Space Telescope Science Institute

Baltimore, Maryland 21218

This report covers the period October 2002 through September 2003.

1 THE INSTITUTE

The Association of Universities for Research in Astronomy Inc. (AURA) operated the Space Telescope Science Institute for the National Aeronautics and Space Administration (NASA) in cooperation with the European Space Agency (ESA). The Director of the Institute was Steven Beckwith. The Institute conducted the science operations of the *Hubble Space Telescope* for astronomers around the world. AURA also established a contract with NASA to develop and operate the Science and Operations Center (S&OC) for the *James Webb Space Telescope* (*JWST*) at the Institute.

The Institute helped the astronomical community to use *Hubble*'s recently upgraded instrumentation to make discoveries and advance scientific understanding. As it improved *Hubble*'s utility, accessibility, and productivity, it planned to do the same for *JWST*. To meet these challenges, the Institute drew upon the experience and skills of its astronomy research staff, itself involved in forefront research, and its expert technical staff. Its dedicated outreach staff engaged the public in discovery and progress on major astronomical issues. Through the Institute's committees, team involvements, and collegial relationships, the community assisted in defining and improving the quality of the Institute's products and services for research and outreach. Through such collaborations, and in pursuit of a shared vision—*bringing the cosmos to Earth*—the Institute laid the groundwork to develop *JWST* with the full involvement of the astronomical community and benefit of lessons learned from *Hubble*.

This report recounts progress in the Institute offerings and involvements, including upgrades to the *Hubble* observatory in orbit, innovations in proposing for *Hubble* observing time as well as archival and theoretical research, new tools and content in the data archive, the ramping up of *JWST* development, management of Institute academic programs, and enhancements of outreach efforts. It also reports the research progress and lists the publications of individual Institute astronomers.

Following launch in 1990, *Hubble* overcame problems and underwent improvements by means of four amazingly successful servicing missions. The most recent occurred in March 2002, when astronauts installed the Advanced Camera for Surveys (ACS) and a cooler to revive the dormant Near-Infrared Camera and Multi-Object Spectrometer (NICMOS), and upgraded several elements of the power systems. The Cycle 11 peer-reviewed observing program took full advantage of the new ACS, the revived NICMOS, and the other instruments on-board the telescope. The Treasury and large programs in Cycle 11 dominated observations through the fall and winter period, and included the Great Observatories Origins Deep Survey (GOODS) survey, a related supernova search program, deep observations of a field in Andromeda, a search for Kuiper Belt objects, and observations of Eta Carina. These observations, as well as the other General Observer (GO) programs, went very well with no unexpected problems with the telescope or instrumentation. The first versions of the processed GOODS data were made available to the community.

The Institute continued to offer a number of important opportunities in Cycle 12 to enable science with *Hubble* in different ways. It continued the *Hubble* Treasury Program to promote the creation of important data sets that would be regretted if not obtained by the end of the *Hubble* mission. Linchpins of the GO program, Treasury programs were designed to address multiple scientific problems through coherent data sets with no proprietary rights. The enhanced data products that are inherent to the Treasury Program began to appear in the *Hubble* data archive during the year, and the community began retrieving and using them. The Institute also continued the Archival Research Legacy Program for homogeneous analysis of well-defined data sets in the archive for the purpose of generating higher-order data products, like catalogs and software tools, to enable a variety of new investigations. The *Hubble* Theory Program, funded as part of the *Hubble* Archival Research Program, proved to be a popular feature of Cycle 12 with almost $1M awarded to theory programs that involved interpretation of *Hubble* archival data.

The Institute received a total of 1046 proposals in Cycle 12, including 819 proposals for about 20,000 orbits of *Hubble* time, of which about 6,000 were requested for Treasury and large programs, which ultimately were awarded about 30% of the orbits available. The oversubscription factors were about six for prime observations, 4 for SNAP observations, and 3.5 for archival and theory proposals. The Cycle 12 peer review involved over 100 community astronomers and lasted six full days and evenings.

The Multimission Archive at Space Telescope (MAST) was one of the world's best and most widely used data archives. It offered users convenient search and retrieval utilities for accessing data from 16 missions and surveys, including *Hubble*. The *Hubble* data archive contained about 15 terabytes of data for about 550,000 science observations. The archive ingest rate reached record levels of 18 gigabytes per day, and the retrieval rate rose to more than 50 gigabytes per day. The Institute improved the tools for navigating MAST, including the abilities to cross correlate and combine data from different missions and to search the science abstracts for *Hubble*, *Far Ultraviolet Explorer* (*FUSE*), *Extreme Ultraviolet Explorer* (*EUVE*), and *International Ultraviolet Explorer* (*IUE*). The archive also added numerous new, fully reduced, high-level science data products, such as Wide Field Planetary Camera 2 (WFPC2) cosmic-ray rejected images, spectral atlases, data previews for *Hubble* and other missions, and the GOODS images and catalogs. The Institute continued working with other data centers to define the data standards and models for the National Virtual Observatory. It

enhanced both the web and StarView archive interfaces to provide better links to other archives and catalogs.

The archive was under stress this past year due to great demand for *Hubble* ACS images, causing its performance to suffer at times. The Institute replaced an outdated complement of computer equipment used for processing, archiving, and retrieving *Hubble* data. The new equipment has considerably more processing power, is inherently more robust, and will support the entire processing system under a single operating system. The bulk processing was transferred successfully to the new equipment, resulting in much reduced turnaround times for data requests.

Since 1996, the Institute and Goddard Space Flight Center (GSFC) partnered to define the mission of *JWST*, the 'First Light Machine' to peer back in the infrared to the era when the first stars, galaxies, and massive black holes were formed. The Institute will be the S&OC for *JWST* and manage the science mission. During the development phase, the Institute is responsible for the science and operations ground system (software and hardware) and for supporting NASA's *JWST* project and the development partners, including ESA and the Canadian Space Agency. In 2003, NASA approved the mission for Phase B (budget and preliminary design) and began the design and development that will lead to a *JWST* launch in 2011.

The Institute conducted fellowship and visitor programs and organized symposia to provide academic opportunities for staff members and the community to learn from each other and communicate scientific understanding. The Hubble Fellowship Program selects recipients on the basis of their excellence in scientific research and appraises them annually. In the reporting year, the Institute selected 12 new Hubble Fellows and supported 34 Hubble Fellows nationwide. The annual Hubble Fellowship Symposium allowed all fellows to present their latest scientific results. The Institute Postdoctoral Fellowship Program selects the recipients based on the strength of their proposed research. In addition, the Institute hosts many regular postdoctoral fellows and graduate students, whose research is guided and supported by individual staff members. In 2003, the Institute had two Institute Fellows and hosted approximately 28 regular postdoctoral fellows. It also hosted 22 graduate students, 60% of whom were enrolled in the Physics and Astronomy Department at The Johns Hopkins University (JHU).

The Institute conducted a variety of programs to host scientific visitors at the Institute. The Collaborative Visitor Program supported collaborators on research projects with Institute staff members for visits of one to four weeks. The Journal Club Visitor Program supported external scientists who came to give one or more seminars during visits of one to two weeks. The Distinguished Visitor Program supported outstanding astronomers to join the Institute for typically one month. In the last year, the Institute hosted four Journal Club Visitors, forty Collaborative Visitors, and two Distinguished Visitors.

Each spring, the Institute organizes a symposium on an astronomical topic of major interest and with important new developments. The title of the 2003 symposium was ''The Local Group as an Astrophysical Laboratory.'' About 130 scientists participated, discussed the properties of the universe at large, including structure formation, star formation in different environments, and central black holes.

The Institute shared *Hubble*'s amazing discoveries and science results with the public. This year a new audience was introduced to the majesty of *Hubble* imagery with the release of *Touch the Universe: A NASA Braille Book of Astronomy.* Originally funded by a *Hubble* education and public outreach grant, this innovative Braille book enables the visually impaired to feel embossed *HST* images of planets, nebulae, and galaxies.

During 2003 our news team issued 22 press releases and 17 photo releases and organized one NASA Space Science Update. Thanks to a major Institute-wide effort, images of Mars, obtained within minutes of its closest approach on 2003 August 27, were released online just eight hours after exposure. These proved to be a major public highlight for the year, generating over 450 news stories and major TV coverage, which included a live interview with the principal investigator on the NBC *Today* show. In addition to the press coverage, the Institute's public Internet portal (hubblesite.org) received over 59 million hits in the five days following the release of the Mars images.

2 SOLAR SYSTEM

I. Griffin continued his collaboration with J. Parker (SWRI) and C. Veillet (CFHT) to derive the properties of the binary KBO object 1998 WW31 using *Hubble* data obtained in Cycle 11. He was also active in the astronomy education field.

P. R. McCullough led the XO project, the first objective of which is to find Jovian planets transiting bright stars ($V < 12$) by photometry. Each XO camera consists of a 200-mm f/1.8 lens coupled to a 1024 x 1024 pixel CCD. Two XO cameras were deployed in July 2002 on the 10,000-foot Haleakala summit on Maui. The robotic system operated autonomously for a period of time sufficient to develop the camera control and data analysis pipeline and to verify that the end-to-end system performance met or exceeded requirements in all areas except the equatorial mount, which is being upgraded ahead of schedule. The system produces better than 1% photometry of thousands of stars per month at a cadence of a few observations of a given star per hour in order to sample well the two-hour-duration transit characteristic of a hot Jupiter.

M. McGrath, with collaborators E. Lellouch (Obs. de Meudon), D. Strobel, P. Feldman (JHU), and R. Johnson (UVa), summarized their own and others work with a major review of the Galilean satellite atmospheres for the book *Jupiter: Planet, Satellites, Magnetosphere.* This book provides a major retrospective of the Jupiter system following the completion of the *Galileo* mission, the first such comprehensive review of the Jupiter system since the 1976 University of Arizona book *Jupiter*.

McGrath, with JHU graduate student L. Feaga, detected atomic chlorine in Io's atmosphere via its electron impact excited emission from the 1350 and 137x Å multiplets using archival GHRS data. They have estimated the abundance of

chlorine relative to the other atmospheric species SO_2, SO, S, O, and Na, and conclude that the Cl is most likely of volcanic origin.

McGrath, with S. Jurac, J. Richardson (MIT), R. Johnson (UVa), V. Vasyliunas (Max Planck Institut für Aeronomie), and A. Eviatar (Tel Aviv Univ.), found that the major source of water for the Saturn magnetosphere is associated with the icy satellite Enceladus. However, the proposed sources (sputtering of Enceladus's surface by magnetospheric plasma; micrometeorite bombardment) fail by at least an order of magnitude to account for the source rate derived from *Hubble* observations of OH emission. They propose that chunks of debris associated with Enceladus, possibly located at the leading and/or trailing Lagrange points, provide the increased surface area needed to account for the inferred source rate. They currently possess the only comprehensive 2-d model that calculates the distribution of plasma and neutrals in the Saturn magnetosphere. The dominant neutral inside eight Saturn radii is OH, which can only be observed directly by *Hubble*. The *Cassini* spacecraft will not be able to detect OH (its density is too low for the fields and particle instruments, and the UV spectrometer does not cover the appropriate wavelengths). *Hubble* therefore provides critical information not obtainable in any other way, data that will naturally complement the in situ measurements to be made starting in 2004 by the *Cassini* space craft.

McGrath worked with several collaborators to make predictions about the atmospheres and associated pick-up ions for the icy Saturn satellites Dione and Enceladus in advance of the arrival of *Cassini*. They used a model based on *Voyager* and *Hubble* data. Their work provides guidance on the best distances of closest approach to these satellites to maximize the science return during the *Cassini* tour.

3 EXTRASOLAR PLANETS

R. Brown analyzed the completeness of searches for faint companions by direct imaging considering obscuration effects only. He focused on a 'water-friendly' population of orbits with semi-major axes uniformly distributed over 0.7 to 1.5 AU for a sun-like star and with eccentricities uniformly distributed over 0 to 0.35. He studied the distribution of apparent separations for randomized orbit orientations and mean anomalies. He measured the fraction of planet positions with apparent separation larger than the obscuration radius. He found the projected obscuration must be significantly smaller than the smallest orbit of interest to achieve high completeness on a single observing visit. For example, the obscuration must be less than 0.3 AU in radius to achieve 95% completeness in one visit. If the obscuration is less than 0.7 AU, three or fewer well-timed visits can achieve 100% completeness in six months or less. For intermediate obscuration sizes, between 0.7 and 1.5 AU, six well-timed visits over two-to-five years can discover all the planets that ever appear unobscured.

K. Sahu and R. Gilliland explored the astrophysical implications of near-field microlensing and its effects on stellar transit observations, with a special emphasis on the *Kepler* mission. The main goal of *Kepler* is to detect a large number of extrasolar, earth-like planets by obtaining near-continuous photometry of >100,000 F, G, and K dwarfs for four years. At the expected photometric precision of *Kepler* (90 micromag), the effect of microlensing by a transiting companion can be significant. This effect can be used to break the degeneracy between a planetary-mass object for which the microlensing effect is negligible, and a more massive object of the same size. *Kepler* will be sensitive to white dwarfs, neutron stars, and black holes in binaries through their microlensing signatures. These observations can be used to derive the frequency of such compact objects in binaries, and to determine their masses.

E. Nelan, with G. F. Benedict (UTx), B. E. McArthur (UTx), T. Forveille (CFHT), X. Delfosse (Grenoble Obs.), R. P. Butler (Carnegie), W. Spiesman (UTx), G. Marcy (UCB), B. Goldman (NMSU), W. H. Jefferys (UTx) & M. Mayor (Obs. de Geneve) combined ground based radial velocity data with high precision astrometric data obtained with *Hubble* FGS1r to measure the reflex motion induced upon the nearby M-dwarf GL876 by its Jupiter class planetary companion. This was the first direct astrometric detection of a planetary companion, and the first mass determination of an extrasolar planet in a non-eclipsing orbit. The peak-to-peak amplitude of the star's reflex motion was found to be $\sim$0.5 mas, indicating the mass of the perturbing planet to be $\sim$1.9 times that of Jupiter.

K. Noll led a large *Hubble* program to obtain photometric observations of trans-neptunian objects (TNO) using the NICMOS and WFPC2 instruments on *Hubble*. A total of 160 orbits were exposed during *Hubble* Cycles 10 and 11 (July 2001–June 2003), approximately evenly divided between optical and infrared observations. This work resulted in one of the largest and most uniform photometric databases of TNOs yet obtained. Noll, D. Stephens (STScI), and colleagues have searched for correlations between color, as determined from *Hubble* photometry, and orbital parameters such as dynamical class, inclination, rms velocity, perihelion distance, absolute magnitude, etc. Contrary to claims based on smaller data samples, the team found no correlations more significant than 2-σ as measured by the Spearman rank-correlation test for colors from measured *V*, *R*, and *I* magnitudes. In Stephens et al., the team has hypothesized that the spectral component sensitive to dynamical parameters, such as inclination, if it exists, must be active at wavelengths shorter than the F555W filter in WFPC2.

Noll led two large TNO observing programs, which resulted in the discovery of four new TNO binary systems, the largest single contribution to the sample of nine such systems that are known. The discovery of binary systems with orbits that can be determined has made it possible for the masses of a sample of TNOs to be measured, a goal that would otherwise not be achievable in the foreseeable future. From the discovery rate, Noll has concluded that 4% of TNOs have binary companions separated by at least 0.15 arcsec and less than a magnitude fainter than the primary. The surprisingly large fraction of binaries discovered is an important constraint on the dynamical history of the Kuiper belt.

Noll and team conducted follow-up observations to one object, 1997 CQ29, which have determined the period and have constrained the orbit to have a large eccentricity.

T. Geballe (Gemini), S. J. Kim (Kyunghee Univ.), Noll, and C. Griffith (UAz) reported the detection of a surprisingly strong series of emission lines due to HCN in the 3-μm spectrum of Titan. These emission features had not previously been detected. The radiative transfer modeling of this fluorescent emission depended on the collisional de-excitation rate of HCN with N_2 and the determination of the rotational temperature of the HCN. At one extreme, the models indicated an unusually high abundance of HCN in Titan's mesosphere. Less extreme models also fit, depending on assumptions made about the temperature dependence of the collisional de-excitation coefficient. HCN is an important precursor species for the production of more complex molecules of potential biological interest. HCN is also an important coolant for Titan's thermosphere, of interest to the Huygens entry probe.

4 STARS

C. Blades continued to explore the nature of the planetary nebulae in the Magellanic Clouds along with collaborators at STScI, NOAO and the University of Washington. Since 1999 this group, led by L. Stanghellini, has been engaged in an extensive study of MC PN morphologies, evolution, central stars, and progenitors. Several *Hubble* observational programs aimed at STIS slitless spectroscopy and broadband photometry of LMC and SMC PNs were completed. The group published results for 29 PNs that were spatially resolved for the first time. Images in the light of Hα and forbidden N II and O II were presented together with line intensities. The images obtained present a unique data set that includes a wealth of morphological and spectral information. The group found that the surface brightness decline with photometric radius is the same in most of the emission lines and that the asymmetric PNs form a well-defined cooling sequence in the excitation-surface brightness plane, confirming their different origin and large progenitor mass.

R. Bohlin and L. Bianchi (JHU) completed a draft of a paper on STIS observations of slash stars (Ofpe/WN9) in M33 and started to analyze the STIS UV reddening curves measured for M33 stars.

H. E. Bond and collaborators used *Hubble* and the new ACS camera to obtain polarimetric images of the extraordinary light echo around V838 Monocerotis. *Hubble* observations were obtained at five epochs in 2002. Apparent angular expansion rates and imaging polarimetry were used to derive a distance to the star of six kpc, implying that its outburst was extremely luminous, and of an unprecedented type not seen before in the Milky Way. The observations also permit unambiguous three-dimensional mapping of the previously ejected dust envelope around V838 Mon, showing it to have a complex and highly non- spherical structure.

Bond, R. L. White, R. H. Becker (UCa–Davis), and M. S. O'Brien have identified a radio source from the FIRST survey with a previously unknown Galactic cataclysmic binary, FIRST J102347.6+003841. This marks the first time that a CV has been discovered on the basis of its radio emission.

Bond, D. L. Pollacco (Queen's Univ. Belfast), and R. F. Webbink (UIl) have investigated the central star of WeBo 1, a new planetary nebula discovered on the DSS by Webbink and confirmed as a PN by Bond. They have shown that the central star is a red giant with enhanced abundances of carbon and *s*-process elements—a classical barium star. This discovery strongly confirms the standard picture that barium stars are created in binary systems, in which one component evolves to become an AGB star, dredges up carbon and *s*-process elements, and then contaminates its companion.

Bond and M. H. Siegel have continued a program aimed at establishing post-AGB stars as standard extragalactic candles. They have established standard stars for a new photometric system that combines Gunn-Thuan *u* (which measures the size of the Balmer jump) with the conventional *BVI* bandpasses. Ground-based *uBVI* frames of the halos of Local Group galaxies have been searched successfully for post-AGB stars, and an absolute-magnitude calibration based on similar stars in Galactic globular clusters has yielded distances to the galaxies that agree extremely well with other methods, but require only a tiny fraction of the observing time needed for, e.g., Cepheids.

Bond, S. N. Shore (Indiana Univ.), S. Starrfield (Arizona State Univ.), and collaborators completed a study of the early ultraviolet spectral evolution of the bright classical nova V382 Velorum, based on STIS observations obtained in 1999. These are the highest signal-to-noise UV spectra ever obtained of a classical nova.

Bond, P. M. Garnavich (Notre Dame), G. H. Jacoby (WIYN Obs.), and collaborators made ground-based and *Hubble* spectroscopic and imaging observations of SBS 1150+599A, a high-Galactic-latitude emission-line object that has proven to be an extremely metal-poor planetary nebula.

Bond, E. Nelan, M. Burleigh and M. Barstow (Leicester Univ., UK), J. Holberg (LPL, UAz), and collaborators used *Hubble* UV imaging to monitor the orbital motions of several visual binaries containing hot white dwarfs, including Sirius and several other Sirius-like systems. In a separate program, Bond, Nelan, R. Gilliland, T. Girard (Yale), and D. Gudehus (Georgia State) used direct imaging and FGS astrometry to follow the orbits of Procyon and its white dwarf companion, the double white dwarf G 107–70, and the metal-poor binary μCas. These observations will ultimately lead to directly dynamically-determined masses for the white dwarfs, limits on the presence of third bodies (down to planetary mass) in the systems, and (in the case of μ Cas) the helium content of the stars.

D. Calzetti, in collaboration with J. Harris, J. S. Gallagher (UWi), D. A. Smith, C. J. Conselice (Caltech), N. Homeier (ESO/Germany), and L. Kewley (CfA), analyzed the role of non-photoionizing processes in local starburst galaxies using WFPC2 narrow-band images in the light of Hα, Hβ, [O III] and [S II]. From this unique dataset, the authors derived that the non-photoionized (shock) component contributes about 3–4% of all the ionized gas in the starbursts. This implies that a significant fraction, about 70–100%, of the mechanical output from the starburst is being deposited in the surrounding ISM, presumably in the form of large-scale motions. Such strong feedback is likely responsible for triggered/propagating star formation, and therefore, for the extended durations of the starbursts, measured to be about 100–300 Myr.

In parallel, in a collaboration led by Harris, Calzetti, Gallagher (UWi), Smith, and Conselice (Caltech) analyzed the *Hubble* broad-band UV, *V* and *I* images of two of the starburst galaxies in the sample above, NGC 5253 and NGC 3077, to investigate the age and mass distributions of their stellar cluster populations. The results show striking differences between the populations of the two dwarf galaxies, despite the fact that the two have similar large-scale characteristics, including being in interaction with nearby massive galaxies. In particular, the cluster population in NGC 5253 appears to evaporate after about 20 Myr, dissolving into the field population (and confirming the previous results of Tremonti, Calzetti, et al. 2001), while the clusters in NGC 3077 show clearly longer lives up to about 300 Myr. The difference between the two populations is attributed by the authors to differences in the local environment of the centers of the two dwarfs, in particular to the smaller central velocity dispersion of NGC 3077 in comparison to NGC 5253.

In a collaboration led by R. Chandar, Calzetti, C. Leitherer, and C. Tremonti (UAz) investigated the age characteristics of the stellar clusters and the diffuse population in the nearby starburst galaxy Henize 2–10, using long-slit UV spectra from STIS. They found that the two populations are both very young (about 4–5 Myr old) and similar in stellar content. This result is strikingly different from that of Tremonti et al. (2001) on NGC 5253, where the diffuse population was found to be significantly older than the cluster population. One proposed interpretation is that Henize 2–10 contains a larger fraction of more loosely bound 'scaled-up' OB associations than NGC 5253, which, at the larger distance of He 2–10, are being associated with the diffuse population. This was the first paper of a series devoted to the systematic investigation of the nature of the diffuse UV association in starburst galaxies, and based on an approved STIS long-slit UV spectroscopy program of about 15 local starbursts.

In a collaboration led by R. C. Kennicutt (UAz), Calzetti and the members of the SINGS team have reported the science scope of the *SIRTF* Legacy Project SINGS (SIRTF Nearby Galaxies Survey). The project, one of only six *SIRTF* Legacy programs, aims at providing a full understanding of star formation processes in local galaxies on both local and global scale, using a combination of *SIRTF* (mid to far infrared) and UV/optical/near IR/sub-mm/radio data. The multiwavelength approach is the only one that can ensure a full budget of star formation in the diverse environments of galaxies (from low density, low dust regions to high density, dusty ones) and, thus, can provide a reliable cross-calibration of star formation rate indicators at different wavelengths. The unprecedented resolution of the *SIRTF* data (a few arcseconds) combined with the ground-based data will afford a unique picture of star formation in galaxies on scales as small as 100 pc (the typical size of an H II region).

O. Gnedin, Fall, and other collaborators modeled the chemical enrichment of the globular star cluster Omega Centauri. This object is unique among clusters in the Milky Way in having multiple stellar generations and a large internal spread in metallicity, indicative of self-enrichment. One explanation for this is that, since Omega Centauri is the most massive Galactic globular cluster, it is more capable than other clusters of retaining the ejecta from its own stars. This cannot be the whole story, however, because several other clusters (with lower masses) have higher escape velocities, but little or no self-enrichment. A more promising explanation is that Omega Centauri is the surviving central part of a galaxy with a deeper potential well that lost its outer parts by tidal stripping.

D. Figer, F. Najarro (CSIC), and collaborators obtained and analyzed the highest resolution near-infrared spectra of the most massive stars in the Arches cluster, doubling the number of known massive stars in the cluster, and showing that these stars are bona-fide Wolf-Rayet stars with helium-burning cores. In addition, the work confirmed the extraordinarily flat initial mass function slope for the cluster reported by Figer et al. (1999). The new analysis validated a previously suggested model in which the cluster provides the heat and ionizing flux to explain effects on nearby molecular clouds, thus removing a long-standing puzzle in Galactic center research.

A. Stolte (MPIA), Figer, and collaborators, obtained and analyzed Gemini/AO and VLT/AO data to further confirm the flat initial mass function slope for the Arches cluster, as measured by Figer et al. (1999). These results removed a lingering doubt regarding the slope concerning the fact that the original results were obtained with 'non-standard' filters in NICMOS. As the most massive starburst cluster in the Galaxy, the work is particularly interesting for determining the stellar content and nature of super-star clusters in nearby galaxies and in the early Universe.

Figer, M. Morris (UCLA), and collaborators completed the first stage of their project to measure the accelerations of stars surrounding the massive black hole in the center of the Galaxy in order to map the matter distribution in that region at spatial scales much larger than has currently been done. The group analyzed their Keck high-resolution near-infrared spectroscopy of 85 cool stars to determine line-of-sight velocities with errors of $\sim$1 km s^{-1} . These errors improve the state of the art by an order of magnitude for large sets of velocity data in the Galactic Center. S. Kim, M. Lee (CIW, Seoul Natl. Univ.), and Figer analyzed the Gemini Galactic Center Demonstration Data Set to obtain the surface density profile of the old stellar population in the central few parsecs of our Galaxy in two broadband filters (*H* and *K′*) and two narrowband filters (*K* continuum and *Co* band). Kim used results in Figer (1995) to carefully calibrate the photometry, and made corrections for incompleteness and reddening to the final profile.

A. Fruchter, as a member of the GRB Afterglow Collaboration at ESO (GRACE), used the VLT and other telescopes at ESO to obtain photometric and spectroscopic observations of GRBs. J. Hjorth et al. obtained superb spectra of GRB 030329 that showed the presence of a supernova spectrum in the afterglow. These observations, along with separate observations obtained by another group at Keck, unambiguously proved that at least a significant fraction of GRBs are formed by the collapse of massive stars, and that the nearly ubiquitous 'red bumps' in GRB light curves are indeed evidence for underlying SNe. Observations by J. Gorosabel et al. revealed the host and local environment of the dark GRB

000210. J. Hjorth et al. discovered a very high column density, yet low reddening towards GRB 020124 at $z = 3.20$. This no longer appears to be a rare phenomenon, but rather another example of low-metallicity in a GRB host. This is further emphasized by the work of J. Fynbo et al., which found that a surprisingly large fraction of GRB hosts are Lyα emitters, again perhaps suggesting that these hosts have an unusually low metallicity.

R. Gilliland, in collaboration with P. Edmonds, J. Grindlay (Harvard-Smithsonian Center for Astrophysics) and others continued analyses of millisecond pulsar binaries, cataclysmic variables, and other X-ray sources in the core of the globular cluster 47 Tucanae. The MSP 47 Tuc W first detected in radio searches from Parkes has now been revealed through detection in the optical with *Hubble*, and X-rays with *Chandra* to be a rare instance of a millisecond pulsar in orbit with a main-sequence star. The large-amplitude optical variations for this faint ($V = 22.3$) blue star are in agreement with the radio timing to within 0.5 s and 1.2 minutes for the 3.19-hour binary to the period and phase—well within 1-σ errors. The combined analysis of extensive *Chandra* and *Hubble* observations have provided the most extensive census yet of X-ray active stars in a globular cluster and has provided firm identification of type (cataclysmic variables, BY Dra stars, low-mass X-ray binaries, etc.) for a large number of cases.

C. Keyes, in collaboration with J. Sokoloski and S. Kenyon (CfA), B. Espey (Trinity Coll. Dublin), S. McCandliss (JHU), and P. Charles (Southampton), led the *FUSE* component of a combined multi-wavelength investigation into the cause and nature of symbiotic star outbursts. Observations at X-ray, FUV, optical, and radio wavelengths with *FUSE*, *XMM*, *Chandra*, MERLIN, the VLA are combined with ground-based spectroscopic and high time-resolution photometric observations. The campaign proved the concept, utility, and need for coordinated multi-wavelength observations in order to make progress in understanding the nature of the outburst mechanisms in symbiotic stars.

Keyes was PI for the *FUSE* Cycle 2 and Cycle 3 programs (total of 120 Ksec) that obtained observations of class prototype Z And throughout its 2000–2002 major outburst and were just completed this summer with the very important quiescence observation. Based upon the initial outburst *FUSE* observations, the group proposed a new disk-instability trigger model for the outburst mechanism in classical symbiotic systems. They hypothesize that a disk instability caused the initial brightening of Z And in 2000, but that the outburst emission later became dominated by a response from the nuclear burning shell.

Keyes, Kenyon, D. Proga, R. Downes and W. Hack (STScI) analyzed their STIS ultraviolet survey spectra of sixteen symbiotic stars, including 11 that had never before been observed in the ultraviolet. This program facilitated a 50% increase in the number of symbiotics for which quantitative physical parameters are known. Prior to this work only about 10% of known symbiotics had been observed in the UV, which is critical to any detailed understanding of symbiotic systems. Keyes and Kenyon produced a summary of hot component temperatures and types and nebular region diagnostics for the sample.

C. Leitherer, in collaboration with R. González Delgado (Granada), G. Stasinska (Paris), and T. Heckman (JHU), obtained high spatial resolution ultraviolet and optical STIS spectroscopy and imaging of the metal-rich nuclear starburst in NGC 3049. The stellar continuum and the absorption-line spectrum in the ultraviolet were used to constrain the massive stellar population. The strong, blueshifted stellar lines of C IV and Si IV detected in the UV spectra indicate a metal-rich, compact, massive (10^6 solar masses) cluster of age 3–4 Myr emitting the UV-optical continuum. The authors found strong evidence against a depletion of massive stars in this metal-rich cluster. The derived age and the upper mass-limit cutoff of the initial mass function are also consistent with the detection of Wolf-Rayet (W-R) features at optical wavelengths. As a second, independent constraint on the massive stellar content, the nebular emission-line spectrum was modeled with photoionization codes using stellar spectra from evolutionary synthesis models. The morphology of the nuclear starburst of NGC 3049 from the STIS images indicated a simple geometry for the nebular emission-line region. However, the nebular lines were badly reproduced by 3–4 Myr old instantaneous bursts, as required by the UV line spectrum, when unblanketed W-R and/or Kurucz stellar atmospheres are used. The corresponding number of photons above 24 and 54 eV in the synthetic models was too high in comparison with values suggested by the observed line ratios. Since the ionizing spectrum in this regime is dominated by emission from W-R stars, this discrepancy between observations and models is most likely the result of incorrect assumptions about the W-R stars. Thus, the authors conclude that the nebular spectrum of high-metallicity starbursts is poorly reproduced by models for W-R-dominated populations. However, the new model set of Smith et al. with blanketed W-R and O atmospheres and adjusted W-R temperatures predicts a softer far-UV radiation field, providing a better match to the data.

Leitherer, in collaboration with Calzetti and L. Martins, studied the effect of time-dependent dust obscuration on synthetic ultraviolet line profiles of a young stellar population. If the youngest and most massive stars are more obscured than the older, less massive stars, the C IV 1550 and other stellar wind lines are significantly diluted with respect to a simple foreground screen model for the dust. They proposed to use stellar wind lines as a probe of the dust-obscuration model instead of the previously employed nebular emission lines. Since purely stellar diagnostics were utilized, uncertain assumptions on the nebular properties are unnecessary. Photoionization models demonstrated that the C IV 1550 emission is typically dominated by stellar winds and nebular contamination is negligible. A first comparison with a galaxy sample observed with the *Hopkins Ultraviolet Telescope* favored a dust geometry affecting ionizing and nonionizing stars equally. The authors pointed out the need for higher quality data for a more rigorous comparison. *Hubble* is capable of obtaining such data in the future.

Leitherer, in collaboration with M. Mas-Hesse (Madrid), D. Kunth (Paris), G. Tenorio-Tagle (Puebla), R. Terlevich

(Cambridge), and E. Terlevich (Puebla) presented the results of a high resolution UV 2-D spectroscopic survey of star forming galaxies observed with STIS. The main aim was to map the Ly-α profiles to learn about the gas kinematics and its relation with the escape of Ly-α photons and to detect extended Ly-α emission due to scattering in gaseous halos. The authors combined their data with previously obtained UV spectroscopy of other star-forming galaxies. They found that the P-Cygni profile is spatially extended, smooth, and spans several kiloparsecs covering a region much larger than the starburst itself. The authors proposed a scenario whereby an expanding supershell is generated by the interaction of the combined stellar winds and supernova ejecta from the young starbursts, with an extended low-density halo. The variety of observed Ly-α profiles, both in their sample and in high redshift starbursts, was explained as phases in the time evolution of the super-shell expanding into the disk and halo of the host galaxy. The observed shapes, widths and velocities were in excellent agreement with the super-shell scenario predictions and represent a time sequence. The authors confirm that among the many intrinsic parameters of a star-forming region that can affect the properties of the observed Ly-α profiles, velocity and density distributions of neutral gas along the line of sight are by far the dominant ones, while the amount of dust will determine the intensity of the emission line, if any.

Leitherer, in collaboration with M. Mouhcine (UCa), A. Lançon (Strasbourg), D. Silva (ESO), and M. Groenewegen (ESO), presented near-infrared spectroscopy of the massive intermediate age star cluster W3 in the merger remnant and proto-elliptical galaxy NGC 7252, obtained with the NTT telescope. This cluster has an age when the integrated near-infrared properties of a stellar population are dominated by the cool and luminous Asymptotic Giant Branch (AGB). The authors compared the data with instantaneous burst model predictions from new evolutionary synthesis models that include: (i) the computation of the evolution through the thermally pulsing AGB (TP-AGB) for low- and intermediate-massive stars, with the initial mass and metallicity-dependent formation of carbon stars; and (ii) spectroscopic data from a new stellar library in which differences between static red giants, variable oxygen rich TP-AGB stars, and carbon stars are accounted for. The new evolutionary model predicted that the contribution of carbon-rich stars to the luminosities in the near-IR passbands is a strong function of metallicity. The comparison of the data to the models clearly showed that carbon stars are present; for the first time, carbon-rich star spectral features were thus detected directly outside the Local Group galaxies. Good fits to the available optical/near-IR photometry and the near-IR spectrum of NGC 7252–W3 were found for an age of 300–400 Myr. The models showed that these parameters depend weakly on the model metallicity, with higher likelihood for solar metallicity models. At solar metallicity, a mixture of carbon-rich and oxygen-rich stars is predicted. The strength of the near-IR molecular bands that originated from oxygen-rich AGB stars could be used to constrain the absolute effective temperature scale of these objects, i.e., a relation between color and temperature. The authors found that, in the framework of their set of evolutionary tracks, the data are more consistent with the temperature scale calibrated on Long Period Variables than on giant stars. At a given color, variable AGB stars have a lower temperature than static (or quasi-static) M giants.

