirit as the original Hubble Deep Field campaigns. This possibility was one of the topics discussed during the Hubble Treasury Workshop, which was held at the Institute November 12-14. (The director actively solicits further community feedback on this idea—**svwb@stsci.edu**.) The workshop brought together experts in many different areas to discuss ideas for future Hubble Treasury Programs. ACS featured prominently in these discussions, and we are all looking forward to many proposals from the community for Cycle 12.

We tested all the modes of the ACS during the first few months after installation and held the close-out review of the Servicing Mission Orbital Verification (SMOV) phase in late September 2002. Overall, ACS is performing remarkably well. In many areas, it is doing significantly better than the pre-launch specifications. All modes of ACS are fully operational. The only exception is that Cycle 11 coronagraphy proposals remain temporarily on hold while we develop commanding to correct for drifts in the coronagraphic masks due to gravity release.

The hot pixel coverage for ACS is still well below the values for the Space Telescope Imaging Spectrograph (STIS) and the Wide Field Planetary Camera 2 (WFPC2). However, for the ACS Wide Field Channel, the rate of hot pixel growth is larger than we expected. This is due to a lower than expected rate at which hot pixels are repaired during monthly anneals (periods during which the detectors are heated to room temperature and subsequently cooled down again.) We are currently studying this situation and do not believe it is a major concern. Even if in a few years' time a typical ACS exposure has similar numbers of hot pixels as cosmic-ray affected pixels, the problem can be adequately remedied with proper dithering. Also, we expect the hot pixel situation to improve after the next servicing mission (currently scheduled for February 2005), when the installation of an Aft Shroud Cooling System (ASCS) will allow operation of the detectors at lower temperature.

ACS is not only doing observations for GO and GTO projects; it is also obtaining important calibration data, which we are actively analyzing. Our current state of understanding of the instrument is summarized in the newly released Cycle 12 ACS Instrument Handbook. (**http://www.stsci.edu/hst/acs/documents/handbooks/cycle12/cover.html**) We urge all current and prospective ACS users to study this document. We updated almost all sections from last year's Handbook to reflect the knowledge gained from on-orbit measurements. The Hubble Calibration Workshop on October 17 and 18 provided a forum to address directly the community of ACS observers, and we were pleased to see a strong turnout. Our calibration plans for the next year focus on determining reliable calibrations for the most common modes and on improving our ACS software tools, like PyDrizzle. We will also start the calibrations of special modes, such as those involving polarimetry, ramp filters, and coronagraphy. With both ACS science observations and calibrations progressing steadily, we are looking forward to many exciting new science results in the coming years. Ω

James Webb Space Telescope (JWST) News

Roelof de Jong, *dejong@stsci.edu,* **John Mather, Massimo Stiavelli, and Peter Stockman**

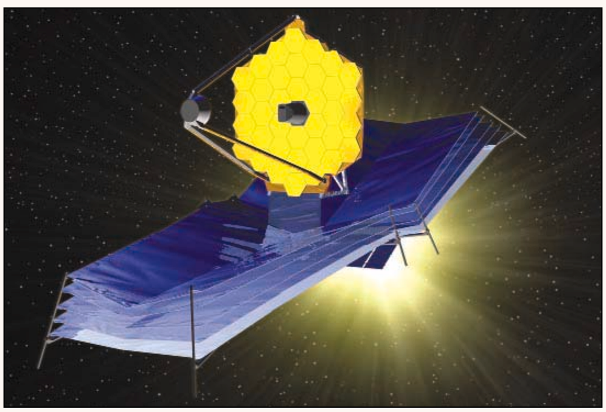

Figure 1: *The James Webb Space Telescope design of TRW.*

On October 10, 2002, NASA signed the $834M prime contract with TRW to develop the James Webb Space Telescope (JWST). While the formal beginning of the implementation phase awaits review committee approval and an independent cost assessment, the JWST team celebrated the end of the procurement 'black out' and the start of integrated planning in a kickoff meeting at the TRW offices in Redondo Beach, California on October 23-24. Representatives from NASA centers, the European Space Agency, the Canadian Space Agency, the Institute, and the Science Working Group met to discuss their designs and to share their plans for the future. TRW presented its design for the observatory and displayed demonstration models that it and its corporate partners had tested. For the whole JWST team, the celebratory meeting was an opportunity to make new acquaintances and forge working relationships for the work ahead to make JWST a reality.

Figure 1 shows the TRW telescope as it was proposed. The design features a hexagonal primary mirror of 36 1-m segments of beryllium or ultra-low expansion glass, which technicians will figure to the correct off-axis surface for the 40 K working temperature. Together, the mirror segments will comprise an effective aperture of 29.4 m^2, roughly equivalent to a 6.5-m circular primary mirror.

The 5-layered sunshade will provide remarkable thermal stability for the passively cooled optics. It will reduce the 300 kilowatts intercepted from the Sun to a mere 23 milliwatts striking the primary mirror and metering truss. As a result, internal heat sources will govern the mirror temperature, which will be independent of spacecraft attitude. TRW constructed and tested a 4-m model of the sunshade, including its deployment mechanisms. For those who have seen both this model and the Hubble spacecraft before launch, the scale of this sunshade seems enormous.

Three actuators on each mirror segment will co-align them by movements in tip, tilt, and piston. A fourth actuator will adjust the radius of curvature. (See Figure 2 on page 12) The JWST secondary mirror will have six degrees of adjustment to achieve collimation and overall focus. Once aligned, the telescope will be diffraction-limited at 2 microns wavelength. TRW estimates that JWST will need wavefront-control adjustments less frequently than once a month.

Technicians from Kodak, a corporate partner of TRW, will test the entire telescope optics at the Plum Brook Space Power Facility at the NASA Glenn Research Center near Sandusky, Ohio. (**http://facilities.grc.nasa.gov/spf/spf_gallery.html**.) This huge chamber—36 m high, 30 m wide—has been used to test the deployment of large space systems and the Mars Pathfinder airbag landing system. It offers low vibration

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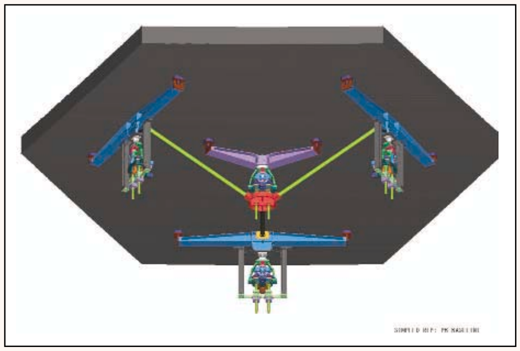
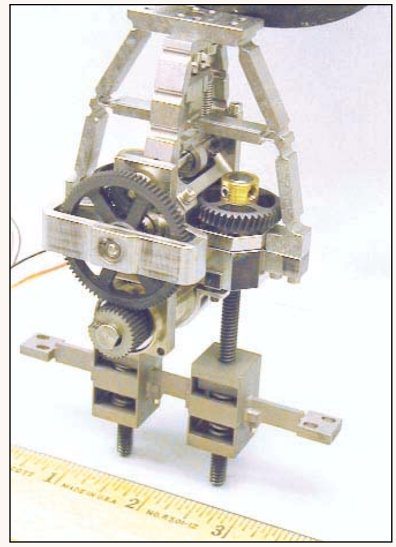
Figure 2: Left, JWST segment actuators. Right, an actuator that has been proven at both cryogenic and ambient temperatures.





levels, and, when it is outfitted with liquid helium shrouds, it will simulate the thermal environment at the L2 operating location of JWST. A 30-m test stand will hold JWST upside-down, provide additional vibration isolation, and compensate for the effect of gravity on the telescope structure. Test equipment at the bottom of the tower will measure the phasing of the mirrors before and during the thermal vacuum tests.

