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NEWSLETTER

Space Telescope Science Institute

STScI-PRC02-11c, an image of the center of the Omega Nebula taken by the newly installed ACS aboard NASA's Hubble Space Telescope.

Science Opportunities for Hubble Cycle 12

Duccio Macchetto, *macchetto@stsci.edu,* **and Robert Williams,** *wms@stsci.edu*

We are preparing for Cycle 12 amidst the excitement of early observations with the refurbished Hubble telescope. The early-release images from the Advanced Camera for Surveys (ACS) are head-turning, and the rejuvenated Near Infrared Camera and Multi-Object Spectrometer (NICMOS) is better than ever. Hubble is now executing approved Cycle 11 programs. There is every indication that the upcoming competition for Hubble observing time will offer unprecedented science opportunities.

As announced in the last Newsletter, we have adjusted the timeline to reduce the time between proposal submission and the start of Cycle 12 observations, which will begin in July 2003. The Cycle 12 timeline has the following important dates: (a) Call for Proposals (CP) released on 14 October, 2002, (b) Hubble Treasury Program workshop at the Institute on 12-14 November, 2002, (c) Phase 1 proposals due on 24 January, 2003, (d) Time Allocation Committee (TAC) and panels meeting on 24-29 March, 2003, and (e) notification of PIs in mid to late April 2003.

The Cycle 12 proposal categories will be small and large proposals, coordinated proposals with the National Optical Astronomy Observatories (NOAO) and the Chandra X-Ray Center (CXC), and the special categories of Hubble Treasury, Theory, and Archival Legacy.

As in earlier cycles, panels will peer review smaller proposals and the TAC, consisting of panel chairs and led by the TAC Chair, will review larger and specialized proposals.

Recently, the Space Telescope Institute Council (STIC) initiated a thorough review of Institute policies and procedures for peer review, which is a most important responsibility of the Institute. The external committee formed by STIC and chaired by Juri Toomre of the University of Colorado met for three days to consider the scientific effectiveness of the TAC and its panels, the process by which Hubble Treasury programs are selected, and the quality of the written feedback to PIs. The review committee found no fundamental flaws in the process, and was impressed by its efficacy. It attested to the overall integrity of the TAC process and made recommendations intended to improve an already sound process. (The report is available at **http://www.aura-astronomy.org/nv/TAC_Review.pdf**.)

We will do our best to implement the review committee's recommendations in Cycle 12. The recommendations include: (1) At least one expert in the field should review each proposal. (2) The Institute should relax its conflict of interest rules to allow review of proposals by colleagues at the PI's institution. (3) A fraction of panelists should serve for consecutive cycles to achieve 'memory' and continuity for the annual TAC and panels. (4) The Institute should provide feedback to proposers based on written comments of the primary and secondary reviewers and modified to reflect the TAC or panel consensus.

Finally, following Hubble Second Decade Committee's original recommendations, the review committee recommended that the Institute should constitute a standing, community-based committee to advise the Director on topics for workshops on potential Hubble Treasury programs. The workshops should foster collaborations among interested parties and clarify science objectives and observing strategies. The Institute should organize the workshops in the months before each annual TAC meeting. In response, we will hold the first such workshop at the Institute on 12-14 November, 2002. The Director is appointing the standing committee, which will meet before the workshop to formulate recommendations on key research topics to be considered for future Treasury programs as well as other pertinent issues.

We will post updates on the status of Cycle 12 and the Treasury workshop at **http://www.stsci.edu/ftp/proposer/cycle12/announce.html**, which should be consulted regularly by all scientists interested in participating in Cycle 12. Ω

Fall [2002]

Good Luck

Steven Beckwith, *swvb@stsci.edu*

A colleague of mine once advised me, "When you're good, you're also lucky." By that metric, the teams maintaining the Hubble Space Telescope are unusually good, having had a string of luck since the first servicing mission and continuing today. The recent luck started with the serendipitous discovery of SN2002dd in the Hubble Deep Field by the Advanced Camera for Surveys (ACS) team during orbital verification. This type Ia supernova at a redshift of 1.06 will be one of the very few high redshift objects that help confirm or deny the acceleration of the universe. We are especially lucky to have Hubble as a tool during the time when it became apparent that supernova of type Ia can be used to measure the expansion history of the universe, showing that the universe is accelerating.

An added piece of luck was the availability of Near Infrared Camera and Multi-Object Spectrometer (NICMOS) to get the infrared magnitudes essential to the calibration of high redshift supernovae, a task that is currently impossible with ground-based telescopes. Restored to operation by the NICMOS Cooling System (NCS), it is more sensitive now than it was when first installed, thanks to the happy coincidence that the detector can now be run at a higher temperature to boost the overall quantum efficiency. That luck resulted from a very good team at Goddard Space Flight Center and in industry.

Good luck gave us the unusual nova, V838 Mon, which erupted in January of this year and was first observed with ACS at the end of April. V838 Mon is surrounded by circumstellar material, which reflects the light from the outburst after the travel-time delay. This creates a light echo, which can be used to reconstruct the full three-dimensional distribution of material by watching it light up at different times. Institute astronomer Bill Sparks is unusually lucky—and, therefore, unusually good—for having published a detailed analysis of this very phenomenon in 1994, when the most recent other example of a nova with such a light echo erupted in 1901. Good foresight, Bill.

Luck was on our side when astronomers finally localized gamma-ray burst sources well enough to study them with optical telescopes during the Hubble era. Hubble became particularly important for revealing their locations within the distant galaxies that give rise to them in the first place.

Extrasolar planets were unknown at the time of Hubble's launch and only just discovered when the Space Telescope Imaging Spectrograph (STIS) was installed during the second servicing mission. Nevertheless, STIS observations of HD 209458b, an extrasolar planet that eclipses its parent star, revealed sodium in the planet's atmosphere. It was a big surprise that we could study extrasolar planet atmospheres without a dedicated mission. We are probably 20 years ahead of our time because of Hubble and STIS—very lucky indeed.

We are lucky to be living in a time when we have a cornucopia of astronomical discoveries and the tools to study them well. Although only designed to study a few of these phenomena, Hubble has been an important part of the analysis in almost every subfield of astronomy. We astronomers are especially lucky to be living in this era.

Imagine now what it would be like to be without Hubble's capabilities. We would consider ourselves extremely unlucky if Hubble were not around to follow up the next equivalent of the SN Ia or GRB phenomena or to study the atmospheres of new exo-planets. Thus far we have been saved by the miracle of servicing. Visiting Hubble every two or three years has kept it in good operating condition, albeit with a gap of a month or so when the gyros failed in 1999. But we will need even better luck after the next servicing mission in 2004 for Hubble to maintain its superlative output until 2010, when NASA plans to terminate the Hubble mission.

Fortunately, the Hubble team is exceptionally good, and so we can hope for exceptional luck to remain with us to the end of Hubble's life. My hope is that if we are especially good, we can extend our use of Hubble right on up to the launch of NGST, when many of Hubble's capabilities will be superceded with superior ones. That will be good luck, indeed. Ω

Institute Postdoctoral Fellowship Program

Michael Fall, *fall@stsci.edu*

The Institute supports outstanding young researchers through the Institute Postdoctoral Fellowship Program. We select Institute Fellows, usually one per year, on the basis of their accomplishments and promise in research in any area of astrophysics or planetary science in which the Institute has expertise, including theory, observation, and instrumentation.

The Institute Postdoctoral Fellowships are for research alone and carry no other responsibilities, although it is expected that the recipients will participate actively in the scientific life of the Institute. The awards include a generous salary, benefits, and funds for research expenses. Institute Postdoctoral Fellowships are intended to be equivalent to 'prize fellowships' at other major research institutions.

Current Institute Fellows are Chris Fassnacht and Oleg Gnedin. Fellow-elect Leon Koopmans will join the Institute in November 2002. Recent holders of Institute Fellowships include James Rhoads, Sally Oey, Roeland van der Marel, and Mark Dickinson.

We plan to select another Institute Postdoctoral Fellow in winter 2002/3 for an appointment to begin in the fall. Applications and letters of reference are due on December 2, 2002. Details of the application process will be announced soon in the AAS Job Register, in *Physics Today*, and at the Institute web site (**http://www.stsci.edu/stsci/STScI_Fellow.html**). Interested persons may contact Dr. Michael Fall for more information. Ω

Hubble Fellowship Program

Michael Fall, *fall@stsci.edu*

Hubble Fellowships are awarded annually to outstanding young scientists engaged in research related to the Hubble mission. The research may be observational—either space-based or ground-based—or theoretical. The Hubble Fellowships provide three years of salary and other support at a U.S. host institution of the Fellow's choice (subject to a maximum of one new Hubble Fellow per institution per year).

A selection committee met at the Institute in January 2002 to review more than 100 applications for Hubble Fellowships to start in autumn 2002. The new Hubble Fellows are listed in the accompanying table.

Hubble Fellows present the results of their research each year at the Hubble Fellows Symposium. The 2001/2 Symposium was held at the Institute on October 4 & 5, 2001, and the 2002/3 Symposium will be held on March 6 & 7, 2003. Anyone interested is welcome to attend.

We plan to select approximately 12 new Hubble Fellows in winter 2002/3 for positions to start in fall 2003. The Announcement of Opportunity, available at **http://www.stsci.edu/stsci/hubblefellow/ao.html**, provides instructions and requirements for the application process. The deadline for receipt of applications (hard-copy only) is November 4, 2002. Eligible candidates must have received their Ph.D. degrees after December 31, 1999. Ω

2002 Hubble Fellows

Name	Ph.D. Inst./year	Host Inst.
James Bullock	U.C. Santa Cruz/1999	CfA
Hsiao-Wen Chen	S.U.N.Y Stony Brook/1999	M.I.T.
Neal Dalal	U.C. San Diego/2002	I.A.S
Jarrod Hurley	Cambridge U./2000	A.M.N.H.
Robert Hynes	Open University/1999	U. Texas
Inese Ivans	U. Texas/2002	Caltech
Michael Liu	U.C. Berkeley/2000	U. Hawaii
Lucas Macri	Harvard U./2001	N.O.A.O
Robert Metcalf	U.C. Berkeley/1999	U.C. Santa Cruz
Barbara Mochejska	Copernicus Ctr./2002	CfA
Feryal Ozel	Harvard U./2002	I.A.S.
Todd Thompson	U. Arizona/2002	U.C. Berkeley

Tenth Annual Summer Students Invasion

David Soderblom, *drs@stsci.edu*

This year was the tenth anniversary of the Institute's Summer Student Program. For 2002, we received about 100 applications from students in the U.S. and abroad. Of these, we selected 17 undergraduates and 2 high school seniors from the US and 6 foreign countries to come to the Institute for a summer of astronomical research.

Each student is assigned to a member of the scientific staff, who supervises their research activities and mentors them. The students spend 10 weeks at the Institute, where each works closely with staff astronomers and meets other students from different backgrounds with similar motivations. Their supervisors focus their attention on productive research activities for an intensive period, usually involving Hubble observations. The results are mutually beneficial. Indeed, many of today's front-rank astronomers had similar opportunities during their college years to help guide their early career choices. The research experience and the encounter with an observatory are also helpful when applying to graduate schools.

