Space Telescope Science Institute

Baltimore, Maryland 21218

[S0002-7537(98)06801-2]

This report covers the period October 1996 through September 1997.

1. INTRODUCTION

The Space Telescope Science Institute (ST ScI), operated by the Association of Universities for Research in Astronomy (AURA), directs science operations for the *Hubble Space Telescope* (*HST*), which was launched into a near-Earth orbit in the Spring of 1990. ST ScI is also the home to an active scientific staff of more than 100 people employed by AURA, the European Space Agency (ESA), and the Computer Science Corporation (CSC), which is under contract to provide ground support and data analysis facilities.

Most of this year's activities concentrated around the second *HST* Servicing Mission (SM2), which was launched on February 13, 1997. The main goal of the mission was to replace the *Goddard High Resolution Spectrograph* (*GHRS*) and the *Faint Object Spectrograph* (*FOS*) with the *Space Telescope Imaging Spectrograph* (*STIS*) and the *Near Infrared Camera and Multi-Object Spectrometer* (*NICMOS*). *NICMOS* and *STIS* were both installed during the first Extra-Vehicular Activity (EVA-1) on February 14, 1997. For each instrument, teams of engineers and scientists were on hand, both at the ST Operations Control Center at Goddard Space Flight Center and at the ST ScI to perform immediately the analysis of data from the instruments. Formal pass/fail criteria had been established for each instrument which were used to determine the success of the installation. In a matter of a few hours from the start of the EVA, both instruments were declared successfully installed. On subsequent EVAs, installation and testing of the new *Fine Guidance Sensor* (*FGS*) and *Solid State Recorder* (*SSR*) met with similar success.

A reboost of *HST*'s orbit using the Vernier Reaction Control System jets was performed in four separate steps, after each of the last three EVAs. The lower thrust of the VCRS system was necessitated by the fact that the solar arrays remained deployed during the servicing mission. The reboost amounted to approximately 8 nautical miles, resulting in an *HST* orbit of approximately 335 by 320 nautical miles. Another reboost is planned for the 1999 mission, which occurs around the time of solar maximum.

The release of the telescope from the shuttle on February 19 at 1:42 a.m. EST marked the start of the Sevicing Mission Observatory Verification (SMOV) period. SMOV consisted of a suite of tests for each instrument, scheduled over a several-month period, with the goal of commissioning *NICMOS* and *STIS* for science operations and *FGS1* for fine guidance.

Very early in the SMOV process, GO science observations with *WFPC2* and *FOC* were resumed after a short recommissioning period. Of special note are images of Mars taken on March 10, 1997 with the recommissioned *WFPC2*. These images, taken just before Mars opposition, show the planet during transition between Spring and Summer in the Northern Hemisphere. These data were used to support the NASA Pathfinder mission, at the time en route to Mars.

The commissioning process did not occur without its own special brand of pitfalls. On February 24, barely 5 days after the Servicing Mission, the susceptibility of the *STIS*'s electronics to charged particle impacts first appeared. Within a few more days, *NICMOS* electronics displayed the same susceptibility. Then, on March 4, the cool-down curve of the *NICMOS* dewar displayed an inflection which could only be interpreted as a thermal short that would lead to unexpected equilibrium temperatures for the detector and the filters, as well as the possibility of a seriously shortened lifetime for the *NICMOS* instrument. By March 14, it became apparent that this thermal anomaly was causing dewar expansion such that the *NICMOS* Camera 3 was no longer within the Pupil Alignment Mechanism range of focus. Later in SMOV, other *STIS* and *NICMOS* anomalies caused delays and modifications to the original plans before the relevant science could be enabled.

Fortunately, these problems did not delay the focus and alignment activities for *STIS* and for *NICMOS* Cameras 1 and 2.

With the focus and alignment activities complete except for continuous focus monitoring, by the first week of April, *NICMOS* SMOV activities shifted to execution of the Early Release Observations (EROs) and the series of basic science calibration programs needed to enable regular GO science.

The *NICMOS* Early Release Observation (ERO) program, modified to use only cameras 1 and 2, resulted in several fine images, two of which, an image of the Orion Molecular Cloud 1 (OMC1) and an IR image of the Egg Nebula, were presented at the May 12 Press conference to demonstrate *HST*'s new capabilities. Since then, several more EROs have been carried out for publication at the June AAS meeting and elsewhere.

A set of *STIS* CCD spectroscopic ERO observations were carried out for the May 12 press conference (SN1987A and M84) and, like *NICMOS*, several more have been performed since then for presentation at the AAS meeting and elsewhere.

Cycle 7 *NICMOS* science observations began the week of June 2 and are continuing at a progressively higher rate each week. Aside from Camera 3/Grism science, the one remaining science mode yet to be completely enabled is that of coronography. Plans for this mode include a flight software upgrade and subsequent testing that are planned for completion within a few weeks.

STIS SMOV was designed to commission the CCD separately from the *NUV* and *FUV MAMA*s. By June, *STIS* Cycle 7 science has been enabled, involving CCD imaging and CCD long-slit spectroscopy, using point source acquisitions or certain types of diffuse source acquistions, and slits at least 0.2 arcseconds wide. CCD coronographic verification proceeded nominally and CCD coronographic science is now enabled.

In the case of the *MAMA*s, the electronics' South Atlantic Anomaly susceptibilities, similar to those of the CCD, presented a potential health and safety problem, and therefore the initiation of *MAMA* SMOV was delayed by over five weeks, from March 23 to April 28, while the problems were studied and operational and flight software protections were devised.

By the week of May 19, the *MAMA*s were being used extensively to carry out their planned SMOV calibrations and EROs. *MAMA* imaging, first-order spectroscopy, and coronography are now enabled. Flight software upgrades to correct an on-board Doppler processing deficiency and the truncation problem, which had prevented échelle spectroscopy and CCD acquisition peak-ups for narrow-slit (<0.2 arcsecond) spectroscopy, are now installed. Such science is now enabled, with the first observations scheduled to start in October.

Although the last SMOV activity did not occur until late September, both *NICMOS* and *STIS* had been doing normal science, interleaved with their commissioning activities, since the first week of June.

Over the course of the 218-day SMOV period, more than 130 SMOV proposals were executed and over 780 *HST* orbits of pointed observations, an average of about 3.6 orbits per day, were dedicated to the observatory's recommissioning. Meanwhile, the other *HST* orbits were dedicated to science as the SMOV Program quickly re-enabled the *WFPC2* and *FOC* for resumption of Cycle 6 observations, and enabled *NICMOS* and *STIS*, mode-by-mode, for the initiation of Cycle 7. At this point, *STIS* spectroscopy is being performed in all three detectors and *NICMOS* infrared astronomy is being carried out routinely in Cameras 1 and 2.

In view of the expected shortened lifetime of *NICMOS*, a special call for proposals for a cycle dedicated to *NICMOS* observations has been issued. This resulted in 450 proposals being submitted.

On October 16–18, 1996, a workshop was held at ST ScI titled *Planets Beyond the Solar System and the Next Generation of Space Missions*. The purpose was to bring together researchers in the rapidly growing field of the detection of extra-solar planets with those planning and designing future space missions that can hope to enlarge capabilities in that area. About 100 US and European astronomers attended, and the proceedings have now appeared as volume 119 in the ASP Conference Series, edited by D. R. Soderblom.

As a part of its contribution to the promotion of scientific interaction, ST ScI hosted during the past year its annual May Symposium, on the topic of *The Hubble Deep Field* (*HDF)*. The meeting was held at ST ScI on May 6–9, 1997. Thirty invited talks were presented during the meeting, which was attended by about 150 participants. Works on a variety of topics, ranging from deep surveys aimed at the high redshift universe to searches for normal stars and white dwarfs, were presented and discussed extensively. It was quite astonishing to discover how much research has been inspired by the HDF.

2. SOLAR SYSTEM

M. Hauser, in collaboration with Lisse and A'Hearn (U. MD), Lien (Bucknell), and Kelsall, Moseley, Reach, and Silverberg (GSFC), studied four comets observed in the *COBE Diffuse Infrared Background Experiment* (*DIRBE*) all-sky survey. The extended dust tails revealed variations in particle properties and mass loss rate. Estimated mass loss rates were sufficiently high to supply the interplanetary dust cloud.

A. Storrs has continued his analysis of *HST* images of asteroids. In particular, images of asteroid 4 Vesta has resulted in three refereed publications: Zellner *et al.* (1997), Thomas *et al.* (1997), and Binzel *et al.* (1997). Additional observations were reported in Zellner *et al.* (1996). A summary paper of all *HST* observations of asteroids is in preparation. Observations of small Uranian satellites were reported in Storrs *et al.* (1996) and a refereed paper is in preparation.

3. STARS

R. Bohlin has been working with L. Colina on redefining the UV/optical absolute flux standards. *STIS* observations to extend the current standards to 1.02 microns are starting to be executed.

An *HST* GO program to observe a set of PN in the LMC and SMC is in progress with M. Dopita as PI. E. Vassiliadis is returning for a six week visit to continue the work. They were awarded time by the TAC in every cycle except 4 and 7, when they did not apply.

C. Cacciari has been working on the RR Lyrae variables in the globular cluster M3.

Fullton is researching post-asymptotic giant branch stars with H. Bond, A. Saha, K. Schaefer (ST ScI) and R. Saffer (Villanova). A photometric search for post-asymptotic giant branch (PAGB) stars is being conducted in Local Group galaxies to study the application of PAGB stars to a number of outstanding astronomical problems:

1. Late stellar evolution and galactic chemical evolution—The time for a star to transit the HR diagram from the asymptotic giant branch to the planetary nebulae central star stage is poorly known, primarily since theoretical calculations depend on uncertainties concerning the mass-loss rates. Statistics of the number of PAGB stars found in the Local Group survey will help reveal this poorly known timescale, and constrain the mass-loss rates.
2. Extent and structure of galactic halos—PAGB stars in galactic halos are more numerous than globular clusters and planetary nebulae. Additionally, these are the visually brightest Population II stars (they are about 4 magnitudes brighter than RR Lyraes in *V*), therefore, they should be good tracers of the spatial properties of galactic halos.
3. Extragalactic distance scale—Stellar evolution theory predicts that PAGB stars should have a very narrow luminosity function in old stellar populations. The Local Group survey seeks to establish these stars as Population II standard candles that can provide reliable stellar distances to galaxies that do not contain Cepheids (*e.g.* elliptical galaxies). PAGB stars appear in

small numbers in Milky Way globular clusters. With new subdwarf parallaxes, distances to these clusters can be obtained, allowing calibration of the PAGB luminosity in the globulars, the Magellanic Clouds, and M31. This calibration would be completely independent of the Cepheid distance scale. PAGB stars are bright enough that they could be applied to galaxies as far as the Virgo Cluster.

Fullton is also conducting a search for binaries in a *WPFC2* Survey of Planetary Nebulae with H. Bond and K. Schaefer (ST ScI), R. Ciardullo and M. Sipior (Penn State). A Cycle 5 *WFPC2* snapshot survey of Galactic Planetary Nebulae (PNe) was conducted to search for close, resolved binary companions that can be used to determine distances to the PNe through photometric parallaxes. The survey provides a group of objects with accurate distances, which can be used to calibrate other methods of determining PNe distances. Shoring up the Galactic PNe distance scale provides further understanding of the birth rate and evolution of PNe, and gives context for the use of PNe as extragalactic distance indicators. Seventeen visual binaries have been discovered in the course of the survey. Additionally, the high-resolution images contain a great deal of information concerning the nebulae themselves (*e.g.* a resolved circumstellar disk and jets around the proto-planetary nebulae HD 44179).

With Jacoby (NOAO), Fullton is also searching for planetary nebulae in globular clusters. The Galactic globular cluster (GC) system consists of approximately 150 clusters, 133 of which were imaged in an on-band/off-band photometric survey at 5007 Å ([OIII]) to search for member Planetary Nebulae (PNe). The survey was conducted across a variety of telescopes, but most clusters were observed with the KPNO 2.1m or the CTIO 1.5m. Two new PNe were discovered in the course of the survey (Jacoby *et al.* 1997), bringing the total number of PNe in Galactic globular clusters to four. The globular cluster luminosity function and the observed PN production rate for metal-poor populations can be used to estimate the expected number of globular cluster PNe in the Galaxy. Adjusting these numbers to account for survey depth, theory predicts that there should have been 16 PNe imaged in the survey if every star produces a visible PN. A possible explanation of this discrepancy is that globular cluster AGB stars have inadequate mass to produce visible PNe unless they are binaries. Supporting this hypothesis is the observed correlation between GC PNe and clusters with significant X-ray luminosities, sometimes considered an indication of the presence of interacting binaries. Spectra of the new PNe found in Pal 6 and NGC 6441 suggest that [O/Fe] in these clusters' PNe are lower than the value usually assumed in stellar evolution models.

As part of his PhD thesis, Gäng participated in the LBV-workshop in Kona, Hawaii, in October 1996. For this project he and his collaborators in Utrecht and Heidelberg obtained very high resolution ($R = 60000-100000$) optical ($\lambda = 3600-7000$ Å) spectra of about 20 Luminous Blue Variables (LBVs) and LBV candidates on various telescopes. Due to the high quality data (high resolution *and* S/N) he was able to see previously undetected wiggles and substructures in the spectral lines indicating inhomogeneities in the stellar winds.