1st Science Working Group Meeting

The JWST Science Working Group (SWG) held its first meeting at the Institute on September 24 and 25, 2002. The first day consisted of project status presentations and overviews of the science interests of the members, which range from re-ionization of the universe to Solar System studies. The second day focused on planning the Science Requirements Document (SRD) to guide the development of JWST towards its scientific goals. The SRD will be organized around four science themes: 'first light in the universe,' 'assembly of galaxies,' 'formation and early evolution of stars,' and 'planetary systems and the origins of life.'

Simon Lilly will coordinate the two extragalactic themes. The first will address the detection of the earliest luminous objects, locate the epoch of re-ionization, and identify the sources responsible for it. The second will address the formation of the Hubble sequence of Galaxies, the assembly of dark halos, the production of metals and their dispersal into the intergalactic medium, and the connection between galaxies and active galactic nuclei.

***Figure 3:** Attendees of the first JWST Science Working Group meeting held on September 24-25, 2002 at the Institute.*

Mark McCaughrean will coordinate the stellar theme, which will address molecular cloud fragmentation, the formation of stars and substellar objects, the formation and early evolution of circumstellar and proto-planetary disks, and planet formation.

Heidi Hammel and Jonathan Lunine will coordinate the planet and life theme, which will address the origin of planetary systems, the effect of giant planets on the development of terrestrial planets, the early evolution of planetary systems including pathways to habitability, and the conditions for life to arise.

The SWG feels that the 6-meter class JWST with its complement of three instruments will have a powerful impact on each of these thematic areas of science. A main task of the SWG is ensuring the core science capabilities of JWST to perform this research.

The SWG will be involved in the JWST 're-optimization', a process aimed at reconciling the TRW architecture concept with the various instrument concepts and at fitting the mission within budget constraints. Initially, this process will be mostly in the hands of the instrument Principal Investigators, who are members of the SWG. The entire SWG will review and rank the options produced by the re-optimization process. The SWG will devote particular attention to the pointing accuracy requirements of the coronagraph in the NIRCAM instrument and to the moving targets capabilities needed to study Solar System objects.

NASA has selected Matt Mountain, director of the Gemini Observatory, as the Telescope Scientist for the JWST. Mountain, as Telescope Scientist, has become a member of the SWG.

The SWG vice-chair selected will rotate among the six Interdisciplinary Scientists, with Massimo Stiavelli serving for the first year.

Change in JWST Project Manager

NASA has replaced Bernie Seery, the JWST Project Manager since 1995, with Phil Sabelhaus. Seery brought to JWST great experience in mirror technology, wavefront sensing, and infrared detectors, as well as familiarity with the industrial and university teams developing technology for JWST. He oversaw the maturation of these technologies to support the detailed design, and he shepherded the international teams and the competing contractors through the long process that culminated in the selection of TRW as the prime contractor. During his tenure, the National Research Council's Decadal Survey Committee ranked the JWST (NGST in those days) as the highest priority in astronomy for this decade.

Phil Sabelhaus brings strong experience in launching flight projects to his new stewardship of the JWST mission. At GTE Spacenet, he managed launch vehicle integration for three communications satellites. At the Goddard Space Flight Center, he was Deputy Project Manager for the Flight Telerobotic Servicer and the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) projects. Later, he was Deputy Project Manager for the Geostationary Operational Environmental Satellites (GOES), Project Manager for the Total Ozone Mapping Spectrometer (TOMS), and Project Manager for Landsat 7. In 1998, Sabelhaus was appointed Deputy Associate Director of Flight Projects for EOS (Earth Observing System) development. As part of those duties, he served as the EOS Aura Project Manager, the Earth System Science Pathfinders (ESSP) Vegetation Canopy Lidar (VCL) Project Manager, and, most recently, the EOS Aqua Project Manager. Ω

Read More...

If you would like to read more about James E. Webb visit:
www.jwst.nasa.gov/Bios/JamesEWebb.html
or
www.stsci.edu/jwst/overview/jameswebb.html

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

Paolo Padovani on behalf of the MAST team, *padovani@stsci.edu*

The Hubble data archive now contains about 10.4 terabytes of data in about 290,000 science data sets. The archive ingestion rate set another record in September 2002 at almost 16 gigabytes per day. The retrieval rate also set records in August 2002, reaching 46 gigabytes per day.

Wide Field Planetary Camera 2 Associations

MAST, in collaboration with the Canadian Astronomy Data Centre (CADC) and the Space Telescope European Coordination Facility (ST-ECF), announces the availability of Wide Field Planetary Camera 2 (WFPC2) Associations. These associations are co-added, cosmic-ray-rejected WFPC2 images, which provide researchers with an important new archive tool for data mining, proposal preparation, and basic astronomical research.

MAST, CADC, and ST-ECF released this tool simultaneously on November 8, 2002. Users may access the WFPC2 association retrieval interface at any of the three archive centers, namely:

http://cadcwww.hia.nrc.ca/wfpc2/ (CADC)

http://archive.stsci.edu/hst/wfpc2/ (MAST)

http://archive.eso.org/archive/hst/wfpc2_asn/3sites/ (ST-ECF)

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Over 16,000 combined images, created using algorithms developed at CADC, are available in this initial release. More details are available at the above websites. The collaborating data centers will augment the library of available co-added data simultaneously at all three sites on a regular basis. Future releases will also provide the association (ASN) files, which will enable users to employ the PyDrizzle algorithm to create their own co-added images.

Figure 1 shows the improvement afforded by the WFPC2 associations in the case of WFPC2 images of the Chandra Deep Field South (CDF-S).