Leitherer, in collaboration with C. Robert (Quebec City), A. Pellerin (Quebec City), A. Aloisi (JHU), C. Hoopes (JHU), and T. Heckman (JHU) generated a set of far-ultraviolet stellar libraries using spectra of OB and Wolf-Rayet stars in the Galaxy and the Large and Small Magellanic Cloud. The spectra were collected with *FUSE* and cover a wavelength range from 1003.1 to 1182.7 Å at a resolution of 0.127 Å. The libraries extended from the earliest O to late-O and early-B stars for the Magellanic Cloud and Galactic libraries, respectively. Attention was paid to the complex blending of stellar and interstellar lines, which can be significant, especially in models using Galactic stars. The most severe contamination was due to molecular hydrogen. Using a simple model for the H_2 line strength, the authors were able to remove the molecular hydrogen lines in a subset of Magellanic Cloud stars. Variations of the photospheric and wind features of C III 1176, O VI 1032, 1038, P V 1118, 1128, and S IV 1063, 1073, 1074 were discussed as a function of temperature and luminosity class. The spectral libraries were implemented into the LavalSB and Starburst99 packages and used to compute a standard set of synthetic spectra of star-forming galaxies. Representative spectra were presented for various initial mass functions and star formation histories. The valid parameter space was confined to the youngest ages of less than ten Myr for an instantaneous burst, prior to the age when incompleteness of spectral types in the libraries sets in. For a continuous burst at solar metallicity, the parameter space was not limited. The suite of models is useful for interpreting the rest-frame far ultraviolet in local and high-redshift galaxies.

Leitherer, in collaboration with M. Sirianni (JHU), A. Nota, G. De Marchi, and M. Clampin (GSFC) performed a new study of the low end of the stellar IMF of NGC 330, the richest young star cluster in the SMC, from deep broadband *V* and *I* images obtained with WFPC2. They detected stars down to a limiting magnitude of $m555 = 24.9$, which corresponds to stellar masses of about 0.8 solar masses at the distance of the SMC. A comparison of the cluster color-magnitude diagram with theoretical evolutionary tracks indicated an age of 30 Myr for NGC 330, in agreement with previously published results. The authors derived the cluster luminosity function, which they corrected for background contamination using an adjacent SMC field, and constructed the mass function in the 1–7 solar mass range. Given the young cluster age, the MF can well approximate the IMF. The authors found that the IMF in the central cluster regions (within 30) is well reproduced by a power law with a slope consistent with Salpeter's. In addition, the richness of the cluster allowed them to investigate the IMF as a function of radial distance from the center. They found that the IMF becomes steeper at increasing distances from the cluster center (between 30 and 90 arcsec), with the number of massive stars (>5 solar masses) decreasing from the core to the outskirts of the cluster five times more rapidly than the less-massive objects (about one solar mass). The authors believe

the observed mass segregation to be of a primordial nature rather than dynamical since the age of NGC 330 is 10 times shorter than the expected relaxation time of the cluster.

Leitherer, in collaboration with G. Vazquez, T. Heckman (JHU), D. de Mello (GSFC), G. Meurer (JHU), and C. Martin (UCa) observed the brightest super star cluster NGC 1705−1 in the nearby dwarf galaxy NGC 1705 with STIS in the echelle mode between 1200 and 3100 Å. The data allowed a study of the young stellar population at hitherto unprecedented spectral resolution and signal-to-noise. A comprehensive list of strong and weak stellar and interstellar absorption lines was given, together with the measured line parameters. Four distinct velocity systems were identified: stellar lines at the measured H I velocity, blueshifted interstellar lines from outflowing gas, Milky Way foreground absorption, and a high-velocity cloud. Comparison with stellar template spectra indicated an equivalent spectral type of B0 to B1, with mostly dwarf and giant stars contributing. When placed on a theoretical Hertzsprung-Russell diagram, these stars constrained the age of NGC 1705−1 to 12 Myr. Since this age was derived purely from spectroscopy, it is independent of reddening corrections. A comparison of the observed and theoretical mass-to-light ratio for the derived age was performed. The authors found no significant evidence for an anomalous IMF at the low-mass end, contrary to suggestions found in the literature. The stellar population of NGC 1705−1 is similar to that in other massive clusters, like 30 Doradus or NGC 1569−A, after taking into account age differences and model uncertainties. The authors discuss the difficulty of relating observed and theoretical mass-to-light ratios because of the unknown gas mass fraction lost by the cluster and the uncertain mass-loss rates of AGB stars in population synthesis models.

K. S. Long, S. P. Reynolds (NC State), J. C. Raymond (SAO), P. F. Winkler (Middlebury), K. Dyer (NRAO) and R. Petre (NASA/GSFC) completed a *Chandra* X-ray study of the synchrotron-dominated NE limb and the thermally-dominated NW limb of the remnant of SN 1006 AD. The brightest features in the X-ray images correspond closely with radio features in the NE and with Balmer-dominated filaments in the NW. The spectra of the brighter filaments in the NE are harder, with less prominent line emission than those in the NW. In addition to highly elongated filaments, both images show clumps of emission well inside of the shock front that appear to be dominated by emission from oxygen. These probably arise from shock-heated ejecta. There is no evidence for a halo of X-ray emission outside the shock to the NE, as predicted by the Fermi shock-acceleration picture, in which relativistic electrons should be diffusing ahead of the shock. The limits on upstream emission are less than 1.5% of the post-shock levels in regions where the SNR is brightest. This strongly suggests that the bright rims are flattened sheets nearly perpendicular to the plane of the sky, and that the magnetic field strength jumps at the shock by a factor significantly larger than four, as has been proposed if the shock puts significant energy into accelerating nonthermal ions. The spectra obtained of the NW rim are all dominated by the helium-like ions of O, Ne, Mg, and Si, expected from shocks with ionization (n_e t) parameters of order 100 cm^{-3} yr and electron temperatures of 0.5−1 keV, far lower than the post-shock ion temperature implied by estimates of the shock speed obtained from the shape of the Hα line.

Long, Winkler, and G. Gupta (Middlebury) remeasured the proper motion of the filaments on the NW limb of SN1006, which enabled them to improve previous estimates of the distance to SN1006 and to re-discuss the historical evidence that it is the remnant of a Type IA supernova. Using this and their previous measurement of the shock speed (Ghaviamian et al. 2003), they find that the remnant lies at 2.18 ± 0.08 kpc and that the historical data suggest V_{max} = 7.5 ± 0.4, squarely in the middle of the range for Type IA.

Long, C. S. Froning (UCo), B. T. Gaensicke (Southampton), C. Knigge (Southampton), E. M. Sion (Villinova), and P. Szkody (UWa) continued their study of WZ Sge, the system that underwent an outburst in July 2001, the first such outburst in 22 years. In outburst, their *FUSE* observations showed an extremely high excitation outburst spectrum dominated by continuum from the disk and broad O VI emission from the wind. From their October *FUSE* spectrum, they showed that the outburst had heated the WD from 14,000 to at least 25,000 K (immediately after the disk faded) feature and the disk spectrum in outburst and O VI from a wind and a WD cooling from 25,000 K in October to 23,000 K in November. The WD spectrum was punctuated by metal lines, which, if they arise from the WD, indicate it is rotating at 200−300 km s^{-1}, much less than the value reported in GHRS spectra prior to outburst. However, one of the STIS observations in outburst showed strong pulsations with a period of 15 s; one interpretation of this is that the WD in WZ Sge is rapidly rotating and has a magnetic field that can channel the flow very near the WD. If this is correct, then the 200 km s^{-1} lines that are observed in the post-outburst spectra must arise from some other location than the WD photosphere, e.g., a vertically extended disk chromosphere or an accretion stream.

Long, R. Prinja (Univ. Coll., London), Froning, and Knigge completed a study of the low inclination nova-like variable SW Sex. Their *FUSE* observations showed substantial variability in the line profiles on the orbital time-scales. This cyclic increase in absorption depth was accompanied by a shift in the maximum absorption velocity from ∼−1000 km s^{-1} to near zero velocity. They developed a phenomenological picture of the UV profile variability where the symmetry of a confined bipolar wind in RW Sex is broken by assuming that the outflow is oblique, perhaps because it emanates from a warped or tilted disc.

Long, Froning, Knigge, and R. Baptista (Universidade Federal de Santa Catarina) also completed studies of two eclipsing nova-like variables—UX UMa with *FUSE* and V348 Pup with GHRS. The time-resolved spectra showed substantial evolution as the secondary star eclipsed the disk in both systems. The analyses indicated a substantial amount of low-ionization material rotating at low velocity with the disk in both systems. In the higher inclination system V348 Pup, it is likely that the outer disk occults the inner disk.

Long, J. E. Drew (Imperial), L. Hartley (STScI) and J. van der Walt (SAAO) combined ground-based optical and

STIS data of the nova-like QU Car to conclude it may be as far as two kpc away (instead of the previously estimated 500 pc). This would make QU Car, already very bright for a CV at 500 pc, exceptionally luminous. The optical spectra were also atypical, and indicated large C IV/He II and C/O abundance ratios, suggesting that the companion is a C star. If correct, this is the first CV system with a companion of this type.

J. Maíz-Apellániz, in collaboration with N. R. Walborn, R. Barbá, and M. Rubio, used a combination of *Hubble* (WFPC2, STIS, and NICMOS) and ground-based (optical, NIR, and submillimeter) data to analyze the interaction between the massive stars in 30 Doradus and the surrounding ISM. The observations clearly show that what is observed as a giant H II region in optical emission lines is a thin (~1 pc thick) region sandwiched between the hot cavity around R136 and the surrounding molecular cloud. At the interface between the H II region and the molecular material is a photo dissociation region, where non-ionizing UV radiation is gradually destroying the dust particles and converting molecular hydrogen into atomic hydrogen.

Maíz-Apellániz, in collaboration with Walborn, J. W. MacKenty, E. Pérez, and J. M. Mas-Hesse, studied NGC 604, a scaled OB association in M33 using objective-prism NUV spectroscopy, WFPC2 imaging, and multiwavelength archival data. The goal is to understand the composition and interaction of this massive young cluster with its environment and to establish a comparison with 30 Doradus.

Maíz-Apellániz, in collaboration with L. Úbeda and MacKenty, analyzed the dwarf starburst galaxy NGC 4214, probably the best candidate of its class in the combined terms of proximity, inclination, obscuration, and variety of star-forming regions.

Maíz-Apellániz, in collaboration with Walborn, H. Á. Galué, and L. Wei, created the first comprehensive Galactic O star catalog, which includes spectral, photometric, and astrometric information for 378 Galactic O stars.

P. R. McCullough was responsible for the photometric and astrometric calibration of the Southern H-Alpha Sky Survey Atlas (SHASSA). The *Wilkinson Microwave Anisotropy Probe* (*WMAP*) team used the SHASSA to identify the free-free contribution to *WMAP* data in the southern sky. McCullough et al. (2002) used SHASSA to discover the 24-degree diameter Antlia supernova remnant, which is the nearest supernova remnant to the sun except the one that the sun is inside, called the 'local bubble.'

B. McLean, in collaboration with D. Carollo, A. Spagna, M. Lattanzi, R. Smart (Osservatorio Astronomico di Torino) and S. Hodgkins (Cambridge Univ.) are continuing to search for high proper motion white dwarfs (WDs) in the galactic halo using the GSC-II. The goal was to verify a previous claim (Oppenheimer 2001) that there is a sufficient space density of WDs to provide the missing mass in our Milky Way. The team pursued a spectroscopic follow-up of a number of candidates with extreme colors and has a high success rate at identifying these objects. Their results to date from a survey of 1100 square degrees is in disagreement with the previous claim and is consistent with a reanalysis of the Oppenheimer sample correcting for the Malmquist bias and using the derived kinematics to isolate the true halo WDs. In addition, a number of exotic objects have been discovered. Of particular interest was the identification of a DQ-type carbon-rich WD, which appears to be particularly cool and cannot be modeled by the existing theoretical codes. The GSC-II database will eventually allow large-scale comparisons of galactic models to an all-sky catalog.

B. Margon, joining a collaboration lead by Z. Ioannou (Keele Univ.), presented *Hubble* UV observations of the high-inclination low mass X-ray binary AC211 (X2127 +119), which is located in the globular cluster M 15. They discovered a C IV P Cygni profile in this system, which confirms the existence of an outflow from AC211. The UV spectrum exhibited several absorption features due to O, Si, and C. The very strong He II line at 1640 Å was not seen to modulate strongly with orbital phase, suggesting its origin lies in the outer parts of the system. In contrast, the eclipse of the UV continuum was short compared with the X-ray and optical eclipses.

Margon, together with P. Szkody (UWa) and colleagues, described two newly identified magnetic cataclysmic variables discovered in the Sloan Digital Sky Survey, SDSS J155331.12+551614.5 and SDSS J132411.57+032050.5. These peculiar stars had spectra showing highly prominent, narrow, strongly polarized cyclotron humps with amplitudes that varied on orbital periods of 4.39 and 2.6 hr, respectively. In the former, the spacing of the humps indicated the third and fourth harmonics in a magnetic field of ~60 MG. The narrowness of the cyclotron features and the lack of strong emission lines implied very low temperature plasmas and very low accretion rates, so that the accreting area is heated by particle collisions rather than accretion shocks. The detection of rare systems like these exemplifies the ability of the SDSS to find the lowest accretion rate close binaries.

Margon, together with L. Homer, S. F. Anderson (UWa) and S. Wachter (IPAC), obtained STIS low-resolution ultraviolet spectra of the X-ray pulsar 4U 1626–67 (= KZ TrA). This system is unusual even among X-ray pulsars because of its ultrashort binary period (P = 41.4 minutes) and remarkably low mass function ($\leqslant 1.3 \times 10^{-6}\ M_{\odot}$). Most of the absorption lines were consistent in strength with a purely interstellar origin. However, there was evidence that both C I and C IV require additional absorbing gas local to the system. In emission, the usual prominent lines of N V and He II were absent, while both O IV and O V were relatively strong. They also reported a rarely seen feature at ~1660 Å as the O III] multiplet. The UV spectra therefore provided independent support for the recent suggestion that the mass donor is the chemically fractionated core of either a C-O-Ne or O-Ne-Mg white dwarf. Both the X-ray and far-UV lines are plausibly formed in (or in an corona just above) a Keplerian accretion disk.

Margon led a large collaboration that reported the discovery of 39 faint high-latitude carbon stars (FHLCs) from SDSS commissioning data. The objects, each selected photometrically and verified spectroscopically, range over $16.6 < r < 20.0$ and show a diversity of temperatures as judged by both colors and NaD line strengths. At the completion of the Sloan survey, there will be many hundred homoge-

neously selected and observed FHLCs in this sample. They presented proper-motion measures for each object, indicating that the sample is a mixture of extremely distant (greater than 100 kpc) halo giant stars, useful for constraining halo dynamics, and members of the recently recognized exotic class of very nearby dwarf carbon (dC) stars. Motions, and thus dC classification, were inferred for 40–50% of the sample, depending on the level of statistical significance invoked. The new list of dC stars, although selected from only a small fraction of the final SDSS, doubles the number of such objects found by all previous methods. The coolest FHLCs with detectable proper motions in the sample also displayed multiple CaH bands in their spectra. It may be that CaH is another long-sought, low-resolution, spectroscopic luminosity discriminant between dCs and distant faint giants, at least for the cooler stars.

Margon joined colleagues led by P. Callanan (U. Coll. Cork) to discuss the nature of the IR counterpart of GX 17+2, one of the most luminous of the persistently bright X-ray binaries. Keck *K*-band observations revealed a bright counterpart in the radio and X-ray error 0.9 arcsec north of NP Ser, the long suspected but erroneous identification. Furthermore, the position of this counterpart is consistent with that of the previously-observed 'Star A' to within 0.1 arcsec, implying an amplitude of variation of ~25–33 between the Keck observations and the *Hubble* measurements of Deutsch et al. Subsequent Keck imaging also reveals Star A in an faint state ($K = 18.3$ mag, with a corresponding amplitude of variability of ~22). The *Hubble* and Keck *K*-band variations, however, did not appear to be accompanied by any changes in the overall X-ray luminosity of GX 17+2. They proposed instead that the large radio outbursts observed when the source is in the horizontal branch of its X-ray 'Z-state' are likely to give rise to synchrotron flares in the IR. The amplitude of the radio flares is in agreement with this scenario. Such IR variability, unrelated (directly) to X-ray reprocessing and the gross characteristics of the mass accretion rate, may be present in the IR flux of other low-mass X-ray binaries but harder to see owing to the intrinsically brighter IR fluxes of the longer period systems.

Margon joined a campaign led by D. Pooley (MIT) et al. to determine the nature of the various source populations of the low-luminosity globular cluster X-ray sources, and obtained a *Chandra X-Ray Observatory* image of the globular cluster NGC 6440. They detected 24 sources to a limiting luminosity of $\sim 2 \times 10^{31}$ ergs s^{-1} inside the cluster's half-mass radius, all of which lie within ~2 core radii of the cluster center. They also found excess emission in and around the core that could be due to unresolved point sources. Based on X-ray luminosities and colors, they concluded that there are 4–5 likely quiescent low-mass X-ray binaries and that most of the other sources are cataclysmic variables. They compared these results to *Chandra* results from other globular clusters and find the X-ray luminosity functions differ among the clusters.

M. Meixner and collaborators investigated the circumstellar dust of evolved stars. Meixner and T. Ueta (Royal Obs. Belgium) published their axisymmetric dust code, 2-DUST, and have made the code available for the general astronomical community. Using this code, Meixner, Ueta, A. K. Speck (UMs) and Bobrowsky (Challenger Center) modeled two proto-planetary nebulae (PPN) that represented their respective classes of elliptical (SOLE) and bipolar (DUPLEX) PPN. They found that indeed the two types of proto-planetary nebulae were physically distinct and probably represented lower and higher mass progenitors. Meixner, T. O'Hara (UIl), Ueta, Speck and Bobrowsky used 2-DUST to model the circumstellar shell of HD 168625, a luminous blue variable candidate, which they observed with NICMOS, ISOPHOT and ground-based mid-IR wavelengths. Ueta, Meixner and Murakawa (Subaru Obs.) investigated the near-infrared polarimetry in four elliptical proto-planetary nebulae and found mostly hollowed shells.

Meixner, Ueta, Pyzowksi (UIl), Moser (UIl) and Davis (The Cleveland Museum) published a near-IR (J, H, K') photometric survey of 78 proto-planetary nebula candidates observed with Meixner's near-IR camera, NIRIM, on Mt. Laugna. These data clarified the photometry for many sources, which were previously misidentified and revealed evidence for possible variability in others. Meixner and Speck worked on radiative transfer models for the parsec sized dust shells surrounding proto-planetary nebulae, such as the Egg Nebula.

Meixner and collaborators investigated the circumstellar molecular gas of evolved stars. Meixner, D. K. Fong (SMA/SAO/Harvard), E. C. Sutton (UIl), W. J. Welch (UCa–Berkeley) and A. Zalucha (UIl) finished their CO J = 1-0 survey of eight evolved stars using the Berkeley-Illinois-Maryland Association (BIMA) millimeter array. They analyzed these maps and those in the literature and found that the two types of PPN also have different kinematics. Elliptical (SOLE) PPN had simple expansion while bipolar (DUPLES) PPN had expansion plus collimated outflows. Meixner, Fong and Shah (Boston Univ.) discovered multiple, molecular shells surrounding the famous carbon star, IRC +10216. These shells supported theoretical models that show significant hydrodynamic activity in the shell after a thermal pulse from the star. Meixner, Fong, K. Justtanont (Stockholm Obs.), M. T. Campbell (UIl) detected and mapped the CO J = 1-0 transition in the OH/IR star, OH 26.5+0.6, and modeled the results using a radiative transfer model for the CO emission that they developed. Meixner, Fong, Zalucha and Justtanont compared their BIMA CO observations of HD 56126, a proto-planetary nebula, with radiative transfer models of the gas and found that the mass loss rate increased dramatically at the end of its life and that the gas-to-dust mass ratio was the extremely high value of 800. Meixner, Speck, G. Jacoby (WIYN) and P. Knezek (WIYN) reported on a high angular resolution image of H_2 2.12 micron of the Ring Nebula and found that the molecular gas emission arises in photo-dissociation regions. Meixner, Speck, Hartman and McCullough investigated the H_2 2.12 micron emission in the Helix nebula and found it to extend well beyond the ionized gas regions.

Meixner, Young Owl (UCa–Los Angeles), M. Haas (NASA/Ames), A. Rudolph (Harvey Mudd Coll.), and A. G. G. M. Tielens (Kapteyn Institute) reported on their study of low-excitation photodissociation regions (PDRs) in reflection

nebulae. They showed that the photoelectric heating efficiency was independent of the color temperature of the starlight. They found a correlation between the density of gas and the incident far-ultraviolet radiation incident on the PDR that can be explained by the H II region pressure on the PDR.

E. Nelan, with G. Schaefer (SUNY-SB), M. Simon (SUNY−SB), and S. T. Holfeltz, used data gathered with *Hubble* FGS1r to obtain preliminary orbits of low mass pre-main sequence stars in binary and triple star systems. Although the available data cover only a fraction of the orbital phase for each object, preliminary mass estimates have been derived that are useful for constraining theoretical mass determinations for these low mass stars. This research is continuing with additional *Hubble* and Keck observations that will refine the mass determinations.

Nelan, with collaborators from the University of Texas at Austin: G. F. Benedict, B. E. McArthur, W. H. Jefferys, P. J. Shelus, P. D. Hemenway, R. L. Duncombe, and L. W. Fredrick (UVa), T. Harrison (NMSU), C. L. Slesnick (UVa), J. Rhee (UVa), R. J. Patterson (UVa), M. F. Skrutskie (UVa), O. G. Franz (Lowell), L. H. Wasserman (Lowell), and W. van Altena (Yale), used astrometric data obtained with the *Hubble* FGS3 to measure the parallax of the fundamental distance scale calibrator Delta Cephei to an unprecedented accuracy of 3.66 ± 0.15 mas. This allows for a determination of the LMC distance modulus whose error is now dominated by the uncertainty of the metallicity correction for the Cepheid period-luminosity relation.

Nelan and R. Makidon demonstrated the remarkable performance of *Hubble* FGS1r near its faint limiting magnitude. Using the instrument to obtain interferograms of faint white dwarf stars, binary systems with projected angular separations below *Hubble*'s diffraction limit were interferometrically resolved. Nelan and Makidon developed the analysis techniques required to correct for the instrumental dark plus background counts when observing objects down to $V = 16.7$. These observations have shown the existence of a heretofore unknown and unexpected population of post common envelope evolution white dwarf binary systems with separations larger than several tenths of an astronomical unit.

J. Rhoads, A. S. Fruchter, J. Gorosabel, J. M. Castro Ceron (STScI), and A. Levan (Leicester) continued a program of optical and near-infrared follow-up observations of gamma-ray bursts. Highlights included the discovery of the GRB 030115 afterglow, which is extremely red and may provide a 'rosetta stone' for understanding the nature of optically faint GRB afterglows. Additional observations included GRB 020813. Rhoads was a member of the multinational GRACE collaboration (PI E. van den Heuvel, Amsterdam). GRACE used ESO telescopes to study large numbers of gamma-ray burst afterglows, including GRB 030329, GRB 020405, GRB 021004, and GRB 000210. Rhoads was also a member of the GOSH collaboration (PI Fruchter), which used *Hubble* to study many bursts including GRB 020410 (whose afterglow was discovered with *Hubble*), GRB 030115 (following up on the NOAO discovery), and GRB 030329.

Rhoads continued theoretical work on methods for studying gamma-ray burst collimation by looking for 'orphan afterglows'—afterglow events seen with no accompanying gamma-ray emission. Such events may be caused by either off-axis observations of collimated GRBs or by GRB-like fireballs whose peak Lorentz factor is too low to yield gamma-ray emission. Rhoads showed that monitoring of the optical or radio light curve can be used to distinguish between these origins, provided that the data are of sufficiently high quality.

M. Robberto, in collaboration with S. V. W. Beckwith, N. Panagia, R. Makidon, and J. Song, obtained the first results on a study of the mass accretion rates in the Trapezium Cluster stars. Using the WFPC2 data, they extracted a sample of 40 sources with complete *UBVI* photometry and spectral type between K0 and M5.5. With few exceptions, all sources show excess luminosity in the *U*-band that they attribute to mass accretion. The known correlation between the *U*-band excess and the total accretion luminosity, recalibrated to the *Hubble* photometric system, allows them to estimate the mass accretion rates, which are found to be in the range 10^{-7} to 10^{-10} $M_{\odot}\mathrm{yr}^{-1}$. Even for the youngest stars, lying in the vicinity of the 10^{-5} $M_{\odot}\mathrm{yr}^{-1}$ birth line of Palla and Stahler, the mass accretion rates are $\sim 10^{-7}$ $M_{\odot}\mathrm{yr}^{-1}$, indicating that the main accretion phase has been recently terminated. Robberto and coworkers suggested that the relatively low mass accretion rate could be related to the development of the H II region generated by the Trapezium OB stars. If this is the case, the low-mass end of the Initial Mass Function is affected by the evolution of the most massive cluster's stars, thus inducing an increment of low mass, 'accretion aborted' stars. This would be in agreement with recent findings that the Orion Nebula presents a fraction of low mass stars and brown dwarfs that is roughly twice as high as that measured in Taurus-Auriga.

K. Sahu continued his investigations to find the locations of the lenses for the observed microlensing events towards the Magellanic Clouds. Seven years of monitoring millions of stars towards the Magellanic Clouds has resulted in the detection of more than a dozen microlensing events towards the LMC and two events towards the SMC. However, there is much controversy on the exact location of the lenses, and there is as yet no consensus on whether the lenses are located in the Galactic halo, the local Galactic disk, or within the Magellanic Clouds. Through caustic crossing timescales of binary events, spectroscopy of microlensed sources, and statistics of binary events, Sahu has argued the stars within the Magellanic Clouds play a dominant role as gravitational lenses. This would imply that the contribution of MACHOs to the dark matter is less than 5%. Sahu presented a comprehensive review of these results at the STScI Spring Symposium entitled *The Local Group*.

Sahu and S. Kane carried out a spectroscopic study of microlensed sources towards the Galactic bulge. Through spectroscopy of 17 sources, they have shown that there is an extinction shift between the microlensed population and the non-microlensed population. This would imply that 65% of the microlensing events are caused by self-lensing within the bulge. The sample needs to be increased to ~100 sources to get a clear picture of the kinematics of the bulge.

Sahu, in collaboration with summer student Bakos, updated the Luyten half-second catalog with more accurate coordinates and proper motions using DSS-I and DSS-II images.

Sahu, with collaborators Tej, Chandrasekhar and Ashok, have developed a statistical method to derive the mass functions of open clusters using sky survey data such as 2MASS and the GSC. They have used this method to derive the mass functions in the stellar/substellar regime of three young, nearby open clusters, namely IC 348, σ Orionis and Pleiades. The mass function in the low mass range ($M < 0.50\ M_{\odot}$) is appreciably flatter than the stellar Salpeter function for all three open clusters. The contribution of objects below 0.5 $M_{\odot}$ to the total mass of the cluster is ~40% and the contribution of objects below 0.08 $M_{\odot}$ to the total is ~4%.

Sahu, through PLANET collaboration, carried out spectroscopic and photometric monitoring of the binary lens event EROS BLG−2000−5 during the caustic crossing. This allowed a rare opportunity to study in detail the structure of the stellar surface and allowed them to measure the limb darkening parameters and the mass of the lens. The limb-darkening parameters measured here are among the first for normal giants by any technique and for stars as distant as the Galactic bulge.

Sahu, in collaboration with Albrow and De Marchi, imaged M22 with *Hubble*, which has allowed, for the first time, a detailed and uniform mapping of mass segregation in a globular cluster. Luminosity and mass functions from the turnoff down to the mid- to lower-main sequence were presented for M22 in annular bins from the center of the cluster out to five core radii. Within the core, a significant enhancement was seen in the proportion of 0.5–0.8 $M_{\odot}$ stars compared with their numbers outside the core. The global cluster mass function for M22 is flatter than the Salpeter initial mass function and cannot be represented by a single power law.

D. Soderblom continued his work on an all-sky survey of chromospheric activity in the G dwarfs within 60 pc. Work at this stage involves completion of an on-line database of the results of the observations, together with relevant ancillary data. Collaborator J. King (Clemson) has derived metallicity values for the stars from the blue spectra, and these are being incorporated into the database as well. Results from this survey have informed target selection for a *SIRTF* Legacy program for which M. Meyer (UAz) is principal investigator. The activity survey was also used to estimate an age for HD 107146, a G dwarf observed to have circumstellar material.

Soderblom worked with B. Jones and other collaborators at Lick Observatory to extend work on the analysis and interpretation of the lithium abundances of young solar-type stars. They explored the implications for lithium as an indicator of late accretion of chondritic material onto stellar surfaces, with the conclusion that there is no evidence for such accretion. The same datasets have been used for detailed examinations of elemental abundances in the open cluster M34 (NGC 1039), working with King. Such metallicities are essential for understanding lithium depletion because of the dependence of convection zone depth on opacity.

Soderblom, with collaborators King and S. Adelman (The Citadel), revisited his pre-*Hipparcos* paper on the kinematics and spectroscopic properties of candidate members of the Ursa Major kinematic group. The *Hipparcos* results permit much more precise kinematics for the stars, which enabled additional stars to be excluded as likely members, refined knowledge of this loose association of stars, and shed light on the reality of such kinematic associations.

Soderblom analyzed *Hubble* FGS observations of the HD 98800 system with F. Benedict (UTx) and O. Franz (Lowell) to determine accurate masses for this pair of pre-main sequence stars, a calibration for stellar models.

A. Suchkov, V. Makarov (USNO), and W. Voges (MPE, Germany) studied X-ray properties of ~2000 F stars using *ROSAT* data. They identified a population of F stars whose X-ray emission increases rather than decreases with age, and found that these stars are also unusual in the optical in the sense that their luminosity is too high for their temperature and surface gravity (over-luminous stars). They found strong X-ray emitters to comprise two very different age groups: old, post-zero age main sequence (ZAMS), overluminous stars and young, pre-main sequence (PMS) and ZAMS stars. They found that the X-ray luminosity of soft X-ray emitters correlates with hardness ratio; no such correlation was found for hard X-ray emitters.

Suchkov and R. Hanisch conducted a search for and a study of hard X-ray binaries (HXRB) using the automated X-ray source classifier ClassX. They found 35 new HXRBs in addition to 37 previously known HXRBs listed in the WGA catalog of *ROSAT* sources. The new HXRBs were found to be, on average, much fainter in the X-rays and more obscured in the infrared, which means that they are more distant and/or embedded into a heavily absorbing environment.

Suchkov studied young and pre-main sequence PMS F stars using X-ray, optical, and infrared data as well as *Hipparcos* parallaxes and proper motions. He identified a large number of PMS candidates and established the association of these PMS stars with the known regions of star formation. He examined the relationships between the X-ray, optical, and infrared properties of the candidate PMS F stars and analyzed them in the context of circumstellar dust disks, PMS evolution, and the recent history of star formation in the solar neighborhood.

J. Valenti and C. Johns-Krull (Rice) continued their analysis of magnetic fields on T Tauri stars, using high-resolution infrared spectroscopy to determine the surface distribution of magnetic field strengths and circular spectropolarimetry to constrain magnetic geometry. For individual T Tauri stars, they found field strength distributions ranging from 0–6 kG with a characteristic mean field strength of 2–3 kG, implying that magnetic pressure dominates gas pressure in the photospheres of T Tauri stars. They combined their measured field strengths with magnetospheric accretion models to predict that field lines coupling stars and disks must cover 1–10% of the stellar surface. They found no circular polarization in photospheric absorption lines, ruling out a dipolar magnetic configuration at the stellar surface. They did observe rotationally modulated circular polarization in the 5876 He I emission line, which they reproduced

using a simple magnetic spot model with a uniform radial field.

Valenti, G. Herczeg (Boulder), J. Linsky (Boulder), B. Wood (Boulder), and F. Walter (Stony Brook) continued their study of fluoresced molecular H_2 around T Tauri stars. They used STIS spectra to reconstruct the Lyman-α emission profile seen by the fluoresced H_2. They used a specific disk model to explore the effects of self-absorption and extinction.

Valenti, A. Fallon (Macalester), and C. Johns-Krull (Rice) published an atlas of coadded *IUE* long-wavelength spectra of pre-main-sequence stars, which complements an earlier atlas of *IUE* short-wavelength spectra. They created a web page (http://archive.stsci.edu/prepds/iuepms/) to distribute the coadded spectra. Using the new long-wavelength atlas, they determined Mg II emission line luminosities for T Tauri stars and extinction towards Herbig Ae/Be stars.

Valenti and D. Fischer (UCa–Berkeley) fitted echelle data with synthetic spectra to determine effective temperature, v sin i, and elemental abundances for 800 F, G, and K stars in radial velocity surveys for extrasolar planets. They used this self-consistent catalog of stellar properties to determine the frequency of detectable planets as a function of iron abundance in the parent star, finding a monotonic increase to a probability of 20% at three times the solar iron abundance.

R. van der Marel wrote two reviews on formation theories for and observational constraints on the existence of intermediate-mass black holes (IMBHs), with masses between those of 'stellar-mass' and 'super-massive' black holes. The existence of IMBHs is a real possibility: they might plausibly have formed as remnants of the first generation of stars (Population III), as the result of dense star cluster evolution or as part of the formation process of supermassive black holes. Their cosmic mass density could exceed that of super-massive black holes and observations do not even rule out that they may account for all of the baryonic dark matter in the universe. Unambiguous detections of individual IMBHs currently do not exist, but there are observational hints from studies of microlensing events, 'ultra-luminous' X-ray sources, and centers of nearby galaxies and globular clusters. Gravitational wave experiments will soon provide another method to probe their existence. IMBHs have potential importance for several fields of astrophysics and are likely to grow as a focus of research attention.

N. Walborn conducted a critical analysis of the large scatter found in the absolute magnitudes of O stars at a given spectral type by Garmany and Stencel, A&AS, 94, 211 (1992), finding that it is substantially due to noncospatiality of the O and B stars in several of their presumed associations (the absolute magnitudes of the former being derived with distances determined from the latter). The absolute magnitudes of O stars within each of these associations deviate systematically from the calibration, with much smaller dispersions.

Walborn joined the *FUSE* hot-star team as an associate and in collaboration with A. Fullerton (JHU) and P. Crowther (UCL) designed an extensive atlas of OB spectra in the Magellanic Clouds. The MC stars are more useful than the Galactic counterparts to trace the behavior of stellar features in this wavelength range, because the effects of interstellar H_2 are far less severe. This is the first sample of spectra below Ly α with extent and resolution adequate for this purpose.

Walborn's *Hubble* program with J. Maíz-Apellániz and R. Barbá (Univs. of La Plata and La Serena) on further imaging and spectroscopy in 30 Doradus completed the WFPC2 coverage of the object, providing a spectacular image of the evacuating cavity and molecular-cloud interfaces surrounding R136. In combination with the results from his prior NICMOS program in the region, a new, triggered generation of stars at the interfaces is clearly revealed, involving at least three evolutionary stages of massive dust pillars oriented toward the central cluster.

In collaboration with I. Howarth (UCL), A. Herrero (Instituto de Astrofisica de Canarias), and D. Lennon (Isaac Newton Group), Walborn discovered that the peculiar Of star HD 191612 undergoes extreme, recurrent variations between two spectral states. In one state, the spectral type is O6, C III emission is comparable to N III, and there are strong P Cyg profiles at He II 4686 and Hα. In the other, the spectral type is O8, there is no C III emission, He II 4686 has a unique 'Be' profile, and Hα is in absorption. No radial-velocity variations have been detected. The time scale is long, but the available historical and new coverage is inadequate to establish it or any periodicity. Possible explanations include a long-period, eccentric binary; a rapid rotator with shell effects; or a relationship to Luminous Blue Variables.