Gäng has also been involved in a long-term monitoring program of early-type stars.

Livio, in collaboration with Pringle (Cambridge), showed that accretion disks that are irradiated by a central source can become unstable to warping. They demonstrated by means of a numerical simulation that such disks start to wobble and precess. They used this result to explain the formation of point-symmetric planetary nebulae.

Livio, collaborating with Lubow and Tout (Cambridge), showed that in a close orbiting giant planet, resonant tides can lead to a rapid spin-down. In particular, they showed that 51 Peg B could be spun-down to below Jupiter's rate in 100 years.

Livio, in collaboration with Shahbaz, Southwell, and Charles (Oxford), discovered what appears to be the first collimated jet in a cataclysmic variable system.

With the MACHO collaboration, Livio presented optical photometry of the two LMC supersoft X-ray sources CAL 83 and CAL 87, and showed that these observations are consistent with a model in which these sources represent a white dwarf which accretes mass at such a rate that steady burning occurs on its surface.

K. S. Long pursues research topics in the ultraviolet characteristics of cataclysmic variables, supernova remnants, and X-ray sources in nearby galaxies.

Long and postdoc Knigge, in collaboration with Wade (PSU) and Horne (St. Andrews) have completed the analysis of two sets of high time-resolution FOS spectra of the nova-like variable UX UMa. The eclipse light curves obtained are qualitatively consistent with the gradual occultation of an accretion disk with a radially decreasing temperature distribution. The integrated spectra are not particularly well fit with model spectra constructed for steady-state accretion disks. Better spectral fits are obtained if an optically thin component, perhaps associated with a transition region between the disk and fast wind, is included. In the first set of data, low amplitude, coherent 29-s oscillations are also detected. The spectra of these oscillations are quite blue compared to the time-averaged spectra, suggesting that the ultimate source of the oscillations is a hot, compact region near the disk center.

Long and Knigge are also developing a Monte Carlo spectral synthesis program which models the spectra of high state cataclysmic variables in the far and extreme ultraviolet. Beginning with a kinematic description of the wind, the ionization state of the wind is then determined, followed by a synthesis of the spectrum. In an initial application of the program, Long and Knigge have been able to create spectra which mimic the observed spectrum of U Gem in outburst with EUVE, which supports the hypothesis that most of the features in this spectrum are created by scattering in the wind.

Long and Gilliland (ST ScI) are completing an analysis of a set of *HST/GHRS* spectra in U Gem in quiescence, spectra which are dominated by emission from the white dwarf. The observations permit very accurate determination of the orbital parameters of the U Gem system as well as a direct

measurement of the surface gravity. An abundance analysis shows evidence of CNO processing of material now on the surface of the WD.

Long and Winkler (Middlebury) have completed an analysis of X-ray and optical observations of the bright galactic SNR SN1006. Their improved Hα images show the existence of non-radiative Balmer-dominated filaments around most of the periphery and also across the face of the SNR. They have also identified a quasar behind SN1006, a second UV light bulb, that can be used to probe high velocity, unshocked gas from the SN explosion.

Panagia, in collaboration with Scuderi, Stanghellini, Trigilio and Umana, has discussed the radio observations of fifteen O and B supergiants which were measured with the *Very Large Array* (*VLA*) at 4.85, 8.45, and 14.95 GHz, in order to make a detailed comparative study of the mass-loss rates evaluated from Hα and radio continuum observations and reveal and quantify possible departures from standard wind conditions. Out of the 15 targets, 12 sources were detected, 7 for the first time, thus increasing by 30% the total number of detections of OB supergiants in the northern sky. Radio spectral slopes indicate that the radio emission is mainly of thermal origin in all objects with one exception (HD 190603) out of the 12 detections. These results demonstrate the value of using Hα for mass loss rate determinations, especially for stars that are too distant or too faint to be detected with radio techniques. The relationship $\dot{M}-L$ for supergiants turns out to be appreciably flatter than commonly reported, *i.e.*, $\log M = (1.25\pm 0.30)\log L$.

Panagia, in collaboration with Weiler, Van Dyk, Montes and Sramek, has analyzed the observations of SN 1985L in NGC 5033 with the *Very Large Array* radio telescope, which have resulted in two detections of radio emission at 6 cm wavelength, about 8 and 16 months after optical discovery. Combined with a number of upper limits and a study of possible models, it appears that SN 1985L was probably a fairly normal Type II-L radio supernova, somewhat intermediate in radio properties between the well-studied radio supernovae SN 1979C and SN 1980K. A possible late-time optical detection continues the observed correlation between radio and late-time optical emission. Also radio observations of SN 1986E have shown a clear detection of emission at 6 cm wavelength about 8 months after optical discovery. Combined with new upper limits recently established, it appears that SN 1986E, too, was a normal Type II-L supernova, somewhat similar to SN 1980K, with radio emission at roughly expected levels.

Panagia, in collaboration with Weiler, Van Dyk, Montes and Sramek, has shown that the radio emission from supernovae provides a direct probe of a supernova's circumstellar environment, which was established by mass-loss episodes in the late stages of the progenitor's presupernova evolution. The observed synchrotron emission is generated by the SN shock interacting with the relatively high-density circumstellar medium which has been fully ionized and heated by the initial UV/X-ray flash. The study of radio supernovae therefore provides many clues to and constraints on stellar evolution. This is clearly illustrated by recent results on several cases, including SN 1980K, whose recent abrupt decline provides us with a stringent constraint on the progenitor's initial mass; SN 1993J, for which the profile of the wind matter supports the picture of the progenitor's evolution in an interacting binary system; and SN 1979C, where a clear change in presupernova mass-loss rate occurred about 10^4 years before explosion.

Panagia, in collaboration with Romaniello and Scuderi, has done a study of the stellar population around SN 1987A based on an analysis of multiband *HST-WFPC2* images. The effective temperature, radius and reddening of each star were determined by fitting the measured broad-band magnitudes to the ones calculated with model atmospheres. In addition, all stars with Hα equivalent widths in excess of 8 Å were identified. An inspection of the HR diagram reveals the presence of several generations of stars, with ages between 1 and 150 Myr, superposed on a much older field population. The youngest stars in the field appear to be *T Tau* stars, characterized by strong Hα excesses. It is concluded that SN 1987A is associated with a region in which star formation has been active over a long stretch of time and is still very active at present.

K. Sahu continued his efforts on monitoring on-going microlensing events through the PLANET (Probing Lensing Anomalies NETwork) collaboration, where a network of four 1-meter telescopes, located at appropriately spaced longitudes, is used in order to achieve 24-hour coverage in the monitoring program. PLANET looks for planets around lensing stars, and is the only method sensitive to detection of Earth-size planets around normal stars using ground-based observations. In this ongoing program, more than fifteen events have been monitored so far, and two binary-like anomalies have been detected. If every star has a Jupiter-size planet, then the probability of detection through microlensing is about 15%. Thus, this program should soon produce detection of planets; even non-detection will provide very useful constraints.

This past year, Schaerer has been researching the development of stellar interior and atmosphere models for massive stars, the development of evolutionary synthesis models, and doing studies of massive star populations in starbursts and H II regions.

In the past year, Soderblom continued studies of young solar-type stars in clusters. An analysis of Keck spectra of G and K dwarfs in M34 (NGC 1039), for instance, shows a distribution of lithium abundances similar to the younger Pleiades, with the same lower bound, despite a significantly higher age (M34 is about 250 Myr old versus 100 Myr for the Pleiades). Similar work is being done on G dwarfs in M67, which has the same age and metallicity as the Sun. The M67 stars show a bimodal distribution of lithium abundance, with some having upper limits to Li that are consistent with the solar abundance, but many having about ten times solar.

Soderblom also completed a study of the multiple system HD 98800 that used observations from Hipparcos, *HST*, and the ground. Four stars orbit each other in this system, and the parallax shows it must be only about 10 Myr old, making it a ''post-T Tauri'' star.

In the past year, Soderblom, working with T. Henry, delivered a northern target list to Project Phoenix, which is

working at *NRAO* in Green Bank. Project Phoenix is the descendant of NASA's HRMS, under which auspices the work was begun.

Walborn, in collaboration with C. Blades, completed an optical spectral classification study of 106 OB stars within the 30 Doradus Nebula, which has sharpened the description of the spatial and temporal structures among the associated clusters. Five distinct stellar groups were recognized: (1) the central early-O (Carina phase) concentration, which includes R136; (2) a younger (Orion phase) population to the north and west of R136, containing heavily embedded early-O dwarfs and IR sources, the formation of which was likely triggered by the central concentration; (3) an older population of late-O and early-B supergiants (Scorpius OB1 phase) throughout the central field, whose structural relationship, if any, to the younger groups is unclear; (4) a previously known, older still, compact cluster 3′ northwest of R136, containing A- and M-type supergiants (h and χ Persei phase), which evidently affects the nebular dynamics substantially; and (5) a newly recognized Sco OB1-phase association, surrounding the recently discovered Luminous Blue Variable R143 in the southern part of the nebula. The intricacy of this region and the implications for the interpretation of more distant starbursts were emphasized. The evidence is that the formation of the 30 Dor stellar content was neither instantaneous nor continuous, but rather that it corresponds to discrete events at different epochs.

Walborn presented the above and related results at two specialized workshops during this period, ''Luminous Blue Variables: Massive Stars in Transition'' at Kona, Hawaii, in October 1996, and ''Boulder-Munich II: Properties of Hot, Luminous Stars'' at Windsor, England, in July 1997.

Currently, in collaboration with his postdoctoral fellow R. Barbá, Walborn is investigating compact multiple stellar systems and relationships between IR sources and nebular microstructures in 30 Doradus, by means of archival *HST/WFPC2* images.

In collaboration with D. Ebbets and J. Parker, Walborn studied an *HST/GHRS* ultraviolet observation of the core of Eta Carinae. Surprisingly, the stellar wind spectrum corresponds to a composite B-supergiant type, and it is very similar to that of the fellow LBV P Cygni.

Walborn, in collaboration with A. Danks, K. Sembach, R. Bohlin, E. Jenkins, T. Gull, S. Hulbert, and others, led an *HST/STIS* Early Release Observation of an O star in the Carina Nebula, to investigate the very high interstellar absorption-line velocities in this region with the high-resolution UV échelles. The IUE observation of this star had shown 3 high-velocity components; the STIS data resolve at least 16, and reveal numerous new aspects of the interstellar physics along this sightline. This work will be extended in an *HST* Cycle 7 GO program led by Danks.

4. ISM

D. Calzetti, in collaboration with G. Meurer (JHU), R. Bohlin (ST ScI), D. Garnett (U. MN), A. Kinney (ST ScI), C. Leitherer (ST ScI), and T. Storchi-Bergmann (UFRGS), analyzed *HST/WFPC2* images of the nearby starburst dwarf NGC 5253 to investigate the dust distribution and the recent star formation history in the core of the galaxy. They find that corrections for the effects of dust reddening are important even in the case of metal-poor galaxies: the peak of the star formation activity in NGC 5253 coincides with one of the most obscured regions in the galaxy, with an optical depth of at least 9 magnitudes. Star formation has been active at least over the past 100 Myr in the core of the galaxy, as indicated by the age distribution of both the blue diffuse stellar population and the bright stellar clusters.

In collaboration with K. Gordon (LSU) and A. Witt (Toledo U.), Calzetti modelled the dust distribution in a sample of starburst galaxies, using observed UV, optical and near-infrared spectral energy distributions (SEDs) and a Monte Carlo radiative transfer model of the stellar light through the dust. A combination of a clumpy shell of dust plus a Small Magellanic Cloud-type interstellar extinction curve can explain the observed characteristics of the galaxies. The possible presence of dust reddening in distant (redshift ~ 3) galaxies has been investigated by Calzetti using the observed UV SEDs and the obscuration curve derived in Calzetti *et al.* (1994, ApJ, 429, 582) and Calzetti (1997, AJ, 113, 162). An average factor of 5 in UV flux reduction due to the presence of dust obscuration has been derived for the distant galaxies.

In collaboration with H. Schmitt (UFRGS), A. Kinney (ST ScI), and T. Storchi-Bergmann (UFRGS), Calzetti compiled X-ray-to-radio SEDs for quiescent elliptical, quiescent spiral, starburst, Seyfert 2, and LINER galaxies, and for H II regions, and thermal and non-thermal supernova remnants. Differences among the galaxy activity classes have been investigated with the observed SEDs.

R. A. González, in collaboration with Allen, Dirsch (Sternwarte Bonn), Ferguson, Calzetti, and Panagia, has been working on developing a method for establishing the opacity of spiral galaxy disks by studying the counts and colors of background galaxies seen through the foreground galaxy disk. The method will be used to measure the opacity of several galaxies previously observed with *HST*, and is to be calibrated using the Hubble Deep Field as a reference. The method has been applied first to *WFPC2* images of NGC 4536 (archival) and of the Magellanic irregular NGC 3664. Posters with preliminary results of the work have been presented at the 1997 ST ScI Symposium (*The Hubble Deep Field*) and in the AAS June 1997 meeting. The final results will be submitted for publication shortly.