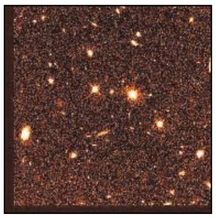

Figure 1: *A single WFPC2 F814W exposure of the Chandra Deep Field South* ***(top)*** *and the combined, cleaned association of eight exposures of the same field* ***(bottom)****.*

First Treasury Program High-level Science Products Available

In the summer 2002 issue of this Newsletter, we announced the opportunity for users to contribute high-level science products (HLSP) to MAST. HLSP are defined as fully processed images or spectra as well as ancillary products like object catalogs. The WFPC2 associations discussed above are examples of HLSP already in MAST. We expect the Archival Legacy, Hubble Treasury, and other large programs established in Cycle 11 to be the main sources of new HLSP.

Advanced Camera for Surveys (ACS) observations from the Great Observatories Origins Deep Survey (GOODS; see **http://www.stsci.edu/science/goods/**) constitute one of the Cycle 11 Treasury Programs. The first HLSP from the GOODS program were delivered to MAST at the beginning of October and made available via anonymous ftp at **http://archive.stsci.edu/pub/goods/**. The GOODS team will supplement these 'best effort', one-epoch, processed data with deeper images combining all epochs of observation. The initial GOODS HLSP include pipeline-processed, cosmic-ray cleaned, drizzled, and co-added images of each 'tile' of the CDF-S in the B, V, i, and z bands. The GOODS team corrected the images for the geometrical distortions introduced by the ACS and put them onto the Guide Star Catalog-2 (GSC-2) astrometric reference system. Users can find more details on the data reduction process in the file *h_goods_s1v05_rdm.txt* in the ftp directory.

As of November 15, 2002, users retrieved almost 75 gigabytes of GOODS HLSP to more than 170 different hosts. MAST is developing ways to ensure that users can discover these and other HLSP easily by all available search methods, including the regular Hubble search interface and the mission cross-correlation tool.

New MAST Interface

MAST has new web search interfaces. While they provide much of the functionality of the previous interfaces, they also include some new features and will make it easier to add features that users request. Here is a sample of what is new:

- Two user-defined query fields that let users query any field in a mission's catalog.
- An output-column selector that lets users add, remove, change the order of, and reset output columns.
- A choice of output format: HTML, spreadsheet (Excel), or comma-separated list,
- A 'distinct' option, for eliminating duplicate rows (for example, to see only the distinct proposal IDs).
- Far Ultraviolet Spectroscopic Explorer (FUSE) preview images, as they become available.
- Spectral co-plotting for most missions that have spectra. (This does not include Hubble yet.)

We have made some little enhancements, too, like a highlighted search button, total number of results reported, and angular separation calculated for all missions. Over the next few months we will add new functionality by user request, including:

- Multiple input targets.
- Better cross-mission capabilities.
- Paging through long lists of results.
- Serendipitous discovery of HLSP, like the GOODS ACS data.
- More interoperability with other data centers and Vizier.
- MyPortal-style customizations.

We hope that you will give the new interface a try and let us know what you think. If you have any suggestions for new functionality, we would be glad to hear them. As usual, send your comments to **archive@stsci.edu**.

Automatic Archive Registration

MAST has automated the registration process for access to Hubble and FUSE data. By filling out the web registration form available at **http://archive.stsci.edu/registration_form.html**, new users will immediately receive confirmation by e-mail, including their archive username and password, which will allow them to start retrieving data. Registration now involves no human intervention and is available 24 hours a day, seven days a week. Ω

The Hubble Helix

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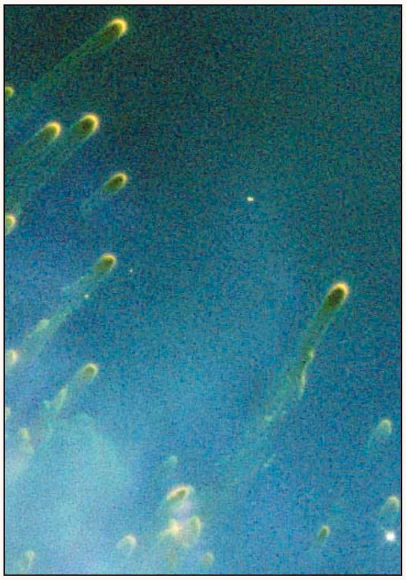

Figure 1: *WFPC2 image of the Helix Nebula from 1996, showing only a small portion of the Helix nebula. The new ACS images cover more than half of the nebula.*

Among the most prominent of meteor showers is the Leonids, which occurred in November. One of the most prominent of planetary nebulae is the Helix Nebula. In 2002 circumstances connected the two in an unusual and interesting way.

The 'roar of the Leonids' was predicted to be especially rich as the Earth passed through the orbit of Comet P/Tempel-Tuttle in 2002. The meteoroids—bits of sloughed cometary material—pose a small but finite risk to the Hubble spacecraft. As in the past several years, we carried out a special procedure to protect Hubble, pointing the spacecraft away from the incoming meteoroids and orienting the solar arrays to minimize their cross-section. We applied restrictions on what components could be operated, such as no multi-anode, microchannel array (MAMA) detectors. This 'stand down' period lasted from 0 to 14 hours Universal Time on November 19, 2002.

While preparing for this special effort, Ian Jordan (see Interview on page 1) checked to see if any objects in current General Observer programs—or even previously observed objects—were within the restricted field opposite the Leonids radiant. Nothing. However, Ian noticed that the Helix Nebula lies just outside this field. Hubble has observed the Helix many times, as illustrated by Figure 1. This was too good an opportunity to miss! We contacted the Hubble Project at Goddard Space Flight Center and got their concurrence to point the telescope slightly beyond the restricted field. Then, we invited a few scientists within the Institute and a few Helix experts from outside to design a program that would make effective use of the nine orbits available during the Leonid fly through.

The Helix science group, led by Margaret Meixner, used the Advanced Camera for Surveys (ACS) to image a quadrant of the large nebula in two colors. This first-epoch dataset will support later imaging to obtain the proper motions of the knots. The Institute will produce a high-quality public image from the ACS data. The Helix group also used the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) to image molecules and the Wide Field Planetary Camera 2 (WFPC2) and the Space Telescope Imaging Spectrograph (STIS) to obtain images in three additional colors, complementing the ACS data. As in the past, the Institute made all data non-proprietary and immediately available in the archive. (**http://archive.stsci.edu/**) Observational details for Program 9700 are available on the Hubble Program Information Page. (**http://www.stsci.edu/public/propinfo.html**) Ω

Formation and Evolution of Elliptical Galaxies

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Among galaxies, ellipticals are only a minority by number, but a very visible one. They are the most massive galaxies and are preferentially located in the centers of rich clusters of galaxies. They host the most massive black holes and are the most powerful radio sources. For these reasons, many believe that understanding their formation and evolution is essential for understanding how galaxies form and the relation between the evolution of galaxies and their nuclear activity.