The Institute's research funds—the Director's Discretionary Fund and staff research grants—support the Summer Student Program.

We will post information about the 2003 Summer Student Program at **http://www.stsci.edu/stsci/summer.shtml** shortly after December 1, 2002. Ω

2002 Summer Students at STScI

Name	School	Institute Supervisor
Tiffany Borders	Sonoma State U.	Keith Noll & Lisa Frattare
Joseph Converse	Colgate U.	Claus Leitherer
Corey Dow	U. Oregon	Paul Goudfrooij
Hector Galué	Monterrey Inst. of Tech.	Nolan Walborn & Jesus Maiz
Peter Hugger	Virginia Military Inst.	Massimo Stiavelli
Heather Knutson	Johns Hopkins U.	John MacKenty
Katarina Kovac	U. Belgrade	Sangeeta Malhotra
Andrew Levan	U. Leicester	Andy Fruchter
Wladimir Lyra	Federal U. of Rio De Janiero	Daniella Calzetti
Pavel Machalek	University College London	Ken Sembach
Natalie Mintz	U. Washington	Letizia Stanghellini
Alan O'Connor	Linganore HS, Frederick, MD	Duccio Macchetto
Shannon Patel	Cornell U.	Massimo Robberto
Leda Pinto	Federal U. of Rio de Janiero	Claus Leitherer
Aviva Presser	UCLA	Melissa McGrath
Andre Questel	Woodlawn HS, Baltimore, MD	Anton Koekemoer
Kristen Shapiro	Williams College	Roeland van der Marel
Elspeth Suthers	U. Washington	Torsten Boeker
Stefania Varano	U. Bologna	Duccio Macchetto & Bill Sparks

Figure 1: *Participants in the 2002 Summer Student Program.* ***Front row****: left to right: Peter Hugger, Hector Galué, Tiffany Borders, Shannon Patel, Katarina Kovac, Stefania Varano, Natalie Mintz, Lauren Rosenblatt (intern), Kristen Shapiro, and Leda Pinto.* ***Back row, left to right:*** *Alan O'Connor, David Soderblom, Elspeth Suthers, Pavel Machalek, Heather Knutson, Joseph Converse, and Andrew Levan.*

ACS Begins Cycle 11 Science Operations

Mark Clampin, *clampin@stsci.edu*

Advanced Camera for Surveys (ACS) is now into the full swing of Cycle 11 science. We completed all the Servicing Mission Orbital Verification (SMOV) programs successfully, several weeks early. ACS has now exercised every primary science capability, and its performance continues to meet or exceed pre-launch expectations. General Observers (GOs) interested in examining the performance of ACS can download processed images from the ACS Early Release Observations program and data from the Great Observatories Origins Deep Survey (GOODs) program. (**http://archive.stsci.edu/hst/acsero.html**, **http://www.stsci.edu/ftp/science/goods/**).

The last major mode of ACS to be commissioned during SMOV was the coronagraphic mode in the High Resolution Camera (HRC). Initial SMOV test programs resulted in some changes to the target acquisition apertures to optimize the placement of the target on the 1.8 and 3.0 arcsec occulting spots. Following these changes, we executed the SMOV calibration programs to exercise the coronagraph. The scattered light profiles obtained with these programs confirm that the coronagraph is behaving according to the design specifications.

In Figure 1 we show the derived coronagraph contrast ratios for the 1.8 arcsec occulting spot. It demonstrates that the ACS coronagraph achieves a factor of ten suppression of the Hubble point-spread function (PSF). Optimal subtraction of the PSF gains two additional orders of magnitude. Detailed analysis of the SMOV programs has shown that commanding changes to coronagraphic imaging and target acquisition procedure can improve repeatability of the PSF subtraction. We will make these changes and advise the PIs of coronagraphic GO programs accordingly once the capability is available for science observations.

In addition to the completion of SMOV, the ACS Instrument Group has produced a number of calibration products from SMOV programs to update pre-launch reference files. The set of flat fields for 13 Wide Field Camera (WFC) filters equalize the photometry of a given star to ~1% (one sigma) for any position in the field of view. We are delivering a corresponding set of files for the High Resolution Channel (HRC). We have made the corresponding updates to the Synphot reference files, so that pipeline processing and the ACS exposure time calculators now use throughput tables based on measurements from SMOV photometric programs. We also incorporated into the geometric distortion reference file (IDCTAB) a distortion solution delivered by the Investigation Definition Team, which exceeds the goal in the ACS Instrument Handbook. It employs a fourth order polynomial, which required a corresponding change in the PyDrizzle software. As ACS operations transition from SMOV to the Cycle 11 calibration plan, we will describe new results in Instrument Science Reports, and incorporate them into reference files. We will also provide updates to the GO community by means of the ACS Space Telescope Advisory Newsletters. The forthcoming HST Calibration workshop will also feature many presentations regarding the calibration of ACS. (**http://www.stsci.edu/stsci/meetings/cal02/**). Ω

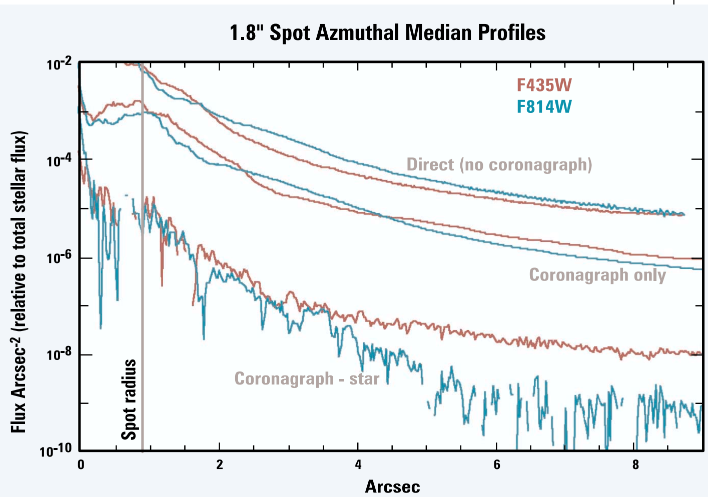

Figure 1: *Contrast ratios for the ACS coronagraph obtained from F435W and F814W images. The plot shows ratios for direct imaging, coronagraphic imaging, and the results of an optimum comparison star subtraction (Courtesy J. Krist).*

NICMOS Recommissioned

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The Near Infrared Camera and Multi-Object Spectrograph (NICMOS), Hubble's window on the infrared universe, became inoperative in 1998, after Cycle 7, when its cryogens were exhausted. In the summer 2002 issue of the Newsletter, Keith Noll described the installation and successful activation of the NICMOS Cooling System (NCS), which has brought NICMOS back to life as a working science instrument. Indeed, all indications are that NICMOS is functioning beautifully and seems an even better instrument than it was in Cycle 7.

The NCS is maintaining the detector temperatures very stably at the programmed set point of 77.1 K. This is excellent news for instrument calibration, since many of the detector properties depend strongly on temperature. The new operating temperature is ~15K warmer than that in Cycle 7, which has two major consequences for the detector. First, the linear dark current is about three times higher than it was in Cycle 7, with values of 0.1 to 0.15 e^-/s/pixel. Fortunately, a 'bump' of highly elevated dark current, which was observed during end-of-life warm-up in Cycle 7, has *not* reoccurred. Therefore, the dark current is rarely, if ever, a limiting factor for observational sensitivity. However, there are significantly more hot pixels peppering the images than before.

The detector quantum efficiency is higher at the warmer temperature, by as much as 80% at 1 micron, 40% at 1.6 micron, and 20% at 2.2 micron. Moreover, the 'flatness' of the flat fields has improved, with smaller peak-to-valley excursions. Both of these changes are a substantial bonus for NICMOS observers, providing higher signal-to-noise ratio in a given exposure time and more uniform sensitivity over the field of view. As expected, the linear dynamic range is about 10% lower than in Cycle 7. The 'shading' pattern, a noiseless but highly structured bias term, is significantly different than in Cycle 7 and somewhat different from end-of-life predictions. Nevertheless, it appears to be stable and subject to calibration. Preliminary analysis of the thermal background at wavelengths longer than 1.8 micron indicates no changes relative to Cycle 7.

Another thing that has not changed since Cycle 7 (unfortunately) is the persistent afterglow from the particle bombardment as the telescope passes through the South Atlantic Anomaly (SAA). This afterglow produces a blotchy pattern of spatially correlated, non-Gaussian 'noise' (really signal), which gradually decays during the subsequent orbit, and which can limit sensitivity for faint-object imaging. In Cycle 11 operations, we are experimenting with methods to ameliorate the effects of afterglow. We now schedule short dark exposures after the telescope emerges from the SAA and before NICMOS science observations. These 'post-SAA darks' are automatically delivered to users retrieving science data from the archive. Early experiments indicate that proper scaling and subtraction of these darks from subsequent science exposures may partially suppress the afterglow signal and improve the noise characteristics of affected images. The Institute's NICMOS group will continue to experiment with this approach, and, if it appears to hold promise, will develop software tools to aid users in applying such corrections to their own data.

The execution of NICMOS programs from the Servicing Mission and Orbital Verification (SMOV) period, as well as the early calibration program, is almost complete. Regular calibration observations have started. The final SMOV program was the coronagraphic performance test. The Institute's NICMOS group is presently analyzing the SMOV data and making calibration reference files for use in the data processing pipeline.

NICMOS General Observer science began on 13 June, 2002, with the execution of a visit from program 9352 (PI: Riess) to observe a supernova at cosmological distances. At present, observers who retrieve Cycle 11 NICMOS data from the archive will receive images processed using old, Cycle 7 reference files. These (not surprisingly) yield unsatisfactory results, and users will certainly wish to reprocess their data when the new reference files are available. This can be accomplished easily by retrieving the data again, which will be automatically reprocessed by the NICMOS On-The-Fly Reprocessing system, which was described in an article in the winter 2002 issue of this Newsletter. (**http://sco.stsci.edu/newsletter/pdf/2002/winter_02.pdf**).

We are in the process of updating the NICMOS Instrument Handbook to describe the instrument behavior under NCS operations. Please consult the Institute's NICMOS web pages for information as it becomes available. (**http://www.stsci.edu/hst/nicmos**). Ω

James Webb Space Telescope (JWST) News

Roelof de Jong, *dejong@stsci.edu,* **and Marcia Rieke**

Prime Contractor Selected

On September 10, 2002, NASA announced the selection of TRW as the prime contractor to build Next Generation Space Telescope (NGST), which NASA renamed the James Webb Space Telescope (JWST), named after James E. Webb, NASA's second administrator.

Figure 1 shows the TRW design for JWST, which has a 6-meter deployable primary mirror comprised of three hinged segments, each of which consists of hexagon segments, in the manner of the Keck telescopes. Under the terms of the contract, which is valued at $824.8 million, TRW will design and fabricate the observatory's primary mirror and spacecraft. TRW also will be responsible for integrating the science instrument module into the spacecraft, performing the pre-flight testing, and checking out the observatory on orbit.