From the galaxy number counts, NGC 4536 shows an extinction $A_I \sim 1$ mag in the Northwestern arm region, and lower than 0.5 mag in the corresponding interarm region (no correction for inclination has been attempted). However, from the galaxy colors, the same reddening of $E(V-I) \sim 0.2$ is observed in both the arm and the interarm regions. The combination of extinction and reddening yields a galactic reddening law in the interarm region, but a much greyer extinction law in the arm. These results are consistent with a diffuse absorbing component everywhere in the disk, and more opaque clumps in the arms. The results for NGC 3664 (a greyer than galactic extinction law) are also consistent with a clumpy dust distribution.

M. Hauser, in collaboration with colleagues on the *COBE*

science team, has studied the properties of infrared cirrus clouds using data from the *COBE Diffuse Infrared Background Experiment* (*DIRBE*) and *Far Infrared Absolute Spectrophotomer* (*FIRAS*). The data are generally well represented by a model including polycyclic aromatic hydrocarbon molecules as well as graphite and silicate grains. A separate study yielded a three-dimensional model of the galactic infrared emission from dust in the atomic, molecular, and ionized gas phases of the ISM. Galactic gradients of dust and the interstellar radiation field were determined, and it was found that the Galaxy would be optically transparent if viewed externally at low inclination angle.

Panagia, in collaboration with Gilmozzi, Scuderi and Kirshner, has analyzed several *HST-FOS* spectra of portions of the inner ring and the northern outer ring around SN 1987A, complemented with *HST-WFPC2* narrow-band imaging and ground-based spectroscopy. This study has revealed that these circumstellar features consist of highly N-enriched material that was ejected by the supernova progenitor in two distinct episodes, the inner ring corresponding to the last, more N-rich ejection.

R. E. Williams continued his research on the interpretation of emission lines in the presence of large inhomogeneities. With J. Kingdon and N. Panagia, he is developing methods whereby lines which are formed in different regions of a gas may be deconvolved into their distinct kinematical components, and the resulting flux ratios used to determine physical conditions in the gas. Principal Component Analysis has been used to deconvolve line profiles so that different kinematical components can be identified. A kinematical model is then assumed for the gas and used as a basis for determining flux ratios of the different components of the lines. Densities, temperatures, and abundances of the gas can be calculated for distinct regions of gas in this manner. Kingdon and Williams have also used the CLOUDY ionization code to determine those lines which are most invariant to changes in density and temperature, and which are therefore best to be used in abundance determinations. A grid of models was run that has been used to define the best networks of lines to be used in the Emission-Line Chart for abundance determinations. Williams has also participated in some of the follow-up interpretive work on the Hubble Deep Field, and in the planning for the southern HDF campaign that is to be carried out in 1998/99.

R. Gehrz, J. Truran, and Williams have finished work on a review of abundance determinations of novae ejecta, and an analysis of the contribution of novae to the composition of the ISM in the Galaxy.

5. GALAXIES

R. J. Allen, Bohlin, and Knapen (U. Hertfordshire) completed their analysis of the H I, Hα, and UIT-UV data in M81. The morphology of these tracers is understood in the context of a photodissociation region model, where the H I is produced by photodissociation of an underlying layer of molecular gas. A paper has been published on these results. A follow-on project on M101 is planned.

C. Cacciari has been studying globular clusters in the Galaxy, using both *HST* and ground-based observations to study the stellar population, especially in the cores, as well as globular clusters in M31, and using *HST* data to study the morphology and characteristics of the horizontal branch and red giant branch. She has also been observing the nearby halo population (HB stars, RR Lyraes) to study the characteristics of the local halo.

Fall is collaborating with Whitmore, Miller, and Schweizer (DTM) on a program of *HST/WFPC* observations of the star clusters in interacting and merging galaxies. Many of these clusters formed recently, evidently in response to the interactions. The luminosity functions of the young clusters have power-law form, not the lognormal form exhibited by the luminosity functions of old globular clusters. The mass functions of the young clusters could in principle deviate from the power-law form, but this is severely limited by the relatively narrow range of colors and hence ages of the clusters. Further investigation, both observational and theoretical, is needed to understand the evolution of the mass functions of the star clusters in interacting galaxies.

Fall continued his study of damped Lyman-α galaxies in collaboration with Charlot (IAP, Paris) and Pei (JHU, now at ST ScI). The main focus has been on the global properties of galaxies at different redshifts, including the mean comoving densities of star formation, gas consumption, and metal production between $z=4$ and the present. The results of this work, which is based entirely on quasar absorption-line observations, are remarkably consistent with subsequent results from imaging observations with the *CFHT*, *HST*, and *Keck Telescope*. The global star formation history, when combined with stellar population sythesis models, predicts correctly the mean intensity of cosmic background radiation over an extremely wide rage of wavelengths (roughly 0.1 to 1000 microns).

With collaborators S. Balachandran and R. Bell (U. MD), B. W. Carney (UNC-CH), John Laird (Bowling Green U.) and P. Stetson (DAO), Fullton studied extreme metallicity globular clusters near the Galactic Center. They are using *WFPC2* and *NICMOS* aboard *HST* to image globular clusters near the Galactic Center that are at the extremes of the globular cluster metallicity distribution. Photometry of the images will produce color-magnitude diagrams suitable for determining the relative ages of these clusters compared to ones of similar composition farther out in the halo. In conjunction with imaging, high-resolution échelle spectra are being obtained to provide accurate elemental abundances that will enable them to choose appropriate isochrones and comparison clusters of similar abundance. These observations will help answer the question of whether star formation began first in the dense central regions of the Galaxy, or conversely, if the outer clusters formed first, while the inner clusters were formed from leftover halo gas.

The target clusters span the range $-0.2<$ [Fe/H] $<+2.0$ dex in metallicity. If metallicity increased monotonically with time and enrichment of the interstellar medium was rapid, then the chosen clusters will likely span the range of formation times of the inner halo. The observations will provide evidence concerning the duration of star formation in the inner halo and the length of time required to enrich the ISM from [Fe/H] $=-2.0$ to near solar metallicity.

P. Goudfrooij and G. Trinchieri (Brera) are obtaining high spatial resolution imaging at X-ray (*ROSAT* HRI) and optical wavelengths of nearby X-ray bright, Hα-emitting early-type galaxies in an attempt to study the physical relation between the hot, warm and cold components of the ISM in early-type galaxies. First results on NGC 5846, the dominant galaxy of a small group of galaxies, have been finalized: they used new deep *ROSAT* HRI and *ESO* NTT broad-band images as well as existing *ESO* 3.6m narrow-band imagery. A filamentary dust lane with a dust mass of $\sim 7\times 10^3$ $M_\odot$ is detected in the central few kpc of NGC 5846. The optical extinction properties of the dust features are consistent with those of dust in our Galaxy. The morphology of the dust features is strikingly similar to that observed for the optical nebulosity *and* the X-ray emission. A physical connection between the different phases of the interstellar medium therefore seems likely. They discuss three different options for the origin of the dusty nebular filaments: condensation out of a cooling flow, mass-loss of late-type stars within NGC 5846, and material donated by a small neighbouring galaxy. They conclude that the dust as well as the optical nebulosity are most likely products of a recent interaction with a small, relatively gas-rich galaxy, probably of Magellanic type. Dust grains in the dust lane are destroyed by sputtering in the hot, X-ray-emitting gas in $\leqslant 10^7$ yr, which is shorter than the crossing time of a (small) galaxy through the central 5 kpc of NGC 5846. This indicates that the dust must be replenished to be consistent with the observed dust mass, at a rate of $\sim 10^{-3}$ $M_\odot$ yr^{-1}. They argue that this replenishment can be achieved by evaporation of cool, dense gas cloudlets that were brought in during the interaction. The evaporation rate of cool gas in NGC 5846 is consistent with the ''mass deposition rate'' derived from the X-ray measurements. The energy lost by the hot gas through heating of dust grains and evaporation of cool gas clouds in the central few kpc of NGC 5846 is adequately balanced by heat sources: transport of heat by electron conduction into the core of the X-ray-emitting gas and loss of kinetic energy of the infalling galaxy. There does not seem to be a need to invoke the presence of a ''cooling flow'' to explain the X-ray and optical data.

Goudfrooij, D. Minniti (LLNL), M. Kissler-Patig (UCSC) and G. Meylan (ESO) have used the *ESO NTT* in MOS mode to obtain radial velocity measurements of 53 globular cluster candidates in the giant elliptical galaxy NGC 1399, the dominant galaxy of the Fornax cluster. The globular cluster candidates were chosen to cover a suitable range in $V-I$ color in order to study the nature of the putative bimodal color distribution of globular clusters in NGC 1399. Some candidate young and super metal-rich star clusters were also observed. From the radial velocities, all candidate young and super metal-rich star clusters turn out to be foreground halo stars or background galaxies. From the *bona fide* globular clusters, 18 objects were selected—from their magnitudes and colors—to be metal rich. For this cluster sample, they measure a mean velocity of $v_{\rm rad}=1353\pm 79$ km s^{-1}, and a velocity dispersion of $\sigma=338\pm 56$ km s^{-1}. Using a few different mass estimators, this implies a M/L ratio in the range 50–130 within a radius of 28 kpc, consistent with a rising M/L with radius. These values for M/L are intermediate between the M/L computed from the integrated stellar light at smaller radii, and that computed from recent X-ray observations at larger radii.

Goudfrooij, M. V. Alonso (Cordoba) and D. Minniti (LLNL) have used the *ESO/MPI* 2.2m telescope to obtain deep near-IR imaging of NGC 1316 (= Fornax A) and NGC 1399, two giant ellipticals in the Fornax cluster. The main aim is to obtain optical-IR color-color diagrams of the globular clusters in these galaxies and to study the difference of the two cluster systems as they are in rather different environment (NGC 1316 is a recent merger remnant, whereas NGC 1399 is embedded in a cooling flow). The near-IR observations reach only the brightest clusters, but provide a much larger color baseline (compared to existing *HST/WFPC2* photometry) to identify intermediate-age clusters such as those found in the LMC and—by this group—in NGC 5128 (= Cen A), and to measure more accurate metallicities, particularly at the metal-rich extreme of the distribution. Preliminary results show that the globular clusters in NGC 1399 span a wide color range: $1.7<B-H<4.2$. This implies a wide range in metallicity for the cluster system of NGC 1399, confirming previous results obtained with optical photometry. Using the integrated color of Galactic globulars to estimate metallicities, the range implied is $-2.5<$ [Fe/H] $<+0.5$. Indeed, some of these bright clusters in NGC 1399 are redder than the reddest Milky Way clusters.

Livio, in collaboration with Yungelson and Tutukov (Moscow), calculated the expected nova rates in galaxies of different morphological types, masses, and star formation history. They showed that in irregular and spiral galaxies, the currently observed nova rates are determined mainly by the present disk star formation rate, while in ellipticals the rate depends mainly on the mass of the galaxy. This explains the differences in the observed nova rates per unit K luminosity in different galaxies.

L. Loinard, in collaboration with P. Thaddeus (CfA), T. Dame (CfA), J. Lequeux (Obs. de Paris) and M. Heyer (FCRAO), finished his CO survey of the southern half of M 31 with the *FCRAO* 14 meter radiotelescope. Though much of the CO emission is confined to two prominent molecular spiral arms, faint CO emission is ubiquitous across the disk of the galaxy. The CO emission is well correlated with the atomic gas, the IR (100 microns) emission and the dust as seen on optical pictures. As in the Milky Way. the ratio of the CO to H I emission peaks at a radius of 2–3 kpc, but if in the Galaxy this radius corresponds to a region of high CO brightness, in M 31, it corresponds to a region where the CO emission is very faint. The results will be published shortly.

Loinard and Allen carried out CO(1-0) observations of a dust cloud in the inner disk of M 31 with the *Owens Valley Radio Interferometer* at a resolution of $\sim 5''$. This cloud had previously been observed with the *IRAM* 30 meter radiotelescope. Only 10–20% of the flux density recorded by the 30-m is recovered by the interferometric observations, showing that most of the emission comes from an extended, very smooth source larger than about $15''$. Hence, the dilution in the beam of the 30-m ($23''$) must be very low, and the CO intensity detected with the 30m closely represents the true

CO brightness of the source and can be used to obtain an estimation of the kinetic temperature of the gas, providing the gas is thermalized. To check that last point, they obtained a CO(3-2) spectrum at the center of the cloud in collaboration with R. Tilanus (U. HI). The CO(3-2) brightness measured is in perfect agreement with that expected for a thermalized gas at the temperature deduced from the CO(1-0) and CO(2-1) observations: $T_{kin} = 3.25$ K. These results suggest that large amounts of very cold molecular gas that have escaped detection so far may be hidden in galactic disks. The analysis of the interferometric and CO(3-2) observations will be published shortly.

Long, Dubus (Paris), and Charles (Oxford) have begun analyzing a multi-year set of *ROSAT* HRI observations of the nearby galaxy M33. They have identified a total of 39 point sources in these images. A detailed study of the nuclear source X-8, the brightest point source in the Local Group, reveals a 156 day periodicity which suggests that the object is a binary black hole system, rather than a mini-quasar or collection of discrete sources. A similar timing analysis of X-7 confirmed the 3.45-d periodicity known from earlier observations and revealed a 0.31-s pulse period, implying that this system has a neutron star as its compact object.

R. Lucas, in collaboration with K. Borne (Hughes/ STX), H. Bushouse (ST ScI) and L. Colina (ST ScI), has been participating in an I-band *HST/WFPC2* snapshot program to observe Infrared Ultraluminous Galaxies. About 120 of the approximately 160 objects in the sample have been observed so far, and these observations are being used to address the question of the fraction of this sample which shows an AGN-like structure versus that which indicates the presence of a starburst. Although the effects of obscuration by dust still call for more high-resolution infrared imaging, there are many new details of morphological fine-structure seen in the I-band images, and they are strongly correlated with the view of ULIRGs being predominantly interaction-related.