For many years, students of the formation of elliptical galaxies have split into two camps advocating two rather different scenarios. In one scenario, ellipticals are formed at high redshifts in a monolithic collapse.[1] In the other, they are assembled hierarchically from smaller proto-galaxies.

Monolithic collapse ensures uniformly old stars and a small dispersion in the mass-to-light ratio of different ellipticals, which produces a tight, well-defined color-magnitude relation[2] and high uniformity in the properties of present-day ellipticals. Presumably, proto-ellipticals would be self-enriched and enshrouded in dust when they form[3, 4] so that we would never see a very blue, young, elliptical galaxy. This model naturally explains many properties of local ellipticals. Unfortunately, it appears to over-predict the number of ellipticals at high redshifts. [5]

Hierarchical assembly is more compatible with standard cosmologies and better fits our present understanding of how structures form in the universe. In a 'cosmology-based' scenario, ellipticals would form only by mergers, possibly between disk galaxies different from present-day spirals[6] and would evolve strongly for at least half of the present age of the universe, so that few ellipticals would be in place at high redshifts.

For a long time, observational limitations made it very hard to distinguish between these scenarios. However, recent availability of improved instrumentation has produced two breakthroughs that allow us to test these ideas in detail.

The first advance is the ability to observe the internal properties of elliptical galaxies up to redshift $z = 1$. We can study the evolution of the Fundamental Plane of elliptical galaxies as a function of redshift and place strong constraints on the galaxy formation models. The Fundamental Plane is a surface in the three dimensional space defined by the radius containing half of the light, the mean surface brightness within this radius, and the velocity dispersion of stellar motions.[7, 8] Elliptical galaxies have properties that lie on this surface. Because ellipticals are self-gravitating systems in dynamical equilibrium, their stars satisfy the virial theorem. However, this is not enough to guarantee the existence of a Fundamental Plane in the absence of a correlation between the mass and the mass-to-light ratio of ellipticals, which is ultimately a correlation between dynamics and stellar population properties. The evolution of the Fundamental Plane with redshift allows us to probe directly the evolution of the correlation between the mass and the mass-to-light ratio. As the stellar populations of ellipticals become younger at increasing redshifts, we expect their mass-to-light ratios to decrease. By measuring this evolution we can derive the average age of ellipticals.[9] In principle, we could even determine the variation with mass of the mean age of ellipticals by detecting a change in the slope of the relation between the mass and mass-to-light ratio. So far, no such change in slope has been found.

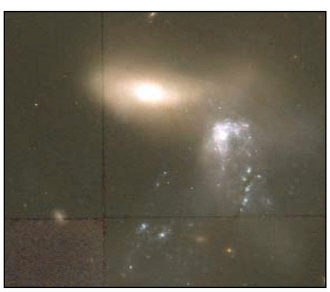

__Figure 1:__ The interacting pair of galaxies NGC 454 as seen by Hubble's Wide Field Planetary Camera 2 in the B (F450W), V (F606W), and I (F814W) bands. The red object at the top is the dominant early-type component. The blue, star forming, object is a low-mass disk galaxy, which is being tidal disrupted by the more massive early type component. The Hubble data reveal that the stellar populations in the distorted tail of the early-type component are being polluted by stars stripped from the star-forming blue component[11].

By studying the evolution of the Fundamental Plane in the field we have also been able to test directly whether ellipticals evolve with different rates in clusters and in the field, as predicted by hierarchical models of galaxy formation. Indeed, we have found evidence for such a difference.[10]

If all stars were formed in a single burst, ellipticals in the field would have formed them at redshift $z = 1$, while those in clusters would have formed their stars at redshift $z = 1.5$ to 2. However, a small amount of star formation could change the appearance of an old galaxy, making it look much younger. For instance, a 10% addition of young stars at redshift just below $z = 1$ would be sufficient to rejuvenate an old elliptical formed at redshift $z = 3$. Such effects are predicted by the models and are observed in the local universe (e.g., Cen A or NGC 454 and Figure 1[11]). Thus, the age difference between field and cluster could be an artifact of field galaxies experiencing more secondary star-forming activity at late times.

A more basic problem with diagnostics based on the Fundamental Plane is that they probe the age of star formation rather than that of galaxy assembly. Stars could be old even if their galaxy was assembled at low redshifts.

Luckily, the second breakthrough permits us to address this problem directly. The development of efficient infrared imaging instruments has enabled optical and near-infrared surveys, which have found a number of 'extremely red objects' when looking for galaxies with extreme optical to near infrared colors. A fraction of these galaxies are elliptical galaxies at a redshift $z = 1$ to 2 (see Figure 2).[12, 13, 14] Thus, such surveys have shown that there are indeed some ellipticals at high redshift even though perhaps fewer than predicted by the monolithic collapse model.[15, 16]

A preliminary assessment of the observational constraints suggests that ellipticals formed in a way that is the synthesis of the two simple-minded scenarios. Seed galaxies formed at relatively high redshift and then grew by accreting smaller objects. Stellar populations appear younger than they are because of the rejuvenating effect of star formation, and ellipticals appear very uniform because of the fact that we classify them as elliptical galaxies only 1 to 2 Gyr after their most recent interaction or star formation episode.[17]

In the next few years a lot of effort will go into testing this new, combined scenario. With continuing progress in instrumentation, particularly in efficient, near-infrared spectrometers, we should be able to extend Fundamental Plane studies beyond redshift $z = 1$.[18, 19] At the same time, new surveys should improve statistics on the number density and luminosity function of ellipticals at high redshift.

Some effort will also go into testing the robustness of our methods. As an example, the classical interpretation of the evolution of the Fundamental Plane is in terms of the evolution of the stellar populations. However, a similar effect could be produced by an evolution in the dynamical state of ellipticals, e.g., by variation of the baryonic mass to dark halo ratio or by a change in the orbital structure of these galaxies. These effects could be tested directly by deriving the Fundamental Plane properties of ellipticals acting as gravitational lenses, so that the dynamical mass could be compared to the gravitational mass.[20, 21] They could also be tested indirectly by comparing color evolution with mass-to-light ratio evolution.

Figure 2: *Portion of the Hubble Deep Field South NICMOS field. The image is obtained by combining visible data obtained with STIS with J (F110W) and H (F160W) data obtained with NICMOS. Several 'extremely red objects' are visible throughout the field.*

To summarize, the combined scenario of forming ellipticals by hierarchical growth of seed proto-galaxies may receive crucial tests in the next few years. This will be an important step in understanding the star formation and assembly history of ellipticals. It will provide solid ground for understanding the origin of the tight correlations between nuclear and global properties[22, 23] and dynamics and stellar populations.[24] Ω

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Canvassing the Neighborhood

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Over 60 years ago, Gerard Kuiper summarized the scientific rationale for studying the nearest stars: individually, they supply detailed information on stellar properties; collectively, they measure the statistical properties of the Galactic disk population. Amongst the latter parameters are the stellar mass function (how gas reassembles as stars), the metallicity distribution, the age distribution, stellar binarity and, most recently, the frequency of planetary companions as a function of stellar type. These calculations depend on two assumptions: that the local sample is representative of the parent population and that sources of incompleteness are well characterized. Satisfying the latter constraint has become possible only in the last few years.