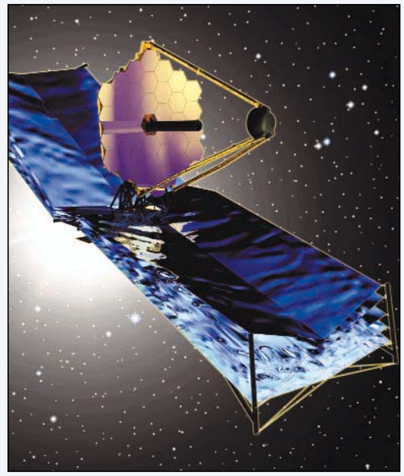

Figure 1*. The recently selected TRW design for the James Webb Space Telescope, formerly known as the Next Generation Space Telescope.*

James Webb

While he is best known for leading NASA during the Apollo program of human landings on the Moon, James Webb also initiated a vigorous space science program at the agency, which conducted more than 75 launches during his tenure, including America's first interplanetary probes. Less widely known is Webb's advocacy—as early as 1965—of a large space telescope, which became the Hubble Space Telescope.

Webb favored strengthening NASA's core of scientists and engineers with outside participants to ensure the success of science missions. Today the Space Telescope Science Institute is one embodiment of this idea. In 1998, NASA selected the Institute to manage the science program for the new space telescope.

Science and Instrument Teams Selection

On June 20, 2002, NASA announced the selection of several of the science and instrument teams for JWST. NASA selected a team led by the University of Arizona to build the Near-Infrared Camera (NIRCam). Marcia Rieke is Principal Investigator (PI) of this team.

NASA chose the U.S. portion of the U.S./European team that will construct the mid-infrared instrument (MIRI). The members of this team are Dr. George Rieke (Team Lead, University of Arizona), Dr. Thomas Greene (NASA Ames Research Center), and Dr. Margaret Meixner (University of Illinois, soon moving to the Institute). They will oversee the construction of MIRI in collaboration with scientists and engineers from the Jet Propulsion Laboratory, led by Dr. Gene Serabyn, and the European MIRI Consortium, led by Gillian Wright (UK Astronomy Technology Centre).

NASA also selected several scientists to serve on the JWST Science Working Group (SWG) with the principal observatory and instrument scientists. (See Table 1, page 8.) The SWG will provide guidance on the science goals and capabilities of JWST during the development of the telescope. The first meeting of the SWG was scheduled for September 24-25, 2002, at the Institute. The agenda topics included the SWG charter and organization, JWST Project organization and status, status of individual science instruments, roles and plans of the Institute, and an update of the JWST science requirements.

NIRCam Proposal

JWST needs a sensitive near-infrared camera to achieve its goal of being the 'First Light Machine' by imaging the first light sources in the distant, early cosmos. To achieve this goal, this camera, NIRCam, should be capable of

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JWST
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detecting 1 nJy point sources in a 100-hour integration (an integration time similar to the Hubble Deep Fields). The NIRCam must also enable a host of other projects, like studying the course of galaxy evolution from the earliest luminous objects to present-day galaxies, the process of star formation in our own galaxy, and the nature of planets around other stars. The design of NIRCam must be optimized to support these observations as well as all the other programs outlined in the Design Reference Mission. (**http:// www.stsci.edu/ngst/science/drm**)

Marcia Rieke's team developed the NIRCam design in collaboration with Lockheed-Martin's Advanced Technology Center, COM DEV Space, and EMS Technologies. Table 2 summarizes NIRCam's capabilities as proposed, which the team will bring into accord with the prime contractor's telescope design. In addition to the listed science capabilities, NIRCam also includes wavefront sensing capabilities to help align the primary mirror segments of the JWST.

Table 1. NGST Science Working Group

Name	*Institution*	*Position*
Jonathan Gardner	NASA/GSFC	Deputy Project Scientist
Matt Greenhouse	NASA/GSFC	ISIM Project Scientist
Heidi Hammel	Space Science Institute	Interdisciplinary Scientist
John Hutchings	Dominion Astrophysical Obs.	CSA Project Scientist
Peter Jakobsen	ESA/ESTEC/ESA	NIRSpec Science Representative
Simon Lilly	U. of Toronto	Interdisciplinary Scientist
Jonathan Lunine	U. of Arizona	Interdisciplinary Scientist
John Mather	NASA/GSFC	NASA Project Scientist
Mark McCaughrean	Astrophysics Inst. Potsdam	Interdisciplinary Scientist
George Rieke	U. of Arizona	MIRI Lead Scientist
Marcia Rieke	U. of Arizona	NIRCam Principal Investigator
Massimo Stiavelli	STScI	Interdisciplinary Scientist
Peter Stockman	STScI	STScI Project Scientist
Roger Windhorst	Arizona State U.	Interdisciplinary Scientist
Gillian Wright	U.K. Astronomy Tech. Ctr	ESA MIRI Science Representative

The proposed design of NIRCam consists of four modules that can be used in parallel, two broad- and intermediate-band imaging modules, and two tunable filter imaging modules, each with a 2.3 x 2.3 arcmin field of view. The two identical imaging modules have a short and a long wavelength channel to take images simultaneously in light split by a dichroic at about 2.35 μm. The short wavelength channels are sampled at 4096 x 4096 pixels, the long wavelength channels by 2048 x 2048 pixels. The tunable filter imaging modules have a resolving power of about 100. One tunable filter module is optimized for wavelengths from about 1.2 to 2.5 μm, the other from 2.5 to 4.5 μm. The design has coronagraphs in all modules.

Figure 2 (page 9) shows one of the tunable filter modules. The entire NIRCam design is compact like this module due to refractive camera optics. Figure 2 also shows one of NIRCam's dual filter wheel assemblies—one wheel for filters and one for pupils. The Canadian Space Agency will provide the tunable filters and filter wheels, proposed by the team to be build by EMS Technologies and COM DEV Space, respectively.

The NIRCam team's science program has three components: a deep extragalactic survey, observations of star formation under varying conditions in the Milky Way, and a study of circumstellar material in disks and planets. The team will use NIRCam's tunable filters and coronagraphic modes extensively to accomplish these science programs.

The heart of the galaxy formation program is a deep survey using 50,000 second exposures in six filters and a 100,000 second exposure in the 4.4 μm filter. The detection limits are indicated in Figure 3 (page 10). While the broadband survey uses the two imaging modules, the tunable filter modules will carry out an emission-line survey of the adjacent sky. Repeating the exposures six months later, when the field will have rotated by 180 degrees due to JWST's orbital motion around the Sun, will yield emission line data on the original broadband fields and vice-versa.

Table 2. NIRCam Capabilities

Wavelength Range	0.6 - 5.0 μm
Spectral Resolutions	Selection of R ~ 4 and R ~ 10 discrete filters (complete list at **http://ircamera.as.arizona.edu/nircam/features.html**) R~100 using 2 tunable filters
Fields of View	Imaging: 2.3 x 4.6 arcmin at two wavelengths simultaneously R=100: Two 2.3 x 2.3 arcmin fields (one $\lambda < 2.5$ μm, one $\lambda > 2.5$ μm)
Spatial Resolution	Imaging: 0.034 arcsec/pixel $\lambda < 2.5$ μm 0.068 arcsec/pixel $\lambda > 2.5$ μm R=100: 0.068 arcsec/pixel
Coronagraphy	Choice of coronagraphic spots and pupils in all instrument sections

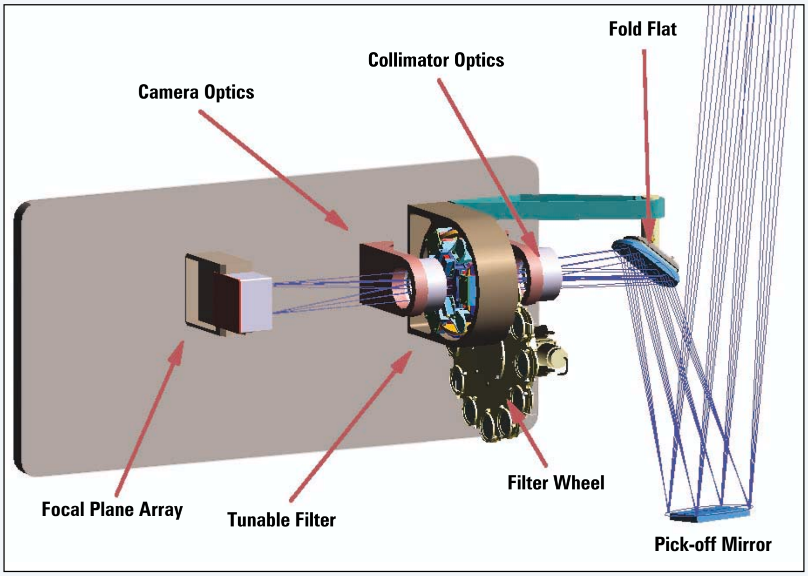

Figure 2. *One of the tunable filter imaging models of the selected NIRCam design. The design has a total of four imaging modules: two tunable filter modules and two identical broad- and intermediate-band imaging modules.*

The emission line survey will subdivide the long, broadband exposure times into series of 3000-second exposures split over wavelength settings covering a range in redshift. Two extra settings will complement the wavelength range searched for Lyman-α emission, to observe the redshifted wavelengths of HeII at 1640Å and either H_β or for P_β. This strategy will guard against detecting a strong line and assuming that it is Lyman α when the line is actually H_α at a much lower redshift. A search for moderately redshifted H_α ($z \sim 2.8$ to 5.9) will use the long wavelength tunable filter module. Two 4.6 x 4.6 arcmin fields will be surveyed, selected from the deep fields studied with SIRTF, Chandra, and XMM.

The star formation program proposed by the NIRCam team addresses three fundamental issues in star formation:

(1) What physical variables determine the shape of the initial mass function (IMF)?
(2) How do cloud cores collapse to form isolated protostars?
(3) Does mass loss play a crucial role in regulating star formation?

The team will address the first issue by determining the IMF as a function of metallicity and by determining whether there is a limit on the low-mass end of the IMF imposed by opacity and cooling limits. The second issue will be addressed by measuring the density profiles in dense molecular clouds by using NIRCam's sensitivity from 2 to 5 μm. The team will construct color-color diagrams of background stars to obtain extinction profiles, which will produce density profiles. The third issue will be addressed by surveying young clusters already known to harbor protostars to find objects with excess emission indicative of disks. Water or polycyclic aromatic hydrocarbons (PAHs) will also be detectable from the survey data. The team will chose objects for more detailed imaging in emission lines with a goal of distinguishing accretion from outflows.

The debris disk and planetary system portion of the NIRCam team's observing program seeks answers to questions such as (a) What are the initial conditions for formation of debris disks? (b) How do these disks evolve in structure and composition? (c) How do Kuiper Belt Object (KBO) surface compositions compare with debris disks? (d) Do giant planets orbit nearby stars? (e) How do giant planets relate to the debris disks?