B. Whitmore reviewed the subject of star cluster formation for the Space Telescope Science Institute May workshop. The emphasis was on contributions arising from observations by *Hubble*, and included both galactic and extragalactic clusters. As part of the review, Whitmore compiled a database from the literature that allowed him to demonstrate that the cluster luminosity function appears to be universal in mergers, starbursts, and normal spiral galaxies. This is based on a plot of the brightest cluster in a galaxy versus the number of clusters. The plot can be explained purely by statistics rather than differences in the luminosity function. What differs is the normalization, with roughly 1000 times more clusters in mergers than in spiral galaxies.

Whitmore, in collaboration with K. Knierman and other coauthors, used V and I images obtained with WFPC2 to investigate compact stellar structures within six regions of tidal debris in the four classic 'Toomre Sequence' mergers: NGC 4038/39 ('Antennae'), NGC 3256, NGC 3921, and NGC 7252 ('Atoms for Peace'). The six tails were found to contain a variety of stellar structures, with sizes ranging from those of globular clusters up to those of dwarf galaxies. NGC 3256 was found to have a large population of blue clusters ($0.2 < V - I < 0.9$), similar to those found in the inner region of the merger. In contrast, NGC 4038/39 had essentially no clusters in the observed region of the tail.

Whitmore reviewed evidence that young globular clusters are currently forming in the local universe. He found good evidence that young massive clusters can form in merging, starbursting, and even normal spiral galaxies. While many of these young clusters are destroyed, the denser, more massive

clusters have all the attributes expected of young globular clusters. Three questions were examined in the review. Can we see the evolution of the cluster luminosity function from a power law to a Gaussian? What triggers the formation of clusters? What fraction of stars is formed in clusters and what fraction is formed in the field?

R. Williams, with E. Jenkins (Princeton) and J. Baldwin (MSU), obtained high resolution UV spectra of the central stars of several PNe with STIS in order to derive column densities of ions. They studied the resonance absorption produced by the nebular shells, which appears against the central star continuum. They compared these column densities directly with the relative ion abundances for the same ions derived from their emission lines, both forbidden and recombination, along an adjacent line of sight in the nebula. This comparison in the PN IC 418, determined independently from column densities derived from UV absorption lines and forbidden emission lines in the nebular shell, showed general agreement with some individual discrepancies. The two methods were used to evaluate which emission lines produce reliable abundances.

5 ISM & IGM

Together with H. Heaton (JHU/APL) and M. Kaufman (San Jose State), R. Allen completed a study of the production of atomic hydrogen in photodissociation regions and a comparison with CO(1-0) emission, and he submitted a paper on this topic to the *Astrophysical Journal*. The results provide a new diagnostic tool for simultaneously determining the far-ultraviolet flux incident on giant molecular clouds (GMCs) and the volume density of the cloud surfaces using ground-based observations of the 21-cm H I line and the 3-mm CO(1-0) line. In the past, such diagnostics have required observations in the infrared from high-flying aircraft and satellites.

Allen, together with Heaton, J. Knapen (Hertfordshire), and L. Loinard (UNAM–Morelia) analyzed observations of faint CO(1-0) emission regions in M81 and compared them with H I data in the context of the photodissociation model.

Allen continued theoretical and observational work examining the role of cosmic rays in controlling the brightness of the observed CO(1-0) emission in galaxies. Building on earlier work with D. Adler and K.-Y. Lo (NRAO), Allen and JHU grad student Ben Waghorn compared simple cosmic ray heating models in the ISM with the CO(1-0) data in nearby galaxies.

Allen continued exploratory work to use the absorption of the cosmic microwave background by gaseous formaldehyde (H_2 CO) as a diagnostic for cold molecular gas in the interstellar medium. Contact was made with the Onsala Radio Observatory in Sweden, and together with T. Wiklind and J. Rajagopal (NASA/GSFC), a proposal was submitted to use their facilities in an attempt to detect this signal from the Galactic GMC G216-2.5 and from a possible general distribution of cool compact clouds in the plane of the Galaxy. Together with Loinard and Rajagopal, Allen submitted a proposal to use the Green Bank Telescope in order to measure the extent of the formaldehyde absorption in the Galactic dark cloud L1204; the results will be used to examine differences in the distribution of cold gas compared to the IR emission from warm dust.

Together with J. Pringle (Cambridge) and S. Lubow, Allen continued to develop a new view on the formation of GMCs, the precursors to stars. In this picture, the raw material for GMC formation is molecular hydrogen, most of it too cold to be identified in the ISM. The H I in the ISM is largely a photodissociation product of the stars, not a precursor to the star formation, and the GMCs themselves are largely artifacts of observational selection in the CO(1-0) line. Observational and theoretical tests of this picture are being explored.

Allen continued his work on a new interpretation of the 'Schmidt Law' of global star formation. This 'law,' widely discussed in the literature, relates the surface density of H I in galaxy disks (viewed as the 'cause') to the star formation rate (viewed as the 'effect'). A conference paper was presented that argues that 'cause' and 'effect' have been reversed, and that the H I is a photodissociation product of the young stars. The global Schmidt Law can be computed in a straightforward way using a simple model of photodissociation and reasonable parameters for the parent molecular clouds.

Allen also presented observational evidence for dissociation as a ubiquitous process in the ISM, responsible for most (and perhaps even all!) of the H I present in galaxies. An earlier invited conference paper describing this view was published this year; it shows examples of H I production by photodissociation in the ISM on size scales from 1 pc to an entire galaxy.

Allen, A. Petrosian (Byurakan Obs.), and R. Swaters (JHU) have begun to examine the possible correlation between H I, disk dark matter content, and ISM metallicity. Such a connection is predicted in the scenario where H I is produced by photodissociation of an underlying molecular gas that is itself in turn a significant component of the dark baryon component in galaxies.

Allen discussed the discovery of young stars in the outer H I disks of nearby galaxies in a talk given at Symposium 220 of the IAU in Sydney. The results, found earlier with J. Cuillandre and J. Lequeux in M31, imply that significant amounts of molecular gas are present in the outer disk of this galaxy, leading to a continuing low level of massive star formation. These young stars photodissociate their progenitor H_2 clouds, producing extensive H I envelopes, which trace the otherwise-dark molecular gas. A quantitative application of a simple photodissociation model is being carried out with R. Miller (STScI) and a paper is in preparation. Estimating the contribution of this component to the baryon content of galaxies requires some assumptions about the geometry of the cold GMCs, but it is not unreasonable to conclude that the contribution may be substantial, at least in the outer disks.

With G. Meurer (JHU), Allen confirmed a prediction that young upper-main-sequence stars would be found in the extended H I disk of the LSB galaxy NGC 2915. They presented a poster on this topic at the Symposium.

Allen continued his collaboration with graduate student B.

Holwerda (STScI, Kapteyn Laboratory) in an extensive observational study applying the 'synthetic field method' (developed earlier by Allen and postdoc R. Gonzalez) to determine the average opacity of spiral galaxy disks from counts of background field galaxies. The method calibrates the foreground confusion caused by the intervening galaxy and provides estimates of disk opacity averaged over areas of typically a few square arcminutes. No assumptions about the relative distribution of stars and gas in the intervening galaxy are required. Over the past three years, significant improvements have been made to the method and Holwerda has succeeded in almost entirely automating the reduction.

Allen reduced and began analyzing a sample of more than 20 galaxies drawn from the WFPC2 archive. He constructed radial distributions of opacity. Noteworthy new results include the discovery of a wide range of opacity in galaxy disks, with large areas that are virtually transparent and other areas almost completely opaque. Many galaxies show average opacities of $Av \sim 1$–2 mag over the main portion of the disk. A poster paper on this work was presented at Symposium 220 of the IAU in Sydney.

M. Fall, S. Savaglio (JHU), and F. Fiore (Osservatorio Astronomico di Roma) measured the absorption lines of several heavy elements in the optical spectra of gamma-ray burst (GRB) sources. They found that the column densities of metals and dust in the circumstellar or interstellar material in the foregrounds of these GRBs are higher than those in most quasar absorption-line systems at similar redshifts. Typical extinctions in the GRBs are $A_V \sim 1$. These results indicate that the lines of sight to GRBs pass through regions of high interstellar density (and star formation), whereas those toward optically selected quasars pass mainly through regions of relatively low interstellar density in foreground galaxies.

S. Friedman continued his studies of the deuterium abundance in the local interstellar medium, as part of the *FUSE* deuterium group, led by W. Moos (JHU). The goal is to understand variations in the D/H ratio, and how this is related to variations in the relative abundances of other species, especially oxygen and nitrogen. The *FUSE* results, when combined with those from *Hubble*, Copernicus, and IMAPS, demonstrate that the D/H ratio is fairly constant within the local bubble, at a distance of approximately 100–150 pc, but appears to be variable outside the bubble. Friedman and collaborators are pursuing more distant targets to determine whether D/H is anticorrelated with O/H and N/H, as might be expected from models of galactic chemical evolution.

In a project led by P. Sonnentrucker (JHU), Friedman and collaborators made a detailed study of the physical conditions in the interstellar medium towards two targets, HD 192639 and HD 185418. These targets were selected from the *FUSE* translucent cloud program, led by T. Snow (Colorado). One principal result of these studies is that the sight lines appear to be composed of multiple diffuse clouds, rather than a single translucent cloud.

Friedman was part of a collaboration, led by D. York along with J. Thorburn (Chicago), studying the correlations of diffuse interstellar bands (DIBs) with molecules, particularly C_2, CN, and CH. Based on high signal/noise optical echelle spectra, they found that seven of 21 diffuse bands correlated well with $N(C_2)/E(B-V)$, and moderately well with $N(CN)/E(B-V)$ and $N(CH)/E(B-V)$. They hope to gain an understanding of the molecules responsible for the DIBs by examining a large number of these correlations over many sight lines.

G. Kriss, working with his Ph.D. student, R. Telfer (JHU/Orbital Sciences), studied elemental abundances in the low-density portions of the intergalactic medium (IGM). Using stacked FOS spectra of several bright quasars with good Keck H I spectra, Telfer et al. (2002) measured the strength of lines from O IV (788 Å) and O V (630 Å). O IV is undetected, but O V is detected at greater than 99% confidence. The ratio is consistent with photoionization by a quasar-like spectrum with a spectral index $\alpha = -1.5$. Using photoionization models to infer the ionization correction, the relative strength of O V and C IV leads to a relative O to C abundance of $[O/C] = 0.3$ to 1.2. This overabundance of O to C suggests enrichment of the low-density IGM by products from Type II supernovae.

G. Kriss, W. Zheng (JHU), M. Shull (Colorado) and the *FUSE* team have carried out further studies of ionized helium in the IGM. Using deep VLT/UVES spectra of the H I Lyman-α forest and reprocessed *FUSE* spectra of the sightline towards the quasar HE2347−4342, Zheng et al. (2003) were able to identify over 90% of the H I absorbers associated with the He II absorption visible in the *FUSE* spectrum. They were also able to trace the He II absorption to wavelengths as short as 920 Å, enabling them to study the He II Lyman β portions of the absorption. This led to two significant results. First, they measured the line widths of isolated He II absorption lines and showed that they were the same as those of the corresponding hydrogen lines, implying that line widths in the IGM are dominated by turbulence rather than thermal motions. Second, by measuring the Lyman β opacity in regions of the spectrum where Lyman α is opaque, they demonstrated that the Lyman α opacity was only 5 ± 1, consistent with the bulk of He II reionization having occurred at epochs at higher redshift than $z = 2.9$. With the same data, Shull et al. (2003) used a model-independent technique to study the fluctuations in the He II to H I column-density ratio in the IGM, which is a tracer for the spectral shape of the ionizing radiation illuminating the gas. They showed that the combination of the natural variation in quasar spectral indices, the resulting difference in the proximity spheres for H I and He II, and radiative transfer through a non-uniform IGM may all conspire to produce the observed variations in the column-density ratio.

C. Leitherer, in collaboration with C. Hoopes (JHU), K. Sembach, T. Heckman (JHU), G. Meurer (JHU), A. Aloisi (JHU), D. Calzetti, and C. Martin (UCa), studied the 905 to 1180 Å spectral range covered by *FUSE*, which includes numerous transitions of molecular hydrogen. This made possible the direct measurement of H_2 column densities without using CO as a tracer. The authors searched for H_2 absorption in five starburst galaxies: NGC 1705, NGC 3310, NGC 4214, M83 (NGC 5236), and NGC 5253. They tentatively detected weak absorption by H_2 in M83 and NGC 5253, and

set upper limits on the H_2 column density in the other galaxies. Conservative upper limits on the mass of molecular gas detected with *FUSE* are many orders of magnitude lower than the H_2 mass inferred from CO measurements for the four galaxies in the sample in which CO has been detected. The difference is too large and in the wrong sense to be caused by a metallicity dependence of the CO H_2 conversion factor. The authors interpret this to mean that almost all of the H_2 is in the form of dense clouds that are opaque to far-UV light and therefore cannot be probed with far-UV absorption measurements. The far-UV continuum visible in the *FUSE* spectra passes between the dense clouds, which have a covering factor < 1. There is very little diffuse H_2 (column densities between 10^{14} and 10^{19} cm^{-2}) between the dense clouds, suggesting that any H_2 that evaporates from the surfaces of the clouds is quickly photodissociated by the far-UV radiation from the starburst or fast shocks in the diffuse interstellar medium. This illustrates the effects of the harsh UV radiation environment on the interstellar medium in starbursts. However, previous UV observations of these starbursts have shown that there is reddening in the diffuse interstellar medium, suggesting that while diffuse H_2 is destroyed in the starburst, diffuse dust is not.

I. N. Reid continued to lead an NStars-funded survey for unrecognized stars within 20 parsecs of the sun. This is a collaborative program with K. Cruz (thesis project, UPa), J. Liebert (UAz), D. Kilkenny (SAAO), J. E. Gizis (UDe), A. J. Burgasser (UCLA), J. D. Kirkpatrick and P. J. Lowrance (IPAC). They are using 2MASS near-infrared photometry to search for late-type dwarfs both directly, using (J, (J-K)) data, and in combination with other resources, notably Luyten's proper motion surveys. Cruz and Reid are the principals in the former study, the first large-scale systematic survey for nearby ultracool (M7–L8) dwarfs. They have whittled down the 300 million sources in the 2MASS Second incremental release (47% of the sky) to 1750 candidates, and follow-up observations have yielded over 300 confirmed ultracool dwarfs, including 52 within 20 parsecs. This more than doubles the local census. Amongst these stars is an M8.5 dwarf only 6.3 parsecs from the sun (Reid et al., 2003). Moreover, the follow-up observations have also identified several chromospherically active dwarfs, including an initial summary of the statistical results is given in Cruz et al. (2003). Forty of the faintest candidates (probably including the nearest, coolest brown dwarfs) still lack confirming observations.

Reid led a search for previously unrecognized nearby mid-type M dwarfs catalogued in Luyten's NLTT proper motion survey. These stars lack the distinctive *JHK* colors of ultracool dwarfs, but can be identified by combining Luyten's optical photometry with 2MASS data. Concentrating on the regions covered by the 2MASS second incremental release, so far the survey has identified 230 additions to the 20-parsec census, a 50% increase. Most of the new stars have spectral types between M4 and M7. The observations have also succeeded in identifying several new dwarf carbon stars (Lowrance et al. 2003).

Reid, S. L. Hawley (UWa) and Gizis (2003) re-analyzed the luminosity function of nearby stars, incorporating data from both the *Hipparcos* catalogue and the Palomar-Michigan State University spectroscopic survey. The resulting mass function is better represented by a combination of power laws, with a significant change of slope near one solar mass, than by a lognormal Miller-Scalo function. Reid was also involved in several surveys for binary systems among the known ultracool dwarf population. Gizis et al. (2003) presented analysis of *Hubble* observations of 110 late-M and L dwarfs, while Burgasser et al. (2003) analyzed similar data for 10 T dwarfs. Both samples show similar properties, with an observed binary fraction of ~20%, corresponding to an intrinsic binarity of ~10%. All of these systems have separations of less than 15 AU. The available high-resolution spectroscopic observations (Reid et al. 2002) suggest a similar proportion of unresolved systems, implying a total binary fraction close to 20%. This is significantly higher than predicted by models that propose brown dwarf formation as ejected stellar embryos.

Reid analyzed high-resolution spectra of the brighter members of the TW Hydrae association, together with observations of sixteen candidate members. Two of the latter have motions consistent with membership. The mean cluster motion is ($U = -10.0$, $V = -17.8$, $W = -4.6$) km sec^{-1}, corresponding to a velocity of 13 km sec^{-1} with respect to the Local Standard of Rest. Working in collaboration with B. Zuckerman (UCLA), D. Koester and Hunsch, Reid completed analysis of high-resolution spectra of approximately 100 white dwarfs in a search for DAs with metal lines. Twenty-five percent of the single white dwarfs in the sample show Ca II lines, while a much smaller fraction exhibit lines due to Mg, Fe, Si and Al. This is surprising given the relatively short photospheric residence time (< 10 million years) predicted for metals in DAs. Possible explanations include accretion of either cometary or asteroidal material.

K. Sembach worked on understanding the properties of the interstellar media of galaxies and the intergalactic medium in the low-redshift universe. This research included an extensive survey of highly-ionized high-velocity gas traced through O VI absorption with *FUSE* and several studies aimed at estimating the baryonic content and physical properties of the warm-hot intergalactic medium.

Sembach, in collaboration with B. Savage, B. Wakker, M. Meade (UWi–Madison), and P. Richter (Osservatorio Astrofisico di Arcetri), compiled and analyzed an extensive set of spectroscopic data for 100 QSOs/AGNs observed by *FUSE* to study the properties of highly ionized gas in the vicinity of the Milky Way. They reported the discovery of an extensive, hot ($\log T = 6$) Galactic corona, the existence and properties of a population of very highly ionized high-velocity clouds traced through their O VI absorption, and the distribution of the hot interstellar medium in the thick disk of the Milky Way.

Sembach, J. Howk (UCa–San Diego), Zsargo (JHU), and Savage also studied the Milky Way O VI absorption toward approximately two dozen halo stars observed by *FUSE*. They found that the hot phase of the interstellar medium traced by O VI in these directions is patchy and that the amount of O VI detected is consistent with the trends expected from the *FUSE* extragalactic dataset.

Sembach, in collaboration with A. Aloisi (JHU), T. Heckman (JHU), C. Hoopes (JHU), and C. Leitherer (STScI), studied the abundances and kinematics of the neutral gas of the starburst galaxy I Zw 18. The investigators found that the abundances are lower than those found in H II region studies, which is consistent with a bimodal star-formation history having both a very old component and a more recent star-formation episode that started 10–100 Myr ago.

Sembach, with B. Otte (JHU), E. Murphy (UVa), Howk, Q. Wang (UMa), and W. Oegerle (NASA/GSFC), detected O VI emission from the edge-on spiral galaxy NGC 4631. The location of this emission in the halo of the galaxy is the same as that found for a soft X-ray bubble. They inferred an O VI luminosity of 0.2–2.0% of the total energy supplied by supernovae in the galaxy, and a mass flux cooling rate of 0.48–2.8 solar masses per year. The findings indicated that the emission arises in cooling, galactic fountain gas.

Sembach, with Heckman, C. Norman (JHU), D. Strickland (JHU), studied the relationship between O VI line widths and O VI column densities in highly ionized systems ranging from the interstellar medium of the Galactic disk to the low-redshift intergalactic medium. They found a strong correlation in the two quantities for O VI systems in the Milky Way, Magellanic Clouds, starburst galaxies, and the intergalactic medium, suggesting that similar collisional ionization processes create the O VI absorbers in many of these environments. They explained this trend by offering several simple analytical expressions for the dependence of line width on velocity for various collisional ionization scenarios.

Sembach, with Hoopes, Hebrard (IAP, France), Moos (JHU), and Knauth (JHU), studied the interstellar deuterium Lyman-series absorption toward two stars in the Galactic disk. They found $D/H < 10^{-5}$ in the gas along the two sight lines, which extend roughly one kiloparsec. This value of *D/H* is considerably less than that observed for nearby clouds in the local interstellar medium, indicating that the degree of deuterium astration is greater in the more distant environments probed along these sight lines. These were the first measurements of Lyman-series D I absorption beyond 500 pc made by *FUSE*.

Sembach continued studying the molecular hydrogen content of interstellar clouds in the Galactic halo in collaboration with Richter, Savage, Wakker, and Howk. He also studied the physical properties of gas along several directions through the Galactic disk and low Galactic halo.

A. Andersson-Lundgren (Stockholm Obs.), in collaboration with T. Wiklind, H. Olofsson (Stockholm Obs.) and Rydbeck (Onsala Space Obs.), constructed the first complete map of the molecular gas distribution and its kinematics of the barred spiral galaxy M83 using the single-dish SEST telescope in Chile. The results showed a strong correlation between active star-forming regions and molecular gas concentrations. The kinematics of the molecular gas showed clear indications of streaming motions as expected from density waves. The molecular gas in the central region was mapped in greater detail than the disk itself. An innovative image deconvolution method, based on the usual MEM, was used to enhance the spatial distribution of the molecular gas.

Wiklind, in collaboration with L. Pagani (Observatoire de Meudon) and the *Odin* Team, participated in deriving the best upper limit to the molecular oxygen abundance in the interstellar medium obtained to date. The *Odin* satellite allows observations of wavelengths not accessible from the ground. The limits to the O_2 abundance have implications on chemical models of the ISM, which in dark and quiescent molecular clouds predicts abundances much higher than the upper limit obtained with *Odin*.

6 GALAXIES

S. Arribas and L. Colina (IEM-CSIC, Madrid) studied a representative sample of low-redshift ultra-luminous infrared galaxies (ULIRG). This program combined integral field optical spectroscopy using the INTEGRAL system at the WHT with high resolution *Hubble* imaging. During the past year, the investigators analyzed two objects in detail: IRAS 15206 +3342 and IRAS 17208–0014. In IRAS–152, they found clear evidence for the presence of gas flowing inward along the tidal tail, feeding the nuclear regions where an arc-shaped chain of young stellar clusters is forming stars at a rate of about 150 $M_\odot$ yr^{-1} . These characteristics indicate that the system is at the final coalescence phase of two disk galaxies with bulges, though no sign for the presence of an AGN was found. Similarly, for IRAS–172 they presented kinematical, morphological, and photometric evidence that supported the idea that this cool ULIRG is at the final coalescence phase of a system composed of two spiral galaxies with $m \leqslant m^*$ evolving into an intermediate-mass ($\sim L^*$) elliptical galaxy. Again in this case the data show no trace of a luminous QSO and indicate that starbursts dominate the energy output in this galaxy.

In a related study, Arribas, as a member of a collaboration led by J. McDowell (CfA), analyzed the extended emission of the ULIRG Arp 220 combining *Chandra* and INTEGRAL data. They found that there is a close morphological correspondence between the Hα and soft X-ray emission on all spatial scales. They interpreted the plumes as a starburst-driven superwind and discussed two interpretations of the emission from the lobes in the context of simulations of the merger dynamics of Arp 220.

Arribas, in collaboration with R. González-Delgado (IAA), T. Heckman (JHU), E. Battaner (Univ. of Granada), and E. Mediavilla (IAC), carried out studies based on integral field spectroscopy of several nearby galaxies. Two galaxies were analyzed: NGC 7331 and NGC 2110. In NGC 7331 they found peculiar velocities in the ionized gas velocity map, which were well interpreted by the presence of an axisymmetric inflow of 40 km s^{-1} at the inner boundary of the large-scale gaseous ring. They inferred an inwards total flux of 1.6 $M_\odot$ yr^{-1} , which is typical of the accretion rate in a hypothetical large nuclear black hole. In NGC 2110 they combined INTEGRAL and WFPC2 and H I data to explore the possibility that the galaxy suffered a collision with a small satellite with a highly inclined orbit that impacted on NGC 2110 close to its center. They suggested that a minor merger might have driven the nuclear activity in NGC 2110.

Arribas, in collaboration with E. Mediavilla, V. Motta, J. A. Munoz (IAC), E. Falco, C. S. Kochanek (CfA) and others, determined the extinction curve in the $z = 0.83$ lens galaxy

of the gravitational lens SBS 0909+532 from the wavelength dependence of the flux ratio between the lensed quasar images ($z_s = 1.38$) from 3400 to 9200 Å. This was the first measurement of an extinction curve at a cosmological distance of comparable quality to those obtained within the Galaxy. The extinction curve has a strong 2175 Å feature, a noteworthy fact because it has been weak or nonexistent in most estimates of extinction curves outside the Galaxy. The extinction curve is fitted well by a standard $R_v = 2.1 \pm 0.9$ Galactic extinction curve. Assuming the standard Galactic extinction laws, the estimated dust redshift of $z = 0.88 \pm 0.02$ is in good agreement with the spectroscopic redshift of the lens galaxy. These results indicate that the widespread assumption that SMC extinction curves are more appropriate models for cosmological dust may be incorrect.

C. Blades, in collaboration with D. Bowen and M. Pettini, published results of a STIS spectroscopic survey of Lyman α absorption lines in the outer regions of nearby galaxies using background QSOs as probes. Lyman α lines were found for all eight galaxies observed within a few hundred km s^{-1} of the systemic velocity. The ubiquity of the detections implies a covering factor of ~100% for low N(H I) gas around galaxies and within ~300 kpc, such was the extreme sensitivity of the survey. The investigators did not reject the hypothesis that the selected galaxies are directly responsible for the observed absorption, but their analysis indicated that absorption by clumpy intragroup gas is an equally likely explanation.

R. Bohlin worked on new UV/optical/IR absolute flux standards, using STIS observations and models to extend pure hydrogen WD stars and solar analog stars into the IR. An observing program for a fainter extension (FASTEX) was complete in the UV; and plans were made for establishing faint IR spectrophotometric standards with NICMOS grism data in Cycle 13. These new faint IR standards are essential for enabling science on WFC3, SNAP, and *JWST* in the long run. In addition, the primary Sloan standard BD +17D4708 was observed to tie the ground-based Sloan Survey directly to the ACS Sloan filters. More recently, Bohlin collaborated with R. Gilliland to get STIS observations of the fundamental flux standard, Vega. Preliminary results show that the STIS fluxes are within ~3% percent of the published spectral energy distributions for both stars. Bohlin and Gilliland wrote the STIS section of the paper on BD +17d4708.

Using the ACS, T. M. Brown, H. C. Ferguson, E. Smith, R. A. Kimble (NASA/GSFC), A. V. Sweigart (NASA/GSFC), A. Renzini (ESO), R. M. Rich (UCLA), and D. A. Vandenberg (Univ. of Victoria) began investigations into the star formation history of the Andromeda halo. With the deepest optical images of the sky ever obtained, Brown and collaborators constructed a color magnitude diagram extending to 31st mag stars on the old main sequence in Andromeda. They found that the Andromeda halo has a surprisingly wide spread in ages, with 30% of the population young (6–8 Gyr) and metal-rich ([Fe/H] > -0.5), suggesting that Andromeda has undergone a more violent merging history than our own Galaxy.

T. M. Brown, H. C. Ferguson, E. Smith (STScI), C. W. Bowers, R. A. Kimble (NASA/GSFC), A. Renzini (ESO), and R. M. Rich (UCLA) used STIS to investigate the ultraviolet emission from elliptical galaxies at a redshift of 0.33 as part of an ongoing series of programs to map the evolution of the 'UV Upturn' phenomenon as a function of redshift. The UV upturn is potentially a sensitive indicator of age, if it can be calibrated. Brown and collaborators found that the UV upturn is significantly weaker at a look-back time of 3.9 Gyr than it is in the current epoch, but similar to that in galaxies at higher redshift.

Using the STIS, Brown, S. Heap, I. Hubeny, T. Lanz, and D. Lindler (all NASA/GSFC) produced a two-dimensional spectroscopic map of the starburst galaxy I Zw 18 to better understand its star formation history and interstellar medium. Brown and collaborators found two massive star clusters dominated by Wolf-Rayet stars, even though stellar evolution theory predicts few of these stars should form at the metallicity of I Zw 18, which has the lowest metallicity of any known galaxy. They also obtained a high-resolution map of the neutral hydrogen, which peaks at a column ten times higher than that measured previously.

H. Bushouse, S. Arribas, R. Lucas, and K. Borne (Raytheon Technical Services) continued to study the nature and evolution of infrared galaxies using a ground-based imaging survey of Very Luminous Infrared Galaxies (VLIRGs). VLIRGs are the less luminous cousins of Ultraluminous IR Galaxies (ULIRGs), with IR luminosities an order of magnitude lower than that of ULIRGs. As such, they provide a link between normal galaxies and the ULIRGs, and offer the opportunity to study variations in fundamental physical and structural properties of galaxies as a function of luminosity. VLIRGs may be the low-redshift analogs to, or the evolutionary result of, cosmological populations of very red, very luminous galaxies. Multi-color *BVI* images were obtained of 26 low redshift ($z < 0.1$) VLIRG systems using the Nordic Optical Telescope at La Palma. The analysis of these data has shown a great deal of similarity between VLIRGs and ULIRGs. Like ULIRGs, a large fraction of the VLIRGs are interacting systems. Many of those that contain only a single galaxy also show morphological evidence of past interaction activity and therefore may be advanced merger systems. The optical colors of the VLIRGs span nearly the same range as those of ULIRGs, indicating similar states of current star formation and star formation histories. The only significant difference between the VLIRGs and ULIRGs is the apparent lack of evidence for AGN in the VLIRG sample. In every other respect, the VLIRGs appear to be simply scaled-down versions of ULIRGs, composed of galaxies of somewhat smaller mass and luminosity, although the interaction process seems to be able to generate the same types of results as in ULIRGs.

R. S. de Jong, E. Bell (MPIA), S. Courteau (UBC) and R. Olling (USNO) presented a simple technique to estimate mass-to-light (M/L) ratios of stellar populations in local galaxies based on two broadband photometry measurements, i.e., a color-M/L relation. They applied the color-M/L relation to galaxy rotation curves, using a large set of galaxies that spanned a large range in *Hubble* type, luminosity, and scale size and that have accurately measured H I rotation curves. With use of the color-M/L relation, they constructed

stellar mass models of the galaxies. They subtracted all known mass components from the observed rotation curves to reveal the dark matter contribution to the rotation curves. They used the dark matter rotation curves to investigate dark matter scaling relations for their set of galaxies. Unfortunately, they had to conclude that the currently available data is insufficient to constrain dark matter profile shapes across the full range of galaxy luminosities, but showed preliminary results on a new set of data that is of sufficient quality.

De Jong, in collaboration with the Hα Galaxy Survey team led by P. A. James (Liverpool), presented the first paper on this data set. It described the sample selection, data reduction, and global star formation properties of the galaxies. The sample was constructed using a combination of diameter and volume selection (i.e., diameter-limited in different volume shells). This selection ensured that all galaxies were observed with the best spatial resolution and did not have the usual drawbacks of volume-limited samples (biased against big galaxies) or diameter/magnitude-limited samples (strongly biased against small galaxies). As seen in earlier studies, the team found a strong correlation between star formation and *Hubble* type, with the strongest star formation in isolated galaxies occurring in the Sc and Sbc type. More surprisingly, they did not find a significant trend between Hα equivalent width or Hα surface brightness and the galaxy *R*-band luminosity.

De Jong, in collaboration with the *Hubble* Mid-UV Galaxy Survey team led by R. A. Windhorst (ASU), presented an imaging survey of 37 nearby galaxies observed with WFPC2 in the F300W and F814W filter, and 11 galaxies in F255W. They also showed ground-based *UBVRJHK* imaging for most of this galaxy sample. The main goal of the survey was to quantify morphological change with wavelength, as a basis for morphological *K*-corrections for high redshift work. In the first paper on this data set, they presented a preliminary analysis predominantly based on an eyeball comparison of galaxy morphologies from the UV to the near-IR. The first qualitative results were: (1) Most early-type galaxies showed mainly a decrease in surface brightness going from the red to the mid-UV, but little morphological change; (2) Half of the mid-type spiral and star-forming galaxies appeared as a later morphological type in the mid-UV; (3) Most of the heterogeneous subset of late-type, irregular and merging galaxies displayed F300W morphologies that were similar to those seen in F814W, but with differences due to recognizable dust features absorbing the bluer light, and due to UV-bright hot stars, star-clusters, and star-forming ridges.

J. H. Knapen (Univ. of Hertfordshire), de Jong, S. Stedman (Univ. of Hertfordshire), and D. M. Bramich (Univ. of St. Andrews) presented near-infrared imaging of a sample of 57 relatively large, northern spiral galaxies with low inclination. They described the selection criteria and some of the basic properties of the sample, and they gave a detailed description of the data collection and reduction procedures. The K_s $\lambda = 2.2$ μm images covered most of the disk for all galaxies, with a field of view of at least 4.2 arcmin. The spatial resolution was better than an arcsec for most images. They fitted bulge and exponential disk components to radial profiles of the light distribution. From this they derived the basic parameters of these components, as well as the bulge/disk ratio, and explored correlations of these parameters with several galaxy parameters.

L. Dressel continued to make emission-line kinematic studies of the nuclei of LINER galaxies. Most spectroscopic studies of these nuclei have been limited by spatial resolution rather than spectral resolution, even for observations made with *Hubble*. To improve the spatial resolution for the galaxy NGC 3998, Dressel combined STIS spectral images dithered along the slit prior to image rectification. The resulting line profiles indicate significantly greater spatial symmetry and kinematic regularity in the ionized disk than the profiles made from earlier, undithered (under-sampled) data.

M. Fall, S. Charlot (MPA, Garching), and their collaborators derived star formation rates, gas-phase metal abundances, and dust absorption optical depths for a sample of 700 low-redshift galaxies from their observed optical broadband and emission-line fluxes (Hα, [O II], and [N II] or [S II]) and far-infrared fluxes (60 and 100 microns). The analysis is based on the recent stellar population/dust absorption/photoionization models of Charlot, Fall, and Longhetti. These models provide a relatively simple but physically consistent treatment of the production of stellar radiation and its transfer through the interstellar media of galaxies. The ultimate goal of this work is to compare the stellar and interstellar properties of galaxies at low and high redshifts.

Fall and V. Kulkarni (South Carolina) measured the absorption lines of heavy elements in new STIS spectra of low-redshift ($z < \sim 1$) damped Lyman-α galaxies. They have also combined previous absorption-line measurements of many damped Lyman-α galaxies over a wide range of redshifts ($\sim 0 < z < \sim 4$) to search for evolution in the cosmic (column-density-weighted) mean interstellar metallicity in galaxies. They find that this mean metallicity increases with decreasing redshift in a manner consistent with the cosmic chemical evolution models of Fall and his collaborators.

Fall, P. Moller (ESO, Garching), and their collaborators searched for and found the emission counterparts of several damped Lyman-α galaxies. They obtained VLT spectra of galaxies near on the sky to quasars with known damped Lyman-α absorption in the foreground to determine which emitters had the same redshifts as the absorbers. In the small sample analyzed so far, the galaxies selected in this way (based partly on absorption) are indistinguishable from galaxies selected by the Lyman-break method (based entirely on emission) when compared at the same redshift and luminosity. These results vindicate the use of damped Lyman-α galaxies to study both the stellar and interstellar properties of typical high-redshift galaxies, as assumed in cosmic chemical evolution models.

H. Ferguson, Fall, and other collaborators measured the sizes and apparent ellipticities of galaxies at redshifts $\sim 1 < z < \sim 5$ in the *Hubble* GOODS images. They find that the typical sizes of the galaxies evolve with redshift approximately as $H(z)^{-1}$ or $H(z)^{-2/3}$, where $H(z)$ is the redshift-dependent *Hubble* parameter. This observational result accords with the theoretical expectation in hierarchical cosmogonies that the typical sizes of the luminous parts of

galaxies should grow in proportion to the growing virial radii of their dark-matter halos.