Any discussion of the nearby stars should start with the standard reference, which is Wilhelm Gliese and Hartmut Jahreiss's painstakingly compiled catalogue of stars known or suspected of being within 25 parsecs of the Sun. As a rough guide, there are 34 systems known within 5 parsecs of the Sun,[1] so we expect 4250 $\pm$ 700 within 25 parsecs. The third edition, the CNS3,[2] includes over 3800 stars in approximately 3000 systems, suggesting relatively high completeness. That compilation, however, has two major problems. First, the individual stars are drawn from many different sources, some of uncertain reliability, and a significant number lie well beyond the nominal distance limit. Second, the catalogue includes few very low luminosity dwarfs. Most of the stars were identified from blue-sensitive photographic proper motion surveys, which can barely detect the latest-type M dwarfs at distances beyond 10 parsecs.

The first problem can be solved by acquiring well-calibrated, internally consistent distance estimates for all candidate nearby stars. Working in collaboration with Suzanne Hawley (U. Washington) and John Gizis (U. Delaware), I took the first step in this process by obtaining red spectra of all potential M dwarfs in the CNS3,[3, 4] deriving spectrophotometric parallaxes from the measured molecular band strengths. Those distances are calibrated using M dwarfs with well-determined trigonometric parallaxes. Over 30% of the stars prove to lie beyond 25 parsecs, including a handful of misclassified giants at distances exceeding 1 kiloparsec.

The Hipparcos satellite provided the second step in this calibration process. Over 2300 CNS3 stars were in the Hipparcos Input Catalogue, including 700 of the brighter M dwarfs and all the earlier type stars. In most cases, Hipparcos provided trigonometric parallax measurements accurate to 1 to 2 milliarcseconds. Those results show that even among the higher luminosity AFGK stars, 40% lie beyond 25 parsecs, including a significant number of subgiants, misclassified previously as dwarfs. In contrast, Hipparcos added relatively few new stars to the 25-parsec sample. This imbalance stems from a Malmquist-like bias. The spatial volume just beyond a given distance limit exceeds the volume just within that limit. Thus, given a uniform density distribution and symmetric uncertainties in parallax, the tendency is to overestimate more parallaxes than one underestimates. This is the origin of the Lutz-Kelker correction.[5]

Combining the Hipparcos data with our M dwarf observations gives reliable distances for all of the stars in the CNS3. We derive statistical completeness limits by examining the run of density with distance at each absolute magnitude.[6] The results show that the CNS3 is complete to 25 parsecs for systems where the brightest component has $M_V < 8.0$. That sample includes 1051 stars in 805 stellar systems, including 41 evolved stars. The multiplicity fraction in the full 25-parsec sample, ~30%, is significantly lower than the 60 to 70% measured for the subset of stars within 10 parsecs. Thus, even though the systemic sample may be complete, approximately 250 lower luminosity companions remain to be discovered.

At fainter absolute magnitudes, incompleteness sets in at smaller distances, with the effective limit dropping from 22 parsecs for M0 dwarfs (M_V=8.5) to only 5 parsecs for late-type M dwarfs (M_V>15). The last-mentioned limit excludes all currently known L [7] and T dwarfs [8] from the sample. Within these limits, however, we can determine space densities and derive the luminosity function, $\Phi(M_V)$, the number of stars per unit volume per unit absolute magnitude. Integrating the stellar luminosity function gives a local space density of 0.107 stars pc^{-3} and 0.073 systems pc^{-3}, with an average separation of 2.4 parsecs between nearest? systems. Integrating the derived densities over the full 25-parsec volume, we expect 6940 stars in 4780 stellar systems. Only 2950 of those stars are catalogued in the CNS3. Thus, our current 25-parsec census is only ~45% complete. All of the missing stars are M dwarfs (or L dwarfs) with M_V >8.

Setting aside for the moment discussion of the missing stars, we can calculate several important quantities from the derived luminosity function. In particular, the present-day mass function, $\psi(M)$, follows from convolution of $\Phi(M_V)$ with the mass-luminosity relation for main-sequence stars. The latter calibration is defined through observations of stars in spectroscopic and astrometric binaries. Interestingly, while most attention in recent years has focused on measurements near the hydrogen-burning limit,[9, 10] the empirical relation is least constrained near 1 solar mass. The derived mass function has a significant change in slope near this mass, and further data for solar-type stars would be extremely useful in calibrating the behavior more exactly. Summing $\psi(M)$ gives the contribution made by main-sequence stars to the local mass density; we derive 0.033 solar masses pc^{-3} from our analysis.

The present-day mass function provides a snapshot of the relative frequency of stars of different masses here and now in the local disk. For low-mass stars, with main-sequence lifetimes exceeding the age of the disk, $\psi(M)$ takes account of the full star formation history. However, at higher masses, the distribution includes only the subset of stars with ages younger than the main-sequence lifetime, making no allowance for older stars of similar mass that have evolved to become red giants or white dwarfs. $\psi(M)$ also takes no account of the distribution perpendicular to the Galactic Plane. Younger stars have lower velocity dispersion, and therefore have a smaller scale height. As a result, a local sample includes a higher fraction of the shorter-lived, higher-mass stars. Both of these effects are taken into account in transforming $\psi(M)$ to give the initial mass function (IMF).

Figure 1 shows the initial mass function, dN/dlog(M), derived from our analysis of the nearby stars. Following Salpeter,[11] the IMF is traditionally represented as a power-law, M^{-a}, where $a = 2.35$ is the Salpeter value. The data are clearly not consistent with a single power-law, and we find that the distribution is better represented by a two-component power-law than by the log-normal form proposed by Miller and Scalo.[12] Formally, we derive indices of $a = 2.8$, somewhat steeper than Salpeter, at high masses, and $a = 1.3$ below $\sim$1.1 solar masses, with uncertainties of $\pm$ 0.25. The most important features in the IMF are, first, the change in slope at $\sim$1.1 solar masses, and, second, the relatively shallow slope at low masses. The former suggests different star formation mechanisms at low and high masses; interestingly, the break falls at the Jeans mass expected in the average molecular cloud ($T \sim 25$ K). The latter rules out low-mass stars and brown dwarfs as potentially significant sources of dark matter.[13]