The team will study circumstellar disks from their formation through their evolution to debris disks. NIRCam's coronagraph will enable detection of the reflected light from a broad range of disk densities. By combining NIRCam data on the reflected light from disks with data on the thermal emission from disks as measured at longer wavelengths with MIRI and SIRTF, the team will build up a picture of the nature and distribution of dust from 1 AU out to beyond 100 AU. Selected disks will be imaged using the coronagraphic mode of the tunable filter modules to measure the comparison of disks in a range of evolutionary states. Comparison of KBOs with disks will begin by observing a suite of bright KBOs in detail to develop a set of KBO template spectra. A subset of these KBOs will be observed at 24 μm to determine radii and albedos,

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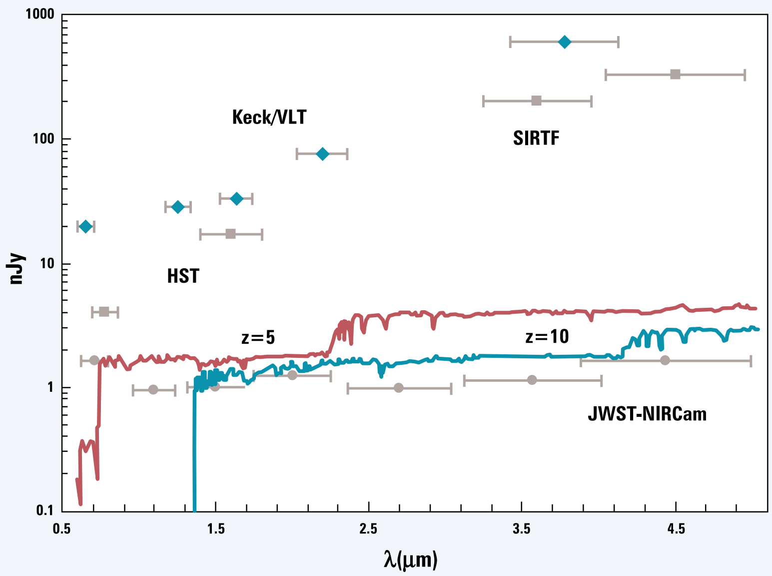

Figure 3. *Detection limits (5σ) for NIRCam on a proto-galaxy at redshift 10 (blue, 30 Myr old, 2.4x10*^{8} *M*$_{sun}$*) and a galaxy at redshift 5 (red, 900 Myr old, 2x10*^{9} *M*$_{sun}$*) compared with Keck/VLT, Hubble, and SIRTF. Integration time is 50,000 sec in all cases. The Lyman break can be detected to redshift 25, if objects exist that are bright enough.*

which can be correlated with surface spectral features. The NIRCam team will address the last two questions by discovering and studying planets around stars selected in three complementary ways. First, the nearest stars will be searched, where the reflected light from Jupiter-sized objects lying 4 to 10 AU from their parent stars can be studied. Second, planet searches will be conducted on stars with known debris disks such as ε Eri and α Lyrae, where millimeter wave and other data suggest that planets must be present. The third planet search will be conducted on stars thought to be young on the basis of spectral or kinematic data. All of these searches rely on the NIRCam's coronagraphs. The atmospheres of detected planets will be studied further using NIRCam's intermediate band filters and the tunable filters. Ω

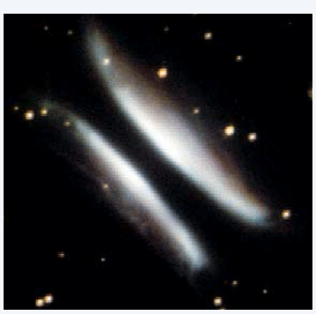

Image Credit: *NASA and The Hubble Heritage Team (STScI/AURA)*

Hubble Astronomers Feast on an Interstellar Hamburger

NASA's Hubble Space Telescope has snapped a photograph of a sun-like star nearing the end of its life. Nicknamed Gomez's Hamburger, the object has already expelled large amounts of gas and dust and is on its way to becoming a colorful, glowing planetary nebula.

This Hubble Heritage image, taken Feb.22, 2002, with the Wide Field Planetary Camera 2, shows the striking dark band of dust that cuts across the middle, which is actually the shadow of a thick disk around the central star seen edge-on from Earth. The star itself, is hidden within this disk, however, light from the star does emerge in the directions perpendicular to the disk and illuminates dust above and below it.

Gomez's Hamburger was discovered on sky photographs by astronomer Arturo Gomez, at the Cerro Tololo Inter-American Observatory in Chile. It is located roughly 6,500 light-years away in the constellation Sagittarius.

http://oposite.stsci.edu/pubinfo/pr/2002/19

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 9.2 terabytes of data in about 280,000 science data sets. The archive ingestion rate set another record in July at almost 13 gigabytes per day. The retrieval rate also set records in April and May, reaching 31 gigabytes per day.

Data Distribution on CD and DVD

The Data Archive and Distribution Service (DADS) now has the ability to write Hubble data requested by users to Compact Discs (CD), Digital Video Discs (DVD), 8mm, or Digital Audio Tape (DAT). StarView and the World Wide Web (WWW) interfaces have been updated to offer users the new options of CD and DVD. We are writing CD-R and DVD-R format disks, all ISO9660 standard with RockRidge extensions. The DVDs are readable by any standard DVD-ROM (Read-Only Memory) drive or any DVD-R drive. The disks are shipped through Federal Express shortly after they are made.

Proposal Information Available for IUE Observations

Archive researchers can now easily access proposal information associated with International Ultraviolet Explorer (IUE) observations. For each IUE program a WWW page gives the title, the Principal Investigator, a link to the proposal abstract, a list of the publications referencing the data, and a summary of the data obtained under the program. To reach this information, one selects a dataset given in the IUE search page results and then selects the 5-character program ID. The abstracts are currently in the form of scanned images because the originals were on paper, but we will soon convert them to text using Optical Character Recognition (OCR) software. Besides for IUE, program pages are currently available for Hubble. We plan program pages for Extreme Ultraviolet Explorer (EUVE) and Far Ultraviolet Spectroscopic Explorer (FUSE).

Preferred Access Pathway for ACS Early Release Observations

MAST has created an anonymous ftp site (**ftp://archive.stsci.edu/pub/ero/**) for access to Advanced Camera for Surveys (ACS) Early Release Observations (EROs), which were publicly released beginning July 1, and other public ACS data for which we expect heavy demand. We urge interested researchers to obtain the data files from this ftp site. We will give lower priority to retrievals through Starview and the WWW, which may take up to a week for delivery. The ftp site will cut the delay and reduce the load on the Hubble processing and distribution systems. We will periodically recalibrate the data on the anonymous ftp site to ensure the data reflect the best available reference files. More details can be found at **http://archive.stsci.edu/hst/fastaccess.html**.

In early July, we used the new access mode for the ACS EROs of UGC 10214 ('Tadpole' galaxy), NGC 4676 ('Mice' galaxies), the Cone nebula in NGC 2264, and the M17 ('Omega') nebulae. We are now releasing via this route the ACS data obtained for the Great Observatories Origins Deep Survey (GOODS) program. We will also make the fully processed GOODS images publicly available in the archive as part of our new High-Level Science Products program approximately one year from the times of the observations. More information on the GOODS and other Hubble Treasury programs can be found at **http://archive.stsci.edu/hst/tall.html**. Ω

Looking Between the Galaxies

Gerard A. Kriss, *gak@stsci.edu,* **and Randal C. Telfer,** *randal.telfer@orbital.com*

The vast reaches of space between the galaxies are not as empty as they might seem. A cosmic web of tenuous gas—the intergalactic medium (IGM)—fills these spaces. Its clumps and filaments of atoms and ions trace the gravity of primordial density fluctuations from the time of the Big Bang. By observing absorption lines at various redshifts, we can study the composition of the IGM and the radiation sources that ionize it.

In the era of recombination after the Big Bang, the neutral intergalactic gas became opaque to ultraviolet light, rendering it difficult to observe. Only at later times and lower redshifts, when the first luminous objects re-ionized the gas, did the IGM become mostly transparent and available for us to study. Using distant quasars as background light sources, we can measure IGM absorption lines, in ultraviolet spectra from space telescopes and in longer wavelength spectra from ground-based telescopes.

Surprisingly, the IGM does not consist simply of the lightest elements, hydrogen and helium. We also find heavy elements—carbon, oxygen, and silicon—which are produced only in stars. We want to know how these heavy elements found their way into the least dense regions of the universe. And we want to identify the sources of the radiation that ionize the IGM.

We can infer the spectral shape of the ionizing sources by comparing the relative column densities of absorption features from species with different ionization states. This is because the ratio of their column densities is directly proportional to the ratio of their photoionization rates—or to the ratio of incident ionizing radiation for the two species, given the laboratory values of their ionization cross sections.

For example, the IGM team of the Far Ultraviolet Spectroscopic Explorer (FUSE) studied neutral hydrogen (H I) and ionized helium (He II) in the direction of the quasar HE2347-4342. Using FUSE spectra, they made the first measurements of individual He II column densities at various redshifts along the line of sight. These they compared to H I column densities at the same redshifts, measured in a Keck spectrum. As shown in Figure 1, the resulting He II/H I column density ratios average about 80, with most less than 100. Such low values imply the ionizing sources have a power-law spectrum with a spectral index of about -1.5. This value is expected for quasars, whose spectra extend to high energies and include ample photons capable of ionizing He II.

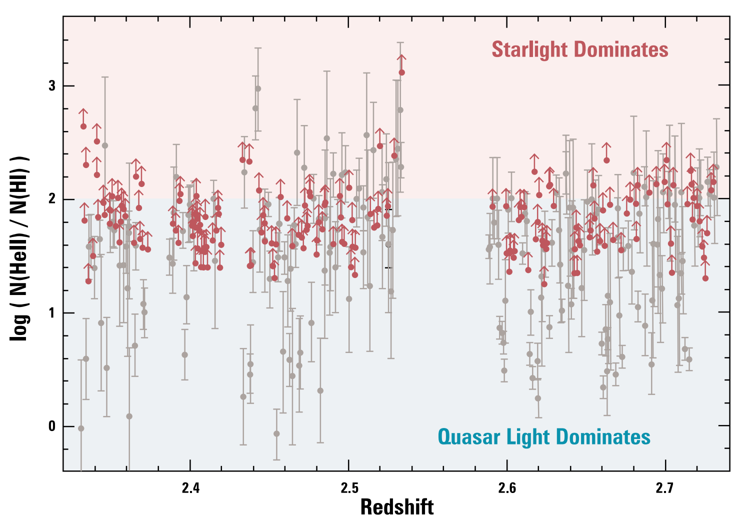

Figure 1. *The ratio of He II to H I column densities is an indicator of the shape of the ionizing spectrum. Gray points with error bars have measured He II column densities from FUSE observations and measured H I column densities from Keck spectra. The red points are lower limits computed using the He II column density measured from the FUSE spectrum and an upper limit of* $10^{12.3}$ *cm*$^{-2}$ *for H I absorption lines in the Keck spectrum. The blue shaded area shows values of He II to H I column density ratios dominated by spectra typical of quasars. In the red shaded area, starlight makes a contribution comparable to or greater than that of quasars.*

The large scatter in the He II/H I column density ratios—even for adjacent features in the FUSE and Keck spectra—indicates that the radiation field is far from uniform. The nearest source of ionizing radiation may exert a strong influence on individual features. We can compute an inferred spectral index from each measured He II/H I column density ratio. In Figure 2, we compare these values to the measured spectral indices of 184 radio-quiet quasars of redshift 0.3 to 3.6 from Hubble data. The two distributions match surprisingly well.