From their observations, they estimate that 80–90% of ULIRGs are examples of the starburst phenomenon, and probably related to an interaction or merger. There is still a small fraction which is AGN-like at the limits of the observations, and these, as well as the others, may benefit from more high resolution infrared imaging. Many new features such as previously undetected dust lanes, multiple nuclei or hot-spots, and objects which may be young super star clusters, etc. have also been detected, adding a new wealth of detail to the investigation of these objects. Some of these data have also been used to simulate what one would expect to see at higher redshift with the detectors and type of optics being considered for the *NGST* (*Next Generation Space Telescope*), and the results were very encouraging.

Miller, Whitmore, Fall, and Schweizer (DTM) continued their efforts to study young star clusters in galaxy merger remnants. They have identified 499 cluster candidates in *HST/WFPC2* images of the young merger remnant NGC 7252. These clusters can be divided into three groups: 1) very young objects with ages less than 10 Myr associated with the central gas disk; 2) 700 Myr-old clusters that were probably formed during the merger; and 3) the brightest of the old (15 Gyr) clusters from the progenitor galaxies. These objects have sizes similar to typical globular clusters, yet the cluster luminosity function is a power law of slope -1.8 down to the completeness limit at $V = 26$. In the dynamically young elliptical NGC 3610 they have tentatively identified a 4 Gyr-old cluster population, indicating that NGC 3610 may be a ''missing link'' between young merger remnants and old ellipticals.

Miller and Fall are using the luminosity functions and colors of the cluster candidates in NGC 7252 and NGC 3921 to investigate the shape of the cluster mass function. All the old globular cluster systems have a Gaussian-shaped luminosity function, while young cluster systems have power-law luminosity functions. Yet, for any spread in ages that reproduces the observed color distributions, simulated clusters drawn from a lognormal mass function do not match the observed power-law luminosity functions. On the other hand, simulations using a power-law cluster mass function reproduce the observations extremely well. This implies that the physical process that form young star clusters are scale-free.

Miller, Whitmore, Ferguson, Stiavelli, Lotz (JHU) and Mack are continuing analysis of data from an *HST* snapshot survey of dwarf elliptical (dE) galaxies. In a sample of 25 galaxies we find that nucleated dEs have higher globular cluster specific frequencies, S_N, than non-nucleated dEs. Also, the value of S_N in the nucleated galaxies is more like giant ellipticals than spirals or irregulars. Finally, many of the ''nuclei'' are offset from the geometrical centers of the galaxies. These may be the most massive globular clusters that are still being dragged into the centers. Therefore, they may be witnessing some process associated with nucleus or bulge formation.

Stiavelli has done work on three topics: an infrared study of the M87 jet and radiolobe, an *HST* study of the bulges of spiral galaxies, and an *HST* study of the interacting system NGC 454. For M87, the deepest K band image of the radiolobe was obtained and used to constrain theoretical models of the synchrotron emission. The data allowed to show that the known apparent shift of the radio to optical spectral index in the jet is actually due to a shift in the break frequency of relativistic electrons. Images of the bulges of spiral galaxies from on-going *HST* snapshot surveys with *WFPC2* and *NICMOS* were analyzed. It was found that many early-type spiral galaxies have nuclear star formation and spiral structure extending down to the center.

Stiavelli, in collaboration with Panagia, Carollo, Romaniello, Heyer and Gonzaga, has studied the *WFPC2* images in the F450W, F606W and F814W filters of the interacting pair of galaxies NGC 454. The data indicate that the system is in the early stages of interaction. A population of young star-clusters has formed around the late component, and substantial amounts of gas have sunk into the center of the earlier component, where it has not yet produced significant visible star formation or nuclear activity. Photometric evidence is found that the star-clusters have strong line emission, which indicate the presence of a substantial component of hot, massive stars which formed less than 5–10 Myrs ago.

6. CLUSTERS AND COSMOLOGY

Koekemoer took up a postdoctoral position at ST ScI at the start of 1997 and has been collaborating with O'Dea, Baum, and Sarazin (U. VA) on *HST/FOS* and *GHRS* absorption-line studies of the intra-cluster medium in the cluster Abell 1030. The presence of a bright quasar in this relatively nearby cluster has allowed them to obtain strong limits on the column densities of a wide range of molecular, neutral and ionized species, with upper limits for each species typically in the range 10^{11}–10^{13} cm^{-2}. Lyman-α and C IV absorption systems (also with low column densities, $\sim 10^{13}$ cm^{-2}), associated with the redshift of the quasar, have been detected, hence this object is likely the closest example of an associated absorption system. They find that the most likely candidates for producing the associated absorption are the ISM of the quasar host galaxy, or otherwise faint foreground tidal filaments from a previous interaction involving the host galaxy. Together with X-ray data on this cluster, currently being analysed, they hope to obtain a more detailed picture of the overall ionization physics of gas in non-cooling flow clusters.

M. Hauser, with collaborators Kashlinsky (NORDITA), Mather (GSFC), and Odenwald (Hughes/STX), searched for evidence of the cosmic infrared background (CIB) through its clustering properties. An analysis of the clustering of the diffuse near-infrared light in the *COBE Diffuse Infrared Background Experiment* (*DIRBE*) maps provided upper limits on the CIB from clustered matter.

Panagia, in collaboration with Gilmozzi, Kirshner and Sonneborn, has used refined reductions of the *IUE* light curves and an extensive set of *HST* images of SN 1987A to repeat and improve an earlier analysis, and obtain a better determination of the distance to the supernova. The absolute size of the inner ring at the time of the UV line maximum intensity is estimated to be $R_{abs} = (6.17 \pm 0.18) \times 10^{17}$ cm and the corresponding angular size $R'' = 808 \pm 18$ mas, whose ratio gives a distance to the supernova $d(SN1987A) = 50.9 \pm 1.8$ kpc. Allowing for a displacement of SN 1987A position relative to the LMC center, the distance to the barycenter of the Large Magellanic Cloud is also estimated to be $d(LMC) = 51.5 \pm 1.9$ kpc. This is 3% higher than the value of 50 kpc canonically adopted after Madore and Freedman (1991, PASP, 103, 933).

Panagia, in collaboration with Saha, Sandage, Labhardt, Tammann and Macchetto, has continued the Cepheid calibration of the peak brightness of type Ia supernovae (SNIa) to be used to determine the Hubble constant. So far seven SNIa in spiral galaxies have been calibrated in this way, resulting in average absolute magnitudes $M_B = -19.52 \pm 0.07$ and $M_V = -19.48 \pm 0.07$. Entering these values into Hubble diagram of more distant SNIa leads to values of the Hubble constant around $H_0 = 58 \pm 2$ km s^{-1} Mpc^{-1}. Allowing for the revised distance to the LMC that affects the Cepheid distance scale, as well as for the dependence of SNIa peak brightness on its decay rate, and for reddening corrections in distant supernovae, one finds $H_0 = 60 \pm 6$ km s^{-1} Mpc^{-1}.

E. Perlman, in collaboration with L. Jones (Birmingham), H. Ebeling (Hawaii), C. Scharf (GSFC/ST ScI) and D. Horner (U. MD), is continuing his work on the Wide-Angle *ROSAT* Pointed Survey (WARPS) for Clusters of Galaxies. So far WARPS has surveyed 187 *ROSAT* fields (approximately 35 square degrees) in the region between $3'$–$15'$ from the pointing. The sample features more than 30 $z > 0.3$ clusters and the highest-redshift X-ray selected cluster now known. Their survey uses VTP, a Voronoi Tesselation and Percolation algorithm, to find low-surface brightness X-ray sources. The survey methods are described in Scharf *et al.* (1997). The first results from 86 *ROSAT* fields show convincingly that the strong negative evolution seen for high-mass clusters of galaxies by the EMSS does not continue to lower masses and X-ray luminosities. This places strong constraints on hierarchical models for structure formation in the early universe. They are continuing to expand the WARPS sample and hope to complete the observational phase in the next year.

Perlman's work with J. van Gorkom (Columbia), Stocke, J. M. Shull (Colorado), and C. Carilli (NRAO) on the H I environment of nearby Lyman-α absorbers has culminated in the publication of a recent paper describing redshifted 21 cm observations of several AGN sightlines. Galaxy counterparts were revealed for some but not all of the H I absorbers.

Postman, Oke (DAO, Caltech), and Lubin (OCIW) completed an extensive observational campaign of 9 distant ($z > 0.6$) clusters using the Low Resolution Imaging Spectrograph on the *Keck I* and *II* 10m telescopes. To date, 1500 redshifts have been measured in these 9 fields. Each field also has BVRIK broad band photometry and all have been or will soon be observed with *WFPC2*. The goal is to study the morphological and spectroscopic properties of the cluster members. The key findings to date are:

(1) The number of cluster members found in each cluster is 22 to 25, that is about 15% of the total sample. The remaining objects represent a pencil beam survey out to a redshift of 1.5.

(2) Allowing for the small number of galaxies for which no redshift could be obtained, between 70 and 80% of all galaxies observed have emission lines. There is no difference in frequency between clusters and non-clusters or as a function of redshift. The central regions of the clusters have a larger fraction of elliptical-like objects and hence a smaller fraction of emission line objects.

(3) The prevalence of emission lines indicates that for most galaxies star formation continued long after the initial burst. The oldest elliptical-like galaxies in the clusters have ages of approximately 3 Gyr. The more active galaxies have apparent ages of 0.5 to 3 Gyr, which indicates that star formation is still very important.

(4) Because they are dealing with young galaxies at these redshifts, the conventional measurement of the 4000 Å break is no longer adequate since the Balmer jump is now important. An algorithm has been developed which measures the break or the jump and also indicates which is more important. Models indicate that the 4000 Å jump, when it dominates at ages greater than 2 Gyr, does not depend on the age. It is therefore a measure of the metallicity. For the two clusters which have been studied in detail, there is no evidence that the metallicity is different from solar.

(5) In order to provide a detailed description of the characteristics of the galaxies in the central region of each cluster, Postman *et al.* are using the *HST* images to perform both a quantitative and qualitative study of the morphological and structural properties of the galaxies; this includes the automated classification procedure of the Medium Deep Survey, as well as expert ''by eye'' classifications according to the standard Hubble scheme. The results of the morphological analyses of the first two clusters indicate that, even at similar epochs, there is a large diversity in cluster galaxy properties. They have found that over 80% of all cluster galaxies brighter than $M_v = -17.5$ in the central 0.5 ($h=1$) Mpc of CL1604+4304 are early-type galaxies (ellipticals and S0s), while approximately 80% of all cluster galaxies in the same region of CL0023+0423 are late-type (spiral or irregular) galaxies. These morphological results imply that CL1604+4304 is a cluster which is already well-formed and relaxed, whereas CL0023+0423 appears to be young and in the process of formation.

(6) The dynamical results also indicate that the two clusters are very different. CL0023+0423 appears to consist of two substructures with mean redshifts of 0.8297 and 0.8459, respectively, each with a dispersion of approximately 350–400 km s^{-1}. The two systems are separated in velocity by approximately 2000 km s^{-1} and also in the plane of the sky. The virial and projected mass estimates are 1.3×10^{13} and 3.4×10^{13} $M_\odot$, respectively, for each of the substructures. The dispersions and masses are thus more consistent with those of local groups of galaxies, implying that they may constitute the merger of two spiral-dominated galaxy groups. CL1604+4304 has a mean redshift of 0.8967 and a velocity dispersion of 816 km s^{-1}. The virial and projected mass estimators give 3.3×10^{14} and 3.4×10^{14} $M_\odot$, respectively, with a mean harmonic radius of 157 kpc ($h=0.75$, $q=0.2$). The velocity histogram is consistent with a Gaussian distribution. The dispersion and mass are consistent with those found in class 1 and 2 Abell clusters.

In a related effort, Postman has completed a wide area ($4°\times4°$) deep I band survey. This is one of the largest, contiguous deep galaxy surveys to date. The 4σ limit is $I=24$. The survey was conducted using the *KPNO* 4m prime focus camera. Co-investigators on the project include T. Lauer (KPNO), W. Oegerle (JHU), and J. Hoessel (U. WI). The goal of the survey is to constrain the evolution of large scale structure from $z\sim1$ to the present epoch. The resulting object catalog contains over 700,000 galaxies down to $I=23.5$. With I. Szapudi (FNAL), an analysis of the angular n-point clustering properties has been completed for this sample. They find the 2-point function is consistent with a power law out to scales of 1 degree over the range $17<I<23$. At the bright end, they confirm the slope and amplitude reported by Maddox *et al.* (1996) for the APM galaxy catalog. The higher moments (3rd and 4th) suggest a further confirmation of the hierarchical clustering scenario. The search for distant clusters in the survey has yielded about 15 candidates per square degree with richness class 1 or higher. They estimate that approximately 70% of these candidates are indeed real systems.