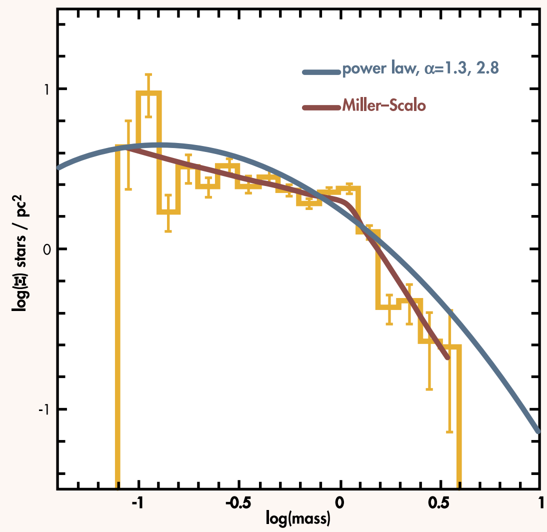

Figure 1: *The initial mass function derived from observations of the nearby stars. The dashed lines plot the best-fit two-component power law; the dotted line is the best-fit log-normal (Miller-Scalo) relation.*

The uncertainties in the IMF at low masses are substantial. This reflects the small number of low luminosity stars contributing to the luminosity function and brings us back to the missing M, L, and T dwarfs in the Solar Neighborhood sample. With effective temperatures below 3000 K, these sources emit substantial flux at infrared wavelengths and have red colors. I am currently leading a project under the auspices of the NASA/NSF Nstars initiative, using near-infrared photometry from the Two-Micron All-Sky Survey (2MASS) to complete the census of stars and brown dwarfs within 20 parsecs of the Sun.

We are using a variety of techniques to identify the missing stars and brown dwarfs. Davy Kirkpatrick and Patrick Lowrance (IPAC) are searching for wide, late-type companions to stars known to lie within 25 parsecs of the Sun. The target stars have known distances, so the search can be tuned to pick out 2MASS sources with colors and magnitudes appropriate to physical companions. To date, several new M and L dwarfs have been discovered,[14,15] including a previously unknown M dwarf companion to υ Andromedae, which also possesses planetary-mass companions.[16]

2MASS itself is adequate for finding wide companions, but there is a growing body of evidence indicating that such systems are rare among low-mass stars. The brighter late-type M dwarfs are accessible to ground-based adaptive-optics observations,[17] but Hubble remains the only viable instrument for resolving fainter, cooler systems. Our Wide Field Planetary Camera 2 observations of L dwarfs[18] find that 20% are resolved as binaries with separations less than 15 AU. Adam Burgasser (UCLA) finds a similar result in his observations of T dwarfs.[19]

Proper motion surveys have proven a fruitful hunting ground for nearby stars. However, segregating the nearest systems from their more distant—and more numerous—counterparts requires photometry of at least moderate accuracy. The latter requirement has long been an obstacle to effective use of the most extensive proper motion survey, Luyten's New Two-Tenths Catalogue (NLTT), which includes stars with $\mu > 0.18$ arcsec/year. However, combining Luyten's m_r magnitude estimates with 2MASS near-infrared data gives a color index with sufficiently long baseline that photometric parallaxes have 20% accuracy despite the substantial uncertainties in the photographic data.

Kelle Cruz (U. Penn.) and I have cross-referenced the NLTT catalogue against data from the 2MASS Second Incremental Release, which covers approximately 47% of the sky. Lacking finding charts (and time), we have simply used positional

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coincidence to identify plausible 2MASS counterparts, with an initial search radius of 10 arcseconds and a subsequent search to 60 arcseconds for residual unpaired objects.[20] This approach does not allow for the occasional positional howlers in the NLTT, but, fortunately, Salim and Gould[21] completed an independent analysis, where they corrected many of the typographical errors. We have combined these results, and selected 2407 stars (from a total sample of 24,000) with photometric parallaxes of less than 20 parsecs. So far we have obtained follow-up spectroscopy (in collaboration with Jim Liebert, U. Arizona, and John Gizis and Suzanne Hawley) and photometry (with Dave Kilkenny, SAAO, and David Golimowski and Christina Williams, JHU) of ~1200 candidates, including all stars with m_r fainter than 14.5. At present, we have only partial results from analysis of those data,[22, 23] but at least 520 dwarfs are confirmed to have distances of less than 20 parsecs.

The NLTT catalogue is an excellent resource for finding mid- and late-type M dwarfs, but most ultracool dwarfs (spectral types M7 and later) are too faint to be visible on the blue-sensitive POSS-I plates used by Luyten. Fortunately, those dwarfs have distinctive near-infrared colors, and we can identify them directly from the 2MASS data. Using late-M and L dwarfs with known distances to define a color-magnitude template, Kelle Cruz has searched the Second Incremental Release for sources with photometric parallaxes exceeding 50 milliarcseconds. For logistical reasons, we exclude regions within 10 degrees of the Galactic Plane, giving residual coverage of 40% of the sky. Only 2200 of the 160 million point sources meet our search criteria, and many of these are either red giants or reddened sources. As with the NLTT stars, our analysis is not complete, but follow-up spectroscopy with Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory telescopes shows that we have discovered at least 25 late-M and 40 L dwarfs within 20 parsecs of the Sun. In fact, our survey will provide the first reliable measurement of the space density of L dwarfs.

A few of the new ultracool dwarfs are surprisingly bright. Figure 2 shows Digitized Sky Survey (DSS) images of one of our candidates, confirmed as spectral type M8.5. The star is clearly visible on the POSS-I plate, with a sizeable proper motion of 0.75 arcsec/year, but it is not included in Luyten's catalogues. A trigonometric parallax measurement made by the U.S. Naval Observatory shows that this star lies at a distance of only 5.67 parsecs, and currently checks in as the 59th nearest star to the Sun.[24] We are not the only group to have discovered this star. 2M1835+32 was identified as a new proper motion star in a survey made by astronomers at the American Natural History Museum.[25] In addition, Stephen Laurie, a British amateur astronomer, not only picked out this star as a potentially interesting object based on the 2MASS survey data, but also measured the proper motion from the DSS scans. It's not just professional astronomers who use the digital databases.

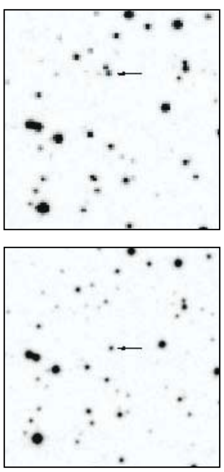

***Figure 2:** POSS I **(top)** and POSS II **(bottom)** images of the M8.5 dwarf, 2MASSI J1835379+325954, which lies at a distance of only 5.67 parsecs.*

So, how complete is our survey? Based on the densities cited earlier in this article, we expect ~1000 stellar systems within 20 parsecs in the high-latitude regions covered by 2MASS. So far, combining the CNS3 and our surveys, we have identified at least 730, and there are sufficient remaining candidates to bring us close to expectations. There is an important caveat: few of the new identifications have trigonometric parallax measurements, and, based on past experience, we can predict more underestimated than overestimated distances. Nonetheless, we are making significant inroads on this problem, and we plan to extend coverage to the full sky once the full 2MASS database is available. Ω

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Personal Recollections of Institute and Hubble Pre-History

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My involvement with the no longer Large—but not yet Hubble—Space Telescope began in November 1979, when I was seconded to the corporate office of the Association of Universities for Research in Astronomy (AURA) from the Cerro Tololo Inter-American Observatory (CTIO) to help write our proposal to NASA to manage the Space Telescope Science Institute. I recall arriving at Dulles Airport, which had seemed near enough to Baltimore to a Tucson travel agent, with my family and no credit card, which meant no rental car and a $50 cab fare to the Homewood Campus of Johns Hopkins University (JHU). Fortunately, such an expense was covered!