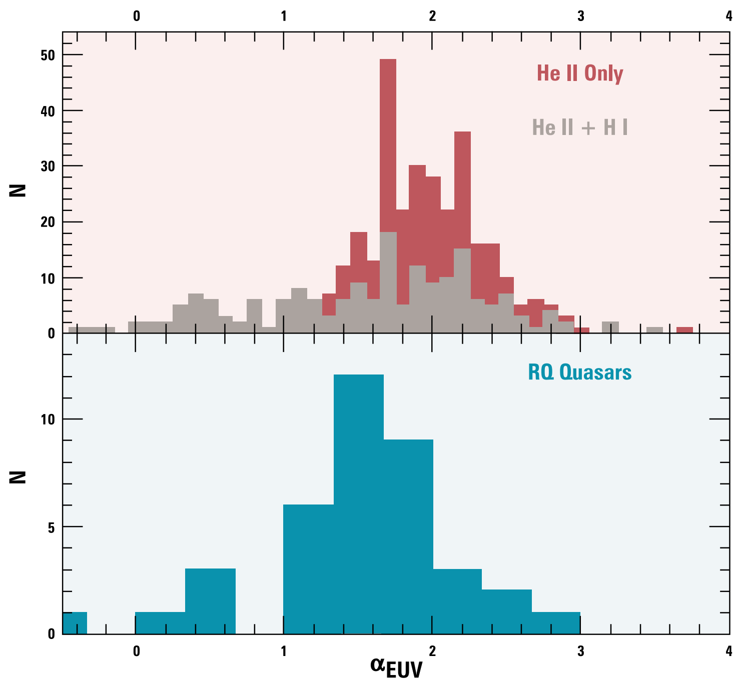

Figure 2. Bottom panel: *The blue histogram is the distribution of extreme ultraviolet spectral indices for radio-quiet quasars.* ***Top panel:*** *The gray histogram is the distribution of spectral indices inferred for the observed ratios of He II to H I column density. This is statistically indistinguishable from the quasar distribution. The red histogram is a distribution of lower-limits to spectral indices derived from spectral features with measured He II column densities and H I upper limits. This distribution has significantly higher spectral indices than does the quasar distribution.*

There are also many points in Figure 1 (page 12) with He II/H I column density ratios greater than 100, even cases where we can see He II absorption but no H I absorption. This is expected for softer ionizing spectra, when the radiation has enough energy to ionize neutral hydrogen but not enough to ionize singly ionized helium. At these redshifts toward HE2347-4342—in apparent voids in the Lyman-α forest and the lowest density regions of the IGM—active star formation may be underway, producing hot young stars to ionize the IGM.

Keck observations of the IGM have established the presence of various ionization states of heavy elements (e.g., C II, C IV, and Si IV). Their relative abundances provide another measure of the ionization state of the IGM as well as its composition. Oxygen is the next-most abundant element after He, and the ion O VI is expected to be its most abundant state in the IGM. Unfortunately, O VI 1032 Å and O VI 1038 Å are hard to measure because of confusion with the Lyman-α and Lyman-β forest lines of H I. We can mitigate this confusion by looking at shorter-wavelength oxygen lines falling in the less dense, lowredshift portion of the Lyman-α forest. In particular, O IV 788 Å and O V 630 Å are useful resonance lines due to their high oscillator strengths.

We have used archival Faint Object Spectrograph (FOS) spectra of four quasars (HS1103+6416, HE1122-1649, HS1700+6416, and HE2347-4342) with good Keck spectra to make the first measurement of the strengths of O IV 788 Å and O V 630 Å in the IGM. We used a composite spectrum approach because the FOS spectra do not have high enough resolution and signal-to-noise ratio to detect individual lines. To do this,

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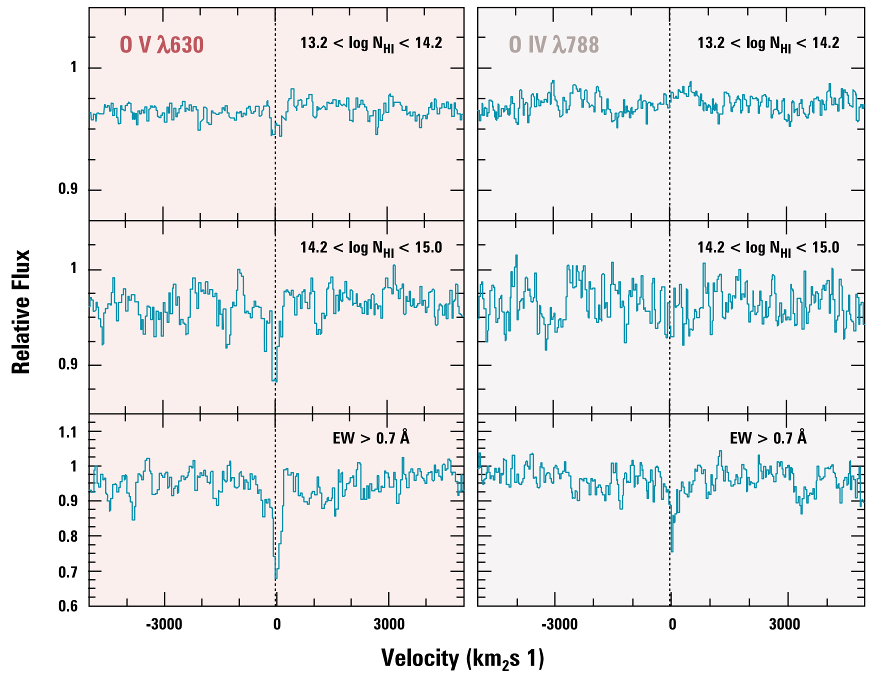

Figure 3. *The panels show composite quasar spectra of IGM absorption by O V 630 Å and O IV 788 Å absorption lines in different column density ranges of the H I Lyman-α forest. Absorption by O V 630 Å is detected down to the lowest density regions of the IGM; O IV 788 Å absorption is significant only in the highest-density regions typical of 'metal-line' absorbers (bottom panels) where the H I Lyman-α equivalent width exceeds 0.7 Å.*

we divided the Keck Lyman-α forest data into three samples of low, medium, and high column density. For each quasar and each Lyman-α forest feature in a sample, we shifted the FOS spectra into the rest frame of the absorber and then formed the composite spectrum. These are shown in Figure 3. The result measures the average strength of the O IV 788 Å and O V 630 Å features in the IGM over a redshift range of 1.6 to 2.9.

We confirm the detection of O V 630 Å in all three density regimes of the IGM by Monte Carlo simulations at better than 99.9% confidence. We see significant O IV 788 Å absorption only in the highest density region of the IGM, which is traditionally associated with metal-line absorption systems in quasars. At low densities, the upper limit on O IV compared to the measured strength of O V implies a hard ionizing spectrum with a power-law index of -1.5, the same as that found by the He II to H I comparison.

It is a puzzle how heavy elements find their way into the low-density portion of the IGM. Possibilities include active star formation in these regions or a much earlier stage of star formation, at high redshift, when dispersal of heavy elements from supernovae was easier. A clue may be provided by the relative abundances of the various elements, which we can calculate after making ionization corrections using a photoionization model with an ionizing spectrum consistent with our He II, H I, O IV, and O V measurements. For the low-density IGM (hydrogen column densities $10^{13.2}$ to $10^{14.2}$ cm^{-2}), we find an oxygen-to-hydrogen abundance ratio in the range $10^{-2.2}$ to $10^{-1.3}$. Comparing this result to other estimates of the carbon abundance in the IGM, we find a ratio of oxygen to carbon that is 2 to 16 times higher than the solar value. Such a high oxygen-to-carbon abundance ratio suggests enrichment of the low-density IGM by high mass stars via Type II supernovae. Given that current models have difficulty producing star formation in low-density regions that is heavily weighted toward massive stars, our results seem to support the idea of an early generation of massive stars, at high redshift, that dispersed their elements widely throughout the IGM.

When it is installed in Hubble in 2004, the Cosmic Origins Spectrograph (COS) will vastly improve our ability to study the IGM. COS will be able to detect individual O IV and O V features formed in low-density regions of the IGM with column densities below $< 10^{14}$ cm^{-2}. Such observations will permit us to examine ionization and abundance variations on the scale of local density fluctuations in the IGM. Ω

The Build-Up of Stellar Mass in the Universe

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It is a common-sense assumption that galaxies have built up their masses over time to achieve their present-day forms. While the stellar content of the universe should start at zero and grow as time passes, the exact form of this evolution is not trivial. It could reveal much about the interaction of large-scale cosmological physics and small-scale star-formation physics. Measuring the rate at which this mass build-up happened and learning the processes that shaped the galaxies are major goals of observational cosmology.

In current models of structure formation, dark matter halos build up in a hierarchical process controlled by the nature of dark matter, the power spectrum of density fluctuations, and the parameters of the cosmological model. The assembly of the stellar content of galaxies is governed by more complex physics, including gaseous dissipation, the mechanics of star formation, and the feedback of stellar energetic output on the baryonic material of the galaxies.

Many early analyses of galaxy evolution concentrated on star formation at high redshift. There are a variety of observables that trace star formation in galaxies with varying degrees of fidelity, including ultraviolet (UV) rest frame luminosity, nebular emission lines, and far-infrared and radio emission. Lilly et al. (1996), Madau et al. (1996), Steidel et al. (1999), and others have used surveys of distant galaxies to measure the redshift evolution of the co-moving UV luminosity density. This density should trace the history of massive star formation but is subject to potentially large and uncertain corrections for the effects of dust extinction. Indeed, mid-infrared and sub-millimeter observations have discovered a substantial population of dust-obscured, star forming galaxies at high redshift. Despite the uncertainties, these studies led to the widely publicized and generally accepted result that the global star formation rate was substantially higher in the past—perhaps 10 times higher at redshift $z = 1$ than today. There is still considerable uncertainty about the peak redshift for star formation, particularly whether it rose, fell, or was flat at $z > 1$.

Studying the stellar *masses* of galaxies is a complementary approach to studying the *rates* at which they form stars. This is, at least indirectly, a common motivation for near-infrared surveys, which observe starlight that provides a reasonable tracer of the total stellar mass. The range of mass-to-light ratios for a mixed stellar population is smaller at longer wavelengths, where light from the longer-lived stars, which make up most of the total stellar mass, dominates over that from the young, massive stars, which are brightest at blue or ultraviolet wavelengths. Moreover, the effects of dust extinction are greatly reduced at longer wavelengths. This is, at least indirectly, a common motivation for near-infrared surveys, which observe starlight that provides a reasonable tracer of the total stellar mass. The global stellar mass density, summed over all galaxies, is, to first order, the time integral of the 'cosmic star formation rate,' but it can be estimated using different observables.