Ferguson and J. Lotz (JHU, Santa Cruz) continued efforts to constrain the formation of dwarf galaxies via observations at high and low redshift. Analysis of the most recent data from an extensive *Hubble* snapshot survey indicates that the *V–I* colors of the globular clusters are bluer than the colors of the underlying stellar halos of their host galaxies. The nuclei of dE galaxies tend to match the globular-cluster colors rather than the colors of the surrounding stellar halo. The color offsets between these stellar populations suggests that stars in dE galaxies were formed in multiple episodes. The investigators found that a Bayesian maximum-likelihood analysis of the HDF color-magnitude-redshift distribution favors a relatively late epoch of formation ($z \sim 1$) of dwarf galaxies.

S. Ravindranath, Fall, and other collaborators measured the sizes and luminosities of disk-like galaxies at redshifts $0.25 < z < 1.25$ in the *Hubble* GOODS images. The size distribution has a lognormal shape, as expected in hierarchical cosmogonies, but with no significant evolution. The luminosity function has undergone mild evolution, with brighter galaxies at higher redshifts. The comoving number density of disk-like galaxies remains fairly constant over the observed range, and only modest evolution, by a factor of four is possible within the 2-σ uncertainties.

M. Giavalisco was the principal investigator of GOODS/ACS, which was successfully completed in May 2003. GOODS, a collaboration of 50 scientists from the USA and Europe, consists of the *Hubble* Treasury program using ACS, a *SIRTF* legacy program led by M. Dickinson, and a major VLT observing program led by C. Cesarsky (ESO). A third space-borne component of GOODS is provided by the *Chandra* and *XMM-Newton* archival data. Additionally, a variety of other ground-based projects led by a number of GOODS team members provide ancillary data.

STScI involvement in GOODS includes M. Giavalisco, M. Dickinson, H. Ferguson, A. Koekemoer, S. Casertano, B. Mobasher, A. Riess, D. Grumm, R. Hook, M. Richardson, R. Somerville, V. Laidler, R. Lucas, S. M. Fall, A. Fruchter, R. Hanisch, M. Hauser, S. Jogee, M. Livio, P. Padovani, M. Stiavelli, E. Schreier, R. Williams, as well as postdoctoral fellows N. Grogin (JHU), S. Ravindranath, L.-G. Strolger, T. Dahlen, and L. Moustakas, and JHU graduate students R. Idzi, C. Kretchmer, Y. Park, and S.-K. Lee.

GOODS was designed as the next step in deep field galaxy surveys, covering 33 times the area of combined the Hubble Deep Fields (North and South; HDF-N and HDF-S) to within a factor of two of the *Hubble* limiting flux. GOODS is somewhat shallower. GOODS observations cover approximately 0.1 square degrees in two fields. The space observations match in area coverage and sensitivity, to provide an integrated multi-wavelength survey to the largest extent possible. As a result, the HDF observations in each field are centered on the two deepest X-ray survey regions: the HDF-N and the Chandra Deep Field South (CDF-S). The *SIRTF* observations cover exactly the same area as the *Hubble* ones and are the deepest planned for the first year of operations. Data from the GOODS survey are non-proprietary and the GOODS team releases processed data products as they become available.

GOODS/ACS consisted of 400 orbits of ACS observations—the largest single program yet executed on *Hubble*. The observing strategy allowed a search for high-redshift type Ia supernovae. Observations were taken at 42–45 day intervals, beginning in August 2002 and ending in May 2003. This cadence was chosen to maximize sensitivity to Type Ia Sne at $z \sim 1.4$. Forty-three high-redshift supernovae were identified and ten type-Ia candidates have been followed by Riess and collaborators to confirm types and obtain light curves. Including a few spectroscopic identifications of candidates taken from the ground, the total number of Type Ia Sne at $z > 1$ identified during the GOODS survey totals fifteen, which includes seven of the eight most distant Type Ia ever discovered.

M. Giavalisco, Fall, and other collaborators have estimated the rest-frame UV luminosity density of Lyman-break (star-forming) galaxies at redshifts $\sim 3.5 < z < \sim 6.5$ in the *Hubble* GOODS images. The results are uncertain because only the brightest galaxies can be seen at the highest redshifts, and assumptions must be made about the contributions of fainter galaxies because much of the UV light from galaxies is absorbed by dust and reradiated at longer wavelengths. Nevertheless, the GOODS observations, when combined with earlier *Hubble* and ground-based observations, suggest that the global comoving rate of star formation may have changed relatively little between $z = \sim 6$ and $z = \sim 1$. These results are consistent with the cosmic chemical evolution models of Fall and his collaborators.

Giavalisco continued research on high-redshift galaxies, using both GOODS/ACS data (the evolution of the star formation activity) and ground-based data supporting the GOODS space program. These data consist of very large area, deep multi-band optical imaging taken with the Subaru 8-m and NOAO 4-m telescopes, and they were primarily aimed at providing data for accurate photometric redshift for GOODS. However, they are excellent to study clustering and large-scale structure at high-redshift. Preliminary measures of the correlation function of Lyman-break galaxies at $z \sim 3$ down to $R \sim 26.3$, a first in this field, were presented at the January AAS in Seattle. The data confirm the clustering segregation discovered by Giavalisco and Dickinson (2000), implying that star formation at high-z is primarily regulated by the total mass (i.e., that of the dark matter) of the galaxies rather than merging and interactions.

Giavalisco, together with Steidel et al. (2003), has published in the ApJ Supplement the full data set of the ground-based $z \sim 3$ Lyman-break galaxies survey that they begun in 1995. This is the best-characterized sample of galaxies at very high redshift, with about 1,000 Keck spectra, and provides a reference measure of luminosity function, clustering properties and SED distribution, which is valuable for quantifying the evolution at higher redshifts.

T. M. Brown, H. C. Ferguson, E. Smith (STScI), R. A. Kimble, A. V. Sweigart (NASA/GSFC), A. Renzini (ESO), R. M. Rich (UCLA), and D. A. Vandenberg (Univ. of Victoria) used ACS to begin investigations into the star formation history of the Andromeda halo. With the deepest optical

images of the sky ever obtained, Brown and collaborators constructed a color magnitude diagram extending to 31st mag stars on the old main sequence in Andromeda. They found that the Andromeda halo has a surprisingly wide spread in ages, with 30% of the population young (6–8 Gyr) and metal-rich ([Fe/H] > -0.5), suggesting that Andromeda has undergone a more violent merging history than our own Galaxy.

Y. Park (JHU) and H. Ferguson (STScI) examined the gravitational-lensing behavior of the Burkert profile. This dark-matter density profile was proposed as an empirical alternative to the Navarro, Frenk, and White (NFW) profile. The Burkert profile appears to provide a reasonable match to rotation curves of dwarf galaxies and spiral galaxies, and it is not ruled out for elliptical galaxies or clusters of galaxies. Park and Ferguson show that the Burkert profile is much less likely to produce strong lensing (multiple images) than the NFW profile. Furthermore, a scale-free version of the Burkert profile cannot simultaneously account for the rotation curves of spiral galaxies and the appearance of strong lensing in the cluster CL0024+1654.

P. Goudfrooij and E. Huizinga, in collaboration with J. Strader (Lick Obs.), L. Brenneman (UMd), M. Kissler-Patig (ESO), and D. Minniti (Univ. Catolica, Chile), studied the globular cluster systems of seven giant, edge-on spiral galaxies using WFPC2 imaging in *V* and *I*. The galaxy sample covers the *Hubble* types Sa to Sc, allowing the team to study the variation of the properties of globular cluster systems along the Hubble sequence. Specific frequencies of globular clusters (S_N values) were evaluated by comparing the numbers of globular clusters found in the WFPC2 pointings with those in the Milky Way that would be detected in the same spatial region if placed at the distance of the target galaxies. Results from this method were found to be consistent with the more commonly used method of constructing radial distribution functions of globular clusters. The S_N values of spirals with a Hubble type later than Sb are found to be consistent with a value of $S_N = 0.55 \pm 0.25$. Goudfrooij et al. suggest that this population of globular clusters represents a 'universal,' old halo population that is present around each galaxy. All but one of the galaxies in the Goudfrooij et al. sample have S_N values that are consistent with a scenario in which globular cluster systems are made up of (i) the aforementioned halo population plus (ii) a population that is associated with bulges, which grows linearly with the mass of the bulge. Such scenarios include the 'merger scenario' for the formation of elliptical galaxies as well as the 'dissipative collapse' scenario, but this finding is inconsistent with the 'secular evolution' scenario in which bulges are formed from disk stars by means of the redistribution of angular momentum through bar instabilities and/or minor perturbations. On the other hand, the early-type spiral galaxy NGC 7814 shows a low S_N value, consistent with those of the latest-type spirals. NGC 7814 is the least luminous galaxy in the Goudfrooij et al. sample. Based on observed luminosity functions of galaxies in poor groups, Goudfrooij et al. suggest that the 'secular evolution' scenario to build bulges in early-type spirals by minor perturbations is most viable for low-luminosity spirals.

Goudfrooij, in collaboration with T. Puzia (Univ. München, Germany), M. Hempel and M. Kissler-Patig (ESO), M. Hilker (Univ. Bonn, Germany), S. Zepf (Michigan State Univ.), and D. Minniti (Univ. Catolica, Chile) have combined archival WFPC2 *V* and *I*-band photometry of globular clusters in four elliptical galaxies (NGC 3115, NGC 4365, NGC 5846, and NGC 7192) with new *K*-band photometry obtained with the ISAAC instrument on the ESO VLT. By comparing the $V - I$ versus $V - K$ color-color diagram of the NGC 7192 globular clusters with stellar populations models, Goudfrooij et al. find that its cluster system is consistent with being a single, old, metal-poor population. In the case of NGC 3115, they find the presence of two major subpopulations of which the color differences are primarily due to a difference in metallicity. The blue (metal-poor) and red (metal-rich) globular cluster sub-populations are coeval to within 3 Gyr. In contrast to the old globular cluster populations in NGC 3115 and NGC 7192, the globular cluster systems of NGC 4365 and NGC 5846 exhibit a more complex age and metallicity structure: Goudfrooij et al. discovered a significant population of intermediate-age, metal-rich globular clusters along with an old population of both metal-rich and metal-poor clusters. Specifically, they observe a large population of globular clusters with red *V*–*K* colors but intermediate $V - I$ colors, for which all current stellar population models give ages and metallicities in the range 2–8 Gyr and 0.5–3 $Z_\odot$, respectively. After 10 Gyr of passive evolution, the intermediate-age globular clusters in NGC 4365 and NGC 5846 will have colors that are consistent with the very metal-rich population of globular clusters in giant elliptical galaxies, such as M87. These results provide important evidence supporting the 'merger scenario' for forming giant elliptical galaxies.

Goudfrooij, in collaboration with E. Emsellem (Obs. de Lyon, France), analyzed WFPC2 images and TIGER integral-field spectroscopy of the E3 galaxy NGC 2974 to derive the kinematics of the stellar and ionized gas components in its central 500 pc. They built a two-integral distribution function from a Multi-Gaussian Expansion (MGE) mass model, which fits all available data very well. The WFPC2 images reveal the presence of a striking, high-contrast, two-arm spiral structure of ionized gas of a size of about 260 pc. Goudfrooij and Emsellem used a de-convolved TIGER data cube to probe the kinematics of this gas at a resolution of about 0.35 arcsec FWHM. Strong departures from circular motions are observed, as well as high-velocity dispersion values on the inner side of the arms. These properties are interpreted as streaming gas flows driven by a 540 pc diameter bar. This hypothesis is strongly supported by a density-wave model. This is the first detection ever of a bar in a galaxy cataloged as elliptical. Goudfrooij and Emsellem suggest that the presence of such inner bars might be more common among early-type galaxies than is generally thought, and that high-resolution emission-line imagery is the best and perhaps only way to detect such structures.

Goudfrooij, in collaboration with C. Maraston (MPE), N. Bastian and M. Kissler-Patig (ESO), R. Saglia (Univ. München), and F. Schweizer (Carnegie Observatories) obtained VLT/UVES spectra of globular cluster W3 in the

merger remnant NGC 7252, the most luminous globular cluster known to date, to measure its velocity dispersion (and hence its virial mass). After careful fitting of the spectrum of W3 to broadened spectra of several template stars and star clusters, Goudfrooij et al. measured an astonishingly high velocity dispersion of 45 $\pm$ 5 km s^{-1} for W3, which translates in a dynamical virial mass of (80 $\pm$ 20) million solar masses. This is almost two orders of magnitude more massive than the most massive Galactic globular cluster. The kinematically derived mass is in excellent agreement with the one derived from M/L ratios predicted by stellar population synthesis models. This result points out that major mergers of gas-rich galaxies are able to form star clusters with masses up to 100 million solar masses, and that M/L ratio predictions by recent stellar population synthesis models can be remarkably accurate.

C. Leitherer, in collaboration with A. Aloisi (JHU), S. Savaglio (JHU), T. Heckman (JHU), C. Hoopes (JHU), and K. Sembach obtained new *FUSE* far-UV spectroscopy of the most metal-poor blue compact dwarf galaxy I Zw 18. The kinematics averaged over the large sampled region shows no clear evidence of gas inflows or outflows. The H I absorption is interstellar with a column density of 2.2 x 10^{21} cm^{-2} . A conservative 3-σ upper limit of 5.25 x 10^{14} cm^{-2} is derived for the column density of diffuse H_2. From a simultaneous fitting of metal absorption lines in the interstellar medium, these authors infer the following abundances: [Fe/H] = -1.76 ± 0.12, [O/H] = -2.06 ± 0.28, [Si/H] = -2.09 ± 0.12, [Ar/H] = -2.27 ± 0.13, and [N/H] = -2.88 ± 0.11. This is in general several times lower than in the H II regions. The only exception is iron, whose abundance is the same. The abundance pattern of the interstellar medium suggests ancient star-formation activity with an age of at least a Gyr that enriched the H I phase. Around 470 SNe Ia are required to produce the iron content. A more recent episode that started 10 to several 100 Myr ago is responsible for the additional enrichment of α-elements and nitrogen in the H II regions.

C. Leitherer, in collaboration with F. Annibali (Trieste), L. Greggio (Munich), M. Tosi (Bologna), and A. Aloisi (JHU), inferred the star formation history in different regions of the blue compact dwarf NGC 1705 by comparing synthetic color-magnitude diagrams with *Hubble* optical and near-infrared photometry. They found that NGC 1705 is not a young galaxy because its star formation commenced at least five Gyr ago. On the other hand, they confirmed the existence of a recent burst of star formation between 15 and 10 Myr ago. They also found evidence for new strong activity, which started three Myr ago and is still continuing. The old population is spread across the entire galaxy, while the young and intermediate stars are more concentrated in the central regions. They derived an almost continuous star formation with variable rate, and exclude the presence of long quiescent phases between the episodes during the last one Gyr. The central regions experienced an episode of star formation of about 0.07 solar masses per year (for a Salpeter initial mass function (IMF) 15 to 10 Myr ago. This coincides with the strong activity in the central super star cluster. They found a rate of about 0.3 solar masses per year for the youngest ongoing burst, which started about 3 Myr ago. This is higher than in other dwarfs and comparable to the rate of NGC 1569. The star formation rate of earlier episodes is not especially high and falls in the range 10^{-3}–10^{-1} solar masses per year. The IMF is close to the Salpeter value or slightly steeper.

Leitherer, in collaboration with R. Chandar, C. Tremonti (Steward Obs.), and D. Calzetti, used new STIS long-slit ultraviolet spectroscopy of region A in the nearby starbursting galaxy He 2–10 to examine properties of both compact individual superstar clusters and diffuse intracluster regions. The four most luminous clusters in the slit formed coevally 45 Myr ago and have lower mass estimates of several times 10^4 to a few times 10^5 solar masses. A fifth cluster is located 200 pc away, and appears to be several Myr older. Extracted spectra of the diffuse light appear to be remarkably similar to those of the young clusters, showing P Cygni profiles from massive stars, and are very well fitted by instantaneous burst models of 45 Myr. Various mechanisms were considered to determine the nature of the underlying diffuse light in He 2–10. The authors rule out scattering of cluster light as the dominant source of the observed field. A scenario including the formation of a large number of lower mass, undetectable but coeval (compact) clusters can explain the field spectra, assuming that the clusters in the center of region A follow a power-law luminosity distribution with an exponent of –2.0. This is somewhat steeper than the power-law slope of –1.7 measured by Johnson et al. for clusters in a larger portion of He 2–10 and implies very high projected (compact) cluster densities within region A. Rather, the authors favor a scenario where the dominant contribution to the field stellar population comes from more diffuse ''scaled OB associations,'' which are not lacking in the most massive stars. The observations establish that the far-UV field light in He 2–10 originates in a different stellar population than found for NGC 5253 and other nearby starbursts, where older, dissolving clusters appear to be the main mechanism responsible for creating the diffuse UV light.

Leitherer, in collaboration with D. Kunth (Paris), M. Mas-Hesse (Madrid), G. Ostlin (Stockholm), and A. Petrosian (Byurakan) obtained the first results from a deep Ly-α imaging program of local starburst galaxies with ACS. The two observed galaxies ESO 350–IG038 and SBS 0335–052 have luminosities similar to those of the Magellanic Clouds but differ in their chemical composition. ESO 350–IG038 has an oxygen abundance of 1/8 solar, whereas SBS 0335–052 is known to have one of the lowest abundances among blue galaxies (about 1/30). The ACS imaging revealed a complex Ly-α morphology, with sometimes-strong offsets between the emission of Ly-α and the location of stellar light, ionized gas traced by H-β, and the neutral gas. Overall, more Ly-α photons escape from the more metal- and dust-rich galaxy ESO 350–IG038. The absence of clear SBS 0335–052 Ly-α emission over all observed knots, whatever their dust content or/and color indices, contradicted model expectations of a lower escape fraction from dust-rich gas due to destruction of Ly-α photons by dust grains. Rather, the results are in qualitative agreement with models suggesting the kinematic properties of the gas as the dominant Ly-α escape regulator.

If the properties of the two observed galaxies are representative for starburst galaxies in general, Ly α will be difficult to interpret as a star-formation indicator, in particular if based on Ly-α imaging at low spatial resolution.

Leitherer, in collaboration with A. Petrosian (Byurakan), R. Allen, J. MacKenty, B. McLean, and N. Panagia performed a comparative study of 524 UV excess (UVX) SBS galaxies and 340 emission line (EL) SBS galaxies. The parameters used for the comparison were apparent magnitude, redshift, spectral class, luminosity, morphology, activity type, and close environment. The main results are as follows: In comparison with the UVX method, the EL method allowed the creation of a deeper sample of peculiar galaxies. The existence of the emission lines also helps to detect fainter objects among the UVX galaxies. The UVX method covered a larger range of redshifts than does the EL method. Fifty-four active galactic nuclei (AGNs) have been discovered with the UVX and 11 with the EL techniques. Among the EL sample objects, there were no Seyfert-like galaxies of type 1 or 1.5. UVX galaxies with AGNs mostly were stellar and semistellar spectral classes objects, of which the majority were strong or moderate UV-excess emitters. Star-forming galaxies with $z < 0.1$ and discovered via UVX had median luminosity higher than galaxies discovered via EL. The difference is mostly caused by a higher rate of high-luminosity ($M < -21.0$) galaxies in the UVX sample; these were mostly galaxies with stellar or semistellar spectra. Another contribution came from the higher rate of low-luminosity ($M < -17.0$) galaxies in the EL sample, most of which had diffuse or semi-diffuse spectra. UVX and EL active and star-forming galaxies did not show major differences in their distribution of morphological type; in both samples, the majority of galaxies were spirals. The UVX and EL samples were similar in their fractions of mergers or interacting systems, as well as the incidence of close pairs or neighbors within $r < 50$ kpc. However, the UVX galaxies with the strongest excess UV radiation were often in mergers, interacting systems, or close pairs. The EL method allowed the creation of a sample with lower apparent magnitudes and higher redshifts among the low-luminosity ($M > -17.0$) galaxies and was more efficient at discovering galaxies with compact or irregular morphology.

Leitherer, in collaboration with D. Raimann (Porto Allegre), T. Storchi-Bergmann (Porto Allegre), R. González Delgado (Granada), R. Cid Fernandes (Florianopolis), T. Heckman (JHU), and H. Schmitt (NRAO) used high signal-to-noise ratio long-slit spectra in the 3600–4700 Å range of the 20 brightest northern Seyfert 2 galaxies to study the variation of the stellar population properties as a function of distance from the nucleus. In order to characterize the stellar population and other continuum sources (e.g., featureless continuum, FC) these authors measured the equivalent width, *W*, of six absorption features, four continuum colors and their radial variations, and performed spectral population synthesis as a function of distance from the nucleus. About half of the sample has Ca II K and *G* band *W* values smaller at the nucleus than at one kpc from it, owing to a younger population and/or FC. The stellar population synthesis showed that, while at the nucleus, 75% of the galaxies present contribution >20% of ages ⩽ 100 Myr and/or of an FC, this proportion decreases to 45% at 3 kpc. In particular, 55% of the galaxies have a contribution >10% of the 3-Myr/FC component (a degenerate component in which one cannot separate what is caused by an FC or by a 3-Myr stellar population) at the nucleus, but only 25% of them have this contribution at three kpc. As a reference, the stellar population of 10 non-Seyfert galaxies, spanning the Hubble types of the Seyfert (from S0 to Sc) was also studied. A comparison between the stellar population of the Seyferts and that of the non-Seyferts showed systematic differences: the contribution of ages younger than one Gyr was in most cases larger in the Seyfert galaxies than in non-Seyferts, not only at the nucleus but up to one kpc from it.

J. MacKenty collaborated with A. Petrosian (Byurakan Astrophysical Obs.) and colleagues at STScI in a continuing study of the first and second Byurakan objective prism surveys of ultraviolet excess galaxies. He also completed a study of the extended emission line structure in the vicinity of the QSO 4C47.43 with A. Stockton, E. Hu, and T. Kim (UHa). With R. Windhorst (Arizona State Univ.) and 13 other co-authors, he published the results of a *Hubble* study of the ultraviolet morphology of nearby galaxies.

B. Mobasher, in collaboration with Afonso (Lisbon Obs.), Hopkins (Univ. of Pittsburgh) and Cram (Univ. of Sydney), completed a deep radio survey (PHOENIX) over an area of three sq. deg. using the Australia Telescope Compact Array (ATCA). The PHOENIX survey is complete to S(1.4) = 0.1 mJy, with a sub-area further surveyed to 40 micro-Jy. The team studied radio source counts to the deepest flux levels and found that the starburst galaxies dominate the sub-mJy/micro-Jy radio population while the brighter radio sources are mostly AGNs.

Mobasher, in collaboration with Georgakakis (Athens Obs.), Afonso, Sullivan (Univ. of Toronto), Chan, and Cram (Univ. of Sydney), completed optical/near-IR and X-ray (*XMM*) survey of the PHOENIX field. They used these data to study the nature of faint radio sources, the star formation rate based on radio and X-ray fluxes, and the Extremely Red Objects (EROs), detected at radio wavelength.

Mobasher and Koekemoer carried out a deep radio survey of the southern GOODS field. They combined these data with the ACS/GOODS images and used them to explore morphologies of the faintest radio sources and to study the relation between star formation rate and galaxy interaction free from dust-induced selection biases.

Mobasher and Afonso studied mid- and far-IR properties of a sample of radio-selected, spectroscopically confirmed star-forming galaxies using data from the *Infrared Space Observatory* (*ISO*). They combined the data with the available data at other wavelengths and studied the relation between infrared luminosity and star formation rate. They used SEDs of galaxies to separate contributions from star formation and AGNs, and they established radio vs. far-IR correlation for sub-mJy sources.

Mobasher, in collaboration with Dickinson, Ferguson, Moustakas, and Giavalisco, performed near-IR spectroscopy on a sample of confirmed star-forming galaxies at $0.8 < z < 1.2$, selected with *ISO* at 15 micron, using Subaru (8m) tele-

scope. At this redshift, Hα shifts to the near-IR J-band. This allows measurement of the star formation rate (SFR) in galaxies at $z \sim 1$ and the correlation between the PAH features and SFR. Given that 15-micron radiation at $z \sim 1$ corresponds to 24-micron luminosity at $z \sim 2$, one could use this to study SFR at $z \sim 2$, using the 24-micron surveys with MIPS on-board the *SIRTF*.

Mobasher, M. Sullivan, R. S. Ellis (Caltech), and Treyer (Marseille Observatory) studied star-formation properties of a UV selected sample of star-forming galaxies. They compared the SFRs for individual galaxies, which measured from Hα line fluxes, UV (2000 Å) and u′ (3600 Å). They found broad correlations between dust-corrected star-formation diagnostics with a scatter larger than observational errors. Spectral synthesis models with varying metallicities and/or IMFs were unable to produce the observed trend. They found a significant fraction of star-forming galaxies to have complex star-formation histories.

Mobasher, in collaboration with T. Bridges (AAO), B. Poggianti (Padova), D. Carter (LJMU), S. Okamura (Univ. of Tokyo) and Y. Komiyama (Subaru Telescope), performed a wide-area photometric and spectroscopic survey of dwarf and giant galaxies in the Coma cluster. They used the strength of the spectral line indices to study differences in physical properties (star formation/stellar population, metallicity, and age) among the dwarfs and between dwarf and giant galaxies as a function of their local environment. They compared the spectroscopic properties of galaxies in the Coma (including the e+a's) with cluster galaxies at higher redshifts. They constructed the luminosity function of galaxies at the core and outskirts of the Coma cluster, and studied the spatial distribution of dwarf and giant galaxies in the Coma.

Mobasher, T. Bridges (AAO), M. Sossy (STScI) and P. Kzeck (NOAO) measured the velocity dispersion of a complete sample of dwarf galaxies in the Coma cluster. They combined these data with photometric and spectroscopic (line indices) observations of Coma dwarfs to establish the fundamental plane of Dwarf galaxies and the origin of the scatter in this relation.

Mobasher, in collaboration with Georgakakis and the PHOENIX collaboration, completed an X-ray survey in the 0.5–2 keV and 2–8 keV bands, using *XMM-Newton*. Combining these data with the available radio, optical and near-IR data, they found that the X-ray luminosity of sub-mJy radio sources is dominated by the star-formation activity with minimal contribution from the AGNs. They found the mean X-ray to optical flux ratio and the mean X-ray luminosity to be higher than that of optically selected spirals and similar to that of the starbursts. They also found the L(X-ray)–L(1.4 GHz) correlation to be similar to that found for local starbursts. They estimate a global SFR density at $z \sim 3$ of $0.029 \pm 0.007\ M_{\odot}\ \mathrm{yr}^{-1}\ \mathrm{Mpc}^{-3}$, similar to that found from samples selected in longer wavelengths.

J. Rhoads and S. Malhotra continued to lead the Large Area Lyman Alpha (LALA) survey, which has now obtained a sample of approximately 300 Lyman-α galaxy candidates at $z = 4.5$, about 20 at $z = 5.7$, and 3 at $z = 6.5$. LALA is the largest survey for high redshift Lyman-α emitting galaxies to date. Rhoads and Malhotra, in collaboration with A. Dey, B. T. Jannuzi, M. J. I. Brown (NOAO), D. Stern (NASA/JPL), S. Dawson, H. Spinrad, and E. Landes (UCa–Berkeley), obtained spectra confirming three of the candidates as real redshift 5.7 galaxies. The large equivalent widths seen in these objects imply young stellar populations with either low metallicity or a top-heavy initial mass function, and further place an upper bound of 10% on the neutral fraction in the nearby intergalactic medium. The spectroscopic confirmation is ongoing and the rates so far have been high: 2/3 at $z = 6.5$, 3/4 at $z = 5.7$, and about 2/3 at $z = 4.5$, where the total confirmed sample has now reached approximately 50 galaxies.

Malhotra, Rhoads, J. X. Wang (JHU), C. Norman (JHU), T. Heckman (JHU) carried out 180 Ksec long observations of the LALA field with *Chandra* to investigate how many of the Lyman-α emitters are type-II AGNs and X-ray bright. None of the 44 Lyman-α emitters in the single *Chandra* field have X-ray counterparts. Composite X-ray image of all 44 Lyman-α emitters also yields no significant detection in X-rays, making the average X-ray/Lyman-α ratio lower than 90% of nearby Seyferts. They conclude that the high equivalent width seen in the Lyman-α line emission is due to starburst rather than AGN activity. Analysis of the detected X-ray sources in the field shows field-to-field number-flux variations consistent with the large-scale structure seen in X-ray sources. Optical identification of all X-ray sources was done using deep *B*, *V*, *R*, *I* and *z* images. Less than 10% of the X-ray sources are at $z > 5$.

Malhotra continued her work on far-infrared emission from normal, nearby galaxies. Detailed study of two nearby galaxies in the main cooling lines [C II] and [O I] was led by A. Contursi (IPAC) and co-authored by Malhotra. A paper characterizing the mid-IR band continuum emission from normal galaxies was led by N. Lu (IPAC) with Malhotra as a co-author.

B. McLean, R. Allen, C. Leitherer, J. MacKenty and N. Panagia, in collaboration with A. Petrosian (Byurakan Obs., Armenia), continued their survey of the environments of Markarian and SBS galaxies. All objects have been morphologically typed, and the density of neighboring galaxies has been measured for all those objects with redshifts and hence distances. All objects have been correlated with the *IRAS* and *ROSAT* all-sky survey catalogues. Results indicate that the presence of a neighboring companion does not significantly determine the type of galactic activity (e.g., Seyfert 1, Seyfert 2, starburst etc.), but does increase the likelihood of activity relative to the control sample. A new study correlating the location of supernova in these active galaxies with galaxy properties is well underway.

M. Regan, in collaboration with P. Teuben (UMd), performed hydrodynamic modeling of gas flow in barred galaxies to study how, where, and why nuclear rings form. Nuclear rings are the sites of significant star formation in barred galaxies, but theories explaining their formation have, until now, been highly qualitative. In their research, Regan and Teuben showed that nuclear rings are directly related to the existence of the orbit family whose major axis is perpendicular to the major axis of the bar (X2). They also showed

that the common assumption that nuclear rings are related to an inner Lindblad resonance is incorrect. In fact, they showed that there is *no resonance* at the inner Lindblad resonance in barred galaxies. They also compared the predictions of their theory to *Hubble* observations and showed that it correctly predicts the observed gas and star formation morphology of nuclear rings.

Regan and Teuben continued their work on barred galaxies in a second paper in which they studied how the characteristics of a bar affect the mass inflow. Although it is generally assumed that bars can drive mass into the nuclear region, how the strength of a bar affects the inflow has never been examined in detail. In this paper they investigated how various parameters of a bar affect the ability of the bar to drive the ISM to smaller radii. They modeled the ISM using high-resolution hydrodynamic simulations and were able to show that weak bars have almost no effect on the radial distribution of the ISM. When a nuclear ring forms the bar becomes very efficient at driving gas down to the inner kiloparsec. Alternatively, when no nuclear ring forms, gas forms a ring at the largest non-looping orbit whose major axis is parallel to the major axis of the bar (x1 orbit). For all but the thinnest bars, this ring is far from the nuclear region. They termed this type of ring an x1 ring and showed that inner rings are a subset of x1 rings and form when there are no looping x1 orbits. In this case the gas accumulates at the largest x1 orbit inside of the looping 4:1 orbits.

Regan, in collaboration with T. Helfer (UCB), M. Thornley (Bucknell), T. Wong (UCB), K. Sheth (CalTech), S. Vogel (UMd), L. Blitz (UCB), D. Bock (UCB), published three papers in the BIMA Survey of Nearby Galaxies (BIMA SONG) series. BIMA SONG is the largest imaging survey of nearby galaxies in the CO(1-0) line made to date. They published the CO data paper this year presenting all the CO maps for the 44 galaxies in the survey. In addition, Sheth published a paper showing the correlation between CO and Hα emission. Also, in collaboration with M. Das, the team published a paper comparing bar ellipticities and bulge sizes and the implications of the correlation (Das et al. 2003). Finally, Sheth et al. submitted a paper showing that the CO in the barred galaxies is more concentrated than in the unbarred galaxies.

Regan, in collaboration with P. Martini (OCIW), J. Mulchaey (OCIW), and R. Pogge (OSU) continued their work on the fueling of active galactic nuclei. They used NICMOS and WFPC2 images to form color maps that revealed the dust structures in the nuclear region of both active and control galaxies. They then performed a detailed matching of Seyfert and control galaxies and showed that the two samples had identical nuclear spiral dust fractions. They published the results of this study and a data paper containing all the NICMOS and WFPC2 images.

Regan, in collaboration with Sheth, N. Scoville (CalTech), and L. Strubbe (CalTech) studied the *Hubble* NICMOS Deep Field North to investigate the bar fraction as a function of red shift. Previous studies had shown a large decrease in the fraction of disk galaxies that contain bars at $z > 0.7$. In their study they were able to show that there is no evidence for a decrease in the barred fraction at high red shifts. The previously claimed decrease is due to both a lack of linear resolution and the band shifting that makes bar identification difficult at $z > 0.7$ using optical filters.

Stiavelli, with Dressel, Gerssen, Macchetto, Scarlata, Sparks, van der Marel, and collaborators, observed 54 nearby spiral galaxies with STIS with the aim of identifying central black holes and probing the black hole versus bulge mass relation for smaller bulge masses. As a first step for this analysis they studied the morphology of gas and dust by combining the spectra with the acquisition and archival images.

Dressel, Gerssen, Macchetto, Scarlata, Sparks, Stiavelli, van der Marel, and collaborators analyzed STIS spectra for the spiral galaxy NGC 4041 and placed an upper limit of 2 x $10^7\ M_\odot$ to the mass of its central black hole. This upper limit is still compatible with the black hole mass versus bulge size correlation identified for larger spheroids.

Scarlata, Stiavelli, Dressel, Gerssen, Macchetto, Sparks, van der Marel, and collaborators studied STIS images for 48 Sbc spiral galaxies complemented with archival WFPC2 images. They found that bulges of Sbc galaxies have properties similar to the bulges of earlier type and are described either by an $R^{1/4}$ or by an exponential light profile. This result shows that the bimodality of bulge profile extends to the faintest bulges. Nuclear compact sources are found in 55% of the objects and are often unresolved. Active host galaxies are found to host brighter central sources.

Scarlata, Stiavelli and collaborators analyzed a sample of 38 spiral galaxies observed with *Hubble* and found that three objects contained nuclear stellar disk. All the nuclear disk hosts are Sb or earlier and none of the hosts is found in a barred galaxy. The fact that nuclear stellar disks are found in elliptical galaxies and the most bulge-dominated spirals suggests that their formation can be a natural part of the formation of the spheroid.

Nipoti, Stiavelli and collaborators used their VLT observations of the cluster of galaxies CL0337−2522 at redshift 0.59 to define the initial conditions for a set of *N*-body simulations to study the future evolution of this cluster. The cluster is of special interest because it doesn't contain a dominant galaxy but has five comparable elliptical galaxies in its central regions. The simulation show that at least four of the five galaxies are likely to merge between $z = 0.59$ and $z = 0$. However, the merger product will not have a cD halo. This suggests that processes other than major mergers are needed to produce a cD halo. The simulations also show that the merger product will satisfy the fundamental plane correlation.

Stiavelli and collaborators reduced the WFPC2 flanking field data obtained as part of the HDF-S program and covering a solid angle of 48 arcmin^2 plus additional, non contiguous, fields. These data were used to support spectroscopic follow-ups of the HDF-S.

E. Roye worked with van der Marel, A. Ptak (JHU) and others on a search for optical counterparts to ultra-luminous X-ray sources in nearby galaxies. X-ray studies have not been able to resolve whether these sources are accreting IMBHs or unusual X-ray binaries. Detection and study of optical counterparts may shed new light on this issue. Archi-

val WFPC2 data were studied for those nearby galaxies with ultra-luminous X-ray sources detected from *Chandra* archival data. Preliminary results indicate that more than half of the sources have an optical source (possibly the optical counterpart) within one arcsec of the IXO position. In spiral, irregular and merger galaxies the counterparts are often diffuse or clump-like, whereas in elliptical galaxies they are generally globular clusters.