K. Sahu, in collaboration with Livio, Petro, Macchetto and others from NASA/MSFC and the University of Amsterdam, observed with *HST* the optical counterpart of GRB 970228, the first ever optical counterpart identified for a GRB. The GRB was observed in two wavebands with *HST*'s *WFPC2* camera about 26 and 38 days after the outburst. The optical counterpart (OT) was clearly detected and the associated extended source was resolved in both photometric bands. The optical decay behavior of the GRB, the size of the extended source, and the apparent constancy between the two epochs of *HST* observations imply that the extended source is the host galaxy of the GRB. The observed decay in the optical is consistent with an impulsive fireball model for the GRB. The OT is about 0.3 arcsec away from the center, which suggests that GRBs, as a class, are not related to nuclear activity of galaxies.

Based on these observations, it was claimed by Caraveo *et al.* that the GRB showed a proper motion of 16 milliarcsec during the twelve days between the two *HST* observations. This was refuted by Sahu and collaborators, who did not detect any proper motion. For a definitive answer, GRB 970228 was observed again about five months later. It showed no proper motion, or fading, strengthening the argument that the extended source is indeed the host galaxy of the GRB.

Sahu and collaborators reported the discovery observations for the optical counterpart of the γ-ray burster GRB 970508, and discussed its light curve in the context of the fireball model. Several aspects of the neutron-star merger model for γ-ray bursts were examined. In particular, this model was used to predict the redshift distribution of γ-ray bursters, and, adopting a recent determination of the cosmic star-formation history, it was shown that the predicted distribution of $\log N - \log P$ relation is consistent with that observed for GRBs.

Sahu, with several other collaborators, used the newly installed *STIS* on-board *HST* to observe the cluster RXJ 1347.5–1145, the most luminous cluster in the X-ray wavelengths. Its relatively high redshift (0.451) and luminosity indicate that this is one of the most massive of all known clusters. The *STIS* images unambiguously show several arcs in the cluster. The *STIS* images also show approximately 100 faint galaxies within the radius of the arcs, whose combined luminosity is $\sim4\times10^{11}$ $L_\odot$. Ground-based spectroscopic observations were obtained for the northern arc, which show one clear emission line at $\sim$6730 Å. This is consistent with an identification as [OII] 3727 Å, implying a redshift of 0.81 for this arc. The mass of the lensing cluster, as derived from the gravitational lensing, is $\sim6.3\times10^{14}$ $M_\odot$. The resultant mass-to-light ratio of $\sim$1500 is higher than what is seen in many clusters.

7. AGN

The single most significant fact about Active Galactic Nuclei (AGN) is their ability to generate extraordinary luminosities in small volumes. The simplest process that can produce such energy is accretion of matter onto a massive black hole. Although this scenario postulates the ultimate power source of AGN, there are many complications in understanding how gravitational energy is transformed into radiation

and kinetic power. Observations that probe close to the heart of the central engine provide important clues to the physics and energetics of the AGN phenomenon. A. Koratkar's research has made use of (1) multi-wavelength spectroscopic studies in the UV, optical and X-rays, (2) UV and X-ray variability, and (3) UV spectropolarimetry to study AGN.

Livio, in collaboration with Xu, has shown that the double-peaked emission lines that are observed in some AGNs have to originate in an accretion disk, and cannot come from a two-sided outflow. The reason is that the disk is expected to be optically thick to such a radial distance that the receding jet is expected to be obscured from view, and therefore it cannot produce the observed red-shifted peak.

Livio, collaborating with Storchi-Bergmann and Ruiz (Brazil), Eracleous and Filippenko (Berkeley), and Wilson (U. MD), showed that the double-peaked lines in the mild AGN NGC 1097 vary in a way which is consistent with the presence of a precessing accretion disk in this system.

O'Dea and Baum have studied the global properties of combined complete samples of GHz Peaked Spectrum (GPS) and Compact Steep Spectrum (CSS) radio sources. The distribution of rest-frame turnover frequency extends above 10 GHz. This reveals the presence of a previously unsuspected population of sources which peak at high frequencies. There is a strong correlation between rest-frame turnover frequency (ν_m) and linear size (LS) of the form $\nu_m \propto LS^{-0.65}$. The continuity on this plane suggests that GPS and CSS sources are related either by evolution or by the mechanism for the turnover or both.

O'Dea and Baum have compared the GPS and CSS sources with the LRL 3CR classical doubles in the redshift range $0.2 \lesssim z \lesssim 1.0$. The GPS and CSS sources in these bright samples would be members of the LRL 3CR if their spectra did not turn over. The number per bin of log size is roughly constant for the GPS and CSS sources, while for the LRL 3CR classical doubles the number increases with increasing size as $N(LS) \propto LS^{0.4}$. These results imply that the GPS and CSS sources evolve in a way that is qualitatively different from the LRL 3CR classical doubles. One possibility is that some of the GPS and CSS sources will not evolve into classical doubles and instead might be transient or frustrated sources. Alternatively, the GPS and CSS sources, due to their interaction with the ISM of the host galaxy, evolve differently from predicted by simple self-similar models.

Assuming that all (or nearly all) the GPS and CSS sources are progenitors of larger sources, O'Dea and Baum have considered the implications for evolution of the GPS and CSS sources and their relationship to the LRL 3CR classical doubles. A simple model where the sources evolve with constant velocity and constant radio luminosity is ruled out. If the sources evolve with constant velocity, the radio luminosity must decrease with linear size as $L_{\rm radio} \propto LS^{-0.5}$. This strong luminosity evolution implies that the GPS and CSS sources evolve into sources which are of intermediate radio luminosity.

E. Perlman, collaborating with J. Biretta, W. Sparks, and F. Macchetto, has used *HST* images of the nearby radio galaxy M87 to produce polarization and spectral index images of its jet with 0.1″ resolution. The polarization image shows several areas with $>50\%$ polarization, near the maximum possible for synchrotron radiation. This implies that the magnetic field in the jet must be extremely well ordered. The spectral index of superluminal knots in the jet appears to be significantly flatter than more diffuse areas, supporting a picture whereby the electrons in the superluminal components are accelerated to higher energies. Interestingly, these areas of the jet, while highly polarized, do not have the highest fraction of polarized flux. Two papers are currently being written on these results.

Perlman, in collaboration with P. Padovani (ST ScI/ II Univ. di Roma), P. Giommi (SAX), R. Sambruna (Penn State), and L. Jones (Birmingham) has continued his work on the Deep X-ray Radio Blazar Survey (DXRBS), which capitalizes on the archived *ROSAT* database to find the faintest blazars known. 119 of 218 candidates now have spectroscopically confirmed identifications, with 111 being blazars—an efficiency of $>90\%$. DXRBS is sampling the low-luminosity end of the blazar luminosity function far better than previous surveys (thanks to its high sensitivity), and has already more than quadrupled the number of flat-radio-spectrum quasars in complete samples at 5 GHz luminosities lower than $10^{33.5}$ erg s^{-1} Hz^{-1}. In addition, DXRBS has discovered that all previous surveys have missed a large population of blazars ($\sim 1/3$ of the DXRBS sample) with high ($>10^{-6}$) ratios of X-ray to radio luminosity. This population is somewhat akin to the X-ray selected BL Lacs in their high ratios of X-ray to radio luminosity, but unlike for BL Lacs, there do not seem to be any FSRQs at $L_x/L_r > 10^{-5}$ (there are BL Lacs known with values of L_x/L_r as high as 10^{-3}). Perlman *et al.* have recently submitted a paper to AJ on these results.

Perlman is also continuing his work following up on low-luminosity BL Lacs in the Einstein Medium Sensitivity Survey with J. Stocke, T. Rector (both of Colorado) and I. Gioia (Hawaii). A total of seven BL Lacs have been added to the list of 36 BL Lacs in the survey, and a paper is being prepared which will recalculate the luminosity function of the sample. The process of identifying new BL Lac objects combines *ROSAT* HRI data, and optical spectroscopy at the *KPNO* 2.1m and *MMT* telescopes.

Perlman also led multiwavelength campaigns with SAX and RXTE on the BL Lac objects 1E1218+304 (RXTE, collaborating with Madejski (GSFC), Stocke and Rector) and 1ES2344+514 (SAX, collaborating with Padovani and Giommi). The results of both campaigns are exciting. Ground-based monitoring of 1E1218+304 during the campaign reveals variations of ~ 0.4 magnitude on timescales less than 1 hour. This will allow placement of strict limits on emission models. The SAX data on 1ES2344+514 show possible evidence for an increasing contribution from inverse-Compton radiation at energies >5 keV, as the character of the variability changes. Below that point, the harder bands are seen to lead softer bands, but above 5 keV, the opposite seems to be the case. Interestingly, however, no evidence for a spectral break is seen.

Perlman also continues his research into the origins of the diffuse gamma-ray background (DGRB). Along with D. Kazanas (GSFC), he has written a paper modeling the DGRB

emission seen by EGRET (in the 30 MeV–10 GeV range) as being due to the low-state gamma-ray emission from blazars.

Urry, O'Dowd, Scarpa, Pesce, Falomo, Treves, and Giavalisco continue their *HST/WFPC2* imaging survey of BL Lac objects, investigating the properties of their host galaxies and environments. The first results describe the detection of host galaxies out to redshift $z = 0.7$. Altogether, *WFPC2* observations of nearly 100 BL Lacs reveal detections of host galaxies in most objects with $z < 0.5$. These results will illuminate the nature of BL Lac objects, their connection to radio galaxies and other AGN, their evolution from $z = 0.1$ to $z = 1$, and the role of interactions in triggering nuclear activity.

Urry has continued multiwavelength monitoring of blazars with Maraschi, Pian, Pesce, Wehrle, and collaborators, carrying out radio-through-gamma-ray campaigns on the UV-bright BL Lac objects Mrk501 and PKS2155–304, and quasars 3C279 and 3C273. Mrk501 underwent a major flare in April 1997, during which its upper synchrotron cutoff increased from below 1 keV to ~100 keV, an unprecedented electron acceleration event. For PKS2155–304, a series of papers has been published describing correlated flares at X-ray, EUV, UV, and visible wavelengths. The detected lags, of order 1 day from one band to the next, can be explained by the energy-dependent cooling of synchrotron-emitting electrons. More recent high-energy monitoring data show similar large-amplitude variability. For 3C279, coordinated variations at gamma-ray through optical/UV wavelengths imply associated changes in both Compton-scattering electrons and seed UV photons, as may happen if the broad-line region is photoionized significantly by the jet radiation. For 3C273, the gamma-ray through radio variations and the gamma-ray spectrum hardening with increasing intensity can be explained by Compton-scattering of lower energy photons or by proton-initiated cascade models. A re-analysis of archival *IUE* spectra of 3C273 shows that intrinsic variability of UV lines is very small, implying that gamma-ray variability must be due to electron acceleration if external comptonization models apply.

With Ulrich and Maraschi, Urry has written a review of AGN variability, covering blazars and normal AGN. The important distinction between the two classes is the dominance of thermal emission in the latter and non-thermal jet emission in the former. For blazars, the presence of very strong gamma-ray emission confirms the importance of relativistic beaming and indicates a distinction between relatively low luminosity blazars (BL Lac objects), for which the synchrotron self-Compton model most likely applies, and higher luminosity blazars (quasars), for which external Compton models are dominant.

Urry continues to study the X-ray properties of AGN, with Sambruna, Grandi and collaborators. With Sambruna, the ASCA spectrum of the high-redshift blazar 0528+134 has been used to constrain the activity of the gamma-ray component, and *ASCA*, *ROSAT* and *BBXRT* spectra of the BL Lac object 1426+428 have been used to constrain the presence of hot, X-ray-absorbing gas. With Grandi, X-ray and gamma-ray data have been combined to investigate the reflection spectra of the Seyfert galaxy MCG+8-11-11 and the broad-line radio galaxy 3C120.

8. INSTRUMENTS AND SOFTWARE

R. J. Allen continued his involvement with the Space Interferometer Mission, serving on the Science Working Group and chairing the Imaging, Interferometry, and Nulling subcommittee.

R. Bohlin is a co-I on the *Ultraviolet Imaging Telescope* (*UIT*) on the Astro 2 Spacelab Mission, launched in March of 1995. The PI is T. P. Stecher of GSFC. Bohlin and his post-doc D. Smith are working on the data analysis.

During the past year, Bohlin has been working mainly on *STIS* calibration.

The DBSA (Database and System Administration team) completed the coordination and implementation of the ASSIST database redesign this past year. The new database was designed to better meet the needs of current and future proposal processing. The PEP database was merged into the ASSIST database, eliminating many redundant and obsolete fields. In addition, many obsolete fields and tables were removed. Visit information that was not stored in the original database was added to the new database.

Some of the structure information in ASSIST was originally duplicated in the PMDB. Hence this information was deleted from ASSIST. This resulted in procedural changes for the population of the PMDB since data needed to be stored at a much earlier phase in the process.

The entire redesign process resulted in a great deal of coordination with other teams around the institute including Trans, Spike, DADs, and SPSS. Many software tools needed to be modified to support the redesign effort. This included the populators for the ASSIST database.

The result of the redesign effort is a database that is more accurate and consistent than ever. Query performance has improved as well due to faster hardware and better designed relations.

Another major development effort for the DBSA team was related to the PC and CS tools. These tools are used by Program Coordinators and Contact Scientists to query and update the ASSIST and PMDB databases. They are easy to use graphical user interface tools that are utilized on a daily basis. These tools are critical for maintaining accurate and consistent information within the databases as well as providing efficient querying capabilities.