I joined my senior CTIO colleague Barry Lasker, sharing an office in Rowland Hall. We interacted most intensively with JHU astronomers Art Davidsen and Bill Fastie, and I recall many work or social occasions with them. Now I'm the sole survivor of those four musketeers, so I had better write these memoirs before it is too late.

I rapidly lost my prior innocence of NASA proposing, faced with a voluminous Request for Proposals (RFP) outlining the requirements for several massive volumes in response, including scientific, technical, administrative, cost, and staffing plans, or some combinations of those and perhaps others.

Barry and I attacked the scientific proposal, with input from Art and Bill based on their considerable experience with NASA. Specifically, I wrote "Section 2.1, Science Management," expounding AURA's rationale for an excellent scientific staff at a national research center, namely that superior facilities and services for the community would arise naturally from the enlightened self-interest of a competent staff using the observatory for its own research. I had become convinced by this philosophy from my experiences at Kitt Peak and Cerro Tololo. Nevertheless, my closest experience to this writing activity was conjuring themes largely from thin air in freshman English. It was far from my subsequent writing of research reports and seemed rather surrealistic at first.

> "By the way, it is amusing to recall that our full staff plan for STScI contained a total of 160 people. Little did we or NASA know what lay ahead!"

A vignette from this period sticks in my memory. One day I encountered on a corridor bulletin board a *Baltimore Sun* article about a local optical genius, who was polishing the mirror for another JHU project in his home laboratory. There was a picture of his desk heaped with papers and materials, and a prominent sign proclaiming, "A neat desk is a sign of a sick mind!" So, I went back and stared at my neat desk for a while, feeling oppressed. Then, some time later, I heard that this person had applied the correction to the sphere with the wrong sign, and the top of the telescope had had to be sawed off so it could be focused. I thought that if his desk had been neater, perhaps that might not have happened, and I felt considerably better!

Prior to this proposal writing stage, AURA had selected JHU from among six universities vying to be the site of the Institute. In addition to its astronomers' experience in space projects, JHU offered the considerable expertise and resources of its Applied Physics Laboratory for the proposal effort. Also, AURA had selected Computer Sciences Corporation (CSC)—of International Ultraviolet Explorer fame—as an operations subcontractor. Thus, we had assembled a strong team with diverse and complementary experience.

Nevertheless, I wish I had $5 for every time during this period I heard, "You're wasting your time—it will obviously go to Princeton!" (I could at least treat myself to a fine meal at the Polo Grill.) That sentiment was not entirely unreasonable, Princeton being the home of Lyman Spitzer, the intellectual father of the Space Telescope, and of several others, such as John Bahcall, whose high levels of scientific and political expertise had initiated and then more than once rescued the project in Washington. There were said to be five competing proposals to manage the Institute, some of which named Princeton as the site.

Our proposal captain was John Teem, the AURA President, who came to Baltimore from his office in Tucson. I think John is the unsung hero of the AURA effort. He brought together the floundering administrative and logistical parts of the proposal, personally doing the cost and staffing plans—and landing in the hospital directly after the proposal due date. By the way, it is amusing to recall that our full staff plan for STScI contained a total of 160 people. Little did we or NASA know what lay ahead!

I took my family back to Chile for the holidays and then returned to Baltimore alone in January, promptly landing in bed with a severe flu no doubt brought on by the extreme climate changes. During this second period, we spent time at the CSC building in Silver Spring producing the final volumes. The firm proposal due date was March 31, 1980. And remember this: we were proposing toward a firm launch date of December 13, 1983! All intervening milestones were carefully laid out, including a NASA decision on the proposals six months after the due date. Slippages began almost immediately, and the decision was finally announced about a year after the deadline.

Rumors, rumors! In view of the delay, AURA decided to pre-select a Director and Deputy Director, who would then be in place already if AURA were the winner. Job announcements were duly posted. Back at CTIO, a northern visitor read these announcements on the bulletin board in La Serena, inferred from them that AURA had won, and then went up the mountain spreading the information without commenting on his source. Excited CTIO staff immediately called down to La Serena with the 'news' from the recent arrival!

Eventually, NASA announced that AURA was indeed the winner. I heard that one of the winning points of the AURA proposal was the Science Management section, which gave me a warm feeling, although I never received any personal comment about it.

Ironically, I was hired to the Institute scientific staff by Princeton astronomer Neta Bahcall, the original chief of the General Observer Support Branch, in January 1984. Those were lean years in space astronomy. I well recall the annual one-year-till-launch parties—suspended for two following the Challenger accident—and one wag's dictum, "The Space Telescope Science Institute: no space, no telescope, and no science!" But then we got 'bookend' additions to the Institute building and finally a launch.

Due either to a clerical error or to unexpectedly warm regard at high levels of NASA for my efforts to resolve the numerous and vehement conflict complaints by the original Guaranteed Time Observers (GTOs), I received one of only four Institute invitations to fly down to the Hubble launch onboard a NASA airplane. However, since I wanted to take my family along, I flew commercial for the April 10, 1990, event. I was even able to get them into the VIP viewing area three miles from the launch pad. Then the excitement was abruptly replaced by the crushing disappointment of a scrub at T minus four minutes due to the failure of a redundant auxiliary power unit aboard the shuttle. This the family accurately perceived as the loss of a once-in-a-lifetime opportunity. I took up the NASA invitation for the second attempt on April 24, flying out of Andrews Air Force Base at 4 AM and directly into the Space Center before dawn, with the floodlit shuttle standing on the pad below, an awesome sight. This time the launch went off flawlessly—and I was back in my office by 2 PM the same day!

Institute staff member Chris Burrows diagnosed spherical aberration just about two months later. I was on an extended trip to conferences in Bali and Sydney, still riding the euphoria of launch, when I first heard confused remarks about a 'problem' from participants at the second conference. Then I read incomprehensible reports of 'myopia' in the Australian press. Surrealism had returned. However, I recall one of those articles concluding prophetically, "The Americans will fix it—their national pride depends on it!"