M. Geha (UCa−Santa Cruz) finished her Ph.D thesis with P. Guhathakurta (Lick) and van der Marel on the internal kinematics of dwarf elliptical (dE) galaxies. These are among the most poorly studied galaxies due to their faint luminosities and characteristic low effective surface brightness. Keck/ESI spectroscopy of 17 dE galaxies in Virgo yielded their mean line-of- sight velocity and velocity dispersion as a function of radius along the major axis. This increases the total number of dEs with spatially resolved stellar kinematics by a factor of approximately three. Four galaxies have major axis rotation velocities consistent with rotational flattening, while the remaining dEs have no detectable major axis rotation. Despite this difference in internal kinematics, rotating and non-rotating dEs are remarkably similar in terms of their position in the Fundamental Plane, morphological structure, stellar populations, and local environment. These findings present a challenge to theoretical dE formation models. The dynamically inferred mass-to-light ratios are in the range 3–6 (*V*-band solar units), consistent with an intermediate-age stellar population. There is no evidence for a significant dark matter component inside an effective radius. The best-fitting mean age and metallicity for the sample inferred from line-strength indices (Hβ, Mgb, Fe5270, Fe5335) are five Gyr and Fe/H = −0.3 dex, respectively, with rms spreads of three Gyr and 0.1 dex. The majority of dEs are consistent with solar α/Fe abundance ratios. By contrast, the stellar populations of classical elliptical galaxies are, on average, older, more metal rich, and α-enhanced relative dEs.

T. Böker, R. van der Marel, and R. Stanek (Univ. Michigan) investigated the stellar disk properties of a sample of 19 nearby spiral galaxies with low inclination and late Hubble type (Scd or later). They combined high-resolution *Hubble I*-band observations with existing ground-based optical images to obtain surface brightness profiles that constrain the properties of stellar bulges at these extremely late Hubble types. Approximately 30% of the sample is 'pure' disk galaxies, with exponential stellar disks that extend all the way to the center (where a nuclear star cluster if often found). The remainder has more complex profiles, consistent either with a non-exponential (Sersic) disk surface brightness profile, or with the presence of an exponential bulge.

J. Walcher (MPIA, Heidelberg) and Böker led a spectroscopic study with van der Marel, Gerssen and others of the nuclear star clusters in late-type spiral galaxies. Some 75% of these galaxies have such clusters. Low-resolution spectra with STIS and high-resolution spectra with VLT/ UVES were obtained for 10–20 galaxies. The light from the majority of the clusters is younger than one Gyr. The masses of the clusters as determined from the velocity dispersion range between 10^6 and 10^8 solar masses and are typically one order of magnitude higher than would be expected from stellar synthesis models. This can be interpreted as an underlying population of older generations of stars that have already faded with time and thus do not show up in the spectrum. Consequently, nuclear cluster formation is a repetitive event in very late type galaxies. This can contribute to the build-up of bulges.

Laine, van der Marel, J. Rossa and several collaborators pursued a study of the nuclear regions in the Toomre Sequence of merging galaxies, based on imaging data gathered with the WFPC2 camera. The broadband morphology of the nuclear regions varies from dust-covered nuclei to a collection of non-nucleated starburst clumps to a nucleated morphology. There is no unambiguous trend in the morphology with merger stage. The emission line morphology is extended beyond the nucleus in most cases, but centrally concentrated (within one kpc) emission-line gas can be seen in the four latest-stage merger systems. There is little evidence for a clear trend in nuclear properties along the merger sequence, other than a suggestive rise in the nuclear luminosity density in the most evolved members of the sequence. The lack of clear trends in nuclear properties is likely due to both the effects of obscuration and geometry, as well as the physical variety of galaxies included in the Toomre Sequence.

T. Wiklind collaborated with S. Bergstrom (Onsala Space Obs., Sweden), D. de Mello (NASA/GSFC), C. Norman (JHU), K. Kellerman (NRAO), P. Rosati (ESO), F. Barrientos (Pontificia Universidad de Chile) and G. Rydbeck (Onsala Space Obs.) on imaging of the Chandra Deep Field South at submillimeter wavelengths using the SIMBA bolometer array on the SEST telescope in Chile. They covered an area of approximately 85 square arcminutes to a noise rms of 2.0 mJy. The data has yielded a number of submm-detected objects to be compared with X-ray, optical, NIR, and radio images.

Wiklind collaborated with Bergstrom, C. Jackson (Mt. Stromlo Obs.), M. Huyn (Mt. Stromlo Obs.), R. Norris (Australia Telescope National Facility) and de Mello on imaging the Hubble Deep Field South at submillimeter wavelengths using the SIMBA bolometer array on the SEST telescope in Chile. They covered an area of approximately 65 square arcminutes to a noise rms of 2.5 mJy. The data has been compared with optical and radio maps of the same region.

J. Afonso (Obs. of Lisbon), Wiklind, B. Mobasher, and S. Bergstrom (Onsala Space Obs.) imaged the Phoenix Deep Field at submillimeter wavelengths using the SIMBA bolometer array on the SEST telescope in Chile. They covered an area of approximately 75 square arcminutes to a noise rms of 2.0 mJy. A large set of optical, NIR and radio data have been compiled for this field as well.

Wiklind used NIR to FIR data compiled on local starburst galaxies and AGNs to construct an average spectral energy distribution of ultra luminous far-infrared galaxies. The dispersion in the average SED was found to be remarkably small in the wavelength range 60–850 μm. Based on this a photometric redshift method was devised using far infrared to submillimeter wavelengths was explored. It was found that if distant submillimeter detected galaxies are similar to local ULIRGs the small dispersion in the long wavelength

SED can be used as a redshift estimator for objects at redshifts $z = 1–5$.

7 AGN

L. Dressel, in collaboration with M. Dopita (ANU) and M. Allen (Strasbourg), STIS long-slit spectral images of the LINER nucleus in NGC 3998 from 1200 to 10000 Å. She decomposed the central continuum emission into a stellar component and a strong power-law component, and measured central and extended line emission. The investigators used emission line diagnostics to study the structure, ionization, and excitation of the gas in the nucleus of this galaxy, which is one of the brightest and most active nearby LINERs.

M. Giavalisco continued work on AGN at high-redshifts. He completed a paper together with Steidel et al. (2003) on the identification of AGN in their $z \sim 3$ survey of Lyman-break galaxies. They found that the fraction of objects in the survey with clear evidence for AGN activity is ~3%. Interestingly, a substantial fraction, perhaps even most, of these objects would not have been detected in even the deepest existing X-ray surveys. These faint AGNs are plausibly hosted by the equivalent of LBGs, and the UV luminosities of the broad-lined AGNs in the sample are compatible with Eddington-limited accretion onto black holes that satisfy the locally determined MBH versus $M_{\rm bulge}$ relation given estimates of the stellar masses of LBGs. The clustering properties of the AGNs are compatible with their being hosted by objects similar to LBGs. The implied lifetime of the active AGN phase in LBGs, if it occurs some time during the active star formation phase, is $\sim 10^7$ yr.

Giavalisco has published, together with Cheung et al. (2003), their near-IR observations of the host galaxies of BL Lac sources at $z \sim 0.3$. The data, obtained at the Carnegie LCO 2.5-m telescope in excellent seeing conditions (~0.5 arcsec), were obtained to study the morphology of the old populations of the hosts. They found that the morphologies match that of elliptical galaxies with de Vaucouleurs $r^{1/4}$ light profile. They also find that the structural parameter of these galaxies follow the same *K*-band Kormendy relationship followed by non-active elliptical galaxies.

R. Gilliland, in collaboration with V. Sarajedini and C. Kasm (UFl–Gainsville) analyzed a third *Hubble* epoch of Hubble Deep Field North imaging in the *V*-band in comparison to the original HDF to investigate the population of Active Galactic Nuclei to redshifts of about unity. The great stability of *Hubble* imaging, combined with the exquisite resolution allowing isolation of nuclear contributions to the light allowed these data, acquired five years apart, to reveal nuclear variability in 16 of 217 galaxies brighter than $V_{\rm nuclear} = 27.5$; with corrections for incompleteness, the fraction of AGN over the redshift range $0.09 < z < 1.8$ was shown to be 8%. Seven of the AGN detected through variability were previously detected in a *Chandra* survey, an additional seven were associated with mid-IR detections at 15 μm, and five were 1.4 GHz radio sources. Evidence for an increase in the number density of faint AGN was found in comparison to the local Seyfert luminosity function, with no evidence of turning over.

A. Koekemoer, in collaboration with members of the GOODS team, discovered a new population of sources described as 'EXOs', with extreme X-ray/optical luminosity ratios. These new sources were detected in ultra-deep *Chandra* observations as well as in deep VLT near-IR imaging, but were not detected in any of the deep multi-band *Hubble* observations in the GOODS program. These data indicate two possible scenarios: (i) if the sources are at redshifts below $z = \sim 6$ (where Lyman-α emission is visible with the ACS), then their host galaxies must be very faint or highly reddened; (ii) if the sources are at higher redshifts, they could be accounted for by moderate-luminosity AGN in relatively bright host galaxies.

G. Kriss continued his studies of the highly ionized gas causing X-ray and UV absorption in low-*z* AGN. Using *FUSE* and *XMM-Newton* observations, Kriss, A. Blustin, and G. Branduardi-Raymont (Univ. Coll. London) showed that the UV and X-ray absorption in the Seyfert 1 galaxy NGC 7469 was a complex assortment of ionization states, possibly even located in different places ranging from interior to the broad-line region to as distant from the central engine as the obscuring torus (Kriss et al. 2003; Blustin et al. 2003). Similarly, STIS observations of O VI absorption in the quasar 3C 351 (Yuan et al. 2002) showed that the kinematically complex UV absorbers were indicative of gas in a different ionization state than that causing the X-ray absorption. As part of ''Team 3783,'' Kriss worked with J. Gabel (Catholic Univ. of America), S. Kaspi (Tel Aviv), and H. Netzer (Tel Aviv) to analyze the large body of data obtained during the *Chandra*, *Hubble*, and *FUSE* monitoring campaign directed at the absorbing gas in the Seyfert 1 galaxy NGC 3783. The UV observations (Gabel et al. 2002) and the *Chandra* X-ray spectra (Kaspi et al. 2003) again show gas in a wide range of ionization states. Models for the X-ray absorbing gas computed by Netzer et al. (2003) demonstrate that the gas is coming from at least three different regions with differing ionization parameters. All these observations of kinematically complex UV and X-ray absorbers displaying a wide range of ionization states are the natural result of a thermal wind driven off the exposed faces of the obscuring torus, as explained by Krolik and Kriss (2001).

C. Leitherer, in collaboration with L. Colina (Madrid), R. González Delgado (Granada), and M. Mas-Hesse (Madrid) used STIS imaging and spectroscopy of the low-luminosity active galactic nucleus (LLAGN) NGC 4303 to identify the previously detected UV-bright nucleus of this galaxy as a compact, massive, and luminous stellar cluster. The cluster with a size (FWHM) of 3.1 pc and an ultraviolet luminosity log L1500 Å (ergs s^{-1} $Å^{-1}$) = 38.33 was identified as a nuclear superstar cluster (SSC) like those detected in the circumnuclear regions of spirals and starburst galaxies. The UV spectrum showed the characteristic broad P Cygni lines produced by the winds of massive young stars and was best fitted by the spectral energy distribution of a massive cluster of 10^5 solar masses (for a Salpeter initial mass function law with lower mass cutoff of 1 solar mass) generated in an instantaneous burst four Myr ago. The ionizing energy produced by this cluster exceeds the flux needed to explain the nuclear *H* luminosity. No evidence for an additional

nonthermal-ionizing source associated with an accreting black hole was detected in the ultraviolet. These new STIS results unambiguously showed the presence of a compact SSC in the nucleus of a low-luminosity AGN, which is also its dominant ionizing source. The authors hypothesize that at least some LLAGNs in spirals could be understood as the result of the combined ionizing radiation emitted by an evolving SSC (i.e., determined by the mass and age) and a black hole accreting with low radiative efficiency (i.e., radiating at low sub-Eddington luminosities) coexisting in the inner few parsecs region. Complementary multifrequency studies gave the first hints of the very complex structure of the central 10 pc of NGC 4303, where a young SSC apparently coexists with a low-efficiency accreting black hole and with an intermediate/old compact star cluster and where, in addition, an evolved starburst could also be present. If structures such as those detected in NGC 4303 are common in the nuclei of spirals, the modeling of the different stellar components and their contribution to the dynamical mass has to be established accurately before deriving any firm conclusion about the mass of central black holes of few to several million solar masses.

M. Livio, in collaboration with Pringle (Cambridge) and King (Leicester), studied astrophysical jets, which are ubiquitous, found in sources ranging from gamma-ray bursts and AGN to young stellar objects and symbiotic systems. Yet, the precise mechanism for jet acceleration and collimation is still not known. The group examined data from AGN and microquasars and proposed that the two states seen in these systems result from a transition from a small-scale to a large-scale magnetic field, the latter accelerating and collimating the jet. Livio, in collaboration with Hujeirat and Camenzind (Heidelberg) proposed detailed models for the connection between the accretion disks in these objects and the jets.

Gerssen, van der Marel, and several other collaborators finished a *Hubble* study of the morphology and kinematics of NGC 6240, one of the nearest and best-studied ultraluminous infrared galaxies. The large-scale broadband morphology is complex, consistent with the merger nature of the galaxy. The emission-line gas shows a spectacular filamentary nebula consistent with a bipolar superwind. The double nucleus, already known from ground-based work, resolves into additional components at *Hubble* resolution, due in part to strong patchy dust obscuration. Stellar and gaseous kinematics were inferred from STIS spectroscopy. The kinematics are complex, indicating that line-of-sight projection effects, dust absorption, and non-equilibrium merger dynamics may be playing an important role. *Chandra* observations of hard X-rays have shown that both of the nuclei contain an Active Galactic Nucleus (AGN). The *Hubble* data show no clear sign of these two AGNs, in either the imaging or spectroscopic data. This underscores the importance of X-ray data for identifying AGNs in highly dust-enshrouded environments. An earlier suggestion of an ultra-massive off-nuclear black hole was not confirmed by the STIS data.

J. Noel-Storr (Columbia) led a study with S. Baum, Verdoes Kleijn, van der Marel, O'Dea and others of a complete sample of 21 nearby, early-type galaxies with radio jets. Medium resolution spectra around Hα were obtained by STIS on *Hubble* to derive the kinematics of the emission line gas present in the nuclei. In 67% of the nuclei the gas appears to be rotating and, with one exception, the cases where rotation is not seen are either face-on or have complex central morphologies. In 62% of the nuclei the fit to the central spectrum is improved by the inclusion of a broad component. Verdoes Kleijn led a detailed study by the same team of the data for one of the radio galaxies with a rotating gas disk, NGC 4335. In combination with ground-based data and detailed dynamical modeling, these data yield an estimate of the mass of the central black hole. This yields an upper limit that falls a factor of approximately six below the mass expected from the stellar velocity dispersion. Thus, NGC 4335 might have an unexpected low black hole mass.

R. L. White, in collaboration with R. Becker (UCa–Davis), X. Fan (Arizona), and M. Strauss (Princeton) studied the ionization state of the universe at $z > 6$ using high-resolution, high signal-to-noise spectra of two high redshift quasars. SDSS J1030+0524 has very black Gunn-Peterson absorption troughs, implying a Lyman-α optical depth greater than 22 for the IGM at $z \sim 6$. SDSS J1148+5251 ($z = 6.37$) does have light detected in the hydrogen absorption troughs, but a variety of lines of evidence led the authors to conclude that the light probably comes from an intervening galaxy along the line of sight (at $z = 4.9$), which is also amplifying the quasar's light through gravitational lensing. The single best measurement to date of the IGM ionization at $z = 6$ comes from the spectrum of SDSS J1030+0524.

White, D. Helfand (Columbia), Becker, M. Gregg (UCa–Davis), Postman, T. Lauer (NOAO), and W. Oegerle (NASA/GSFC) constructed a sample of 35 FIRST radio-emitting quasars from the Deeprange *I*-band survey. Although modest in size, this FIRST/Deeprange Quasar (FDQ) survey is significantly deeper than existing quasar surveys and contains many more red objects than surveys selected using blue magnitudes and colors. The sample contains five quasars with unusually red colors, including three that appear very heavily reddened. The spectra are fitted well with normal blue quasar spectra attenuated by more than 2.5 magnitudes of extinction in the *I*-band. These red quasars are only seen at low redshifts ($z < 1.3$). Even with a magnitude limit $I < 20.5$, the FDQ survey is deep enough to detect only the most luminous of these red quasars at $z < \sim 1$; similar objects at higher redshifts would fall below the *I*-band limit. Indeed, the five most luminous objects (using dereddened magnitudes) with $z < 1.3$ are *all* red. These data strongly support the hypothesis that radio quasars are dominated by a previously undetected population of red, heavily obscured objects. Unless highly reddened quasars are preferentially also highly luminous, there must be an even larger, as yet undiscovered, population of red quasars at lower luminosity. This is likely to be only the most luminous tip of the red quasar iceberg. Another interesting result from the FDQ survey is the discovery that five of the six $z < 1$ quasars are associated with Deeprange cluster candidates having similar estimated redshifts. This association is very unlikely to be the result of chance. It has some surprising implications, including the possibility that up to half of the Deeprange clusters at $z \sim 1$ have associated quasars.

8 CLUSTERS & COSMOLOGY

M. Fall, M. Stiavelli, and N. Panagia developed a new method to predict the observability of the sources of cosmological reionization (which are known to exist at redshifts $z > \sim 6$, but have not yet been detected). The method is based on the fact that reionization requires a known comoving density of ionizing photons (at least one for every atom). This in turn sets a model-independent lower limit to the mean surface brightness of the sources at rest-frame UV wavelengths and hence at observed near-IR wavelengths—a line of slope −1 in a plot of areal number density against flux. If the sources have a mean surface brightness near this limiting value, *JWST* has a good chance of detecting them, while *Hubble* has almost no chance. However, the actual mean surface brightness may be many times higher than this ideal limit if some UV photons are absorbed within the sources themselves and/or if some ionizations are offset by recombinations in the clumpy intergalactic medium. In this more realistic case, *Hubble* has a reasonable chance of detecting the reionization sources in very deep images, especially if the sources have strong Lyman-α emission and/or are observed behind clusters of galaxies, so that they are magnified gravitationally.

A. Fruchter helped produce two works as a member of the Supernova Cosmology Project (SCP). R. Pain et al. used the SCP data to study the Type Ia supernova rate at $z \sim 0.5$. A rate of 0.6 h^2 SNu, or about twice the present local rate, was derived. This is roughly in agreement with expectation, as the Type Ia rate should reflect the higher star-formation rate of earlier epochs, though with some delay. R. Knop et al. used the eleven new Type Ia supernovae with $0.36 < z < 0.86$ to examine the geometry of the universe. An $\Omega_{\rm matter}$ of about 0.25 or equivalently an $\Omega_{\rm lambda}$ of approximately 0.75 (both with errors somewhat less than 0.1) were found under the assumption of a flat universe and a constant value of $w = -1$. When the supernova data were combined with independent measurements of $\Omega_{\rm matter}$ from galaxy redshift distortion data, they provide a measurement of $w = -1 \pm 0.2$, if w is assumed to be constant in time. A $w = -1$ is indicative of a universe with a cosmological constant. In a separate work, M. Sullivan et al. showed that the scatter in the SNe Ia Hubble diagram correlates with the host type. The relation is tightest in early-type systems, but the supernovae in early-type hosts are only $\sim 0.14 \pm 0.09$ mags brighter than those in late-type systems, suggesting little extinction in even the late-type systems.

Livio, in collaboration with Somerville and Bullock (CfA), examined the reionization of the universe. Observations by the Sloan Digital Sky Survey have been interpreted as suggesting that the universe may have been reionized at a redshift ~6.5. At the same time, the most recent WMAP results suggest that the universe may have been reionized as early as $z \sim 20$. In two works, the authors examined the questions: which stars (Pop II or Pop III) are more likely to have reionized the universe? And, can the known problem of structure on small scales that is typical for ΛCDM models be solved if one assumes that the spectral index (characterizing the fluctuations) is smaller than unity or depends on wavelength? The collaboration showed that: (i) contrary to the common belief, Pop II stars are as likely as Pop III to have reionized the universe, and (ii) it is extremely difficult to reconcile a small spectral index with an early reionization. Hence the small-scale problem may need a different solution.

Livio examined recent findings in cosmology and their potential implications for the emergence of life in the universe. In particular, he discussed the requirements for carbon-based life, anthropic implications of the existence of dark energy, the possibility of time-varying constants of nature, and the question of the rarity (or not) of intelligent life.

M. Postman, with collaborators from the ACS team including M. Fran, P. Rosati, and J. Blakeslee, used deep ACS imaging of a distant cluster RDCS1252−2927 ($z = 1.24$) to provide important new constraints on the evolution of the color-magnitude relation of early type cluster galaxies. The early-type population in the $z = 1.24$ cluster defines a very tight sequence in the CM diagram, with an intrinsic scatter in observed $(i - z)$ of 0.029 ± 0.007 mag based on 52 galaxies, or 0.024 ± 0.008 mag for ~30 ellipticals. Simulations using the latest stellar population models indicate an age scatter for the ellipticals of about 34%, with a mean age >2.6 Gyr (corresponding to $z > 2.7$) and the last star formation occurring no later than $z \sim 1.5$. These results indicate there is little or no evolution in the scatter and slope of the CM relation over the range $0 < z < 1.24$.

Postman, with H. Ford, W. Zheng, K. Zekser, D. Coe, and R. White, began a survey for $z > 7$ galaxies by searching for z-band dropouts in deep images of nearby strongly-lensing galaxy clusters. The magnification provided by the clusters can brighten such distant sources up to 30x, making their detection feasible. The detection images in the near IR are being obtained with the Near-IR Imager on the Gemini North telescope. The dropout images are from the GTO ACS cluster survey.

M. Stiavelli, M. Fall, and N. Panagia studied the properties of reionization sources in terms of their average surface brightness. The minimum average surface brightness (in flux, maximum in magnitudes) is derived in a model independent way. They also considered more realistic models including the effects of recombinations in a non-homogeneous universe and finite escape fraction of ionizing photons. They determined the range of allowable properties for these sources and outlined regions in the surface number density versus magnitude plane that are most promising for carrying out searches of reionizing sources.

9 INSTRUMENTS, SOFTWARE & TECHNIQUES

R. Allen, together with J. Rajagopal (GSFC) and T. Böker continued work on modeling the imaging capabilities of new space astrophysics missions. This past year the effort has concentrated on delivering to GSFC workable versions of simulators for the Stellar Imager (SI, Carpenter), the Submillimeter Probe of the Evolution of Cosmic Structure (SPECS, Mathur/Leisawitz), and the Fourier-Kelvin Stellar Interferometer (FKSI, Danchi). Allen presented a review paper on imaging simulators at the SPIE meeting in Kona, and co-authored a paper on the SI simulator and another paper describing the SI mission concept in general.

Allen continued his work on the imaging capability of the Space Interferometry Mission (SIM), for which he is a Mission Scientist and a member of the Science Team. Together with Böker, Rajagopal, and R. van der Marel, a paper was presented at the SPIE meeting evaluating the effects of the latest de-scope of the SIM spacecraft on the ability to measure stellar proper motions in crowded fields.

Allen continued his collaboration with A. Petrosian (Byurakan Obs.) and a team of STScI colleagues including B. McLean, N. Panagia, C. Leitherer, and J. MacKenty on an analysis of the Second Byurakan Survey of active galaxies. They published a paper on a comparison of the 'UV-excess' and the 'emission-line' techniques for identifying active galaxies was published. A paper presenting the complete data base and atlas of Markarian galaxies was in preparation. Many of the optical galaxy images show supernovae, and a paper on the progenitors of SNe and their relation to host galaxy type was also in preparation.

R. Brown developed issues and ideas related to the discovery and study of extrasolar planets. He published the case for a 4-m space telescope including an optical coronagraph, which could both perform much of the mission of the Terrestrial Planet Finder and serve as a near-term successor to *Hubble*. He argued that recent advances in deformable mirror technology enable adequate wavefront correction inside the instrument, relaxing requirements on the primary mirror. Such a coronoagraph on *Hubble* could find and study twins of Earth around the nearest stars, planets like Uranus and Neptune on Mars/Jupiter-like orbits around stars to five pc, as well as planets like Jupiter and Saturn to ten pc.

S. Casertano, with K. U. Ratnatunga and R. E. Griffiths (CMU), developed a statistical technique for the measurement of cosmic shear signal that retrieves unbiased estimates even on scales that contain very small numbers of galaxies. The technique has been validated with extensive simulations and has been applied to the measurement of cosmic shear from the Medium-Deep Survey data with WFPC2. With this technique, the authors measure cosmic shear on scales ranging from the full WFPC2 field of view down to 10−20 arcsec; the resulting signal is somewhat stronger than measured previously.

S. Casertano, R. Brown (STScI), A. Sozzetti (Pittsburgh/CfA), and M. G. Lattanzi (Osservatorio di Torino), carried out a thorough quantitative analysis of the potential astrometric study of extrasolar planets by a SIM-like mission. They considered both single planets and planetary systems; for the latter, special emphasis was placed on the ability of SIM to determine the degree of coplanarity of the orbits of multiple planets. Casertano, with Lattanzi, Sozzetti, and A. Spagna (Torino), have established a plan for double-blind tests of planet discoveries with the planned astrometric mission GAIA, which involves teams of astronomers at various European and American institutions.

D. Figer, B. Rauscher, M. Regan, and collaborators, completed testing of *JWST* near-infrared focal plane arrays. They comparatively characterized both HgCdTe (Rockwell) and InSb (Raytheon) devices in 2K x 2K format in terms of dark current, read noise, persistence, crosstalk, spectral and responsivity, as a function of read mode, temperature, and wavelength. The measurements revealed dark currents as low as 1 electron/1000 seconds/pixel, the lowest ever measured for a 5 micron-cutoff device, and read noises near the *JWST* requirement.

L. Petro, M. Clampin, H. Ford, G. Illingworth (UCa–Lick), J. Krist and collaborators presented their proposed concept for a NASA MIDEX mission to image exo-Jovian planets. The 1.5-m optical telescope and advanced Lyot coronagraph would reduce glare and diffraction by a factor of 10^{-4} with a phase plate matched to remove the surface errors of the mirrors. The telescope would be operated remotely from its site on the *International Space Station*. Image rotation of the alt-az mount would allow calibration, and removal, of the fixed optical system speckles. Fifty stars in the solar neighborhood would be surveyed for the presence of Jupiter-like planets in Jupiter-like orbits.

Petro, Ford, Clampin, Illingworth, Krist, S. Olivier (LLNL), and G. E. Sommargren (LLNL) studied and presented the requirements for a terrestrial planet finder. In their concept, an 8-m diameter telescope, a micro-electrical mechanical systems (MEMS) deformable mirror, and an advanced Lyot optical coronagraph are used to achieve the contrast necessary to detect Earth-like planets in the solar neighborhood. The MEMS deformable mirror, which is under development, is a promising means of necessarily large number of precisely controllable elements.

Petro, Ford, C. Burrows, C. Ftaclas (MTU), M. Roggemann (MTU), and J. Trauger (JPL) presented their concept for a high-contrast telescope that could be operated on a ultra-long duration balloon (ULDB) floating in the stratosphere. They based this concept on their finding that effectively diffraction-limited optical images may be formed at the planned 40-km float-altitude. The telescope and optical system would be similar to that proposed by Clampin and colleagues for the *International Space Station*. The ULDB offers a low-cost alternative for exo-planet imagers.

Petro, N. Jedrich (J&T), T. Gregory (Swales), D. Zimbelman (NASA/GSFC), E. Cheng (NASA/GSFC), M. Buchko (Swales), M. Kaylor (Swales), and F. Dolan (Creare) presented a description of the design and expected performance of the NICMOS cooling system (NCS). NCS has successfully cooled *Hubble*'s NICMOS detectors to 77 K, allowing resumption of scientific operations. A turbo-brayton cycle mechanical cryogenic cooler developed by NASA's GSFC and Creare, Inc. is the basis of NCS.

Petro, H. Stockman, J. Mather (NASA/GSFC), E. Smith (NASA HQ), R. de Jong presented a description of the scientific performance of *NGST* (now named *James Webb Space Telescope*) and of possible science programs. *JWST* imaging is limited by the natural background of interplanetary dust at wavelengths less than 10 micron and by the self-emission of the observatory at longer wavelengths. Near infrared spectrscopy will be limited by detector noise, but mid-infrared spectroscopy may be limited by observatory self-emission. With a 6-m class telescope, nano-Jansky class targets will be detectable with exposures of one-day duration.

A. Sivaramakrishnan developed analytical methods to derive image properties of well-corrected point-spread func-

tions, with J. Lloyd (Caltech), M. Perrin (Berkeley), R. Makidon (STScI), B. Oppenheimer (AMNH), J. Graham (Berkeley) and B. Macintosh (LLNL), characterizing various regimes where residual speckles possess different kinds of symmetries and size modulations. He applied his results to prove analytically that a hitherto promising avenue of speckle noise suppression called speckle decorrelation is in principle unworkable, and devised alternative methods utilizing speckle symmetries and distributions.

Sivaramakrishnan and Lloyd developed an approach to calibrating non-common path error in Lyot coronagraphs for the NSF Center for Adaptive Optics (CfAO) XAOPI coronagraph for an existing 8–10 m class telescope, as well as for the Lyot Project *JHK* band coronagraph (being constructed at AMNH for the 3.6 m AEOS adaptive optics telescope) to explore regions as close as 0.2 arcseconds of stars brighter than $V = 7$, to enable protoplanetary disk, companion planet and brown dwarf studies.

Sivaramakrishnan and Makidon extended previous work to include more instrument effects to match AEOS PSF simulations to data. With Graham, they predicted planet discovery probabilities for the Lyot Project coronagraph. With L. Roberts (Boeing), Oppenheimer and Graham, they quantified the amount of wavefront error the wavefront reconstruction algorithm generates in the AEOS AO PSF. This helped lead to significant AEOS AO performance improvement. For the Lyot Project coronagraph, Oppenheimer and Sivaramakrishnan designed, developed, constructed, and implemented the fastest tip-tilt capability of any civilian AO system.

Lloyd, Gavel (UCSC), Sivaramakrishnan, Graham, M. Voit, and P. Hodge developed a theory of quadrant phase-mask coronagraphy. Their designs enable such high-efficiency coronagraphs to be placed on conventional obstructed-aperture telescopes.

A. Suchkov and collaborators continued the work on the ClassX project. They built a series of classifiers and incorporated them into the ClassX system deployed on the Web. They enhanced the ClassX visualization and data analysis tool, VizX, and augmented it to handle the ClassX classification probabilities. They used ClassX to study the nature of previously unclassified *ROSAT* X-ray sources.

R. Williams, with J. Baldwin and B. Sharpee (MSU), developed the logic for EMILI (EMIssion LIne IDentification), a software package that makes spectral line identifications automatically. EMILI interrogates a large spectral database (the v2.04 Atomic Line List of van Hoof) to determine the most likely identifications for observed spectra based on established criteria. The identification logic uses computed template fluxes for all candidate lines, based on generic cross sections, and searches for expected companion multiplet lines. To test the concept of EMILI, they obtained high spectral resolution ($R = 40{,}000$), high signal-to-noise ground-based spectra of selected high surface brightness nebulae and succeeded in detecting lines with intensities less than 10^{-5} that of Hβ. The software identifications agreed with previous, manually assigned line identifications for approximately 90% of the lines observed.