M. Hauser, in collaboration with members of the *COBE-DIRBE* and *FIRAS* teams, carried out a careful comparison of the absolute calibrations of the *DIRBE* and *FIRAS* instruments in their region of spectral overlap, 100 to 240 microns. The two data sets were found to be consistent within their estimated gain and offset uncertainties.

H. Stockman, collaborating with many staff at the ST ScI, J. Mather at GSFC, and a volunteer science working group, studied the scientific program of the *Next Generation Space Telescope* (*NGST*). The *NGST* is a large aperture (diameter >4 m), passively-cooled space telescope optimized for ultrasensitive imaging and spectroscopy in the near-infrared. NASA and two major aerospace firms have proposed designs that achieve the 1 nJy sensitivity needed to detect the first

stars and galaxies at high redshift, $z>15$. Overviews of the spacecraft designs and the science mission appear in a recently published booklet and a number of conference proceedings.

PUBLICATIONS

This list includes papers published or submitted between October 1996 and September 1997 by ST ScI staff (or by visitors, if a substantial portion of the work was done at ST ScI). Some papers published in this period may have been included as ''submitted'' or ''in press'' in the previous annual report.

Alcock, C. *et al.* 1997, ''The X-Ray Off State of the Supersoft Source CAL 83 and Its Interpretation,'' MNRAS, 286, 483

Alcock, C. *et al.* 1997, ''Optical Photometry of the Eclipsing Large Magellanic Cloud Supersoft Source CAL 87,'' MNRAS, 287, 699

Allen, R. J. 1996, ''Molecular Gas in Spiral Galaxies,'' in *New Extragalactic Perspectives in the New South Africa*, eds. D. L. Block & J. M. Greenberg (Kluwer: Dordrecht), p. 50

Allen, R. J., Knapen, J., & Bohlin, R. 1997, ''Evidence for the Large-Scale Dissociation of Molecular Gas in the Inner Spiral Arms of M81,'' ApJ, 486, in press

Allen, R. J., Loinard, L., McKellar, A. R. W., & Lequeux, J. 1997, ''A Search for the CO–H_2 Dimer in the Galaxy,'' ApJ, 484, in press

Allen, R. J., Peterson, D., & Shao, M. 1997, ''Space Interferometer Mission: Taking the Measure of the Universe,'' in *Optical Telescopes of Today and Tomorrow*, ed. A. Ardeberg, SPIE, 2871, 504

Ajhar, E., Lauer, T. R., Tonry, J., Blakeslee, J., Dressler, A., Holtzman, J., & Postman, M. 1997, ''Calibration of the Surface Brightness Fluctuation Method for use with the Hubble Space Telescope,'' AJ, 114, 626

Allen, R. J., Knapen, J. H., Bohlin, R. C., & Stecher, T. P. 1997, ''Evidence for the Large-Scale Dissociation of Molecular Gas in the Inner Spiral Arms of M81,'' ApJ, in press

Baptista, R., Horne, K., Hubeny, I., Long, K., Mauche, C. W., Rutten, R. G. M., & Wade, R. A. 1996. ''Spectrally Resolved Maps of Optically Thick Accretion Disks,'' in *Cataclysmic Variables and Related Objects*, ed. A. Evans & J. H. Wood (Dordrecht: Kluwer), p. 17

Baum, S. A., O'Dea, C. P., *et al.* 1997, ''HST and MERLIN Observations of 3C264—A Laboratory for Jet Physics and Unified Schemes,'' ApJ, 483, 178

Bianchi, L., Clayton, G. C., Bohlin, R. C., Hutchings, J. B., & Massey, P. 1996, ''UV Extinction by Interstellar Dust in External Galaxies: M31,'' ApJ, 471, 203

Bicknell, G. V., Dopita, M. A., & O'Dea, C. P. 1997, ''Unification of the Radio and Optical Properties of GPS and CSS Radio Sources,'' ApJ, 485, 112

Binzel, R. P., Gaffey, M. J., Thomas, P. C., Zellner, B. H., Storrs, A. D., & Wells, E. N. 1997, ''Geologic Mapping of Vesta from 1994 Hubble Space Telescope Images,'' Icarus, 128, 95

Blair, W. P., & Long, K. S. 1997, ''Identification of Supernova Remnants in the Sculptor Group Galaxies NGC 300 and NGC 7793,'' ApJS, 108, 261

Boller, T., Voges, W., Frontera, F., Costa, E., Piro, L., Pedersen, H., Benetti, S., Turatto, M., Goudfrooij, P., Marconi, A., Jablonka, P., Palazzi, E., Heise, J., Studt, J., & Castro-Tirado, A. J. 1997, ''GRB970228,'' IAUC, 6580, 1

Bowers, C., Hartig, G., Kaiser, M., Kraemer, S., Gull, T., Kimble, R., Woodgate, B., Bohlin, R., Plait, P., Lindler, D., Ebbets, D., Sullivan, J., Hill, R. S., Kinney, E., Sahu, K., Crenshaw, M., Collins, N., Danks, A., Robinson, R., Cornett, R., & Gruzyzak, A. 1997, ''In-flight Optical Performance of the Space Telescope Imaging Spectrograph,'' BAAS, 190, 836

Cacciari, C. 1997, ''Globular Clusters in M31,'' BAAS, 190, 824

Calzetti, D. 1997, ''UV Opacity in Nearby Galaxies and Application to Distant Galaxies,'' in *The Ultraviolet Universe at Low and High Redshift: Probing the Progress of Galaxy Evolution*, eds. W. H. Waller, M. N. Fanelli, J. E. Hollis, & A. C. Danks (New York: AIP Press)

Calzetti, D., Meurer G. R., Bohlin, R. C., Garnett, D. R., Kinney, A. L., Leitherer, C., & Storchi-Bergmann, T. 1997, '' Dust and Recent Star Formation in the Core of NGC5253,'' AJ, in press

Canzian, B., & Allen, R. J. 1998, ''If the Corotation Resonance Radius in a Spiral Galaxy is Known, What Else Can be Learned?,'' ApJ, in preparation

Canzian, B., & Allen, R. J. 1997, ''Spiral Density Wave Theory, Corotation Resonance, and the Velocity Field of NGC 4321,'' ApJ, 479, 723

Carollo, C. M., Stiavelli, M., de Zeeuw, T., & Mack, J. 1997, ''Spiral Galaxies with WFPC2: I. Nuclear Morphology, Bulges and Surface Brightness Profiles,'' AJ, in press

Charbonnel, C., Däppen, W., Bernasconi, P. A., Maeder, A., Meynet, G., Schaerer, D., & Mowlavi, N. 1997, ''Grids of Stellar Models. VII. From 0.4 to 1.0 $M_\odot$ at $Z=0.020$ and $Z=0.001$, with an Adequate Equation of State,'' AP&SSS, in press

Cheng, K. P., Collings, N., Angione, R., Talbert, F., Hintzen, P., Smith, E. P., Stecher, T. P., & the UIT Team, ''UV/Visible Sky Gallery,'' CD-ROM

Ciardullo, R., Sipior, M., Fullton, L. K., Bond, H. E. 1998, ''An HST WFPC2 Snapshot Survey of Companions of Planetary Nebula Nuclei,'' in preparation

Colina, L., & Bohlin, R. C. 1997, ''Absolute Flux Distributions of Solar Analogs from the UV to the Near-IR,'' AJ, 113, 1138

Colina, L., & Koratkar, A. 1997, ''The Nature of the Energy Source in LINERs,'' in *Emission Lines in Active Galaxies: New Methods and Techniques*, eds. B. M. Peterson, F.-Z. Cheng, & A. S. Wilson (San Francisco: Astronomical Society of the Pacific), p. 477

Cornett, R. H., Greason, M. R., Hill, J. K., Parker, J. W., Waller, W. H., Bohlin, R. C., Cheng, K-P., Neff, S. G., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1997, ''UIT: Ultraviolet Observations of the Small Magellanic Cloud,'' AJ, 113, 1011

Cuillandre, J.-C., Lequeux, J., Mellier, Y., & Allen, R. J. 1997, ''Dust and Star Formation in the Outermost Parts of M31,'' A&A, submitted

De Marchi, G., Paresce, F., Stratta, M. G., Gilliland, R. L., & Bohlin, R. C. 1996, ''The Density Profile of 47 Tucanae,'' ApJ, 468, L51

De Vries, W. H., Barthel, P. D., Hes, R., & O'Dea, C. P. 1997, ''Radio Spectra of Gigahertz Peaked Spectrum Radio Sources,'' A&A, 321, 105

De Vries, W. H., O'Dea, C. P., *et al.* 1997, ''Hubble Space Telescope Imaging of Compact Steep Spectrum Radio Sources,'' ApJS, 110, 191

de Vries, W., O'Dea, C., Baum, S., Perlman, E., Lehnert, M., & Barthel, P. 1997, ''Hosts of Powerful Radio Galaxies in the Near-IR: Implications on Radio Source Evolution,'' ApJ, submitted

de Vries, W., O'Dea, C., Perlman, E., Baum, S., Lehnert, M., Stocke, J., Rector, T., & Elston, R. 1997, ''Near-IR Imaging of Gigahertz Peaked Spectrum, Compact Steep Spectrum and Large Scale FR II Radio Galaxies,'' ApJ, submitted

Donahue, M., Sahu, K. C., Livio, M., Petro, L., Stocke, J. T., Groot, P., & van Paradijs, J. 1997, ''GRB970508,'' IAU Circ. 6666

Dopita, M. A., Koratkar, A., Allen, M., Tsvetanov, Z., Ford, F. C., Bicknell, G. V., & Sutherland, R. S. 1997, ''The LINER Nucleus of M87: A Shock Excited Accretion Disk,'' ApJ, 490, in press

Dopita, M. A., Vassiliadis, E., Meatheringham, S. J., Harrington, J. P., Bohlin, R. C., Ford, H. C., Wood, P. R., Stecher, T. P., & Maran, S. P. 1997, ''HST Observations of Planetary Nebulae in the Magellanic Clouds V: Mass Dependence of Dredge-Up and the Chemical History of the LMC,'' ApJ, 474, 188

Dorman, B., Shah, R. Y., O'Connell, R. W., Landsman, W. B., Rood, R. T., Bohlin, R. C., Neff, S. G., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1997, ''UIT Detection of Hot Stars in the Globular Cluster NGC 362,'' ApJL, 480, L31

Dwek, E., Arendt, R. G., Fixsen, D. J., Sodroski, T. J., Odegard, N., Weiland, J. L., Reach, W. T., Hauser, M. G., Kelsall, T., Moseley, S. H., Silverberg, R. F., Shafer, R. A., Ballester, J., Bazell, D., & Isaacman, R. 1997, ''Detection and Characterization of Cold Interstellar Dust and PAH Emission from COBE Observations,'' ApJ, 475, 565

Ebbets, D. C., Walborn, N. R., & Parker, J. W. 1997, ''Ultraviolet Spectral Morphology of the Stellar Core of Eta Carinae,'' ApJL, in press

Ebeling, H., Jones, L., Perlman, E., Scharf, C., Mullis, C., Horner, D., Malkan, M., & Wegner, G. 1997, ''The WARPS Survey: Discovery of an X-ray Selected Cluster at $z = 0.8325$,'' ApJL, submitted

Evans, I. N., Koratkar, A., Allen, M., Tsvetanov, Z., & Dopita, M. 1997, ''Excitation Mechanism of Extended Emission Line Regions in Active Galaxies,'' in *Emission Lines in Active Galaxies: New Methods and Techniques*, eds. B. M. Peterson, F.-Z. Cheng, & A. S. Wilson (San Francisco: Astronomical Society of the Pacific), p. 386

Fall, S. M. 1997, ''A Global Approach to Star and Galaxy Formation,'' in *The Early Universe with the VLT*, ed. J. Bergeron (Berlin: Springer), p. 177

Fall, S. M. 1997, ''A Global Perspective on Star Formation,'' in *The Hubble Space Telescope and the High Redshift Universe*, eds. N. R. Tanvir, A. Aragón-Salamanca, & J. V. Wall (Singapore: World Scientific), p. 303

Fall, S. M., Charlot, S., & Pei, Y. C. 1996, ''Cosmic Emissivity and Background Intensity From Damped Lyman-Alpha Galaxies,'' ApJ, 464, L43

Falomo, R., Urry, C. M., Pesce, J. E., Scarpa, R., Treves, A., & Giavalisco, M. 1997, ''Observations of Host Galaxies in Three Radio-Selected BL Lacertae Objects,'' ApJ, 476, 113

Falomo, R., Urry, C. M., Scarpa, R., Treves, A., Pesce, J., & O'Dowd, M. 1997, ''The HST Snapshot Imaging Survey of BL Lacs,'' in *IAU Symp. 186*, in press

Fanelli, M. N., Collins, N., Bohlin, R. C., Neff, S. G., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1997, ''An Ultraviolet View of Massive Star Formation in Seyfert Host Galaxies,'' AJ, in press

Fanelli, M. N., Waller, W. W., Smith, D. A., Freedman, W. L., Madore, B., Neff, S. G., O'Connell, R. W., Roberts, M. S., Bohlin, R. C., Smith, A. M., & Stecher, T. P. 1997, ''An Ultraviolet and Near-IR View of NGC 4214: A Starbursting Core Embedded in a Low Surface Brightness Disk,'' ApJ, 481, 735