A comprehensive near-infrared census of galaxies out to $z = 3$ requires extremely deep observations like those provided by NICMOS (Near-Infrared Camera and Multi-Object Spectrometer) on Hubble. In Cycle 7, we mapped the Hubble Deep Field North (HDF-N) with NICMOS at 1.1 and 1.6 μm, extending the wavelength baseline of the original HDF-N observations from the Wide Field Planetary Camera 2 (WFPC2). (See Figure 1, page 16.) Our NICMOS observations measure rest-frame optical luminosities and UV-to-optical colors for thousands of distant galaxies, letting us trace their evolution throughout most of cosmic history.

In his Ph.D. thesis, former Johns Hopkins University graduate student Casey Papovich used the HDF-N/NICMOS data to study the stellar populations of 33 Lyman break galaxies (LBGs), which are star forming systems at $2 < z < 3$ that have been selected on the basis of their characteristic color signature. Papovich et al. (2001) fit stellar population models to the UV-to-IR photometry, and found that the stellar mass of a typical LBG is $\sim 10^{10}$ M_{sun}, or $\sim 1/10^{th}$ that of a typical present-day L^* galaxy. Other stellar population parameters were not as well constrained, but the mass estimates are comparatively robust to changing assumptions about past star formation history, metallicity, and dust extinction.

In a new paper (Dickinson et al. 2002), we have extended this work to a larger sample of 737 HDF-N galaxies in order to study the general evolution of stellar mass with redshift. About 170 galaxies have spectroscopic redshifts, and we have estimated photometric redshifts for the others using the combined optical-IR data. Because the HDF-N does not enclose enough volume to provide statistically robust samples at $z < 1$, we match our results to those from shallower, wider-field surveys in order to span the whole timeline out to $z = 3$.

We find that the bright 'envelope' of rest-frame optical luminosities for galaxies has remained roughly constant from $z = 0$ to 3. The rest-frame B-band

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luminosity density seems to have peaked somewhere around $z = 1$ at a level roughly 2.5x that today. However, while distant galaxies have similar optical *luminosities* as those today, this does not mean that they have not evolved. Indeed, there is a dramatic trend toward bluer rest-frame colors at higher redshift, indicating more active star formation, younger stellar populations, and hence lower mass-to-light ratios. Therefore, the high redshift galaxies are less massive than their present-day counterparts. At $z > 1$, we find relatively few galaxies with stellar masses $> 10^{11}\ M_{sun}$ (roughly the mass of a present-day L^* galaxy), and at $z > 2$ there are none, with only a few objects exceeding $10^{10}\ M_{sun}$. The most distant massive galaxies with red colors, which is indicative of a dominant old stellar population, are at $z \sim 1.7$. Virtually everything at $z > 2$ is extremely blue, although our NICMOS observations could have detected older, red galaxies with similar masses out to $z = 3$.

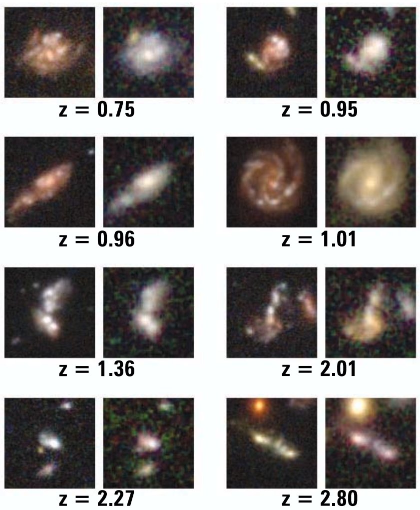

***Figure 1**. Optical and near-infrared views of distant galaxies in the Hubble Deep Field North. For each galaxy, the left panel shows an optical color composite made from WFPC2 images, while the right shows a near-infrared view with NICMOS. At redshift $z \sim 1$, some galaxies have the familiar forms of giant spiral and elliptical galaxies, and our near-infrared analysis suggests that most of their total stellar mass is already in place. At $z \sim 3$, galaxies are smaller and much bluer, indicating that rapid star formation was in progress. Our analysis suggests that their stellar mass was only $\sim 1/10^{th}$ that of the typical galaxy at the present day.*

Summing over the whole HDF-N galaxy population, we find that 50-75% of the total stellar mass density found in galaxies today was already in place by $z \sim 1$, consistent with other estimates from the literature. However, we find that this fraction drops rapidly as we move back in time, to higher redshifts. Allowing for a generous range of systematic error estimates, only 3-18% of the present-day stellar mass density was in place at $2.5 < z < 3$. Figure 2 (page 17) shows the derived stellar mass density evolution from $z = 3$ to the present. The uncertainties are large, but even the upper bounds are important. In particular, they disagree with models in which the bulk of stars in present-day ellipticals and galaxy bulges (estimated to make up at least half of the total stellar mass density at $z = 0$) formed long ago, at very high redshift. In fact, our best estimate of the stellar mass density at $z \sim 3$ is lower than predictions from the current generation of hierarchical models for galaxy formation, although the disagreement may not be significant within the uncertainties of the data (and the models).

The low fraction of stellar mass formed by $z = 3$ presents a paradox, apparently contradicting evidence for considerable star formation at still higher redshifts. For example, current best estimates suggest that the global star formation rates in LBGs were similar at $z = 4$ and $z = 3$. Moreover, if galaxies (as opposed to quasars) were responsible for reionizing the universe sometime at $z > 6$, calculations suggest that the required amount of UV emission from star formation would also have to equal or exceed that observed at $z=3$. However, a constant star formation rate from $z = 3$ to 6 should overproduce the total amount of stellar mass that we find at $z=3$ in the HDF-N/NICMOS observations.

Where did those earlier generations of stars go if they are not in the galaxies we see at $z=3$?

In Ferguson et al. (2001), we have suggested one possible explanation, invoking a non-standard initial mass function (IMF) for star formation in early galaxies. The young, massive stars that dominate the UV luminosity of a star-forming galaxy have short lifetimes, and the total mass is dominated by longer-lived, lower mass stars. By tilting the IMF strongly toward massive stars, a UV-bright, star-forming galaxy at $z = 4$ to 6 would leave proportionately less stellar mass surviving at lower redshifts. Indeed, there are theoretical arguments that the IMF in young protogalaxies might be top-heavy. While we cannot constrain the IMF directly from our observations, these 'continuity arguments' may indirectly support our conjecture.

Ultimately, the small volume of the HDF-N limits our analysis. With only one such dataset, it is hard to be sure that it is representative. Moreover, at $z = 3$ even NICMOS is barely reaching rest-frame optical wavelengths. For a more reliable constraint on stellar mass, we must observe at still longer wavelengths, in the *rest-frame* near-infrared or redshifted wavelengths $> 3\ \mu$m, beyond the limits accessible from the ground or from Hubble. We have begun a project to address these issues: the Great Observatories Origins Deep Survey (GOODS). This program will obtain extremely deep images of two fields, covering 60x more solid angle than the HDF-N and using many facilities over a very wide range of wavelengths. In particular, GOODS will make the deepest observations at 3.6 to 24 μm using the Space Infrared Telescope Facility (SIRTF), scheduled for launch in January 2003. SIRTF imaging at 8 μm will sample rest-frame K-band light from LBGs at $z = 3$ and infrared rest-frame wavelengths $> 1\ \mu$m out to $z = 7$. Moreover, we have just begun very deep, 4-band Hubble imaging of the GOODS fields with the Advanced Camera for Surveys (ACS), as described in the spring 2002 issue of this Newsletter. (**http://sco.stsci.edu/newsletter/pdf/2002/spring_02.pdf**). This will allow us to relate the mass assembly of galaxies to the emergence of the morphological Hubble Sequence.

GOODS will provide a rich data resource for the community with which we expect to answer some basic questions about galaxy formation and mass assembly. In the meanwhile, our HDF-N/NICMOS results give a tantalizing glimpse at the mass build-up in the galaxy population from z = 3 to the present. They demonstrate that this was an extended process, lasting until at least z = 1, by which time most of the stellar content of present-day galaxies had already formed. Ω

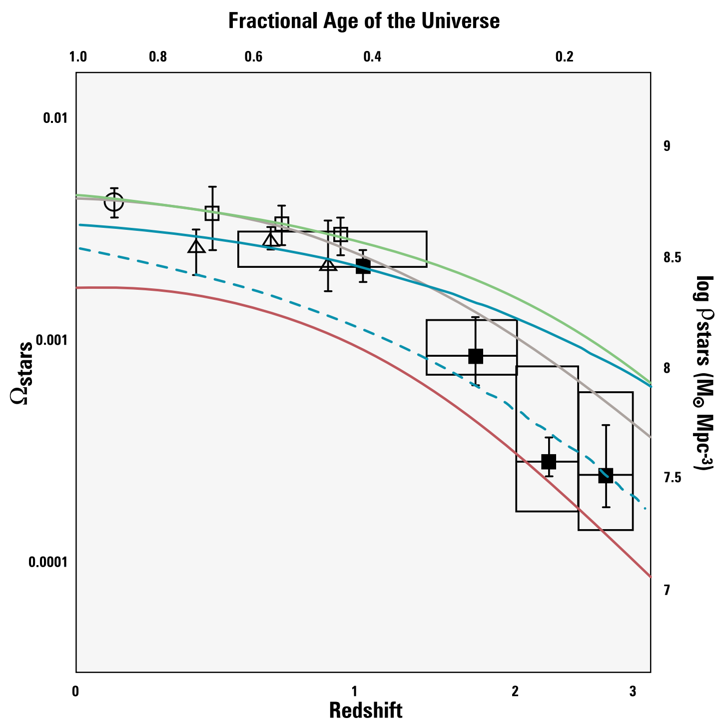

Figure 2. *The redshift evolution of the co-moving stellar mass density, Omega*. The points at 0 < z < 1 are drawn from infrared surveys in the literature, and the points at 1 < z < 3 come from our HDF/NICMOS infrared survey. For the HDF results, the horizontal error bars indicate the extent of each redshift bin, while the point position is the volume midpoint within this range. The vertical error bars show the 68% random errors for one particular family of stellar population models, combining the sampling variance and the mass fitting uncertainties. The vertical extent of the boxes around the points shows the range of systematic uncertainty introduced by varying the metallicity and the star formation histories of the mass-fitting model. The blue and red lines show the result of integrating the cosmic star formation history traced by rest-frame UV light, with and without corrections for dust extinction. The other lines show recent theoretical predictions from semi-analytic galaxy evolution models.*

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Interview: Carol Christian

Carol Christian, *carolc@stsci.edu*

Carol, seven years ago when you came to the Institute, education and public outreach was limited in scope, and its staff was small. In a few years under your leadership, it blossomed into a major program with broad reach, connections with the education community, and real benefits for both astronomers and the public. What were keys to success—the factors and conditions behind this blossoming?