PUBLICATIONS

Afonso, J., Mobasher, B., Hopkins, A., Georgakakis, A., Cram, L. & Chan, B. 2003, ''Galaxy evolution from a microJansky radio survey,'' Ap&SS, 285, 149

Albrow, M., De Marchi, G., & Sahu, K. C. 2002, ''The Spatially-Resolved Mass Function of the Globular Cluster M22,'' ApJ, 579, 660

Albrow, M., et al. 2002, ''A Short, Nonplanetary, Microlensing Anomaly: Observations and Light-Curve Analysis of MACHO 99–BLG–47,'' ApJ, 72, 1031

Allen, M. G., Sparks, W. B., Koekemoer, A., Martel, A. R., O'Dea, C. P., Baum, S. A., Chiaberge, M., Macchetto, F. D., & Miley, G. K. 2002, ''Ultraviolet Hubble Space Telescope Snapshot Survey of 3CR Radio Source Counterparts at Low Redshift,'' ApJS, 139, 411

Allen, R. J. 2002, ''On the Origin of H I in Galaxies: The Sizes and Masses of H I Photodissociation Regions,'' in The Dynamics, Structure, and History of Galaxies, eds. G. Da Costa & H. Jerjen (San Francisco: ASP), 183

Allen, R. J. 2002, ''On The Origin of H I in Galaxies: Photodissociation and the 'Schmidt Law' for Global Star Formation,'' in Seeing Through the Dust—The Detection of H I and the Exploration of the ISM in Galaxies, eds. A. R. Taylor, T. L. Landecker, & A. G. Willis, (San Francisco: ASP), 288

Allen, R. J., Böker, T., & Rajagopal, J. 2003, ''Simulators for Imaging Interferometry in Space'' in Astronomical Telescopes and Instrumentation: Interferometry in Space, ed. M. Shao, Proc. SPIE, 4852, 248

An, J. H., et al. 2002, ''First microlens mass measurement: PLANET photometry of EROS BLG–2000–5,'' ApJ, 572, 521

Araujo-Betancor, S., Knigge, C., Long, K. S., Hoard, D. W., Szkody, P., Rodgers, B., Krisciunas, K., Dhillon, V. S., Hynes, R. I., Patterson, J., & Kemp, J. 2003, ''The System Parameters of DW Ursae Majoris,'' ApJ, 583, 437

Arribas, S. & Colina, L. 2002, ''INTEGRAL Field Spectroscopy of IRAS 15206+3342: Gas Inflows and Starbursts in an Advanced Merger,'' ApJ, 573, 576

Arribas, S. & Colina, L. 2003, ''INTEGRAL Spectroscopy of IRAS 17208–0014: Implications for the Evolutionary Scenarios of Ultraluminous Infrared Galaxies,'' ApJ, 591, 791

Bahcall, N., McKay, T., Annis, J., Kim, R., Dong, F., Hansen, S., Goto, T., Gunn, J., Miller, C., Nichol, R., Postman, M., Schneider, D., Schroeder, J., Voges, W., Brinkmann, J., & Fukugita, M. 2003, ''A Merged Catalog of Clusters of Galaxies from Early SDSS Data,'' ApJS, 148, 243

Baker, A. J., Jogee, S., Sakamoto, K., & Scoville, N. Z. 2003, ''The OVRO MAIN survey: Molecular gas in Active and Inactive Nuclei,'' in Active Galactic Nuclei: from Central Engine to Host Galaxy, eds. S. Collin, F. Combes, & I. Shlosman (San Francisco: ASP), 479

Bakos, G., Sahu, K. C., & Nemeth, P. 2002, ''Revised Coordinates and Proper Motions of the Stars in the Luyten Half-Second Catalog,'' ApJS, 141, 187

Bate, M. R., Lubow, S. H., Ogilvie, G. I., & Miller, K. A. 2003, ''Three-dimensional global calculations of high and

low-mass planets embedded in protoplanetary discs,'' MNRAS, 341, 213

Battaner, E., Mediavilla, E., Guijarro, A., Arribas, S., & Florido, E. 2003, ''Axisymmetrical gas inflow in the central region of NGC 7331,'' A&A, 401, 67

Beckwith, S. V. W., Caldwell, J., Clampin, M., De Marchi, G., Dickinson, M., Ferguson, H., Fruchter, A., Hook, R., Jogee, & S., Koekemoer, A., et al. 2003, ''The Hubble Ultra Deep Field,'' BAAS, 35, 723

Belle, K. E., Howell, S. B., Sion, E. M., Long, K. S., & Szkody, P. 2003, ''Hubble Space Telescope Space Telescope Imaging Spectrograph Spectroscopy of the Intermediate Polar EX Hydrae,'' ApJ, 587, 373

Benedict, G. F., McArthur, B. E., Forveille, T., Delfosse, X., Nelan, E., Butler, R. P., Spiesman, W., Marcy, G., Goldman, B., Perrier, C., Jefferys, W. H., & Mayor, M. 2002, ''A Mass for the Extrasolar Planet Gliese 876b Determined from Hubble Space Telescope Fine Guidance Sensor 3 Astrometry and High-Precision Radial Velocities,'' ApJ, 581, L115

Benedict, G. F, McArthur, B. E., Fredrick, L. W., Harrison, T. E., Slesnick, C. L., Rhee, J., Patterson, R. J., Skrutskie, M. F., Franz, O. G., Wasserman, L. H., Jefferys, W. H., Nelan, E., van Altena, W., Shelus, P. J., Hemenway, P. D., Duncombe, R. L., Story, D., Whipple, A. L., & Bradley, A. J. 2002, ''Astrometry with the Hubble Space Telescope: A Parallax of the Fundamental Distance Calibrator delta Cephei,'' AJ, 124, 1695

Bertero, M., Boccacci, P., Custo, A., De Mol, C., & Robberto, M. 2003, ''A Fourier-based method for the restoration of chopped and nodded images,'' A&A, 406, 765

Blades, J. C. & Siegmund, O. H. W. (eds.) 2002, Future EUV/UV and Visible Space Astrophysics Missions and Instrumentation, Proc. SPIE, Vol. 4854

Blakeslee, J., Franx, M., Postman, M., Rosati, P., Holden, B., Illingworth, G., Ford, H., Cross, N., Gronwall, C., Benitez, N., Bouwens, R., Broadhurst, T., Clampin, M., Demarco, R., Golimowski, D., Hartig, G., Infante, L., Martel, A., Miley, G., Menanteau, F., Meurer, G., Siriani, M., & White, R. 2003, ''ACS Photometry of the Cluster RDCS1252.9-2927: The Color-Magnitude Relation at z = 1.24,'' ApJ, 596, L143

Blakeslee, J. P., Tsvetanov, Z. I., Riess, A. G., Ford, H. C., Illingworth, G. D., Magee, D., Tonry, J. L., Benitez, N., Clampin, M., Hartig, G. F., Meurer, G. R., Sirianni, M., Ardila, D. R., Bartko, F., Bouwens, R., Broadhurst, T., Cross, N., Feldman, P. D., Franx, M., Golimowski, D. A., Gronwall, C., Kimble, R., Krist, J., Martel, A. R., Menanteau, F., Miley, G., Postman, M., Rosati, P., Sparks, W., Strolger, L.-G., Tran, H. D., White, R. L., & Zheng, W. 2003, ''Discovery of Two Distant Type Ia Supernovae in the Hubble Deep Field-North with the Advanced Camera for Surveys,'' ApJ, 589, 693

Blanton, E. L., Gregg, M. D., Helfand, D. J., Becker, R. H., & White, R. L. 2003, ''Discovery of a High-Redshift (z = 0.96) Cluster of Galaxies Using a FIRST Survey Wide-Angle-Tailed Radio Source,'' AJ, 125, 1635

Blustin, A., Branduardi-Raymont, G., Behar, E., Kaastra, J., Kriss, G. A., Page, M. J., Kahn, S. M., Sako, M., & Steenbrugge, K. C. 2003, ''Multi-wavelength studies of the Seyfert 1 galaxy NGC 7469. II—X-ray and UV observations with XMM-Newton,'' AA, 403, 481

Bohlin, R. 2002, ''STIS Flux Calibration,'' in HST Calibration Workshop, eds. S. Arribas, A. Koekemoer, & B. Whitmore, (Baltimore: STScI), 115

Böker, T., Allen, R. J., Rajagopal, J., & van der Marel, R. P. 2003, ''Measuring Stellar Proper Motions in Crowded Fields with SIM,'' in Astronomical Telescopes and Instrumentation: Interferometry in Space, ed. M. Shao, Proc. SPIE, 4852, 639

Böker, T., Stanek, R., & van der Marel, R. P. 2002, ''Searching for bulges at the far end of the Hubble sequence,'' AJ, 125, 1073

Böker, T., van der Marel, R. P., Gerssen, J., Walcher, J., Rix, H. W., Shields, J., & Ho, L. 2003, ''The stellar content of nuclear star clusters in spiral galaxies,'' in Discoveries and Research Prospects from 6- to 10-Meter-Class Telescopes II, ed. P. Guhathakurta, Proc. SPIE, 4834, 57

Bond, H. E., Henden, A., Levay, Z. G., Panagia, N., Sparks, W. B., Starrfield, S., Wagner, R. M., Corradi, R. L. M., & Munari, U. 2003, ''An Energetic Stellar Outburst Accompanied by Circumstellar Light Echoes,'' Nature, 422, 405

Bond, H. E., Henden, A., Panagia, N., Sparks, W. B., Starrfield, S., & Wagner, R. M. 2003, ''HST Imaging Polarimetry of the Light Echo around V838 Monocerotis,'' BAAS, 34, 1161

Bond, H. E., O'Brien, M. S., Sion, E. M., Mullan, D. J., Exter, K., Pollacco, D. L., & Webbink, R. F. 2002, ''V471 Tauri and SuWt 2: The Exotic Descendants of Triple Systems?'' in Exotic Stars as Challenges to Evolution, eds. C. A. Tout & W. Van Hamme (San Francisco: ASP), 239

Bond, H. E. & Pollacco, D. L. 2002, ''HST Observations of Sakurai's Object (V4334 Sgr) and Related Stars,'' Ap&SS, 279, 31

Bond, H. E., Pollacco, D. L., & Webbink, R. F. 2003, ''WeBo 1: A Young Barium Star Surrounded by a Ring-Like Planetary Nebula,'' AJ, 125, 260

Bond, H. E., White, R. L., Becker, R. H., & O'Brien, M. S. 2002, ''FIRST J102347.6+003841: The First Radio-Selected Cataclysmic Variable,'' PASP, 114, 1359

Bouwens, R. J., Illingworth, G. D., Rosati, P., Lidman, C., Broadhurst, T., Franx, M., Ford, H. C., Magee, D., Bentez, N., Blakeslee, J. P., Meurer, G. R., Clampin, M., Hartig, G. F., Ardila, D. R., Bartko, F., Brown, R. A., Burrows, C. J., Cheng, E. S., Cross, N. J. G., Feldman, P. D., Golimowski, D. A., Gronwall, C., Infante, L., Kimble, R. A., Krist, J. E., Lesser, M. P., Martel, A. R., Menanteau, F., Miley, G. K., Postman, M., Sirianni, M., Sparks, W. B., Tran, H. D., Tsvetanov, Z. I., White, R. L., Zheng, W. 2003, ''Star Formation at z $\sim$ 6: i-dropouts in the ACS GTO Fields,'' ApJ, 595, 589

Bowen, D. V., Pettini, M., & Blades, J. C. 2002, ''Lyman α Absorptions around Nearby Galaxies,'' ApJ, 580, 169

Brown, R. A., Burrows, C. J., Casertano, S., Clampin, M., Ebbets, D. C., Ford, E. B., Jucks, K. W., Kasdin, N. J., Kilston, S., Kuchner, M. J., Seager, S., Sozzetti, A., Spergel, D. N., Traub, W. A., Trauger, J. T., & Turner, E. L.

2003, ''The 4-m space telescope for investigating extrasolar Earth-like planets in starlight: TPF is HST2,'' in Future EUV/UV and Visible Space Astrophysics Missions and Instrumentation, eds. J. C. Blades & O. H. W. Siegmund, Proc. SPIE, 4854, 95

Brown, R. J. N., Forbes, D. A., Silva, D., Helsdon, S. F., Ponman, T. J., Hau, G. K. T., Goudfrooij, P., Brodie, J. P., & Bothun, G. 2003, ''Near-infrared Imaging of Ellipticals: Surface Brightness Profiles and Photometry,'' MNRAS, 341, 747

Brown, T. M., Ferguson, H. C., Smith, E., Bowers, C. W., Kimble, R. A., Renzini, A., & Rich, R. M. 2003, ''Far-Ultraviolet Emission from Elliptical Galaxies at z = 0.33,'' ApJ, 584, L69

Brown, T. M., Ferguson, H. C., Smith, E., Kimble, R. A., Sweigart, A. V., Renzini, A., Rich, R. M., & VandenBerg, D. A. 2003, ''Evidence of a Significant Intermediate-Age Population in the M31 Halo from Main-Sequence Photometry,'' ApJ, 592, L17

Brown, T. M., Heap, S. R., Hubeny, I., Lanz, T., & Lindler, D. 2002, ''Isolating Clusters with Wolf-Rayet Stars in I Zw 18,'' ApJ, 579, L75

Burgasser, A. J., Reid, I. N., Kirkpatrick, J. D., Brown, M. E., Miskey, C. L., & Gizis, J. E. 2003, ''Binarity in brown dwarfs: T dwarf binaries discovered with the Hubble Space Telescope WFPC2,'' ApJ, 586, 512

Callanan, P. J., Curran, P., Filippenko, A. V., Garcia, M. R., Margon, B., Deutsch, E., Anderson, S., Homer, L., & Fender, R. P. 2002, ''The Peculiar Infrared Counterpart of GX 17+2,'' ApJ, 574, L143

Cappellari, M., Verolme E. K., van der Marel, R. P., Verdoes Kleijn, G., Illingworth, G. D., Franx, M., Carollo, C. M., & de Zeeuw, P. T. 2002, ''The counterrotating core and the black hole mass of IC 1459,'' ApJ, 578, 787

Carollo, D., Hodgkin, S. T., Spagna, A., Smart, R. L., Lattanzi, M. G., McLean, B., & Pinfield, D. J. 2002, ''Discovery of a New DQ White Dwarf toward the NGP,'' A&A, 393, L45

Carpenter, K. G., Schrijver, C. J., Lyon, R. G., Mundy, L. G., Allen, R. J., Armstrong, J. Thomas, Danchi, W. C., Karovska, M., Marzouk, J., Mazzuca, L. M., Mozurkewich, D., Neff, S. G., Pauls, T. A., Rajagopal, J., Solyar, G., & Zhang, X. 2003, ''The Stellar Imager (SI) Mission Concept,'' in Astronomical Telescopes and Instrumentation, eds. C. Blades & O. H. W. Siegmund, Proc. SPIE, 4854, 293

Carter, D., Mobasher, B., Bridges, T. J., Poggianti, B. M., et al. 2002, ''A Photometric and Spectroscopic Study of Dwarf and Giant Galaxies in the Coma Cluster. V. Dependence of the Spectroscopic Properties on Location in the Cluster,'' ApJ, 567, 772

Carvalho, J. C. & O'Dea, C. P. 2003, ''Luminosity Evolution of Double Radio Sources,'' PASA, 20, 98

Casertano, S., Laidler, V., Capak, P., Cowie, L., & Hicken, M. 2003, ''Supernovae 2002kh, 2002ki, and 2003N,'' IAUC 8052

Casertano, S., Lattanzi, M. G., Sozzetti, A., & Spagna, A. 2003, ''Double-Blind Tests Program for Astrometric Planet Detection with GAIA,'' PSWG-OAT-001 (Pino Torinese: Osservatorio Astronomico di Torino), 1

Castro Ceron, J. M., Castro-Tirado, A. J., Gorosabel, J., Hjorth, J., Fynbo, J. U., Jensen, B. L., Pedersen, H., Andersen, M. I., Lopez-Corredoira, M., Suarez, O., Grosdidier, Y., Casares, J., Pirez-Rammrez, D., Milvang-Jensen, B., Mallen-Ornelas, G., Fruchter, A., Greiner, J., Pian, E., Vreeswijk, P. M., Barthelmy, S. D., Cline, T., Frontera, F., Kaper, L., Klose, S., Kouveliotou, C., Hartmann, D. H., Hurley, K., Masetti, N., Mazets, E., Palazzi, E., Park, H. S., Rol, E., Salamanca, I., Tanvir, N., Trombka, J. I., Wijers, R. A. M. J., Williams, G. G., & van den Heuvel, E. 2002, ''The Bright Optical afterglow of the Long GRB 001007,'' A&A, 393, 445

Chambers, J., Mink, R. G., Ohl, R. G., Connelly, J. A., Mentzell, J. E., Arnold, S. M., Greenhouse, M. A., Winsor, R. S., & MacKenty, J. W. 2003, ''Optical testing of diamond machined, aspheric mirrors for ground-based, near-IR astronomy,'' in Instrument Design and Performance for Optical/Infrared Ground-based Telescopes, eds. M. Iye & A. F. M. Moorwood, Proc. SPIE, 4841, 689

Chandar, R., Leitherer, C., Tremonti, C., & Calzetti, D. 2003, ''The stellar content of Henize 2–10 from Space Telescope Imaging Spectrograph ultraviolet spectroscopy,'' ApJ, 586, 939

Charlot, S., et al. (including Fall, S. M.) 2002, ''Star Formation, Metallicity and Dust Properties Derived From the Stromlo-APM Galaxy Survey Spectra,'' MNRAS, 330, 876

Chiaberge, M., Gilli, R., Macchetto, F. D., Sparks, W. B., & Capetti, A. 2003, ''What Do the Hubble Space Telescope and Chandra Tell Us about the Jet and the Nuclear Region of the Radio Galaxy 3C 270?'' ApJ, 582, 645

Chiaberge, M., Macchetto, F. D., Sparks, W. B., Capetti, A., Allen, M. G., & Martel, A. R. 2002, ''The Nuclei of Radio Galaxies in the Ultraviolet: The Signature of Different Emission Processes,'' ApJ, 571, 247

Clampin, M., Krist, J. E., Ardila, D. R., Golimowski, D. A., Hartig, G. F., Ford, H. C., Illingworth, G. D., Bartko, F., Benitez, N., Blakeslee, J. P., Bouwens, R. J., Broadhurst, T. J., Brown, R. A., Burrows, C. J., Cheng, E. S., Cross, N. J., Feldman, P. D., Franx, M. Gronwall, C., Infante, L., Kimble, R. A., Lesser, M. P., Martel, A. R., Menanteau, F., Meurer, G. R., Miley, G. K., Postman, M., Rosati, P., Sirianni, M., Sparks, W. B., Tran, H. D., Tsvetanov, Z. I., White, R. L., & Zheng, W. 2003, ''Hubble Space Telescope ACS Coronagraphic Imaging of the Circumstellar Disk around HD 141569A,'' AJ, 126, 385

Colina, L., González Delgado, R. M., Mas-Hesse, M., & Leitherer, C. 2002, ''Detection of a super star cluster as the ionizing source in the low luminosity AGN NGC 4303,'' ApJ, 579, 545

Connelly, J. A., Ohl, R. G., Saha, T. T., Hadjimichael, T., Mentzell, J. E., Mink, R. G., Hylan, J. E., Sparr, L. M., Chambers, J., Hagopian, John J.; Greenhouse, M. A., Winsor, R. S., & MacKenty, J. W. 2003, ''Imaging performance and modeling of the Infrared Multi-Object Spectrometer Focal Reducer,'' in Instrument Design and Performance for Optical/Infrared Ground-based Teles-

copes, eds. M. Iye & A. F. M. Moorwood, Proc. SPIE, 4841, 702

Contursi, A., Kaufman, M. J., Helou, G., Hollenbach, D. J., Brauher, J., Stacey, G. J., Dale, D. A., Malhotra, S., Rubio, M., Rubin, R. H., & Lord, S. D. 2002, ''ISO LWS Observations of the Two Nearby Spiral Galaxies NGC 6946 and NGC 1313,'' AJ, 124, 751

Covino, S., Malesani, D., Tavecchio, F., Antonelli, L. A., Arkharov, A., Di Paola, A., Fugazza, D., Ghisellini, G., Larionov, V., Lazzati, D., Mannucci, F., Masetti, N., Barrena, R., Benetti, S., Castro-Tirado, A. J., Di Serego Alighieri, S., Fiore, F., Frontera, F., Fruchter, A., Ghinassi, F., Gladders, M., Hall, P. B., Israel, G. L., Klose, S., Magazzy, A., Palazzi, E., Pedani, M., Pian, E., Romano, P., Stefanon, M., & Stella, L. 2003, ''Optical and NIR Observations of the Afterglow of GRB 020813,'' A&A, 404, L5

Dahlen, T., Conselice, C. J., de Mello, D., Gardner, J. P., Grogin, N. A., Idzi, R., Jogee, S., Lucas, R. A., Mobasher, B., & da Costa, L., et al. 2002, ''Luminosity Function for Different Spectral Types of Galaxies in the GOODS Southern Field,'' BAAS, 34, 1099

Dahn, C. C., et al. 2002, ''Astrometry and Photometry for Cool Dwarfs and Brown Dwarfs,'' AJ, 124, 1170

Das, M., Teuben, P. J., Vogel, S. N., Harris, A., Regan, M. W., & Sheth, K. 2002, ''Mass Concentration and Bar Dissolution in Spiral Galaxies,'' in Disks of Galaxies: Kinematics, Dynamics and Peturbations, ASP Conf. Ser. 275, eds. E. Athanassoula, A. Bosma, & R. Mujica, (San Francisco: ASP), 157

Das, M., Teuben, P. J., Vogel, S. N., Regan, M. W., Sheth, K., Harris, A. I., & Jefferys, W. H. 2003, ''Central Mass Concentration and Bar Dissolution in Nearby Spiral Galaxies,'' ApJ, 582, 190

de Jong, R. S. & Bell, E. F. 2003, ''Stellar M/L Ratios and Spiral Galaxy Dynamics,'' in The Mass of Galaxies at Low and High Redshift, eds. R. Bender & A. Renzini (Berlin: Springer-Verlag), 213

de Jong, R. S., Bell, E. F., Courteau, S., & Olling, R. P. 2002, ''Stellar Mass-to-Light Ratios and Rotation Curves of Spiral Galaxies,'' BAAS, 34, 1114

de Kool, M., Becker, R. H., Gregg, M. D., Arav, N., White, R. L., & Korista, K. T. 2002, ''Absorption from Excited States as a Density Diagnostic for AGN Outflows,'' in ASP Conf. Ser., Vol. 255, Mass Outflow in Active Galactic Nuclei: New Perspectives, eds. D. M. Crenshaw, S. B. Kraemer, & I. M. George (San Francisco: ASP), 183

de Mello, D. F., Wiklind, T., Leitherer, C., & Pontoppidan, K. 2002, ''The nature of submm detected galaxies,'' As&SS, 281, 549

de Vries, W., Becker, R. H., & White, R. L. 2003, ''Long Term Variability of SDSS Quasars,'' AJ, 126, 1217

Della Valle, M., Pasquini, L., Daou, D., & Williams, R. E. 2002, ''The Evolution of Nova V382 Vel 1999,'' A&A, 390, 155

Diaz-Miller, R. I., Quijano, J. Kim, Valenti, J., Proffitt, C. R., Sahu, K. C., Bohlin, R. C., Brown, T. M., & Lindler, D. 2002, ''Recent Improvements to STIS Pipeline Calibration,'' 2002 HST Calibration Workshop, eds. S. Arribas, A. Koekemoer & B. Whitmore (Baltimore: STScI), 190

Dickinson, M., Giavalisco, M., & the Goods Team 2003, ''The Great Observatories Origins Deep Survey,'' 2003, in The Mass of Galaxies at Low and High Redshift, eds. R. Bender & A. Renzini (Garching: ESO), 324

Dickinson, M. E., Papovich, C., Ferguson, H. C., & Budavari, T. 2003, ''The Evolution of the Global Stellar Mass Density at $0 < z < 3$,'' ApJ, 587, 25

Dinescu, D. I., Majewski, S. R., Girard, T. M., Mendez, R. A., Sandage, A., Siegel, M. H., Kunkel, W. E., Subasavage, J. P. & Ostheimer, J. C. 2002, ''Absolute Proper Motions to B $\sim$ 22.5: V. Detection of Sagittarius Dwarf Spheroidal Debris in the Direction of the Galactic Anticenter,'' ApJ, 575, L67

Dominik, M., et al. 2002, ''The PLANET microlensing follow-up network: results and prospects for the detection of extra-solar planets,'' Planetary and Space Sciences, 50, 299

Doxsey, R., Downes, R., Lallo, M., & Reinhart, M. 2002, ''Metrics for Hubble Space Telescope Operations,'' in Observatory Operations to Optimize Scientific Return III, ed. P. Quinn, Proc. SPIE, 4844, 104

Drager, N., R., King, J. R., & Soderblom, D. R. 2002, ''High-Resolution Spectroscopy of Very Active Solar-Type Stars,'' BAAS, 34, 1114

Drake, J. J., et al. 2003, ''The Extraordinary X-ray Light Curve of the Classical Nova V1494 Aquilae (1999 #2) in Outburst: The Discovery of Pulsations and a 'Burst','' ApJ, 584, 448

Dressel, L. L. 2003, ''A Search for Offset Black Holes in LINERS'' in Active Galactic Nuclei: from Central Engines to Host Galaxy, ASP Conference Series v. 290, eds. S. Collin, F. Combes, & I. Shlosman (San Francisco: ASP), 393

Drew, J. E., Hartley, L. E., Long, K. S., & van der Walt, J. 2003, ''QU Car: a very high luminosity nova-like binary with a carbon-enriched companion,'' MNRAS, 338, 401

Drinkwater, M. J., Gregg, M. D., Hilker, M., Bekki, K., Couch, W. J., Ferguson, H. C., Jones, J. B., Phillipps, S. 2003, ''A class of compact dwarf galaxies from disruptive processes in galaxy clusters,'' Nature, 423, 519

Dunlop, J. S., McLure, R. J., Kukula, M. J., Baum, S. A., O'Dea, C. P. & Hughes, D. H. 2003, ''Quasars, their host galaxies, and their central black holes,'' MNRAS, 340, 1095

Edmonds, P. D., Gilliland, R. L., Camillo, F., Heinke, C. O., & Grindlay, J. E. 2002, ''A Millisecond Pulsar Optical Counterpart with Large-Amplitude Variability in the Globular Cluster 47 Tucanae,'' ApJ, 579, 741

Edwards, S. A., Colless, M., Bridges, T. J., Carter, D., Mobasher, B., & Poggianti, B. M. 2002, ''Substructure in the Coma Cluster: Giants versus Dwarfs,'' ApJ, 567, 178

Fall, S. M. 2002, ''Dust Absorption and Emission in Galaxies at High and Low Redshifts,'' in Highlights of Astronomy, Vol. 12, ed. H. Rickman (San Francisco: ASP), 456

Fall, S. M. 2002, ''Formation of Galactic Disks,'' in The Dynamics, Structure and History of Galaxies, eds. G. S.

Da Costa & H. Jerjen (San Francisco: ASP), 289
Fall, S. M. 2002, ''Global Evolution of the Stars, Gas, Metals, and Dust in Galaxies,'' in Cosmic Chemical Evolution, IAU Symposium 187, eds. K. Nomoto & J. W. Truran (Dordrecht: Kluwer), 201
Fall, S. M. 2002, ''Origin of Galactic Disks,'' in Disks of Galaxies: Kinematics, Dynamics and Perturbations, eds. E. Athanassoula, A. Bosma, & R. Mujica (San Francisco: ASP), 389
Fall, S. M. & Zhang, Q. 2002, ''Formation and Disruption of Globular Star Clusters,'' in Extragalactic Star Clusters, IAU Symposium 207, eds. D. Geisler, E. K. Grebel, & D. Minniti (San Francisco: ASP), 566
Fall, S. M. & Zhang, Q. 2003, ''Formation and Dynamical Evolution of Star Cluster Systems,'' in New Horizons in Globular Cluster Astronomy, eds. G. Piotto, G. Meylan, S. G. Djorgovski, & M. Riello (San Francisco: ASP), 429
Fan, X., Narayanan, V. K., Strauss, M. A., Lupton, R. H., Becker, R. H., White, R. L., Pentericci, L., & Rix, H. 2002, ''$z \sim 6$ Quasars from the SDSS: Probing the End of the Dark Ages, in Lighthouses of the Universe: The Most Luminous Celestial Objects and Their Use for Cosmology, Proc. MPA/ESO, 309
Fan, X., Strauss, M. A., Schneider, D. P., Becker, R. H., White, R. L., et al. 2003, ''A Survey of $z > 5.7$ Quasars in the Sloan Digital Sky Survey. II. Discovery of Three Additional Quasars at $z > 6$,'' AJ, 125, 1649
Fang, T., Sembach, K. R., & Canizares, C. R. 2003, ''Chandra Detection of Local O VII He-α Absorption Along the Sight Line toward 3C 273,'' ApJ, 586, L49
Feinstein, C., Macchetto, F. D., Martel, A. R., & Sparks, W. B. 2002, ''Filaments and Ionized Gas in the Vicinity of 3C 244.1,'' ApJ, 565, 125
Ferguson, H. C. 2003, ''Stellar Population Challenges for the Next Decade,'' in Hubble's Science Legacy: Future Optical/Ultraviolet Astronomy from Space,'' eds, K. R. Sembach, J. C. Blades, G. D. Illingworth & R. C. Kennicutt, Jr. (San Francisco: ASP), 148
Ferguson, H. C., Dickinson, M. E., Gardner, J. P., Giavalisco, M., Kretchmer, C., Madau, P., Moustakas, L., Papovich, C., Spinrad, H., Stern, D., Idzi, R., & the GOODS Team 2002, ''The sizes of high-redshift galaxies in the Great Observatories Origins Deep Survey,'' BAAS, 34, 1154
Ferguson, H. C., Dickinson, M., Giavalisco, M., Kretchmer, C., Ravindranath, S., Idzi, R., Taylor, E., Conselice, C. J., Gardner, J. P., Fall, S. M., & 9 coauthors 2003, ''The Lyman-Break Galaxy Size-Redshift Relation,'' BAAS, 35, 723
Ferguson, H. C., Dickinson, M. E., & Papovich, C. 2002, ''Lyman Break Galaxies and the Reionization of the Intergalactic Medium,'' ApJ, 569, L65
Ferguson, H. C., Dickinson, M. E., & Papovich, C. 2003, ''Stellar Masses of High Redshift Galaxies,'' in The Mass of Galaxies at Low and High Redshift, (Garching: ESO), 344
Ferrari, F., Pastoriza, M. G., Macchetto, F. D., Bonatto, C., Panagia, N., & Sparks, W. B. 2002, ''Survey of the ISM in early-type galaxies. IV. The hot dust component,'' A&A, 389, 355
Figer, D. F. 2003, ''Massive Stars and The Creation of our Galactic Center,'' in A Massive Star Odyssey, from Main Sequence to Supernova, IAU Symposium 212, eds. K. A. van der Hucht, A. Herrero, & C. Esteban (San Francisco: ASP), 487
Figer, D. F. & Morris, M. 2002, ''Starburst Clusters in Galactic Nuclei,'' in Modes of Star Formation and the Origin of Field Populations, eds. E. K. Grebel & W. Brandner (San Francisco, ASP), 381
Figer, D. F., et al. 2002, ''Massive Stars in the Arches Cluster,'' ApJ, 581, 258
Figer, D. F., et al. 2003, ''Independent detector testing laboratory and the NGST detector characterization project,'' Proc. SPIE, 4850, 981
Firth, A. E., Lahav, O. & Somerville, R. S. 2003, ''Estimating photometric redshifts with artificial neural networks,'' MNRAS, 339, 1195
Fong, D., Justtanont, K., Meixner, M., & Campbell, M. T. 2002, ''Imaging the circumstellar envelope of OH 26.5 +0.6,'' A&A, 396, 581
Fong, D., Meixner, M., & Shah, R.Y. 2003, ''Discovery of Multiple Molecular Shells in the Outer Envelope of IRC +10216,'' ApJ, 582, L39
Ford, H. C., Clampin, M., Hartig, G. F., Illingworth, G. D., Sirianni, M., Martel, A. R., Meurer, G., McCann, W. J., Sullivan, P., Bartko, F., Benitez, N., Blakeslee, J., Bouwens, R., Broadhurst, T., Brown, R., Burrows, C., Campbell, D., Cheng, E., Feldman, P., Franx, M., Golimowski, D., Gronwall, C., Kimble, R., Krist, J., Lesser, M., Magee, D., Miley, G., Postman, M., Rafal, M., Rosati, P., Sparks, W., Tran, H., Tsvetanov, Z., Volmer, P., White, R., & Woodruff, R. 2003, ''Overview of the Advanced Camera for Surveys On-orbit Performance,'' Proc. SPIE, 4854, 81
Ford, H. C., Clampin, M., Illingworth, G. D., Krist, J. E., Olivier, S. S., Petro, L., & Sommargren, G. E. 2003, ''Requirements for an optical 8-m space telescope with a MEMs deformable mirror to detect Earth-like planets around nearby stars,'' in Future EUV/UV and Visible Space Astrophysics Missions and Instrumentation, ed. J. C. Blades & O. H. W. Siegmund, Proc. SPIE, 4854, 554
Ford, H. C., Petro, L. D., Burrows, C., Ftaclas, C., Roggemann, M. C., & Trauger, J. T. 2002, ''Artemis: a stratospheric planet finder,'' AdvSpRes, 30, 1283
Fox, A. J., Savage, B. D., Sembach, K. R., Fabian, D., Richter, P., Meyer, D. M., Lauroesch, J. T., & Howk, J. C. 2003, ''Origins of the Highly Ionized Gas along the Line of Sight Toward HD 116852,'' ApJ, 582, 793
Froning, C. S., Long, K. S., & Knigge, C. 2003, ''Accretion and Outflow in Interacting Binary Systems: Far Ultraviolet Spectroscopic Explorer Observations of the Nova-like Cataclysmic Variable UX Ursae Majoris,'' ApJ, 584, 433
Fynbo, J. P. U., Jakobsson, P., Mvller, P., Hjorth, J., Thomsen, B., Andersen, M. I., Fruchter, A. S., Gorosabel, J., Holland, S. T., Ledoux, C., Pedersen, H., Rhoads, J., Weidinger, M., & Wijers, R. A. M. J. 2003, ''On the Lyα

Emission from gamma-ray burst host galaxies: Evidence for Low Metallicities,'' A&A, 406, L63

Gabel, J. R., Crenshaw, D. M., Kraemer, S. B., Brandt, W. N., George, I. M., Hamann, F. W., Kaiser, M. E., Kaspi, S., Koratkar, A., Kriss, G. A., Mathur, S., Mushotzky, R. F., Nandra, K., Netzer, H., Peterson, B. M., Shields, J. C., Turner, T. J., & Zheng, W. 2003, ''The Ionized Gas and Nuclear Environment in NGC 3783. II. Time-Averaged HST/STIS and FUSE Spectra,'' ApJ, 583, 178

Galama, T. J., Reichart, D., Brown, T. M., Kimble, R. A., Price, P. A., Berger, E., Frail, D. A., Kulkarni, S. R., Yost, S. A., Gal-Yam, A., Bloom, J. S., Harrison, F. A., Sari, R., Fox, D., & Djorgovski, S. G. 2003, ''Hubble Space Telescope and Ground-Based Optical and Ultraviolet Observations of GRB 010222: A Hard Electron Index and Dust Destruction,'' ApJ, 587, 135

Gaudi, B. S., et al. 2002, ''Microlensing Constraints on the Frequency of Jupiter-Mass Companions: Analysis of Five Years of PLANET Photometry,'' ApJ, 566, 463

Geballe, T. R., Kim, S. J., Noll, K. S., & Griffith, C. A. 2003, ''High- Resolution 3 Micron Spectroscopy of Molecules in the Mesosphere and Troposphere of Titan,'' ApJ, 583, L39

Geha, M., Guhathakurta, P., & van der Marel, R. P. 2002, ''Internal dynamics, structure and formation of dwarf elliptical galaxies: I. A Keck/HST study of six Virgo cluster dwarfs,'' AJ, 124, 3073

Gerssen, J., van der Marel, R. P., Gebhardt, K., Guhathakurta, P., Peterson, R., & Pryor, C. 2002, ''Hubble Space Telescope evidence for an intermediate-mass black hole in the globular cluster M15—II. Kinematical analysis and dynamical modeling,'' AJ, 124, 3270

Gerssen, J., van der Marel, R. P., Gebhardt, K., Guhathakurta, P., Peterson, R., & Pryor, C. 2003, ''Addendum: Hubble Space Telescope evidence for an intermediate-mass black hole in the globular cluster M15—II. Kinematical analysis and dynamical modeling,'' AJ, 125, 376

Giavalisco, M., Dickinson, M., Ferguson, H., Kretchmer, C., Madau, P., Moustakas, L. A., Ravindranath, S., Spinrad, H., Stern, D., Gardner, J. P., Daddi, E., Cristiani, S., Da Costa, L., Arnouts, S., Vandame, B., & the GOODS Team 2002, ''The Clustering Properties of High-Redshift Galaxies in the GOODS,'' BAAS, 34, 1099

Giavalisco, M., Riess, A., Casertano, S., Dahlen, T., Dickinson, M., Ferguson, H., Hook, R., Idzi, R., Koekemoer, A., Mobasher, B., Moustakas, L. A., Ravindranath, S., Strolger, L., Tonry, J., & Challis, P. 2002, ''Supernovae 2002ez, 2002fv, 2002fw, 2002fx, 2002fy, 2002fz, 2002ga,'' IAUC 7981

Gizis, J. E., Reid, I. N., Knapp, G. R., Liebert, J., Kirkpatrick, J. D., Koerner, D. W., & Burgasser, A. J. 2003, ''Hubble Space Telescope Observations of Binary Very-Low-Mass Stars and Brown Dwarfs,'' AJ, 125, 3302

Gnedin, O. Y., Zhao, H., Pringle, J. E., Fall, S. M., Livio, M., & Meylan, G. 2002, ''The Unique History of the Globular Cluster Omega Centauri,'' ApJ, 568, L23

Gonzalez, R. A., Loinard, L., Allen, R. J., & Muller, S. 2003, ''The Opacity of Nearby Galaxies From Counts of Background Galaxies: II. Limits of the Synthetic Field Method,'' AJ, 125, 1182

González Delgado, R. M., Arribas, S., Pérez, E., Heckman, T. 2002, ''Is a Minor Merger Driving the Nuclear Activity in the Seyfert 2 Galaxy NGC 2110?'' ApJ, 579, 188

González Delgado, R. M., Leitherer, C., Stasinska, G., & Heckman, T. M. 2002, ''The massive stellar content in the starburst NGC 3049: a test for hot-star models,'' ApJ, 580, 824

Gorosabel, J., Christensen, L., Hjorth, J., Fynbo, J. U., Pedersen, H., Jensen, B. L., Andersen, M. I., Lund, N., Jaunsen, A. O., Castro Cersn, J. M., Castro-Tirado, A. J., Fruchter, A., Greiner, J., Pian, E., Vreeswijk, P. M., Burud, I., Frontera, F., Kaper, L., Klose, S., Kouveliotou, C., Masetti, N., Palazzi, E., Rhoads, J., Rol, E., Salamanca, I., Tanvir, N., Wijers, R. A. M. J., & van den Heuvel, E. 2003, ''A Multi-Color Study of the Dark GRB 000210 Host Galaxy and its Environment,'' A&A, 400, 127