Fernley, J., Carney, B. W., Skillen, I., Cacciari, C., & Janes, K. 1997, ''The Slope of the RR Lyrae M_V, [Fe/H] Relation,'' MNRAS, in press

Ferguson, H. C., Williams, R. E., & Cowie, L. L. 1997, ''Probing the Faintest Galaxies,'' Phys. Today, 50, 24

Ferraro, F. R., Carretta, E., Corsi, C. E., Fusi Pecci, F., Cacciari, C., Buonanno, R., Paltrinieri, B., & Hamilton, D. 1997, ''The Stellar Population of the Globular Cluster M3. II. CCD Photometry of Additional 10,000 Stars,'' A&A, 320, 757

Ferraro, F. R., Paltrinieri, B., Fusi Pecci, F., Cacciari, C., Dorman, B., & Rood, R. T. 1997, ''HST UV Observations of the Cores of M3 and M13,'' ApJ, 484, L145

Ferraro, F. R., Paltrinieri, B., Fusi Pecci, F., Cacciari, C., Dorman, B., Rood, R. T., Buonanno, R., Corsi, C. E., Burgarella, D., & Laget, M. 1997, ''HST Observations of Blue Straggler Stars in the Core of the Globular Cluster M3,'' A&A, 324, 915

Fixsen, D. J., Weiland, J. L., Brodd, S., Hauser, M. G., Kelsall, T., Leisawitz, D. T., Mather, J. C., Jensen, K. A., Shafer, R. A., & Silverberg, R. F. 1997, ''Comparison of the COBE FIRAS and DIRBE Calibrations,'' ApJ, in press

Galama, T., Groot, P. J., van Paradijs, J., Kouveliotou, C., Robinson, C. R., Fishman, G. J., Meegan, C. A., Sahu, K. C., Livio, M., Petro, L., Macchetto, F. D., Heise, J., in't Zand, J., Strom, R. G., Telting, J., Rutten, R. G. M., Pettini, M., Tanvir, N., & Bloom, J. 1997, ''The Decay of Optical Emission from the Gamma-ray Burst GRB970228,'' Nature, 387, 479

Gallimore, J. F., Baum, S. A., & O'Dea, C. P. 1997, ''A Direct Image of the Obscuring Disk Surrounding the Active Galactic Nucleus of NGC 1068,'' Nature, 388, 852

Gäng, Th., Leitherer, C., Wolf, B., Stahl, O., Chapman, J., van Gent, J., Lamers, H. J. G. L. M., & Scuderi, S. 1997, ''Atmospheric Conditions in LBVs: First Results from a High-Resolution Optical Survey,'' in *Luminous Blue Variables: Massive Stars in Transition*, eds. A. Nota & H. J. G. L. M. Lamers, (San Francisco: Astronomical Society of the Pacific), p. 110

Gaskell, M., & Koratkar, A. 1997, ''The Nature of Fe II Emitting Clouds in Quasars: Ultraviolet Observations of Extreme Fe II Emitting Quasars Mrk 42 and Mrk 957,'' ApJ, submitted

Goad, M., & Koratkar, A. 1997, ''Broad Emission-Line Variability as a Constraint upon the Physical Conditions within the BLR of NGC 5548,'' ApJ, submitted

Goldader, J. D., Leitherer, C., & Schaerer, D. 1997, ''M Supergiants at Low Metallicities: A Cautionary Note for Population and Evolutionary Synthesis in the Near-Infrared,'' ApJ, submitted

González, R. A., Allen, R. J., Calzetti, D., Ferguson, H. C., & Panagia, N. 1997, ''The Opacity of Spiral Disks from Colors and Counts of Background Galaxies: NGC 4536,'' BAAS, 190, 204

González, R. A., Allen, R. J., Calzetti, D., Ferguson, H. C., & Panagia, N. 1997, ''Using the Hubble Deep Field as a Tool to Measure the Opacity of Spiral Galaxy Disks,'' in *The Hubble Deep Field*, ed. M. Livio, ST ScI Symposium Series, in press

González, R. A., Allen, R. J., Dirsch, B., Ferguson, H. C., Calzetti, D., & Panagia, N. 1998, ''The Opacity of Spiral Disks from Colors and Counts of Background Galaxies. I. NGC 4536 & NGC 3664,'' in preparation

Gordon, K. D., Calzetti, D., & Witt., A. N. 1997, ''The Effects of Dust in Starburst Galaxies,'' ApJ, in press

Goudfrooij, P. 1996, ''The Distribution of Dust and Gas in Elliptical Galaxies,'' in *New Extragalactic Perspectives in the New South Africa; Changing Perceptions of the Morphology, Dust Content, and Dust-Gas Ratios in Galaxies*, eds. D. L. Block & J. M. Greenberg (Kluwer: Dordrecht), p. 400

Goudfrooij, P. 1996, ''Dust and Ionized Gas in Elliptical Galaxies,'' in *The Second Stromlo Symposium: The Nature of Elliptical Galaxies*, eds. M. Arnaboldi, G. S. Da Costa, & P. Saha, p. 338

Goudfrooij, P., Alonso, M. V., Minniti, D., Kissler-Patig, M., & Meylan, G. 1997, ''Globular Clusters in the Giant Elliptical Galaxy NGC 1399,'' in *Galaxy Interactions at Low and High Redshift*, ed. D. B. Sanders (Kluwer: Dordrecht), in press

Goudfrooij, P., & Trinchieri, G. 1996, ''The Association of X-ray Emission, Ionized Gas, and Dust Extinction in NGC 5846,'' BAAS, 189, 6710

Grandi, P., Haardt, F., Ghisellini, G., Grove, E. J., Maraschi, L., & Urry, C. M. 1997, ''High Energy Break and Reflection Features in the Seyfert Galaxy MCG+8-11-11,'' ApJ, submitted

Grandi, P., Haardt, F., Ghisellini, G., Grove, E. J., Maraschi, L., & Urry, C. M. 1997, ''Detection of a High Energy Break in the Seyfert Galaxy MCG+8-11-11,'' in *Proc. 4th Compton Symposium*, (Williamsburg, April 1997), in press

Grandi, P., Sambruna, R. M., Maraschi, L., Matt, G., Urry, C. M., & Mushotzky, R. F. 1997, ''Rosat, ASCA, and OSSE Observations of the Broad Line Radio Galaxy 3C120,'' ApJ, in press

Grandi, P., Sambruna, R. M., Maraschi, L., Urry, C. M., & Mushotzky, R. F. 1997, ''The High Energy Spectrum of the Radio Galaxy 3C120,'' in *X-Ray Imaging and Spectroscopy of Cosmic Hot Plasmas*, eds. F. Makino & K. Mitsuda (Tokyo: Universal Academy Press), p. 283

Greeley, B. W., Blair, W. P., Long, K. S., & Knigge, C. 1997, ''The Far Ultraviolet Spectrum of the Intermediate Polar EX Hya,'' ApJ, 488, 419

Heckman, T. M., Meurer, G., Krolik, J., González-Delgado, R., Leitherer, C., Koratkar, A., Kinney, A., & Wilson, A. S. 1997, ''A Powerful Nuclear Starburst in the Type 2 Seyfert Galaxy Mrk 477: Implications for the Starburst—AGN Connection,'' ApJ, 482, 114

Henry, T. J., Soderblom, D. R., Donahue, R., & Baliunas, S. L. 1996, ''A Survey of Ca II Chromospheric Emission in Southern Solar-Type Stars,'' AJ, 111, 439

Hill, J. K., Waller, W. H., Cornett, R. H., Bohlin, R. C., Cheng, K.-P., Neff, S. G., O'Connell, R. W., Roberts, M. S., Smith, A. M., Hintzen, P. M. N., Smith, E. P., & Stecher, T. P. 1997, ''UV Colors and Extinctions of HII Regions in the Whirlpool Galaxy (M51),'' ApJ, 477, 673

Hulbert, S. J., Hodge, P., Lindler, D., Shaw, R., Goudfrooij, P., Katsanis, R., Keener, S., McGrath, M. A., Bohlin, R. C., & Baum, S. A. 1997, ''STIS Calibration Pipeline,'' BAAS, 190, 420

Jacoby, G. H., Morse, J., Fullton, L. K., Kwitter, K. B., & Henry, R. B. C. 1997, ''Planetary Nebulae in the Globular Clusters Pal 6 and NGC 6441,'' AJ, in press

Jones, B. F., Fischer, D., Shetrone, M. D., & Soderblom, D. R. 1997, ''The Evolution of Lithium Abundances of Solar-Type Stars. VII. M34 (NGC 1039) and the Role of Rotation in Lithium Depletion,'' AJ, 114, 352

Jones, B. F., Shetrone, M. D., & Soderblom, D. R. 1996, ''The Evolution of Lithium Abundances of Solar-Type Stars. VI. The End of Lithium in the Pleiades,'' AJ, 112, 186

Jones, D. L., Weiler, K. W., Allen, R. J., Desch, M. M., Erickson, W. C., Kaiser, M. L., Kassim, N. E., Kuiper, T. B. H., Mahoney, M. J., Marsh, K. A., Perley, R. A., Preston, R. A., & Stone, R. G. 1997, ''The Astronomical Low-Frequency Array (ALFA),'' in *IAU Colloquium 164*, in press

Jones, L., Scharf, C., Ebeling, H., Perlman, E., Malkan, M., & Wegner, G. 1997, ''The log N–log S Relation and the X-ray Evolution of Low Luminosity Clusters of Galaxies,'' ApJ, in press

Kaper, L., van Loon, J. T., Augusteijn, T., Goudfrooij, P., Patat, F., Waters, L. B. F. M., & Zijstra, A. A. 1996, ''Discovery of a Bow Shock Around Vela X-1,'' ApJ, 475, L37

Kashlinsky, A., Mather, J. C., Odenwald, S., & Hauser, M. G. 1996, ''Clustering of the Diffuse Infrared Light from

the COBE DIRBE maps. I. C(0) and Limits on the Near-IR Background,'' ApJ, 470, 681

Kazanas, D., & Perlman, E. 1997, ''Low-State Gamma-Ray Emission from Blazars and the Gamma-Ray Background,'' ApJ, 476, 7

Kaufer, A., Stahl, O., Wolf, B., Fullerton, A. W., Gäng, T., Gummersbach, C. A., Jankovics, I., Kovacs, J., Mandel, H., Peitz, J., Rivinius, T., & Szeifert, T. 1997, ''Long-term Spectroscopic Monitoring of BA-Type Supergiants. III: Variability of Photospheric Lines,'' A&A, 320, 273

Kimble, R. A., Argabright, V., Van Houten, C., Dorn, D., Blouke, M., Kraemer, S., Danks, A., Goudfrooij, P., Clampin, M., Beck, T., Malumuth, E., Landsman, W., Hill, R. J., Kaiser, M. B., Bowers, C., Hartig, G., Hayes, J. J. E., Baum, S. A., Bohlin, R. C., Ferguson, H. C., Leitherer, C., Feggans, J., & Sandoval, J. 1997, ''In-Flight Detector Performance of the Space Telescope Imaging Spectrograph,'' BAAS, 190, 4207

Kingdon, J. B., & Ferland, G. J. 1997, ''Grains in Ionized Nebulae II: Heavy Element Depletion,'' ApJ, 447, 732

Kingdon, J. B., & Williams, R. E. 1997, ''Abundance Determinations in Emission-Line Objects: The Revised Emission Line Chart,'' AJ, 113, 2193

Knigge, C., Long, K. S., Blair, W. P., & Wade, R. A. 1997, ''Disks, Winds, and Veiling Curtains: Dissecting the Ultraviolet Spectrum of the Dwarf Nova Z Camelopardalis in Outburst,'' ApJ, 476, 291

Koratkar, A., Evans, I. N., Pesto, S., & Taylor, C. 1997, ''A Detailed Comparison of HST and IUE UV Spectra of Selected Seyfert Nuclei,'' ApJ, 491, in press

Koratkar, A., Goodrich, R., & Antonucci, R. 1997, ''Below the Lyman Edge: UV Polarimetry of Quasars,'' in *Accretion Phenomenon in Astrophysics*, ed. G. Bicknell (San Francisco: Astronomical Society of the Pacific), in press

Koratkar, A., Pesce, J., Urry, M., & Pian, E. 1997, ''Monitoring Ly-Alpha Emission from the Blazar 3C 279,'' ApJ, in press

Koratkar, A., Pesto, S., & Evans, I. N. 1997, ''A Detailed Comparison of HST FOS and IUE UV Spectra of Selected Seyfert Nuclei,'' in *Emission Lines in Active Galaxies: New Methods and Techniques*, eds. B. M. Peterson, F.-Z. Cheng, & A. S. Wilson (San Francisco: Astronomical Society of the Pacific), p. 136

Kulkarni, V. P., Fall, S. M., & Truran, J. W. 1997, ''Abundance Patterns of Heavy Elements in Damped Lyman-Alpha Galaxies,'' ApJL, 484, L7

Landsman, W. B., Sweigart, A. V., Bohlin, R. C., Neff, S. G., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1996, ''UV Imagery of NGC 6752: A Test of Extreme Horizontal Branch Models,'' ApJL, 472, L93

Lauer, T. R., Tonry, J., Postman, M., Ajhar, E., & Holzman, J. 1997, ''The Far-Field Hubble Constant,'' ApJ, submitted