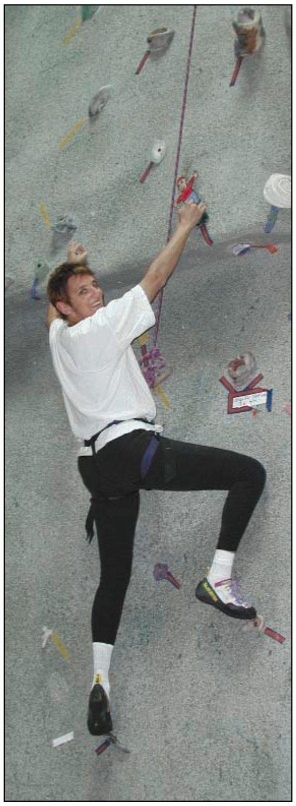
When I came into the Office of Public Outreach (OPO) in 1995, I envisioned a national—even an international—education and outreach program for Hubble, to be commensurate with its expansive science program. Even though NASA was pressing us to establish an exemplary Hubble education effort *instantly*, I knew that a robust program would take 3-5 years to develop. My initial strategy was to keep the good Hubble news flowing to the public *via* mass media while quickly building OPO skills in education, creating a team approach incorporating research scientists in our efforts, and an infrastructure for Internet delivery of our products.

A number of factors helped develop our maturity and credibility in education and outreach. Certainly adequate funding was essential! We had an understanding what educators needed, desired, and *expected* from Hubble. And OPO had unique resources available—the fantastic Hubble data, a wealth of scientific and technical experts all around us, and an extended scientific community we could tap. I began to assemble a diverse, skilled team and devoted considerable care in finding the right expertise to complement the existing OPO talent.

My ambition was to integrate research scientists into our teams, including the news team. I felt this would ensure the scientific currency and integrity of our materials. Furthermore, including scientists in all facets of OPO emphasized—for the staff and the science community in general—the significance of the education/outreach effort at the Institute. This road was not easy, and of course there were cultural adjustments, but I remain convinced that diverse teams of experts are the critical element for producing the high quality, professional resources OPO is now known for.

In my mind, it was a given that OPO needed a strong Internet presence to cover all facets of education, outreach, and public information. I was surprised to find this view was controversial at first, yet I had fears that OPO would be late in the game! Whereas in 1993, when I established my first online education program in Berkeley, only 3% of pre-college schools had Internet access, by 1996 pilot programs had succeeded when both excellent content and connectivity were available and supported by the community. Under these conditions, teachers, museums, and the public could really benefit from online materials.

Internet delivery of OPO products also made economic sense. If we distributed 150,000 hardcopies to educators, we have reached only a small fraction of that community and a minuscule number of students. I felt the limits imposed by the hardcopy media were unacceptable when we had the opportunity of the Internet, to develop computer-based resources and make them accessible to everyone. I knew that in a few years the Internet would become affordable. *Amazing Space* (**http://amazing-space.stsci.edu/**) now reaches all 50 states. Without an early investment in a strong Internet presence, we would be seriously behind when the public was ready. Also, today, our HubbleSite (**http://www.hubblesite.org**) is one of the most popular NASA-related websites.



Carol scales the JHU climbing wall during a cross-divisional team-building exercise. In her hand is her little paper pal, "Flat Stanley" (courtesy of her nephew, Michael). Stanley certainly learned about trusting colleagues at the end of a climbing rope!

After leaving OPO in 2000, you organized efforts to rethink and improve an eclectic set of Institute's processes, like keeping observers informed on the status of their data and streamlining staff travel arrangements. What is the paradigm you apply, and what are the key issues and opportunities for process improvement in an organization our size?

People-watching and story-telling offer to me insights into how people work. I can discover the kinds of 'work arounds' and adaptations people introduce to get their jobs done. It is important to hear personal ideas on improvements. It is also important to realize that our users (internal or external) cannot always be expected to lead innovations, especially if they do not need changes urgently or have instinctively learned to cope with existing systems.

Let's take a particular example: determining the status of any morsel of Hubble data. I looked at how researchers actually do their research, how they use that morsel of data, what they expect to know about it, and what value they place on the data and the services that provide the data. How do they use our expertise? With an enthusiastic team, I created an idealized scenario describing how we could deliver our expertise to that user to improve their knowledge of the data and their use of it. Then we looked at how we currently provide the data and services, including every person, process, or system that interacts with it. We had to decide if all that handling is necessary and plan how we could map our current system to the ideal one.

Looking down from 'ten thousand feet', it is easy to spot many Institute processes that could be improved. However, it is not easy to make changes when the *status quo* seems to work. Our competitors are at our heels however. Furthermore, accurately predicting the benefits of a specific change is difficult, and usually there are no guarantees that a particular experimental approach will work, even if it yields valuable new information and insight. If perfect assurances were needed, though, Hubble would not have been built nor would the Palm Pilot.

You have been in the vanguard of using advanced communications technology to broadcast the stories and messages of Hubble and the Institute to a wide audience via the Internet. Most recently, you arranged a webcast of our Spring Symposium, which permitted astronomers around the world to watch and listen to several days of distinguished speakers discuss the 'Astrophysics of Life'. What is your vision of the role of the Internet for the Institute in the future?

I would love to see the Institute take a leadership role in integrating all kinds of media and technology for communications. We have much capability and knowledge to share. We also have the capacity to capture data, services, and information in a variety of ways. We do more than write good software. We add tremendous value by using our expertise to channel our resources to benefit our external users. There is potential for decreasing costs, increasing productivity, and maintaining a competitive edge through effective use of our hard-won organizational knowledge.

As an information user I want to be able to access data, find links to scientific publications, hear presentations (archived webcasts, videos), see visualizations, and pull up popular articles—all while I am thinking about some subject. And from my wireless device! Wouldn't it be great to sometimes *participate* in a meeting or conference from anywhere *via* 'some technology'? Think of the interesting things we could do together if we could make our knowledge infrastructure really efficient!

You avidly pursue extreme sports, including skydiving and scuba diving in exotic locations. What is the deep meaning of these activities for you as a scientist, technologist, and organizational innovator? Risk takers like you famously crave the new experience—where are you headed next?

Hmmm... *deep meaning*. Well, I like doing them!

On one hand, these activities are totally absorbing to me, and I can always improve my proficiency in the sports I choose. Some of these activities require very quick thinking, and continuous training and learning. On the other, they are fun!

Sometimes, like in skydiving or blue water scuba diving, you have an opportunity to really examine fear and anxiety up close. It is amazing to learn to understand fear, not by eliminating it, but understanding it and looking at it from all angles. Most people who willingly encounter fear actually relish the mastery of it, I think. Also, I have to say it is no secret that adrenaline is addictive. Pulling 'Gs' in an airplane during aerobatics is addictive too. These are addictions I intend to nurture!

If there is any pattern here, and maybe there is, I would say that taking on a challenge—looking at a situation from every angle, turning it upside down, and asking chancy questions—is a risk I enjoy. So I guess in my work, I also like being on the 'perilous edge' of technology or pursuing an experimental approach.

Regarding future sporting activity, I would love to participate in the shark tagging and research in South Africa or Australia. After that, I keep my options open. Getting off the planet would be fun or opening a flight school on Mars.... Ω

Carol also took Stanley skydiving the weekend he visited. The aircraft in the background is a De Havilland Twin Otter at Skydive Delmarva in Laurel, DE. And yes, nephew, Michael received an "A" for his Flat Stanley project!

Reflections on ACS

Holland Ford, *ford@adcam.pha.jhu.edu*

After three intense and consuming years as Project Scientist for COSTAR, a period that ended with a successful servicing mission and removal of spherical aberration in the FOS, FOC, and GHRS, I had no intention of proposing a new camera for Hubble. However, Hubble came to me with a phone call from Garth Illingworth in January 1994 informing me in so many words that I "had" to propose for the Advanced Camera being discussed by NASA. After considerable thought, I reluctantly agreed to propose if Garth would agree to be the Deputy PI. He did, and Jim Crocker, who had led the development of COSTAR, agreed to be Systems Engineer and Experiment Manager for the Advanced Camera for Exploration (ACE), later renamed at NASA's insistence the Advanced Camera for Surveys (ACS). I now had the nucleus of a team.

Holland Ford and Garth Illingworth.

In the meantime, NASA had decided that there would not be enough time to solicit and evaluate proposals. Consequently, there would be an internal competition between the Goddard Space Flight Facility and JPL for the right to build the Advanced Camera. After strategizing with Jim on how to 'pry the door open,' I scheduled a meeting with Peter Stockman; myself; the head of the HST Project, John Campbell; and David Leckrone, the HST Project Scientist. During the meeting I questioned the assumption that there was not enough time for an Announcement of Opportunity. I further argued that a competition of ideas might result in a better camera. I told John that I had an idea for a camera that would be ten times better than WFPC2. John took this in and then rhetorically remarked, "Ten times better?" At the end of the meeting John noted that Roger Thompson also wanted an AO, and he stated that "the community was complaining and he would look into it." Much to John's and NASA's credit, NASA did reconsider and issued an AO for a new instrument.

Lessons Learned

There are many lessons learned from proposing and winning a Hubble instrument. Perhaps the most important is to start with a strong, experienced science and engineering team that is willing to work. Put another way, be sure that the team has bought into the science and the instrument, rather than just being along for the ride in case you win.

Every ACS team member was chosen for particular talents and experiences with HST. Collectively, the team had 133 years of experience with HST instruments and the HST program. Our team began with Frank Bartko, Pierre Bely, Tom Broadhurst, Robert Brown, Chris Burrows, Mark Clampin, Jim Crocker, Paul Feldman, Garth Illingworth, Mike Lesser, George Miley, Marc Postman, William Sparks, Rick White, Robert Woodruff, and myself. After winning, Carolyn Krebs became our extraordinarily capable program manager. When Carolyn left ACS to become a division head at the GSFC, she was replaced by the equally talented Pam Sullivan. After Jim Crocker joined ESO's VLT program, Marc Rafal became the ACS Experiment Manager. The present membership of the ACS science and engineering team also includes George Hartig, Marco Sirianni, Andre Martel, Gerhardt Meurer, William Jon McCann, Pam Sullivan, Narciso Benitez, John Blakeslee, Rychard Bouwens, Doug Campbell, Ed Cheng, Marijn Franx, David Golimowski, Caryl Gronwall, Randy Kimble, John Krist, Dan Magee, Piero Rosati, Hien Tran, Zlatan Tsvetanov, and Paul Volmer.

A second lesson is to have clear science goals to guide the design and subsequent tradeoffs between performance, cost, and schedule. Mark Clampin noted that our goal of a survey capability 10 times better than WFPC-2 at 800 nm was a "distilled metric" that guided us throughout the program. Early on, we decided that two themes should govern our thinking: "keep the science central and keep the instrument simple". Mark further observed that "good managers—Carolyn and then Pam—and partnerships with the major players—Ball, GSFC, and the STScI—are essential." Amplifying this theme, Garth remarked that "government-university-industry partnerships can work well. Together we built an instrument with 10 times the performance of WFPC2 for half the cost of the first-generation instruments."