Goudfrooij, P. 2002, ''3-Gyr-old Globular Clusters in the Merger Remnant NGC 1316: Implications for the Fate of Globular Clusters Formed During Gas-rich Galaxy Mergers,'' in IAU Symp. 207, Extragalactic Star Clusters, eds. E. Grebel, D. Geisler, & D. Minniti (San Francisco: ASP), 245

Greenfield, P., Miller, T., Hsu, J.-C., & White, R. L. 2002, ''An Array Module for Python,'' in ASP Conf. Ser., Vol. 281, Astronomical Data Analysis Software and Systems XI, eds. D. A. Bohlender, D. Durand, & T. H. Handley (San Francisco: ASP), 140

Gregg, M. D., Drinkwater, M. J., Hilker, M. J., Phillipps, S., Jones, J. B., & Ferguson, H. C., 2003, ''Galaxy Threshing and Ultra-Compact Dwarfs in the Fornax Cluster,'' Ap&SS, 285, 113

Griffin, I. 2003, ''The Hubble Space Telescope Education & Public Outreach Program'' in Communicating Astronomy (Dordrecht: Kluwer), 139

Griffin, R. G. & Suchkov, A. A. 2003, ''The nature of overluminous F stars observed in a radial-velocity survey,'' ApJS, 147, 103

Groves, B., Dopita, M. A., Williams, R. E., & Hua, C.-T. 2002, ''The Internal Extinction Curve of NGC 6302 and its Extraordinary Spectrum,'' PASA, 19, 425

Grumm, D. M. & Casertano, S. 2003, ''Self-calibration for the SIRTF GOODS Legacy Project,'' in Astronomical Data Analysis Software and Systems XII, eds. H. E. Payne, R. I. Jedrzejewski, & R. N. Hook (San Francisco: ASP), 199

Hall, P. B., et al. 2002, ''Unusual Broad Absorption Line Quasars from the Sloan Digital Sky Survey,'' ApJS, 141, 267

Hamilton, T. S., Casertano, S., & Turnshek, D. A. 2002, ''The Luminosity Function of QSO Host Galaxies,'' ApJ, 576, 61

Harris, D. E., Biretta, J. A., Junor, W., Perlman, E. S., Sparks, W. B., & Wilson, A. S. 2003, ''Flaring X-Ray Emission from HST-1, a Knot in the M87 Jet,'' ApJ, 586, L41

Hartig, G. F., Krist, J. E., Martel, A. R., Ford, H. C., & Illingworth, G. D. 2003, ''On-orbit Alignment and Imag-

ing Performance of the HST Advanced Camera for Surveys,'' Proc. SPIE, 4854, 532

Hebrard, G., et al. 2002, ''The Deuterium-to-Oxygen Ratio in the Local Interstellar Medium from FUSE Observations,'' Planetary & Space Science, 50, 1169

Heckman, T. M., Norman, C. A., Strickland, D. K., & Sembach, K. R. 2002, ''On the Physical Origin of O VI Absorption-Line Systems,'' ApJ, 577, 691

Helfer, T. T., Thornley, M. D., Regan, M. W., Wong, T., Sheth, K., Vogel, S. N., Blitz, L., & Bock, D. C.-J. 2003, ''The BIMA Survey of Nearby Galaxies (BIMA SONG). II. The CO Data,'' ApJS, 145, 259

Hempel, M., Hilker, M., Kissler-Patig, M., Puzia, T. H., Goudfrooij, P., & Minniti, D. 2003, ''Extragalactic globular clusters in the near-infrared III. NGC 5846 and NGC 7192. Quantifying the age distribution of subpopulations,'' A&A, 405, 487

Heydari-Malayeri, M., Meynadier, F., & Walborn, N. R. 2003, ''Tight LMC Massive Star Clusters R127 and R128,'' A&A, 400, 923

Hill, R. J., Waczynski, A., Giavalisco, M., Johnson, S. D., Polidan, E., & Stiavelli, M. 2002, ''Strategies for Mitigating the Degradation of Charge Transfer Efficiency for the WFC3 CCDs,'' BAAS, 34, 1255

Hill, R. J., Waczynski, A., Wen, Y., Johnson, S. D., Polidan, E., Malumuth, E., & Robberto, M. 2003, ''Detailed Performance of IR Detectors for WFC3,'' BAAS, 35, 703

Hjalmarson, A., et al. 2003, ''Highlights from the first year of Odin observations,'' A&A, 402, L39

Hjorth, J., Sollerman, J., Moller, P., Fynbo, J. P. U., Woosley, S. E., Kouveliotou, C., Tanvir, N. R., Greiner, J., Andersen, M. I., Castro-Tirado, A. J., Castro Cersn, J. M., Fruchter, A. S., Gorosabel, J., Jakobsson, P., Kaper, L., Klose, S., Masetti, N., Pedersen, H., Pedersen, K., Pian, E., Palazzi, E., Rhoads, J. E., Rol, E., van den Heuvel, E. P. J., Vreeswijk, P. M., Watson, D., & Wijers, R. A. M. J. 2003, ''A Very Energetic Supernova Associated with the Gamma-ray Burst of 29 March 2003,'' Nature, 423, 847

Holwerda, B. W., Allen, R. J., & van der Kruit, P. C. 2002, ''Automating the Synthetic Field Method: Application to Sextans A,'' in The Dynamics, Structure, and History of Galaxies, eds. G. Da Costa & H. Jerjen (San Francisco: ASP), 337

Homer, L., Anderson, S. F., Wachter, S., & Margon, B. 2002, ''The Ultraviolet Spectrum of the Ultracompact X-Ray Binary 4U 1626–67,'' AJ, 124, 3348

Hoopes, C. G., Sembach, K. R., Hebrard, G., Moos, H. W., & Knauth, D. C. 2003, ''Deuterium Toward Two Milky Way Disk Stars: Probing Extended Sight Lines with the Far Ultraviolet Spectroscopic Explorer,'' ApJ, 586, 1094

Hopkins, A. M., Afonso, J., Chan, B., Cram, L. E., Georgakakis, A., & Mobasher, B. 2003, ''The Phoenix Deep Survey: The 1.4 GHz Microjansky Catalog,'' AJ, 125, 465

Horner, D. J. & Goudfrooij, P. 2002, ''Hot Gas Halos in Elliptical Galaxies with Large Scale Dust Lanes,'' BAAS, 34, 1311

Howk, J. C., Sembach, K. R., & Savage, B. D. 2003, ''Ionized Gas in the First 10 Kiloparsecs of the Galactic Halo,'' ApJ, 586, 249

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

Hujeirat, A., Camenzind, M., & Livio, M. 2002, ''Ion Dominated Plasma and the Origin of Jets in Quasars,'' A&A, 394, L9

Hunt, M. P., Steidel, C. C., Shapley, A. E., Adelberger, K. L., Pettini, M., Dickinson, M., Giavalisco, M., & Connolly, A. J. 2003, ''Faint Optically selected AGN at z = 3,'' in Active Galactic Nuclei: from Central Engine to Host Galaxy, eds. S. Collin, F. Combes, & I. Shlosman (San Francisco: ASP), 613

Hutchings, J. B., Frenette, D., Hanisch, R. J., Mo, J., Dumont, P. J., Redding, D. C., & Neff, S. G. 2002, ''Imaging of z $\sim$ 2 QSO host galaxies with the Hubble Space Telescope,'' AJ, 123, 2936

Inada, N., et al. 2003, ''SDSS J092455.87+021924.9: An Interesting Gravitationally Lensed Quasar from the Sloan Digital Sky Survey,'' AJ, 126, 666

Ioannou, Z., van Zyl, L., Naylor, T., Charles, P. A., Margon, B., Koch-Miramond, L., & Ilovaisky, S. 2003, ''Understanding the LMXB X2127+119 in M 15. II. The UV Data,'' A&A, 399, 211

Ivezic, Z., et al. 2002, ''Optical and Radio Properties of Extragalactic Sources Observed by the FIRST Survey and the Sloan Digital Sky Survey,'' AJ, 124, 2364

Jablonka, P., Gorgas, J., & Goudfrooij, P. 2002, ''Stellar Populations in Bulges of Spiral Galaxies,'' Ap&SS, 281, 367

Jackson, N., Beswick, R., Pedlar, A., Cole, G. H., Sparks, W. B., Leahy, J. P., Axon, D. J., & Holloway, A. J. 2003, ''Observations of the neutral gas and dust in the radio galaxy 3C 305,'' MNRAS, 338, 643

Jacoby, G. H., Feldmeier, J., Claver, C. F., Garnavich, P. M., Noriega- Crespo, A., Bond, H. E., & Quinn, J. 2002, ''Confirmation of SBS 1150+599A as an Extremely Metal-Poor Planetary Nebula,'' AJ, 124, 3340

Jedrich, N. M., Gregory, T., Zimbelman, D. F., Cheng, E. S., Petro, L., Cottingham, C., Buchko, M. M., Kaylor, M., & Dolan, F. X. 2002, ''Cryogenic cooling system for restoring IR science on the Hubble Space Telescope,'' in IR Space Telescopes and Instruments, ed. J. C. Mather, Proc. SPIE, 4850, 1058

Jenkins, E. B., Bowen, D. V., Tripp, T. M., Sembach, K. R., Leighly, K., Halpern, J. P., & Lauroesch, J. T. 2003, ''Absorption-Line Systems and Galaxies in Front of the Second Brightest Quasar, PHL 1811,'' AJ, 125, 2824

Jogee, S. 2002, ''Bar-Driven Galaxy Evolution,'' STScI Annual Report, 2002, 23

Jogee, S., Conselice, C., Ravindranath, S., Shlosman, I., Knapen, J. H., Mobasher, B. Koekemoer, A. M., Lucas, R. A., Laine, S. Hornschemeier, A., and the GOODS

Team 2002, ''Structure and Evolution of Disk Galaxies in the GOODS Fields,'' BAAS, 34, 1100

Jogee, S., Reddy, N., & Scoville, N. Z. 2002, ''IRAS 17208: An Advanced Merger with a Gas-Rich Starburst Evolving towards an Elliptical Galaxy?'' in Active Galactic Nuclei: from Central Engine to Host Galaxy, eds. S. Collin, F. Combes, & I. Shlosman (San Francisco: ASP), 513

Jogee, S., Shlosman, I., Englmaier, P., Knapen, J. H., Laine, S., Scoville, N. Z., & Wilson, C. D. 2002, ''Grand-Design Spiral Structure from 100 pc to 10 kpc Scales: Implications for Disk Evolution,'' in Disks of Galaxies: Kinematics, Dynamics, & Perturbations, eds. E. Athanassoula & A. Bosma (San Francisco: ASP), 27

Jogee, S., Shlosman, I., Englmaier, P., Knapen, J. H., Laine, S., Scoville, N. Z., & Wilson, C. D. 2003, ''Bar-Driven Disk Evolution: Grand-Design Nuclear Spirals,'' in Active Galactic Nuclei: from Central Engine to Host Galaxy, eds. S. Collin, F. Combes, & I. Shlosman (San Francisco: ASP), 437

Jogee, S., Shlosman, I., Laine, S., Englmaier, P., Scoville, N. Z., Knapen, J. H., & Wilson, C. D. 2002, ''Gas Dynamics in the Barred Spiral NGC 5248: Fueling a Circumnuclear Starburst Ring of Super Star Clusters,'' ApJ, 575, 156

Jurac, S., McGrath, M. A., Johnson, R. E., Richardson, J. D., Vasyliunas, V. M., & Eviatar, A. 2003, ''Saturn: Search for a Missing Water Source,'' GRL, 29, 25-1

Kane, S. R. & Sahu, K. C. 2003, ''Studying the Galactic Bulge through Spectroscopy of Microlensed Sources. II. Observations,'' ApJ, 582, 743

Kaper, L., et al. 2002, ''Gamma-ray bursts: the most powerful cosmic explosions,'' ESO Messenger, 109, 37

Kaspi, S., Brandt, W. N., George, I. M., Netzer, H., Crenshaw, D. M., Gabel, J. R., Hamann, F. W., Kaiser, M. E., Koratkar, A., Kraemer, S. B., Kriss, G. A., Mathur, S., Mushotzky, R. F., Nandra, K., Peterson, B. M., Shields, J. C., Turner, T. J., & Zheng, W. 2002, ''The Ionized Gas and Nuclear Environment in NGC 3783. I. Time-Averaged 900 ks Chandra Grating Spectroscopy,'' ApJ, 574, 643

Kennicutt, R. C. Jr., Armus, L., Bendo, G., Calzetti, D., Engelbracht, C. W., Gordon, K. D., Helou, G. X., Hollenback, D. J., Jarrett, T. H., Kewley, L., Leither, C., Li, A., Malhotra, S., Regan, M. W., Rieke, G. H., Rieke, M. J., Rousell, H., Smith, J. D., Thornley, M. D., & Walter, F. 2003, ''SINGS: The SIRTF Nearby Galaxies Survey,'' PASP, 115, 928

King, J. R., Villarreal, A. R., Soderblom, D. R., Gulliver, A. F., & Adelman, S. J. 2003, ''Stellar Kinematic Groups. II. A Re-Examination of the Membership, Activity, and Age of the Ursa Major Group'' AJ, 125, 1980

Klypin, A., Zhao, H.-S. & Somerville, R. S. 2002, ''LCDM-based Models for the Milky Way and M31. I. Dynamical Models,'' ApJ, 573, 597

Knauth, D. C., Howk, J. C., Sembach, K. R., Lauroesch, J. T., & Meyer, D. M. 2003, ''On the Origin of the High Ionization Intermediate Velocity Gas Toward HD 14434,'' ApJ, 592, 964

Knigge, C., Hynes, R. I., Steeghs, D., Long, K. S., Araujo-Betancor, S., & Marsh, T. R. 2002, ''Discovery of 15 Second Oscillations in Hubble Space Telescope Observations of WZ Sagittae following the 2001 Outburst,'' ApJ, 580, L151

Koekemoer, A. M., O'Dea, C. P., & Baum, S. A. 2003, ''Emission Line Properties of GPS/CSS Galaxies,'' PASA, 20, 147

Komiyama, Y., Sekiguchi, M., Kashikawa, N., Yagi, M., Doi, M., Iye, M., Okamura, S., Shimasaku, K., Yasuda, N., Mobasher, B., Carter, D., Poggianti, B. M., & Bridges, T. J. 2002, ''A Photometric and Spectroscopic Study of Dwarf and Giant Galaxies in the Coma Cluster. I. Wide-Area Photometric Survey: Observation and Data Analysis,'' ApJS, 138, 265

Kozhurina-Platais, V., Casertano, S., & Koekemoer, A. M. 2002, ''Toward a Multi-Wavelength Geometric Distortion Solution for WFPC2,'' in The 2002 HST Calibration Workshop: Hubble after the Installation of the ACS and the NICMOS Cooling System, eds. S. Arribas, A. Koekemoer, & B. Whitmore (Baltimore: STScI), 356

Kretchmer, C., Conselice, C., Dickinson, M., Ferguson, H., Gardner, J. P., Giavalisco, M., Madau, P., Moustakas, L. A., Papovich, C., Ravindranath, S., & 9 coauthors 2002, ''Lyman break galaxies in the Great Observatories Origins Deep Survey,'' BAAS, 34, 1100

Kriss, G. A., Blustin, A., Branduardi-Raymont, G., Green, R., Hutchings, J., Kaiser, M. E. 2003, ''Multi-wavelength studies of the Seyfert 1 galaxy NGC 7469. I—Far UV observations with FUSE,'' A&A, 403, 473

Krist, J., Hartig, G., Clampin, M., & Golimowski, D. 2003, ''The Advanced Camera for Surveys Coronagraph on the Hubble Space Telescope,'' Proc. SPIE, 4860, 20

Krist, J. E., Clampin, M., Petro, L., Woodruff, R. A., Ford, H. C., Illingworth, G. D., & Ftaclas, C. 2002, ''Jovian Planet Finder optical system,'' in High-Contrast Imaging for Exo-Planet Detection, ed. A. B. Schultz, Proc. SPIE, 4860, 288

Kulkarni, V. P. & Fall, S. M. 2002, ''Metallicity Evolution of Damped Lyman-α Galaxies,'' ApJ, 580, 732

Laidler, V. G. & White, R. L. 2003, ''Canaries in the Data Mine: Improving Trained Classifiers,'' Statistical Challenges in Astronomy, eds. E. D. Feigelson & G. J. Babu (Berlin: Springer-Verlag), 453

Laine, S., van der Marel, R. P., Lauer, T. R., Postman, M., O'Dea, C. P., & Owen, F. N. 2003, ''Hubble Space Telescope Imaging of Brightest Cluster Galaxies,'' AJ, 125, 478

Lattanzi, M. G., Casertano, S., Sozzetti, A., & Spagna, A. 2002, ''The GAIA Astrometric Survey of Extra-Solar Planets,'' in GAIA: A European Space Project,'' eds. O. Bienaymé & C. Turon (EDP Sciences), 207

Lauer, T. R., Gebhardt, K., Richstone, D., Tremaine, S., Bender, R., Bower, G., Dressler, A., Faber, S. M., Filippenko, A., Green, R., Grillmair, C., Ho, L., Kormendy, J., Magorrian, J., Pinkney, J., Laine, S., Postman, M., & van der Marel, R. P. 2002, ''Galaxies with a minimum in central stellar luminosity density,'' AJ, 124, 1975

Lehner, N., Fullerton, A.W., Massa, D., Sembach, K.R., & Zsargo, J. 2003, ''Far Ultraviolet Spectroscopic Explorer

Snapshot Survey of O VI Variability in the Winds of 66 OB-Type Stars,'' ApJ, 589, 526
Leitherer, C. 2002, ''Star formation in starbursts and active galactic nuclei,'' in The Central kpc of Starbursts and AGN, eds. J. H. Knapen, J. E. Beckman, I. Shlosman, & T. J. Mahoney (San Francisco: ASP), 457
Leitherer, C. 2003, ''Massive stellar populations in the infrared,'' in A Massive Star Odyssey, eds. K. A. van der Hucht, A. Herrero, & C. Esteban (San Francisco: ASP), 652
Leitherer, C. 2003, ''Starburst galaxies,'' in Star Formation through Time, eds. E. Perez, R. M. Gonzalez Delgado, & G. Tenorio-Tagle (San Francisco: ASP), 183
Leitherer, C., Calzetti, D., & Martins, L. P. 2002, ''Ultraviolet spectra of star forming galaxies with time dependent dust obscuration,'' ApJ, 574, 114
Liebert, J., Kirkpatrick, J. D., Cruz, K. L., Reid, I. N., Burgasser, A., Tinney, C. G., & Gizis, J. E. 2003, ''A Flaring L5 dwarf: The Nature of Hα emission in Very Low Mass (Sub)stellar Objects,'' AJ, 125, 343
Livio, M. 2002, ''The Golden Ratio and Aesthetics,'' Plus, 22
Livio, M. 2002, The Golden Ratio, the Story of Phi, the World's Most Astonishing Number (Doubleday Broadway)
Livio, M. 2003, ''Is God a Mathematician?'' Mercury, 32, 26
Livio, M. 2003, ''Searching for the Golden Ratio,'' Astronomy, 31, 52
Livio, M. 2003, ''Splendid Spirals,'' Science & Spirit, 14, 54
Livio, M. 2003, ''The Golden Number,'' Natural History, 112, 64
Livio, M., Noll, K., & Stiavelli, M. (eds.) 2003, A Decade of Hubble Space Telescope Science (Cambridge: Cambridge Univ. Press)
Livio, M., Panagia, N., Sahu, K. C. (eds.) 2002, Gamma Ray Bursts: the Biggest Explosions Since the Big Bang (Cambridge: Cambridge Univ. Press)
Livio, M., Riess, A., & Sparks, W. 2002, ''Will Jets Identify the Progenitors of Type Ia Supernovae?'' ApJ, 571, L99
Lloyd, J. P., Gavel, D. T., Graham, J. R., Hodge, P. E., Sivaramakrishnan, A., & Voit, G. M. 2003, ''Four-Quadrant Phase Mask Coronagraph: Analytical Calculation and Pupil Geometry,'' Proc. SPIE, 4860, 171
Long, K. S., Froning, C. S., Gaensicke, B., Knigge, C., Sion, E. M., & Szkody, P. 2003, ''WZ Sagittae: FUSE Spectroscopy of the 2001 Outburst,'' ApJ, 591, 1172
Long, K. S., Reynolds, S. P., Raymond, J. C., Winkler, P. F., Dyer, K. K., & Petre, R. 2003, ''Chandra CCD Imagery of the Northeast and Northwest Limbs of SN 1006,'' ApJ, 586, 1162
Lowrance, P. J., Kirkpatrick, J. D., Reid, I. N., & Cruz, K. L. 2003, ''The Discovery of Two Nearby Carbon Dwarfs,'' ApJ, 584, L95
Lu, N., Helou, G., Werner, M. W., Dinerstein, H. L., Dale, D. A., Silbermann, N. A., Malhotra, S., Beichman, C. A., & Jarrett, T. H. 2003, ''Infrared Emission of Normal Galaxies from 2.5 to 12 Microns: Infrared Space Observatory Spectra, Near-Infrared Continuum, and Mid-Infrared Emission Features,'' ApJ, 588, 199
Lucas, R. A., Baum, S. A., Brown, T. M., Casertano, S., Conselice, C., de Mello, D., Dickinson, M. E., Ferguson, H. C., Fruchter, A. S., Gardner, J. P., Gilmore, D., Gonzalez-Lopezlira, R., Heyer, I., Hook, R. N., Kaiser, M. E., Mack, J., Makidon, R., Martin, C. L., Mutchler, M., Smith, T. E., Stiavelli, M., Teplitz, H. I., Wiggs, M. S., Williams, R. E., & Zurek, D. 2003, ''The Hubble Deep Field South Flanking Fields,'' AJ, 125, 398
Lucas, R. A, Conselice, C. J., Chatzichristou, E., Dahlen, T., de Mello, D., Gardner, J. P., Giavalisco, M., Grogin, N. A., Hornschemeier, A., Jogee, S., Koekemoer, A. M., Mobasher, B., Ravindranath, S., Urry, C. M., and the GOODS Team 2002, ''Normal Galaxies and Mergers: The Morphological Mix of Galaxies,'' BAAS, 34, 1100
MacKenty, J. W., Greenhouse, M. A., Green, R. F., Sparr, L., Ohl, R. G., & Winsor, R. S. 2003, ''IRMOS: an infrared multi-object spectrometer using a MEMS micromirror array'' in Instrument Design and Performance for Optical/Infrared Ground-based Telescopes, eds. M. Iye & A. F. M. Moorwood, Proc. SPIE, 4841, 953
Maíz-Apellániz, J. 2002, ''Photometry of saturated stars in CCD images,'' in 2002 HST Calibration Workshop, eds. S. Arribas, A. Koekemoer, & B. Whitmore (Baltimore: STScI), 346
Maíz-Apellániz, J. 2002, ''The Size Distribution of Massive Young Clusters,'' in Extragalactic Star Clusters, IAU Symposium 207, eds. E. Grebel, D. Geisler, & D. Minniti (San Francisco: ASP), 697
Maíz-Apellániz, J. & Walborn, N. R. 2003, ''A spectroscopic, photometric, and astrometric Galactic O-type star database,'' in A Massive Star Odyssey, from Main Sequence to Supernova, IAU Symposium 212, eds. K. A. van der Hucht, A. Herreo, & C. Esteban (San Francisco: ASP), 560
Maíz-Apellániz, J., Walborn, N. R., & Barbá, R. H. 2002, ''An HST View of 30 Doradus,'' in Extragalactic Star Clusters, IAU Symposium 207, eds. E. Grebel, D. Geisler, & D. Minniti (San Francisco: ASP), 691
Maíz-Apellániz, J., Walborn, N. R., MacKenty, J. W., Norman, C. A., Pérez, E., & Mas-Hesse, J. M. 2002, ''Objective-prism spectroscopy with STIS-HST,'' in Galaxies, the Third Dimension, eds. M. Rosado, L. Binette, & L. Arias (San Francisco: ASP), 43
Makidon, R. B., Sivaramakrishnan, A., Roberts, L. C., Jr., Oppenheimer, B. R., & Graham, J. R. 2003, ''Waffle Mode Error in the AEOS Adaptive Optics Point-Spread Function,'' Proc. SPIE, 4860, 315
Malhotra, S., Wang, J. X., Rhoads, J. E., Heckman, T. M., & Norman, C. A. 2003, ''No X-Ray-bright Type II Quasars among the Lyman-α Emitters,'' ApJ, 585, L25
Maller, A. H., Prochaska, J. X., Somerville, R. S., & Primack, J. R. 2003, ''Damped Lyman α systems and galaxy formation models—II. High ions and Lyman-limit systems,'' MNRAS, 343, 268
Marconi, A., Axon, D. J., Capetti, A., Maciejewski, W., Atkinson, J., Batcheldor, D., Binney, J. J., Carollo, C. M., Dressel, L., Ford, H., Gerseen, J., Hughes, M. A., Mac-

chetto, D., Maciejewski, W., Marconi, A., Merrifield, M., Ruiz, M. Sparks, W., Stiavelli, M., Tsevetanov, Z., & van der Marel, R. P. 2003, ''Is there really a black hole in the center of NGC 4041? Constraints from gas kinematics,'' ApJ, 586, 868

Margon, B., Anderson, S. F., Harris, H. C., Strauss, M. A., Knapp, G. R., Fan, X., Schneider, D. P., Vanden Berk, D. E., Schlegel, D. J., et al. 2002, ''Faint High-Latitude Carbon Stars Discovered by the Sloan Digital Sky Survey: Methods and Initial Results,'' AJ, 124, 1651

Martel, A. R., Ford, H. C., Tran, H. D., Illingworth, G. D., Krist, J. E., White, R. L., Sparks, W. B., Gronwall, C., Cross, N. J., Hartig, G. F., Clampin, M., Ardila, D. R., Bartko, F., Benitez, N., Blakeslee, J. P., Bouwens, R. J., Broadhurst, T. J., Brown, R. A., Burrows, C. J., Cheng, E. S., Feldman, P. D., Franx, M., Golimowski, D. A., Infante, L., Kimble, R. A., Lesser, M. P., McCann, W. J., Menanteau, F., Meurer, G. R., Miley, G. K., Postman, M., Rosati, P., Sirianni, M., Tsvetanov, Z. I., & Zheng, W. 2003, ''Coronagraphic Imaging of 3C 273 with the Advanced Camera for Surveys,'' AJ, 125, 2964

Martel, A. R., Sparks, W. B., Allen, M. G., Koekemoer, A. M., & Baum, S. A. 2002, ''Discovery of a Star Formation Region in Abell 2052,'' AJ, 123, 1357

Martini, P., Mulchaey, J. S., Regan, M. W., & Pogge, R. W. 2003, ''Circumnuclear Dust in Active and Inactive Galaxies: Implications for the fueling and lifetime of AGN,'' in Active Galactic Nuclei: From Central Engine to Host Galaxy, ASP Conf. Ser. 290, eds. S. Collin, F. Combes, & I. Shlosman, (San Francisco: ASP), 533

Martini, P., Regan, M. W., Mulchaey, J. S., & Pogge, R. W. 2002, ''Circumnuclear Dust in Nearby Active and Inactive Galaxies. II. Bars, Nuclear Spirals and the Fueling of Active Galactic Nuclei,'' ApJ, 589, 774

Martini, P., Regan, M. W., Mulchaey, J. S., & Pogge, R. W. 2003, ''Circumnuclear Dust in Nearby Active and Inactive Galaxies. I. Data,'' ApJS, 146, 353

Masetti, N., Palazzi, E., Pian, E., Simoncelli, A., Hunt, L. K., Maiorano, E., Levan, A., Christensen, L., Rol, E., Savaglio, S., Falomo, R., Castro-Tirado, A. J., Hjorth, J., Delsanti, A., Pannella, M., Mohan, V., Pandey, S. B., Sagar, R., Amati, L., Burud, I., Castro Cersn, J. M., Frontera, F., Fruchter, A. S., Fynbo, J. P. U., Gorosabel, J., Kaper, L., Klose, S., Kouveliotou, C., Nicastro, L., Pedersen, H., Rhoads, J., Salamanca, I., Tanvir, N., Vreeswijk, P. M., Wijers, R. A. M. J., & van den Heuvel, E. P. J. 2003, ''Optical and Near-infrared Observations of the GRB020405 Afterglow,'' A&A, 404, 465

McCullough, P. R. 2003, ''Photometric and Astrometric Calibration of the Southern H-α Sky Survey Atlas,'' in Astronomical Data Analysis Software and Systems, eds. H. E. Payne, R. I. Jedrzejewski, & R. N. Hook (San Francisco: ASP), 121

McCullough, P. R., Fields, Brian D., & Pavlidou, V. 2002, ''Discovery of an Old, Nearby, and Overlooked Supernova Remnant Centered on the Southern Constellation Antlia Pneumatica,'' ApJ, 576, L41

McDowell, J. C., Clements, D. L., Lamb, S. A., Shaked, S., Hearn, N. C., Colina, L., Mundell, C., Borne, K., Baker, A. C., & Arribas, S. 2003, ''Chandra Observations of Extended X-Ray Emission in Arp 220, ApJ, 591, 154

McGlynn, T., et al. 2002, ''Classifying the High Energy Universe with ClassX,'' Proc. SPIE, 4846, 43

McGlynn, T., et al. 2002, ''ClassX: Prototyping the Virtual Observatory with an X-ray Classifier,'' in ASP Conf. Ser., Vol. 281, Astronomical Data Analysis Software and Systems XI, eds. D. A. Bohlender, D. Durand, & T. H. Handley (San Francisco: ASP), 50

McGrath, M. A., Lellouch, E., Strobel, D. F., Feldman, P. D., & Johnson, R. E. 2003, ''Satellite Atmospheres,'' in Jupiter: Planet, Satellites, Magnetosphere, eds. F. Bagenal & T. Dowling (Cambridge: CUP), Chapter 19

McMahon, R. G., White, R. L., Helfand, D. J., & Becker, R. H. 2002, ''Optical Counterparts for 70,000 Radio Sources: APM Identifications for the FIRST Radio Survey,'' ApJS, 143, 1

Meixner, M. 2002, ''IR and Molecular Outflows in Axisymmetric Proto-Planetary Nebulae,'' BAAS, 34, 1142

Meixner, M., Ueta, T., Bobrowsky, M., & Speck, A. K. 2002, ''Two Subclasses of Proto-Planetary Nebulae: Model Calculations,'' ApJ, 571, 936

Meurer, G. R., Lindler, D., Blakeslee, J. P., Cox, C., Martel, A. R., Tran, H. D., Bouwens, R. J., Ford, H. C., Clampin, M., Hartig, G. F., Sirianni, M., & DeMarchi, G. 2003, ''Calibration of Geometric Distortion in the ACS Detectors,'' Proc. SPIE, 4854, 507

Mobasher, B., Colless, M., Carter, D., Poggianti, B., Bridges, T. J., Kranz, K., Komiyama, Y., Kashikawa, N., Yagi, M. & Okamura, S. 2003, ''A Photometric and Spectroscopic Study of Dwarf and Giant Galaxies in the Coma Cluster. IV. The Luminosity Function,'' ApJ, 587, 605

Moller, P., Warren, S. J., Fall, S. M., Flynbo, J. U., & Jakobsen, P. 2002, ''Are High-Redshift Damped Lyman-α Galaxies Lyman-Break Galaxies?'' ApJ, 574, 51

Monet, D. G., et al. 2003, ''The USNO-B Catalog,'' AJ, 125, 984

Morgan, N. D., Gregg, M. D., Wisotzki, L., Becker, R. H., Maza, J., Schechter, P. L., & White, R. L. 2003, ''CTQ 327: A New Gravitational Lens,'' AJ, 126, 696

Motta, V., Mediavilla, E., Muñoz, J. A., Falco, E., Kochanek, C. S., Arribas, S., García-Lorenzo, B., Oscoz, A., Serra-Ricart, M. 2002, ''Detection of the 2175 Å Extinction Feature at z = 0.83,'' ApJ, 574, 719

Mouhcine, M., Lançon, A., Leitherer, C., Silva, D., & Groenewegen, M. A. T. 2002, ''First spectroscopic evidence for carbon stars outside the Local Group,'' A&A, 303, 101

Moustakas, L. A. & Somerville, R. S. 2002, ''The Masses, Ancestors, and Descendants of Extremely Red Objects: Constraints from Spatial Clustering,'' ApJ, 577, 1

Nelan, E. & Makidon, R. 2002, ''Optical Interferometry with HST FGS at V > 15,'' Proc. SPIE, 4853, 230

Noll, K., Stephens, D., Grundy, W., Cruikshank, D., Tegler, S., & Romanishin, W. 2002, ''2001 QC_298,'' IAUC 8034