Here is a brief account of the 'problem', in case you haven't heard it or don't remember the details. At the Perkin-Elmer Corporation, the reflective null corrector—an optical device used to test and monitor the primary mirror during polishing—had been incorrectly assembled because of a laser measurement error, resulting in a field lens being 1.2 mm out of position. During assembly, the screws designed to hold the lens were found to have the wrong length (because of the incorrect position), so washers were arbitrarily added to compensate! (Can you imagine adding unspecified macroscopic spacers to a precision optical device without investigating the reason they seemed to be needed?) Consequently, the primary mirror was exquisitely polished to the wrong figure to compensate the error in the corrector. The result was a 0.002 mm excess downturn at the edges of the mirror, producing a 40 mm difference between the focal points of its inner and outer parts—spherical aberration.

"The firm proposal due date was March 31, 1980. And remember this: we were proposing toward a firm launch date of December 13, 1983!"

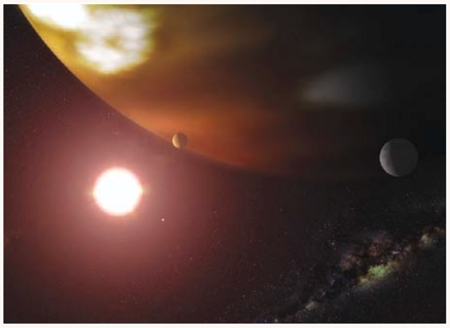
To add insult to injury, at least a half dozen independent indications of the error were uncovered by the subsequent investigation. In addition to the unheeded screw/washer warning, I recall a check with a less accurate refractive null corrector that detected the aberration, an inverse null test of the reflective corrector that showed it, records of excessive weight of material removed during the figuring, and a crude knife-edge or similar test that also showed the huge error. If such an array of correlated evidence were shown to any competent astronomer, there would be scorched earth all around. Incredibly, the technicians involved were evidently able to discount or conceal all of it.

The Hubble mirror was finished by 1980 and sat in storage until final assembly of the telescope, its horrendous flaw not to be discovered until it was in orbit, over a decade later. Ironically, you can read an article in the April 1990 *Physics Today* about the unprecedented perfection of the mirror, based, of course, on the circular reflective null corrector results. Some of the best astronomical optics experts in the world were involved in the oversight committees, including Bill Fastie, but none ever received a hint of the flaw from what they were shown.

I won't go into the mood in late summer and early fall 1990 at the Institute, in the astronomical community, and in the Congress which came within 0.002 mm of cutting Hubble off. (Interestingly, a lousy, aberrated image of one of my favorite objects, R136 in 30 Doradus, contributed to saving it for the moment!) Instead, let me move on to a small meeting of the Institute senior scientific staff in the Director's Office, at which I saw Hubble rescued before my very eyes. Holland Ford placed on the table a proposition that *we—the Institute—* should fix Hubble! (Holland was a Faint Object Spectrograph GTO with an intense desire to do his science. At that moment he exemplified the AURA rationale for a scientific staff described above.) Our taking the lead sounded like a crazy idea to my naive ears, but I saw Riccardo Giacconi's eyes light up instantly—and later Bob Brown's and Jim Crocker's. The contributions of those four people were essential to Hubble's rescue. Of course, WFPC2 was corrected independently by its team under John Trauger. However, the Institute's Corrective Optics Space Telescope Axial Replacement (COSTAR) brilliantly fixed the spectrographs and ESA's Faint Object Camera. Selected from among thirty solutions proposed by the Strategy Panel convened by the Institute, COSTAR used only standard Hubble refurbishment procedures and deployed independent, fail-safe optical correctors for each of the three instruments. Moreover, the incredibly stringent constraints on the optical prescriptions and positioning of the tiny corrective mirrors in both COSTAR and WFPC2 were met.

Thus, Hubble began to perform as designed following the successful installation of COSTAR and WFPC2 by the astronauts during the first servicing mission, in December 1993, exactly 10 years after the launch date addressed by the AURA proposal—remember? The rest is history. By now we are accustomed to Hubble consistently pushing the envelope of astronomical knowledge, but we should not forget the sobering lessons its pre-history could hold for the future. Ω

Hubble Makes Precise Measure of Extrasolar World's True Mass



Science Credit: *NASA, G.F. Benedict, and B. McArthur (McDonald Observatory/U. of Texas at Austin)*

Illustration Credit: *NASA and Greg Bacon (STScI)*

NASA Hubble Space Telescope's crisp view has allowed an international team of astronomers to apply astrometry for making a precise measurement of the mass of a planet outside our solar system. The Hubble results place the planet at 1.89 to 2.4 times the mass of Jupiter. Previous estimates, about which there are some uncertainties, place the planet's mass between 1.9 and 100 times that of Jupiter's.

The Fine Guidance Sensors (FGSs) measured a small "side-to-side" wobble of the red dwarf star Gliese 876 due to the tug of an unseen companion object, designated Gliese 876b (Gl 876b).

The observations were made over two years by George F. Benedict and Barbara McArthur (University of Texas at Austin), members of the international observing team led by Thierry Forveille (Canada-France-Hawaii Telescope Corporation, Hawaii and Grenoble Observatory, France). The results are published in the December 20, 2002 issue of *Astrophysical Journal Letters.*

The target planet, Gl 876b, is the more distant of two planets orbiting Gliese 876. It was originally discovered by two groups, led by Xavier Delfosse (Geneva/Grenoble Observatory) and Geoffrey Marcy (U.C. Berkeley and San Francisco State University). Marcy's group discovered a smaller planet closer to Gliese 876 a year later, in 1999. These initial discoveries were made by using the radial velocity technique.

Benedict and McArthur combined the astrometric information with the radial velocity measurements to determine the planet's mass by deducing its orbital inclination. The planet's orbit turns out to be tilted nearly edge-on to Earth, verifying its low-mass.

To read the full Press Release go to **http://hubblesite.org/newscenter/archive/2002/27/**. Ω

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Cycle 12 observations begin	July 2003

MAY SYMPOSIUM

The Local Group as an Astrophysical Laboratory

5 - 8 May, 2003

Space Telescope Science Institute
3700 San Martin Drive
Baltimore, Maryland 21218

The next May Symposium will be held at the Institute on May 5-8, 2003. The subject will be advances in galactic, extragalactic, and cosmological science made possible by Hubble's resolution of nearby galaxies, which has permitted investigations comparable to traditional studies of the Milky Way. Symposium registration and reception will occur on Sunday, May 4, 2003. The firm deadline for receipt of early registration is April 3, 2003, with a registration fee of $275. After that, the registration fee will be $300. Payment at the door will be by check or cash only. Make checks payable to Space Telescope Science Institute. The registration fee covers the opening reception, the conference dinner on May 7, 2003, and morning and afternoon snacks. Ω

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