Even in the best of partnerships there will be disagreements and pressures to descope the instrument. This is where our willingness to prioritize the science stood us in good stead. As an example, we made the case that the Solar Blind Camera, with an excellent STIS flight spare detector, was likely to be the least used camera. This enabled us to focus our attention on achieving the demanding performance specifications for the WFC and the HRC. We also were helped by the fact that the HST Project wanted ACS to have a far-ultraviolet camera.

Every army needs generals who will fight, and the HST Project certainly has a General Patton. When the tanks began to roll, we found that a position behind the tanks was much better than one ahead of the tanks.

A further lesson learned was not to underestimate the difficulty of getting flight detectors. We relearned why detectors always top the list of problems. I recall my incredulity when Carolyn informed us that we could expect a 1% yield from our CCD procurements. Approximately 400 CCDs and several million dollars later, with two good CCDs in a flight build and two spares that were "not choir boys," it was clear to me that she knew what she was talking about.

Garth and I agreed that a key lesson is, "Ask questions, ask questions, ask questions, assume nothing, and hold lots of reviews." Even when you think a subsystem is OK, hold a one-day review. Process control is extraordinarily important. Continuity of engineers and managers is important. When in trouble, assemble independent experts and convene a focused review.

There are other little technical gems we learned. Do not use Thermo Electric Coolers as structural elements; the bismuth-telluride columns in TECs have a strength somewhere between blue cheese and chalk. Do not mount anything on four points; after shaking and thermal cycling you will have a three-point mount.

High Points and Light Points

A light point was our first meeting at Ball where we were told we could not use the acronym "ACE" because it was already taken by another NASA mission. Consequently, we had a naming contest that was won by Antonella Nota with the current name and acronym.

The first high point was being selected in mid-December 1994, a "Christmas present" as recalled by George Hartig. The euphoria from winning an HST instrument lasts about one day before reality sets in. Reality includes contracts to be written, people to be hired, reviews to attend, critical reviews to prepare for, and white papers to be written advocating inclusion of that which you have learned you must have but didn't put in the proposal. Another high point was vibration testing of our 4k × 4k focal plane cemented to a four-stage TEC. The TEC did not break!

A flawless launch and the subsequent superb servicing mission were peak experiences. One hour after installation of ACS in the HST, George Hartig was showing those of us at GSFC the telemetry that demonstrated that the HRC and WFC CCDs were cooling to their preset temperatures. The TECs had survived launch!

First light was not what George had hoped for—"I expected better image quality out of the bag – damn, where did all of that coma come from?" I got the bad news from Mark during lunch on the Colorado ski slopes. The good news was that George was confident we could focus the instrument. I was sufficiently confident in George's judgment that I continued skiing rather than rush back to Baltimore for what could have been the mother of all crises. My confidence in George was based on some twenty-plus years of working with him, and it was validated once again by the superb focus that he quickly achieved.

A final high point was the visit of the astronauts to the Johns Hopkins Bloomberg Center for Physics and Astronomy and to the Institute. Those of us who have worked with the crew and followed the servicing mission cannot say enough about their professionalism and accomplishments. We owe our jobs and our science to their willingness to train hard for years and then risk their lives to service Hubble.

The ACS has met or exceeded its specifications for image quality and sensitivity. It is the most sensitive instrument that Hubble has had. The ACS is a high- quality instrument because of the work of a large number of dedicated, hard- working people at Ball, GSFC, STScI, and the members of the ACS science and engineering team. Ω

Alphabet Soup:

ACE	Advanced Camera for Exploration
ACS	Advanced Camera for Surveys
AO	Announcement of Opportunity
Ball	Ball Aerospace & Technologies Corp.
CCD	Charge Coupled Device
COSTAR	Corrective Optics Space Telescope Axial Replacement
ESO	European Southern Observatory
FOC	Faint Object Camera
FOS	Faint Object Spectrograph
GSFC	Goddard Space Flight Center
HRC	High Resolution Camera
HST	Hubble Space Telescope
PI	Principal Investigator
SBC	Solar Blind Camera
STIS	Space Telescope Imaging Spectrograph
STScI	Space Telescope Science Institute
TEC	Thermo-Electric Cooler
VLT	Very Large Telescope
WFC	Wide Field Camera
WFPC2	Wide Field Planetary Camera 2

The Birth of the Snapshot Programs

John Bahcall, Institute for Advanced Study, *jnb@ias.edu*

The Snapshot program originated in a lunchtime conversation between Rodger Doxsey and myself in the STScI cafeteria sometime in the spring of 1989. We were both late to lunch and probably were the only people in the cafeteria. The principal topic of conversation was the expected low observing efficiency of the HST. Rodger described the extraordinary difficulty in making a schedule that would use a reasonable percentage of the available time for science observations. Slewing was slow and changing instruments or modes of observing was time consuming. Also, the scheduling software that existed in 1989 was not very powerful.

I asked Rodger, without thinking very carefully about what I was saying, if it would be possible for the software he was developing to insert new objects in the holes in the schedule. I wondered aloud if one could improve the efficiency by choosing new objects, close to the directions of the scheduled targets, from a previously prepared list of interesting objects scattered over the sky. I remember that Rodger suddenly became very quiet, thought about the question, and finally replied something like: "In principle, it is possible."

The Snapshot program was born at that lunch.

The subsequent early history was stormy. I proposed the concept of a "Non-Proprietary Survey" at an HST science working group meeting shortly thereafter. All hell broke loose. The instrument PIs and other principal GTOs (guaranteed time observers; I was an Observatory Scientist) all argued heatedly that this project would use up precious HST resources, which were in critically short supply before launch. The other members of the working group felt that STScI resources should be focused on the high priority GTO and GO (general observer) programs, not on some subsidiary (albeit non-proprietary) program.

Riccardo Giacconi, the first STScI director, saved the program from infanticide. Calming the waters, Riccardo persuaded everyone to allow him to work with me and with Rodger to see if we could develop a program in which all the work would be done in Princeton and no STScI resources would be required.

With the enthusiastic help of Rodger, Jim Gunn, Opher Lahav, and Don Schneider, I drew up a science program (HST Program 2775, which subsequently had many aliases including 3034, 3092, ...) which proposed WFPC images of relatively bright quasars (463 objects), large angular diameter, peculiar, and interacting galaxies from the ESO and UGC catalogs (402 objects), and selected star fields (17 areas). We had several meetings in the summer and winter of 1989 to set the ground rules for the project. Peter Stockman summarized the results of these meetings in a memo dated August 7, 1989.

The conditions for the implementation of the program may seem stringent by today's operating standards. We agreed that Don and I would search all fields for bright stars that might affect subsequent observations, that we would provide the software and algorithms for feeding the objects to the scheduling system, that we would process and annotate each data tape (including object description, image quality, and science), and that we would deliver the annotated tapes for public distribution every three months. Rodger agreed to develop the capability to assign generic parallel observations in the scheduling system. The Non-Proprietary program was to be assigned the lowest scheduling priority.

In a January 5, 1990, meeting with Rodger, Duccio Macchetto, Larry Petro, and Peter Stockman, we agreed that all of the exposures would be made on gyro control, with no guide stars. This decision was motivated by our desire to have the least possible impact on the overloaded STScI resources.

> "All hell broke loose. The instrument PIs and other principal GTOs all argued heatedly that this project would use up precious HST resources..."

The 'gyro-only' policy had a far-reaching science implication that we did not anticipate at the time. We removed the star fields, since they required longer exposures. The science team decided to replace the star fields by exposures of bright but distant (Z > 1) quasars. Although they were originally only a small part of the Non-Proprietary Survey, the distant quasars were slated to become our primary science program after the mirror problem was found.

The Non-Proprietary Survey—which was dubbed the Non-Proprietary "Snapshot Survey" by (I think) Peter Stockman—was approved by Riccardo for director's discretionary time on a trial basis for the early HST observations. Riccardo felt that he had fulfilled his commitment to the HST working group not to use significant STScI resources for the project. We were awarded a magnanimous grant of $20,000 to prepare the target lists, measure positions and magnitudes of all objects, develop the required software, measure and report regularly on the gyro performance and the telescope pointing accuracy, do the science analysis, publish our results, and deliver the annotated tapes.

The situation changed drastically when, after launch in April 1990, spherical aberration was discovered in the HST images. The wide-field images of galaxies no longer made sense. But, after discussions among the science team, we realized that we could still do a gravitational lens survey of bright but distant quasars, using the sharp core of the PSF to look for close, multiple images. Riccardo allowed me to revise our director's discretionary time proposal and the Snapshot lensing survey became one of the principal early programs of HST. Dani Maoz was hired as a postdoc at the Institute for Advanced Study, assuming responsibility for the initial technical and scientific analysis.

Our survey played a minor but useful role in the thrilling, frustrating, and stressful early days of bringing the HST observatory into routine science observations. We obtained frequent observations under standard conditions (same filters, same observing time, similar objects) in the pre-Cycle 0 phase as part of the Science Assessments Tests program. Dani measured large telescope pointing errors (median error 25 arcseconds) and large image drift rates during the exposures. These were traced to the fact that corrections for the effect of stellar aberration had not been activated in the pointing and guiding software for the gyro-only mode. Once this was fixed, it brought about a large reduction in failed target acquisitions in other HST programs. In observing Cycles 0 and 1, we obtained many valuable science observations as the observatory performance improved. Snapshot observations were scheduled almost routinely.

The Snapshot survey for gravitational lenses was initially described in Bahcall et al., *ApJ*, **387**, 56-68 (1992) and summarized, following a series of other papers in Maoz et al. *ApJ*, **409**, pp. 28-41 (1993). The survey included a total of 498 quasars (as well as star count data) and provided (in addition to other significant scientific results) the first systematic measurement of the frequency of lensing among a large sample of bright quasars, especially in the subarcsecond image regime that only HST could probe.

In observing Cycle 2, STScI announced the Snapshot survey mode as a standard observing option. By this time, the process of finding guide stars for targets had become computer intensive rather than personnel intensive. As a result, Snapshot proposals were permitted to make use of guide stars and could therefore cover a wider range of science programs. Today, Snapshot surveys are frequently used and contribute to HST's effectiveness. I am glad that Rodger and I were late for lunch on that spring afternoon in 1989. Ω

Hubble Spots an Icy World Far Beyond Pluto

NASA's Hubble Space Telescope has measured the largest object in the solar system ever seen since the discovery of Pluto 72 years ago. Approximately half the size of Pluto, the icy world is called "Quaoar" (pronounced kwa-whar). Quaoar is about 4 billion miles away, more than a billion miles farther than Pluto. Like Pluto, Quaoar dwells in the Kuiper belt, an icy belt of comet-like bodies extending 7 billion miles beyond Neptune's orbit.

http://oposite.stsci.edu/pubinfo/pr/2002/17

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SPACE TELESCOPE European Coordinating Facility

ST-ECF Newsletter

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

Richard Hook *(Editor)*

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Cycle 12 observations begin	July 2003

Fellowship Programs

Hubble Fellowship Application Deadline	4 November, 2002
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