Noll, K., Stephens, D., Grundy, W., Millis, R., Buie, M., Spencer, J., Tegler, S., Romanishin, W., & Cruikshank, D. 2002, ''Discovery of Trans- Neptunian Binaries with

the Hubble Space Telescope,'' BAAS, 34, 849
Noll, K., Stephens, D., Grundy, W., Spencer, J., Millis, R., Buie, M., Cruikshank, D., Tegler, S., & Romanishin, W. 2002, ''1997 CQ_29,'' IAUC 7959
Noll, K. S., Stephens, D. C., Cruikshank, D., Grundy, W., Romanishin, W., & Tegler, S. 2003, ''1999 RZ_253,'' IAUC 8143
Noll, K. S., Stephens, D. C., Grundy, W. M., Millis, R. L., Spencer, J., Buie, M. W., Tegler, S. C., Romanishin, W., & Cruikshank, D.P. 2002, ''Detection of Two Binary Trans-Neptunian Objects, 1997 CQ29 and 2000 CF105, with the Hubble Space Telescope,'' AJ, 124, 3424
O'Dea, C. P., De Vries, W. H., Koekemoer, A. M., Baum, S. A., Axon, D. J., Barthel, P. D., Capetti, A., Fanti, R., Gelderman, R., Morganti, R., & Tadhunter, C. 2003, ''Jet-Cloud Interactions in Compact Steep Spectrum Radio Sources,'' PASA, 20, 88
Ogilvie, G. I. & Lubow, S. H. 2003, ''Saturation of the Corotation Resonance in a Gaseous Disk,'' ApJ, 587, 398
O'Hara, T. B., Meixner, M., Speck, A. K., Ueta, T., & Bobrowsky, M. 2002, ''The Dust Ring of LBV Candidate HD 168625,'' BAAS, 34, 1185
Ohl, R. G., Preuss, W., Sohn, A., Conkey, S. B., Garrard, K., Hagopian, J. G., Howard, J. M., Hylan, J., Irish, S. M., Mentzell, J. E., Schroeder, M., Sparr, L., Winsor, R. S., Zewari, S. W., Greenhouse, M. A., & MacKenty, J. W. 2003, ''Design and fabrication of diamond machined, aspheric mirrors for ground-based, near-IR astronomy,'' in Instrument Design and Performance for Optical/Infrared Ground-based Telescopes, eds. M. Iye & A. F. M. Moorwood, Proc. SPIE, 4841, 677
Oka, T., Thorburn, J. A., McCall, B. J., Friedman, S. D., Hobbs, L. M., Sonnentrucker, P., Welty, D. E., & York, D. G. 2003, ''Observations of C3 in Translucent Sight Lines,'' ApJ, 582, 823
Oppenheimer, B. R., Sivaramakrishnan, A. & Makidon, R. B. 2003, ''Imaging Exoplanets: The Role of Small Telescopes'' in The Future of Small Telescopes, ed. T. Oswalt (Kluwer, Dordrecht), 155
Otte, B., Murphy, E. M., Howk, J. C., Wang, Q. D., Oegerle, W. R., & Sembach, K. R. 2003, ''Probing O VI Emission in the Halos of Edge-on Spiral Galaxies,'' ApJ, 591, 821
Pagani, L., et al. 2003, ''Low upper limits on the O_2 abundance from the Odin satellite,'' A&A, 402, L77
Pain, R., Fabbro, S., Sullivan, M., Ellis, R. S., Aldering, G., Astier, P., Deustua, S. E., Fruchter, A. S., Goldhaber, G., Goobar, A., Groom, D. E., Hardin, D., Hook, I. M., Howell, D. A., Irwin, M. J., Kim, A. G., Kim, M. Y., Knop, R. A., Lee, J. C., Lidman, C., McMahon, R. G., Nugent, P. E., Panagia, N., Pennypacker, C. R., Perlmutter, S., Ruiz-Lapuente, P., Schahmaneche, K., Schaefer, B., & Walton, N. A. 2002, ''The Distant Type Ia Supernova Rate,'' ApJ, 577, 120
Palma, C., Majewski, S. R., Siegel, M. H., Patterson, R. J., Ostheimer, J. C. & Link, R. P. 2003, ''Exploring Halo Substructure with Giant Stars IV: The Extended Structure of the Ursa Minor Dwarf Spheroidal,'' AJ, 125, 1352
Papovich, C., Dickinson, M. E., & Ferguson, H. C. 2003, ''Stellar Masses of High Redshift Galaxies,'' in The Mass of Galaxies at Low and High Redshift (Garching: ESO), 296
Park, Y. & Ferguson, H. C. 2003, ''Gravitational Lensing by Burkert Halos,'' ApJ, 589, L65
Pellerin, A., Fullerton, A. W., Robert, C., Howk, J. C., Hutchings, J. B., Walborn, N. R., Bianchi, L., Crowther, P. A., & Sonneborn, G. 2002, ''An Atlas of Galactic OB Spectra Observed with the Far Ultraviolet Spectroscopic Explorer,'' ApJS, 143, 159
Peng, E. W., Ford, H. C., Freeman, K. C., & White, R. L. 2003, ''A Young Blue Tidal Stream in NGC 5128,'' AJ, 124, 3144
Petrosian, A., Allen, R. J., Leitherer, C., MacKenty, J. W., Panagia, N., & McLean, B. 2003, ''Studies of the Second Byurakan Survey Galaxies: II. Comparison of UV-Excess and Emission-Line Techniques,'' AJ, 125, 86
Pizzella, A., Corsini, E. M., Morelli, L., Sarzi, M., Scarlata, C., Stiavelli, M., & Bertola, F. 2002, ''Nuclear disks in spiral galaxies,'' ApJ, 573, 131
Pooley, D., Lewin, W. H. G., Verbunt, F., Homer, L., Margon, B., Gaensler, B. M., Kaspi, V. M., Miller, J. M., Fox, D. W., & van der Klis, M. 2002, ''Chandra Observation of the Globular Cluster NGC 6440 and the Nature of Cluster X-Ray Luminosity Functions,'' ApJ, 573, 184
Primack, J. R., Wechsler, R. H., & Somerville, R. S. 2003, ''The Masses of Lyman Break Galaxies,'' in The Mass of Galaxies at Low and High Redshift, eds. R. Bender & A. Renzini (ESO Astrophysics Symposia, Springer-Verlag), 284
Prinja, R. K., Long, K. S., Froning, C. S., Knigge, C., Witherick, D. K., Clark, J. S., & Ringwald, F. A. 2003, ''FUSE and HST ultraviolet observations of the disc wind of RW Sextantis,'' MNRAS, 340, 551
Proffitt, C. R., Goudfrooij, P., Sahu, K., et al. 2002, ''STIS Calibration Status,'' in 2002 HST Calibration Workshop, eds. S. Arribas, A. Koekemoer & B. Whitmore (Baltimore: STScI), 97
Puzia, T. H., Zepf, S. E., Kissler-Patig, M., Goudfrooij, P., Hilker, M., & Minniti, D. 2002, ''Extragalactic Globular Clusters in the Near-Infrared. II. The Globular Cluster Systems of NGC 3115 and NGC 4365,'' A&A, 391, 453
Rachford, B. L., et al. 2002, ''A FUSE Survey of Interstellar Molecular Hydrogen in Translucent Clouds,'' ApJ, 577, 221
Raimann, D., Storchi-Bergmann, T., González Delgado, R. M., Cid Fernandes, R., Heckman, T., Leitherer, C., & Schmitt, H. 2003, ''Stellar population gradients in Seyfert 2 galaxies: northern sample,'' MNRAS, 339, 772
Rajagopal, J., Boeker, T., Allen, R. J., & Carpenter, K. G. 2003, ''Simulating Dilute-Aperture Imaging: The Stellar Imager,'' in Astronomical Telescopes and Instrumentation: Interferometry in Space, ed. M. Shao, Proc. SPIE, 4852, 652
Rauscher, B. J., et al. 2003, ''Ultra-Low Background Operation of Near-Infrared Detectors Using Reference Pixels for NGST,'' Proc. SPIE, 4850, 962
Ravindranath, S., Conselice, C., Chatzichristou, E., de Mello, D., Ferguson, H. C., Gardner, J. P., Giavalisco, M., Grogin, N. A., Hornschemeier, A., Jogee, S., et al. 2003,

''Evolution of Structural Parameters of Galaxies in the GOODS-South field,'' BAAS, 34, 1099

Regan, M. W. 2002, ''Gas Kinematics in Spiral and Barred Galaxies,'' in Disks of Galaxies: Kinematics, Dynamics and Peturbations, ASP Conf. Ser. 275, eds. E. Athanassoula, A. Bosma, & R. Mujica (San Francisco: ASP), 201

Regan, M. W. & Teuben, P. J. 2003, ''The Formation of Nuclear Rings in Barred Spiral Galaxies,'' ApJ, 582, 723

Reid, I. N. 2003, ''Activity and Kinematics of members of the TW Hydrae Association,'' MNRAS, 342, 837

Reid, I. N., Cruz, K. L., Laurie, S. P., Dahn, C. C., Harris, H. C., Guetter, H. H., Stone, R. C., Canzian, B., Luginbuhl, C. B., Levine, S. E., Monet, A. K. B. & Monet, D. G. 2003, ''Meeting the Cool Neighbors, IV: 2M1835+32, a newly-discovered M8.5 dwarf within 6 parsecs of the Sun,'' AJ, 125, 354

Reid, I. N., Gizis, J. E., & Hawley, S. L. 2002, ''The Palomar/MSU Nearby Star Spectroscopic Survey IV: The Luminosity Function in the Solar Neighborhood and M Dwarf Kinematics,'' AJ, 124, 2721

Reid, I. N. & Hawley, S. L. 2003, ''Recent advances in understanding star and planet formation,'' Astrophysics Update, 1, 1

Reid, I. N., Kirkpatrick, J. D., Liebert, J., Gizis, J. E., Dahn, C. C., & Monet, D. G. 2002, ''High resolution spectroscopy of ultracool M dwarfs,'' AJ, 124, 519

Rhoads, J. E. 2003, ''Dirty Fireballs and Orphan Afterglows: A Tale of Two Transients,'' ApJ, 591, 1097

Rhoads, J. E., Dey, A., Malhotra, S., Stern, D., Spinrad, H., Jannuzi, B. T., Dawson, S., Brown, M. J. I., & Landes, E. 2003, ''Spectroscopic Confirmation of Three Redshift z = 5.7 Lyman-α Emitters from the Large-Area Lyman α Survey,'' AJ, 125, 1006

Richter, P., Sembach, K. R., & Howk, J. C. 2003, ''H_2 Absorption in a Dense Interstellar Filament in the Milky Way Halo,'' A&A, 405, 1013

Richter, P., Wakker, B. P., Savage, B. D., & Sembach, K. R. 2003, ''A Far Ultraviolet Spectroscopic Explorer Survey of Molecular Hydrogen in Intermediate Velocity Clouds in the Milky Way Halo,'' ApJ, 526, 230

Robberto, M. 2003, ''Infrared Astronomy with the Hubble Space Telescope and the Next Generation Space Telescope,'' Memorie Soc. Astr. It., 74, 230

Robberto, M. 2003, various portions of The design and construction of large optical telescopes, ed. P. Y. Bely (Heidelberg: Springer)

Robberto, M., Baggett, S. M., Hanley, C., Hilbert, B., MacKenty, J. W., Cheng, E. S., Hill, R. J., Johnson, S. D., Malumuth, E. M., Polidan, E., Waczynski, A., Wen, Y., Haas, A, Montroy, J. T., Piquette, E., Vural, K., & Hall, D. N. B. 2002, ''Infrared Detectors for WFC3 on the Hubble Space Telescope,'' Proc. SPIE, 4850, 121

Robberto, M., Baggett, S. M., Hilbert, B. N., MacKenty, J. W., Stiavelli, M., Hill, R. J., Waczynski, A., Wen, Y., Johnson, S. D., Polidan, E., Malumuth, E., & Kimble, R. A. 2003, ''Performance of the FC3-IR flight detectors,'' BAAS, 35, 703

Robberto, M., Baggett, S. M., Hilbert, B., MacKenty, J. W., Stiavelli, M., Kimble, R. A., Hill, R. J., Cottingham, D. A., Delo, G., Johnson, S. D., Landsmanm, E. M., Malumuth, E. M., Polidan, E., Russel, A. M., Waczynski, A., Wen, Y., Haas, A., Montroy, J. T., Piquette, E., Vural, K., Cabelli, C., & Hall, D. N. B. 2003, ''Selection of the Infrared Detectors for Wide Field Camera 3 on the Hubble Space Telescope,'' Proc. SPIE, 5167, 19

Robberto, M., Beckwith, S. V. W., & Panagia, N. 2002, ''The Infrared Emission of Circumstellar Envelopes, Dark Silhouettes, and Photoionized Disks in H II Regions,'' ApJ, 578, 897

Robert, C., Pellerin, A., Aloisi, A., Leitherer, C., Hoopes, C., & Heckman, T. M. 2003, ''Synthetic high-resolution line spectra of star-forming galaxies below 1200 Å,'' ApJS, 144, 21

Rodriguez, L. F., Goss, W. M., & Williams, R. 2002, ''VLA Observations of H I in the Helix Nebula (NGC 7293),'' ApJ, 574, 179

Rol, E., Wijers, R. A. M. J., Fynbo, J. P. U., Hjorth, J., Gorosabel, J., Egholm, M. P., Castro Cersn, J. M., Castro-Tirado, A. J., Kaper, L., Masetti, N., Palazzi, E., Pian, E., Tanvir, N., Vreeswijk, P., Kouveliotou, C., Miller, P., Pedersen, H., Fruchter, A. S., Rhoads, J., Burud, I., Salamanca, I. & van den Heuvel, E. P. J. 2003, ''Variable Polarization in the Optical Afterglow of GRB 021004,'' A&A, 405, L23

Romanishin, W., Tegler, S., Noll, K., Stephens, D., Grundy, W., Spencer, J., Millis, R., Buie, M., & Cruikshank, D. 2002, ''2000 CF_105,'' IAUC 7962

Sahai, R., Brillant, S., Livio, M., Grebel, E. K., Brander, W., Tingay, S., & Nyman, L.-A. 2002, ''Proper Motions in the Knotty Bipolar Jet in Hen 2–90,'' ApJ, 573, L123

Sahu, K. C. 2002, ''Gravity's Lens,'' STScI Newsletter, winter 2003 issue

Sahu, K. C., Anderson, J., & King, I. R. 2002, ''A Re-examination of the 'Planetary' Lensing Events in M22,'' ApJ, 565, L21

Sahu, K., Fruchter, A., Burud, I., & Sembach, K. 2002, ''GRB 021004: HST/STIS spectroscopic observations,'' GCN, 1608, 1

Sahu, K. C. & Gilliland, R. L. 2003, ''Near-Field Microlensing and Its Effects on Stellar Transit Observations by the Kepler Mission,'' ApJ, 584, 1042

Savage, B. D., Sembach, K. R., Wakker, & B. P., et al. 2003, ''Distribution and Kinematics of O VI in the Galactic Halo,'' ApJS, 146, 125

Savaglio, S., Fall, S. M., & Fiore, F. 2003, ''Heavy-Element Abundances and Dust Depletions in the Host Galaxies of Three Gamma-Ray Bursts,'' ApJ, 585, 638

Schmidt, R. W., et al. 2002, ''Optical monitoring of the gravitationally lensed quasar Q2237+0305 from APO between June 1995 and January 1998,'' A&A, 392, 773

Schuler, S. C., King, J. R., Soderblom, D. R., Fischer, D., & Jones, B. F. 2003, ''Spectroscopic Abundances of Solar-Type Dwarfs in the Open Cluster M34 (NGC 1039)'' AJ, 125, 2085

Schultz, A. B., Calzetti, D., Arribas, S., Bergeron, L. E., Böker, T., Dickinson, M., Malhotra, S., Mobasher, B., Noll, K., Roye, E., Sosey, M., Wiklind, T., & Xu, C.

2003, ''On-orbit Performance of NICMOS,'' BAAS, 35, 703

Schultz, A.B., et al. 2003, ''Post-NCS Performance of the HST NICMOS,'' Proc. SPIE, 4850, 858

Sembach, K. R., Blades, J. C., Illingworth, G. D., & Kennicutt, R. C. (eds.) 2003, Hubble's Science Legacy: Future Optical/Ultraviolet Astronomy from Space (San Francisco: ASP)

Sembach, K. R., Wakker, B. P., & Savage, B. D., et al. 2003, ''Highly Ionized High Velocity Clouds in the Vicinity of the Galaxy,'' ApJS, 146, 165

Sharma, U., et al. 2003, ''Intra-pixel sensitivity in NIR detectors for NGST,'' Proc. SPIE, 4850, 1001

Sheth, K, Regan, M. W., Scoville, N. Z., & Strubbe, L. E. 2003, ''Barred Spirals at z $>$ 0.7: NICMOS Hubble Deep Field-North Observations,'' ApJ, 592, L13

Sheth, K., Vogel, S. N., Regan, M. W., Teuben, P. J., & Harris, A. I. 2002, ''Molecular Gas and Star Formation in Bars of Nearby Spiral Galaxies,'' AJ, 124, 2581

Sheth, K., Vogel, S. N., Teuben, P. J., Harris, A. I., Regan, M. W., Thornley, M. D., & Helfer, T. T. 2002, ''Comparing Molecular Gas and Star Formation Properties in the Central Regions of Barred and Unbarred Spirals,'' in Disks of Galaxies: Kinematics, Dynamics and Perturbations, ASP Conf. Ser. 275, eds. E. Athanassoula, A. Bosma, & R. Mujica (San Francisco: ASP), 263

Shore, S. N., et al. 2003, ''The Early Ultraviolet Evolution of the ONeMg Nova V382 Velorum 1999,'' AJ, 125, 1507

Siegel, M. H. & Bond, H. E. 2002, ''Post-Asymptotic Giant Branch Stars in the Local Group,'' BAAS, 34, 1304

Siegel, M. H., Majewski, S. R., Reid, I. N. & Thompson, I. B. 2002, ''Starcounts Redivivus. IV. Density Laws Through Photometric Parallaxes,'' ApJ, 578, 151

Sion, E. M., Gaensicke, B. T., Long, K. S., Szkody, P., Cheng, F-H, Howell, S. B., Godon, P., Welsh, W. F., Starrfield, S., Knigge, C., & Sparks, W. M. 2003, ''Hubble Space Telescope Spectroscopy of the Unexpected 2001 July Outburst of the Dwarf Nova WZ Sagittae,'' ApJ, 592, 1137

Sirianni, M., Clampin, M., Hartig, G. F., Ford, H. C., Illingworth, G. D., Argabright, V., Burmester, B., De Marchi, G., Koldewyn, W., Martel, A. R., Mutchler, M., Riess, A., Schrein, R. J., & Sullivan, P. C. 2003, ''Characterization and On-orbit Performance of the Advanced Camera for Surveys CCDs,'' Proc. SPIE, 4854, 496

Sirianni, M., Nota, A., De Marchi, G., Leitherer, C., & Clampin, M. 2002, ''The low end of the IMF in young clusters. II. Evidence for primordial mass segregation in NGC 330 in the SMC,'' ApJ, 579, 275

Sivaramakrishnan, A., et al. 2002, ''NIRCAM Image Simulations for JWST,'' BAAS, 34, 1239

Sivaramakrishnan, A., et al. 2003, ''NIRCAM image simulations for NGST wavefront sensing,'' Proc. SPIE, 4850, 388

Sivaramakrishnan, A., Hodge, P. E., Makidon, R. B., Perrin, M. D., Lloyd, J. P., Bloemhof, E. E., & Oppenheimer, B. R. 2003, ''Structure of Moderate and High Strehl Adaptive Optics Images,'' Proc. SPIE, 4860, 161

Sivaramakrishnan, A., Lloyd, J. P., Hodge, P. E., & Macintosh, B. M. 2002, ''Speckle Decorrelation and Dynamic Range in Speckle Noise-Limited Imaging,'' ApJ, 581, L59

Soderblom, D. R., & Meyer, M., et al. 2002, ''The Formation and Evolution of Planetary Stems: A SIRTF Legacy Science Program Progress Report,'' BAAS, 34, 1140

Somerville, R. S. 2003, ''Studying Galaxy Formation with Hubble's Successor,'' in Hubble's Science Legacy: Future Optical/Ultraviolet Astronomy from Space, eds. K. R. Sembach, J. C. Blades, G. D. Illingworth and R. C. Kennicutt, Jr. (San Francisco: ASP), 229

Somerville, R. S., Barden, M., Beckwith, S. V. W., Bell, E., Borch, A., Caldwell, J. A. R., Jahnke, K., Jogee, S., McIntosh, & D. H., et al. 2003, ''Morphologies and SEDs for 10,000 Galaxies to z = 1.2: Early Results from GEMS,'' BAAS, 35, 723

Song, J., Robberto, M., Beckwith, S. V. W., Makidon, R. B., & Panagia, N. 2003, ''First results from an HST study of the Mass Accretion Rates in the Trapezium Cluster,'' BAAS, 35, 736

Sonnentrucker, P., Friedman, S. D., Welty, D. E., York, D. G., & Snow, T. P. 2002, ''Abundances and Physical Conditions in the Interstellar Gas toward HD 192639,'' ApJ, 576, 241

Sozzetti, A., Casertano, S., Brown, R. A., & Lattanzi, M. G. 2002, ''Narrow-Angle Astrometry with the Space Interferometry Mission: The Search for Extrasolar Planets. I. Detection and Characterization of Single Planets,'' PASP, 114, 1173

Sozzetti, A., Casertano, S., Brown, R. A., & Lattanzi, M. G. 2003, ''Narrow-Angle Astrometry with the Space Interferometry Mission: The Search for Extra-Solar Planets. II. Detection and Characterization of Planetary Systems,'' PASP, 115, 1072

Sparks, W. B. & Ford, H. C. 2002, ''Imaging Spectroscopy for Extrasolar Planet Detection,'' ApJ, 578, 543

Speck, A. K. Meixner, M., Fong, D., & Ueta, T. 2002, ''ISOPHOT Observations of Post-AGB Stars: Fossil Records of Mass Loss,'' in ISOPHOT Workshop on P32 Oversampled Mapping, eds. B. Schilz & S. Peschke, ESA-SP, 482, 93

Speck, A. K., Meixner, M., Jacoby, G. H., & Knezek, P. 2003, ''Molecular Hydrogen in the Ring Nebula: Clumpy Photodissociation Regions,'' PASP, 115, 170

Stanghellini, L., Shaw, R. A., Muthcler, Max, Palen, S., Balick, B., & Blades, J. Chris 2002, ''Optical Slitless Spectroscopy of Large Magellanic Cloud Planetary Nebulae: A Study of the Emission Lines and Morphology,'' ApJ, 575, 178

Steidel, C. C., Adelberger, K. L., Shapley, A. E., Pettini, M., Dickinson, M., & Giavalisco, M. 2003, ''Lyman Break Galaxies at Redshift z $\sim$ 3: Survey Description and Full Data Set,'' ApJ, 592, 728

Steidel, C. C., Hunt, M. P., Shapley, A. E., Adelberger, K. L., Pettini, M., Dickinson, M., & Giavalisco, M. 2002, ''The Population of Faint Optically Selected Active Galactic Nuclei at z $\sim$ 3,'' ApJS, 576, 653

Stephens, D. C., Noll, K. S., Buie, M., Grundy, W., Millis, R., Spencer, J., Cruikshank, D., Romanishin, W., &

Tegler, S. 2002, ''HST Broad-band V, R, and I Photometry of 76 Kuiper Belt Objects,'' BAAS, 34, 871

Stiavelli, M. 2003, ''Exploring the cosmic dark ages with the next generation of space- and ground-based facilities,'' in Future Research Direction and Visions for Astronomy, ed. A. Dressler, Proc. SPIE, 4835, 122

Stockton, A., MacKenty, J. W., Hu, E. M., & Kim, T. S. 2002, ''The Extended Emission-Line Region of 4C 37.43,'' ApJ, 572, 735

Stolte, A., Brandner, W., Grebel, E. K., Figer, D. F., Eisenhauer, F., Lenzen, R., & Harayama, Y. 2003, ''NAOS-CONICA performance in a crowded field—the Arches cluster,'' The Messenger, 111, 9

Stolte, A., Grebel, E. K., Brandner, W., & Figer, D. F. 2002, ''The mass function of the Arches cluster from Gemini adaptive optics data,'' A&A, 394, 459

Stolte, A., Grebel, E. K., Brandner, W., & Figer, D. F. 2003, ''The Mass Function of the Arches Cluster from Gemini Adaptive Optics Data,'' in Galactic Star Formation Across the Stellar Mass Spectrum (San Francisco: ASP), 433

Stys, D. J., Walborn, N. R., Busko, I., Goudfrooij, P., Proffitt, C. R., & Sahu, K. C. 2002, Sensitivity Monitor Report for the STIS First-Order Modes,'' 2002 HST Calibration Workshop, eds. S. Arribas, A. Koekemoer & B. Whitmore (Baltimore: STScI), 206

Stys, D. J., Walborn, N. R., Busko, I., Goudfrooij, P., Proffitt, C., & Sahu, K. 2002, ''Sensitivity Monitor Report for the STIS First-Order Modes,'' BAAS, 34, 746

Suchkov, A. A., Hanisch, R. J., & ClassX Team 2003, ''Astrophysics with ClassX: Candidate Stars and Extragalactic Objects from ROSAT pointed observations,'' BAAS, 35, 732

Suchkov, A. A., Hanisch, R. J., White, R. L., Postman, M., Donahue, M. E., McGlynn, T. A., Winter, E. L., Angeline, L., Corcoran, M. F., Drake, S. A., Pence, W. D., White, N., Genova, F., Ochsenbein, F., Fernique, P., Derriere, S., & Voges, W. 2003, ''Astrophysics with ClassX: Candidate stars and extragalactic objects from ROSAT pointed observations,'' BAAS, 35, 742

Suchkov, A. A., Makarov, V. V., & Voges, W. 2003, ''ROSAT view of the HIPPARCOS F stars,'' ApJ, 595, 1206

Suchkov, A. A., McGlynn, T., Angelini, L., Corcoran, M., Drake, S., Winter, E., Pence, W., White, N., Hanisch, R., White, R., Donahue, M., Postman, M., Genova, F., Ochsenbein, F., Fernique, P., & Derriere, S. (ClassX Team) 2003, ''Automated object classification with ClassX,'' in Astronomical Data Analysis Software and Systems XII, ASP Conf. Ser., Vol. 295, eds. H. F. Payne, R. I. Jedrzejewski, & R. N. Hook (San Francisco: ASP), 419

Sullivan, M., Ellis, R. S., Aldering, G., Amanullah, R., Astier, P., Blanc, G., Burns, M. S., Conley, A., Deustua, S. E., Doi, M., Fabbro, S., Folatelli, G., Fruchter, A. S., Garavini, G., Gibbons, R., Goldhaber, G., Goobar, A., Groom, D. E., Hardin, D., Hook, I., Howell, D. A., Irwin, M., Kim, A. G., Knop, R. A., Lidman, C., McMahon, R., Mendez, J., Nobili, S., Nugent, P. E., Pain, R., Panagia, N., Pennypacker, C. R., Perlmutter, S., Quimby, R., Raux, J., Regnault, N., Ruiz-Lapuente, P., Schaefer, B., Schahmaneche, K., Spadafora, A. L., Walton, N. A., Wang, L., Wood-Vasey, W. M., & Yasuda, N. 2003, ''The Hubble Diagram of Type Ia Supernovae as a Function of Host Galaxy Morphology,'' MNRAS, 340, 1057

Szkody, P., Anderson, S. F., Schmidt, G., Hall, P. B., & Margon, B., et al. 2003, ''Two Rare Magnetic Cataclysmic Variables with Extreme Cyclotron Features Identified in the Sloan Digital Sky Survey,'' ApJ, 583, 902

Teegarden, B. J., Pravdo, S. J., Covey, K., Frazier, O., Hawley, S. L., Hicks, M., Lawrence, K., McGlynn, T., Reid, I. N., & Shaklaa, S. B. 2003, ''Discovery of a new nearby star,'' ApJ, 589, L51

Tej, A., Sahu, K. C., Chandrasekhar, T., & Ashok, N. M. 2002, ''Substellar Mass Function of Young Open Clusters as Determined through a Statistical Approach Using 2MASS and GSC Data,'' ApJ, 578, 523

Tej, A., Sahu, K. C., Chandrasekhar, T., & Ashok, N. M. 2003, ''Determination of Substellar Mass Function of Young Open Clusters Using 2MASS and GSC Data,'' in Brown Dwarfs, Proceedings of IAU Symposium 211, ed. Eduardo Martín, (San Francisco: ASP), 175

Telfer, R. C., Kriss, G. A., Zheng, W., & Davidsen, A. F. 2002, ''Extreme Ultraviolet Absorption Lines in Lyman α Forest Absorbers and the Oxygen Abundance in the Intergalactic Medium,'' ApJ, 579, 500

Thorburn, J. A., et al. 2003, ''Some Diffuse Interstellar Bands Related to Interstellar C2 Molecules,'' ApJ, 584, 339

Tran, H. D., Meurer, G. R., Ford, H. C., Martel, A. R., Sirianni, M., Bohlin, R. C., Clampin, M., Cox, C., DeMarchi, G., Hartig, G. F., Kimble, R. A., & Argarbright, V. 2003, ''On-Orbit Performance of the ACS Solar-Blind Channel,'' Proc. SPIE, 4854, 686

Tran, H. D., Sirianni, M., Ford, H. C., Illingworth, G. D., Clampin, M., Hartig, G., Becker, R. H., White, R. L., Bartko, F., Benitez, N., Blakeslee, J. P., Bouwens, R., Broadhurst, T. J., Brown, R., Burrows, C., Cheng, E., Cross, N., Feldman, P. D., Franx, M., Golimowski, D. A., Gronwall, C., Infante, L., Kimble, R. A., Krist, J., Lesser, M., Magee, D., Martel, A. R., McCann, W. J., Meurer, G. R., Miley, G., Postman, M., Rosati, P., Sparks, W. B., & Tsvetanov, Z. 2003, ''Advanced Camera for Surveys Observations of Young Star Clusters in the Interacting Galaxy UGC 10214,'' ApJ, 585, 750

Trinchieri, G. & Goudfrooij, P. 2002, ''The peculiar small-scale X-ray morphology of NGC 5846 observed with Chandra,'' A&A, 386, 472

Ueta, T. & Meixner, M. 2003, ''2-Dust: an axisymmetric dust radiative transfer code,'' ApJ, 586, 1338

Ueta, T., Meixner, M., Moser, D. E., Pyzowski, L. A. & Davis, J. P. 2003, ''Near-Infrared Photometric Survey of Proto-Planetary Nebula Candidates,'' AJ, 125, 2227

Urry, C. M., Scarpa, R., O'Dowd, M., Giavalisco, M., Falomo, R., Pesce, J. E., & Treves, A. 2002, ''Host galaxies and the unification of radio-loud AGN,'' NewAR, 46, 349

Valenti, J. A., Fallon, A. A., & Johns-Krull, C. M. 2003, ''An IUE Atlas of Pre-Main-Sequence Stars. III. Co-

added Final Archive Spectra from the Long-Wavelength Cameras,'' ApJS, 147, 305

van der Marel, R. P., Alves, D. R., Hardy, E., & Suntzeff, N. B. 2002, ''New understanding of Large Magellanic Cloud structure, dynamics and orbit from carbon star kinematics,'' AJ, 124, 2639

van der Marel, R. P., Gerssen, J., Guhathakurta, P., Peterson, R., & Gebhardt, K. 2002, ''Hubble Space Telescope evidence for an intermediate-mass black hole in the globular cluster M15—I. STIS spectroscopy and WFPC2 photometry,'' AJ, 124, 3255

Verdoes Kleijn, G., van der Marel, R. P., de Zeeuw, P. T., Noel-Storr, J., & Baum, S. A. 2002, ''Gas kinematics and the black hole mass at the center of the radio galaxy NGC 4335,'' AJ, 124, 2524

Vermeulen, R. C., et al. 2003, ''Observations of H I Absorbing Gas in Compact Radio Galaxies at Cosmological Redshifts,'' A&A, 404, 861

Verolme, E. K., Cappellari, M., Copin, Y., van der Marel, R. P., Bacon, R., Bureau, M., Davies, R. L., Miller, B. M., & de Zeeuw, P. T. 2002, ''A SAURON study of M32: measuring the intrinsic flattening and the central black hole mass,'' MNRAS, 335, 517

Voges, W., Suchkov, A. A., White, R. L., Postman, M., Hanisch, R. J., McGlynn, T. A., Winter, E. L., Angeline, L., Corcoran, M. F., Drake, S. A., Pence, W. D., White, N., Genova, F., Ochsenbein, F., Fernique, P., Derriere, S., & Donahue, M. 2003, ''Astrophysics with ClassX: Candidate stars and extragalactic objects from the ROSAT All-Sky Survey,'' BAAS, 35, 732

Wakker, B., et al. 2003, ''The Far Ultraviolet Spectroscopic Explorer Survey of O VI Absorption In and Near the Galaxy,'' ApJS, 146, 1

Walborn, N. R. 2002, ''On the Absolute Magnitudes of the O Stars,'' AJ, 124, 507

Walborn, N. R. 2003, ''The Earliest O-Type Stars,'' in IAU Symp. No. 212, A Massive Star Odyssey: from Main Sequence to Supernova, eds. K. A. van der Hucht, A. Herrero, & C. Esteban (San Francisco: ASP), 13

Walborn, N. R. 2003, ''The Early Barrier Broken Again: Definition of Spectral Type O_2,'' in The Garrison Festschrift, eds. R. O. Gray & A. G. D. Philip (Schenectady: L. Davis Press), 17

Walborn, N. R., Fullerton, A. W., Crowther, P. A., Bianchi, L., Hutchings, J. B., Pellerin, A., Sonneborn, G., & Willis, A. J. 2002, ''Far Ultraviolet Spectroscopic Explorer Atlas of OB Stars in the Magellanic Clouds,'' ApJS, 141, 443

Walborn, N. R., Howarth, I. D., Herrero, A., & Lennon, D. J. 2003, ''The Remarkable Alternating Spectra of the Of?p Star HD 191612,'' ApJ, 588, 1025

Walborn, N. R., Maíz-Apellániz, J., & Barbá, H. R. 2002, ''Further insights into the structure of 30 Doradus from the Hubble Space Telescope instruments,'' AJ, 124, 1601

White, R. L., Becker, R. H., Fan, X., & Strauss, M. A. 2003, ''Probing the Ionization of the Universe at $z > 6$,'' AJ, 126, 1

White, R. L., Helfand, D. J., Becker, R. H., Gregg, M. D., Postman, M., Lauer, T. R., & Oegerle, W. 2003, ''An I-Band-Selected Sample of Radio-Emitting Quasars: Evidence for a Large Population of Red Quasars,'' AJ, 126, 706

White, R. L., Suchkov, A. A., Hanisch, R. J., Postman, M., Donahue, M. E., McGlynn, T. A., Winter, E. L., Corcoran, M. F., Drake, S. A., Pence, W. D., White, N., Angelini, L., Genova, F., Ochsenbein, F., Fernique, P., Derriere, S., & Voges, W. 2002, ''Preliminary census of ROSAT bright sources: results from ClassX,'' BAAS, 34, 1244

Whitmore, B. 2003 ''The Formation of Globular Clusters in the Local Universe,'' in Extragalactic Globular Cluster Systems, ed. M. Kissler-Patig (New York: Springer), 336

Whitmore, B. C. 2003, ''The Formation of Star Clusters,'' in A Decade of HST Science, eds. M. Livio, K. Noll, & M. Stiavelli (Cambridge: Cambridge University Press), 153

Wiklind, T. 2002, ''Close Encounters of the Tidal Kind,'' Nature, 420, 38

Wiklind, T. 2003, ''Photometric Redshift Using the Far-infrared SED,'' ApJ, 588, 736

Wiklind, T. & Alloin, D. 2003, ''Gravitational Lensing at Millimeter Wavelengths,'' in ''Gravitational Lensing: An Astrophysical Tool,'' eds. F. Courbin, D. Minniti, Springer Verlag's Lecture Notes on Physics, Chapter 4.

Wilden, B. S., Jones, B. F., Lin, D. N. C., & Soderblom, D. R. 2002, ''The Evolution of the Lithium Abundances of Solar-Type Stars. X. Does Accretion Affect the Lithium Dispersion in the Pleiades?'' AJ, 124, 2799

Williams, R., Jenkins, E. B., Baldwin, J. A., & Sharpee, B. 2003, ''Comparative Absorption and Emission Abundance Analyses of Nebulae: Ion Emission Densities for IC 418,'' PASP, 115, 178

Windhorst, R. A., et al. 2002, ''A Hubble Space Telescope Survey of the Mid-Ultraviolet Morphology of Nearby Galaxies,'' ApJS, 143, 113

Winkler, P. F., Gupta, G., & Long, K. S. 2003, ''The SN 1006 Remnant: Optical Proper Motions, Deep Imaging, Distance, and Brightness at Maximum,'' ApJ, 585, 324

Winsor, R., Sivaramakrishnan, A., Cauwenberghs, G., Cohen, M., Frazier, M., Kruger, M., & Myers, T. 2002, ''Detector Array for Direct Control of a Deformable Mirror,'' Proc. SPIE, 4825, 228

Winsor, R. S. & Sivaramakrishnan, A. 2003, ''A Shack-Hartmann Wavefront Sensor/Detector with an Integrated On-Chip Reconstructor,'' Proc. SPIE, 4839, 186

Wu, W., Clayton, G. C., Gordon, K. D., Misselt, K. A., Smith, T. L., & Calzetti, D. 2002, ''A New Database of Observed Spectral Energy Distributions of Nearby Starburst Galaxies from the UV to the Far-IR,'' ApJS, 143, 377

Young Owl, R. C., Meixner, M., Fong, D., Haas, M. R., Rudolph, A., & Tielens, A. G. G. M. 2002, ''Testing Models of Low-Excitation Photodissociation Regions With Far-Infrared Observations of Reflection Nebulae,'' ApJ, 578, 885

Yuan, Q., Green, R. F., Brotherton, M., Tripp, T. M., Kaiser, M. E., & Kriss, G. A. 2002, ''Associated Absorption Lines in the Radio-Loud Quasar 3C 351: Far-Ultraviolet

Echelle Spectroscopy from the Hubble Space Telescope,'' ApJ, 575, 687
Zalucha, A., Fong, D., & Meixner, M. 2002, ''BIMA CO Observations of IRAS 07134+1005,'' BAAS, 34, 1253
Zsargo, J., Sembach, K. R., Howk, J. C., & Savage, B. D. 2003, ''Highly Ionized Gas in the Galactic Halo: A FUSE Survey of Absorption Toward 22 Halo Stars,'' ApJ, 586, 1019