Lisse, C. M., A'Hearn, M. F., Hauser, M. G., Kelsall, T., Lien, D. J., Moseley, S. H., Reach, W. T., & Silverberg, R. F. 1997, ''Infrared Observations of Comets by COBE,'' ApJ, in press

Livio, M. & Pringle, J. E. 1997, ''Wobbling Accretion Disks, Jets, and Point-Symmetric Nebulae,'' ApJ, 486, 835

Livio, M. & Xu, C. 1997, ''On the Evidence for Accretion Disks in Active Galactic Nuclei,'' ApJ, 478, L63

Loinard, L., & Allen, R. J. 1998, ''Cold Massive Molecular Clouds in the Inner Disk of M31,'' ApJ, in preparation

Long, K. S. 1996, ''Far Ultraviolet Observations of Dwarf Novae Made with the Hopkins Ultraviolet Telescope,'' in *Cataclysmic Variables and Related Objects*, ed. A. Evans & J. H. Wood (Dordrecht: Kluwer), p. 233

Lubow, S., Tout, C. A. & Livio, M. 1997, ''Resonant Tides in Close Orbiting Planets,'' ApJ, 484, 866

Lucas, R. A., Borne, K. D., Bushouse, H., & Colina, L. 1997, ''A Hubble Space Telescope Survey of Ultraluminous IR Galaxies,'' BAAS, 29, 838

Mack, K.-H., Klein, U., O'Dea, C. P., Willis, A. G. 1997, ''Multi-frequency Radio Continuum Mapping of Giant Radio Galaxies,'' AP&SSS, 123, 423

Mather, J., Bely, P. Y., Burg, R., Seery, B. D., Smith, E. P., Stiavelli, M., & Stockman, H. S. 1997, ''The Next Generation Space Telescope: Building from HST,'' in *The Hubble Deep Field*, ed. M. Livio, ST ScI Symposium Series, in press

Mather, J., Bely, P. Y., Stockman, H., & Thronson, H. 1997, ''NGST Capabilities and Design Concepts,'' in *Science with NGST*, ed. E. Smith, (San Francisco: Astronomical Society of the Pacific), in press

Mather, J., Bely, P. Y., Stockman, H., & Thronson, H. 1997, ''NGST Capabilities for Planet and Planet Formation Studies,'' in *Planets Beyond the Solar System and the Next Generation of Space Missions*, ed. D. Soderblom, (San Francisco: Astronomical Society of the Pacific), in press

Marshall, H. L., Urry, C. M., Pesce, J. E., Konigl, A., Maraschi, L., & Wehrle, A. 1997, ''A Possible New Absorption Feature in the EUV Spectrum of PKS2155–304,'' BAAS, 28, 1311

Martin, C. L., & Kennicutt, R. C. 1997, ''Measurements of HeI 5876 Å Recombination-Line Radiation from the Diffuse, Warm Ionized Medium in Irregular Galaxies,'' ApJ, 483, 698

Meynet, G., Mowlavi, N., Schaerer, D., & Pindao, M. 1997, ''Evaporating Stars in the Galactic Center?'' in *The Central Regions of the Galaxy and Galaxies*, ed. Y. Sofue, in press

Miller, B. W., & Fall, S. M. 1997, ''The Shape of the Initial Cluster Mass Function in Young Merger Remnants,'' ApJ, submitted

Miller, B. W., Whitmore, B. C., Schweizer, F., & Fall, S. M. 1997, ''The Star Cluster System of the Merger Remnant NGC 7252,'' AJ, in press

Montes, M. J., Van Dyk, S. D., Weiler, K. W., Sramek, R. A., & Panagia, N. 1997, ''Radio Detection of SN 1986E in NGC 4302,'' ApJ, 482, L61

Montes, M. J., Weiler, K. W., & Panagia, N. 1997, ''An HII Region Associated with SN1978K?'' ApJL, 488, in press

Montes, M. J., Weiler, K. W., & Panagia, N. 1997, ''An HII Region Associated with SN1978K?'' in *SN 1987A: Ten Years After*, eds. M. Phillips and N. Suntzeff, (San Fran-

cisco: Astronomical Society of the Pacific), in press
Montes, M. J., Weiler, K. W., Van Dyk, S. D., Panagia, N., & Sramek, R. A. 1997, ''A Review of Radio Supernovae,'' in 10^{51} *Ergs: The Evolution of Shell SNRs*, (Minneapolis, March 1997), in press
Mowlavi, N., Schaerer, D., Meynet, G., Bernasconi, P. A., & Maeder, A., 1997, ''Grids of Stellar Models. VIII. From 0.8 to 60 $M_\odot$ at Z=0.10,'' AP&SSS, in press
Nomoto, H., & Williams, R. E. 1997, *The Universe Revealed by Hubble Space Telescope*, (Tokyo: Iwanami Publishers)
O'Connell, R. W., Dorman, B., Shah, R. Y., Rood, R. T., Landsman, W. B., Bohlin, R. C., Neff, S. G., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1997, ''Ultraviolet Imaging of the Globular Cluster 47 Tuc,'' AJ, in press
O'Dea, C. P., & Baum, S. A. 1997, ''Constraints on Radio Source Evolution from the Compact Steep Spectrum and GHz Peaked Spectrum Radio Sources,'' AJ, 113, 148
Panagia, N. 1997, ''HST Study of the Stellar Population within 30 pc of SN 1987A,'' in *SN 1987A: Ten Years After*, eds. M. Phillips & N. Suntzeff, (San Francisco: Astronomical Society of the Pacific), in press
Panagia, N. 1997, ''The Hubble Constant: Age and Expansion of the Universe,'' in *Multi-frequency Behaviour of High Energy Cosmic Sources*, ed. F. Giovannelli, (Italian Astronomical Society CP), in press
Panagia, N., Gilmozzi, R., Kirshner, R. P. 1997, ''Improved Distance Determinations to SN 1987A and the LMC,'' in *SN 1987A: Ten Years After*, eds. M. Phillips & N. Suntzeff, (San Francisco: Astronomical Society of the Pacific), in press
Panagia, N., Scuderi, S., Gilmozzi, R., & the SINS Collaboration 1997, ''The Nature of the Circumstellar Rings around SN 1987A,'' in *SN 1987A: Ten Years After*, eds. M. Phillips & N. Suntzeff, (San Francisco: Astronomical Society of the Pacific), in press
Parker, J. W., Hill, J. K., Bohlin, R. C., O'Connell, R. W., Neff, S. G., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1996, ''Ultraviolet Imaging Telescope Observations of the N11 Region of the LMC,'' ApJL, 472, L29
Perlman, E., Biretta, J., Sparks, W., & Macchetto, D. 1997, ''HST Polarimetry of the M87 Jet,'' in preparation
Perlman, E., Biretta, J., Sparks, W., & Macchetto, D. 1997, ''The Spectral Energy Distribution of the M87 Jet at 5 pc Resolution,'' in preparation
Perlman, E., Padovani, P., Giommi, P., Sambruna, R., Jones, L., Tzioumis, A., & Reynolds, J. 1997, ''The Deep X-ray Radio Blazar Survey (DXRBS): I. Methods and First Results,'' AJ, in press
Pesce, J. E., O'Dowd, M., Scarpa, R., Urry, C. M., Falomo, R., Kim, J., & Paske, A. 1997, ''The Large-Scale Environments of Radio Galaxies and BL Lacertae Objects,'' BAAS, 28, 1285
Pesce, J. E., Urry, C. M., Maraschi, L., Treves, A., Grandi, P., Kollgaard, R. I., Pian, E., Smith, P. S., Aller, H. D., Aller, M. F., Barth, A. J., Buckley, D. A. H., Covino, E., Filippenko, A. V., Hooper, E. J., Joner, M. D., Kedziora-Chudczer, L., Kilkenny, D., Knee, L. B. G., Kunkel, M., Layden, A. C., Magalhaes, A. M., Marang, F., Margoniner, V. E., Palma, C., Pereyra, A., Rodrigues, C. V., Schutte, A., Sitko, M. L., Tornikoski, M., van der Walt, J., van Wyk, F., Whitelock, P. A., & Wolk, S. J. 1997, ''Multiwavelength Monitoring of the BL Lacertae Object PKS2155−304 in May 1994. I. The Ground-Based Campaign,'' ApJ, 486, 770
Pesto, S., Koratkar, A., Blitz, E., & Evans, I. 1997, ''Complete Atlas of Re-calibrated Archival HST FOS Spectra of Quasars and AGN,'' in *Emission Lines in Active Galaxies: New Methods and Techniques*, eds. B. M. Peterson, F.-Z. Cheng, & A. S. Wilson (San Francisco: Astronomical Society of the Pacific), p. 138
Pian, E., Urry, C. M., Treves, A., Maraschi, L., Penton, S., Shull, J. M., Pesce, J. E., Grandi, P., Kii, T., Kollgaard, R. I., Madejski, G., Marshall, H., Wamsteker, W., Celotti, A., Courvoisier, T. J.-L., Falomo, R., Fink, H. H., George, I. M., & Ghisellini, G. 1997, ''Multiwavelength Monitoring of the BL Lacertae Object PKS2155−304 in May 1994. II. The IUE Campaign,'' ApJ, 486, 784
Pian, E., Vacanti, G., Tagliaferri, G., Ghisellini, G., Maraschi, L., Treves, A., Urry, C. M., Fiore, F., Giommi, P., Palazzi, E., Chiappetti, L., Sambruna, R. M. 1997, ''BeppoSAX Observations of Unprecedented Synchrotron Activity in the BL Lac Object Mkn501,'' ApJ, submitted
Postman, M. 1997, ''The Data Archive Facilities for the Hubble Space Telescope,'' Baltic Astronomy, 6, 328
Postman, M. 1997, ''The Linearity of the Hubble Flow,'' in *The Extragalactic Distance Scale*, Cambridge University Press, eds. M. Livio, M. Donahue, & N. Panagia, p. 49
Raymond, J. C., Blair, W. P., Long, K. S., Vancura, O., Edgar, R. J., Morse, J., Hartigan, P., & Sanders, W. T. 1997, ''The Ultraviolet Spectrum of a Face-on Shock in the Vela Supernova Remnant,'' ApJ, 482, 881
Rivinius, T., Stahl, O., Wolf, B., Kaufer, A., Gäng, T., Gummersbach, C. A., Jankovics, I., Kovacs, J., Mandel, H., Peitz, J., Szeifert, T., & Lamers, H. J. G. L. M. 1997, ''Variations of the Stellar Wind in Early B Hypergiants,'' A&A, 318, 819
Saha, A., Sandage, A., Labhardt, L., Tammann, G. A., Panagia, N., & Macchetto, F. D. 1996, ''Cepheid Calibration of Peak Brightness of SNe Ia−V−SN 1960F in NGC 4496A,'' ApJS, 107, 693
Saha, A., Sandage, A., Tammann, G. A., Labhardt, L., Macchetto, F. D., & Panagia, N. 1997, ''Cepheid Calibration of the Peak Brightness of SNe Ia. VIII: SN 1990N in NGC 4639,'' ApJS, 486, 1
Sahu, K. C. 1997, ''Detecting Planets Through Microlensing,'' in *Planets Beyond the Solar System and the Next Generation of Space Missions*, ed. D. Soderblom, (San Francisco: Astronomical Society of the Pacific), p. 73
Sahu, K. C. 1997, ''Search for Extra-solar Planets Through Monitoring Microlensing Events from Antarctica,'' in *Astrophysics from Antarctica*, (San Francisco: Astronomical Society of the Pacific), in press
Sahu, K. C., Livio, M., Petro, L., Bond, H. E., Macchetto, F. D., Galama, T., Groot, P., van Paradijs, J., & Kouveliotou, C. 1997, ''Observations of GRB 970228 and GRB 970508, and the Neutron Star Model,'' ApJL, in press
Sahu, K. C., Livio, M., Petro, L., & Macchetto, F. D. 1997, ''GRB970228,'' IAU Circ. 6606

Sahu, K. C., Livio, M., Petro, L., & Macchetto, F. D. 1997, ''HST Observations of Recent GRBs,'' in *Proc. Huntsville Symp. on Gamma-Ray Bursts*, in press

Sahu, K. C., Livio, M., Petro, L., Macchetto, F. D., Galama, T., Groot, P., van Paradijs, J., & Kouveliotou, C. 1997, ''HST Observations of GRB970228,'' BAAS, 190, 849

Sahu, K. C., Livio, M., Petro, L., Macchetto, F. D., van Paradijs, J., Kouveliotou, C., Fishman, G. J., Meegan, C., Groot, P., & Galama, T. 1997 ''GRB970228,'' IAU Circ. 6619

Sahu, K. C., Livio, M., Petro, L., Macchetto, F. D., van Paradijs, J., Kouveliotou, C., Fishman, G. J., Meegan, C., Groot, P., & Galama, T. 1997, ''The Optical Counterpart to Gamma-ray Burst GRB970228 Observed Using the Hubble Space Telescope,'' Nature, 387, 476

Sahu, K. C., Shaw, R. A., Kaiser, M. E., Baum, S. A., Ferguson, H. C., Hayes, J. E., Gull, T. R., Hill, R. J., Hutchings, J. B., Kimble, R. A., Plait, P., & Woodgate, B. E. 1997, '' Imaging and Spectroscopy of Arcs Around the Most Luminous X-ray Cluster RXJ 1347.5-1145,'' ApJL, in press

Sambruna, R. M., George, I. M., Madejski, G. M., Urry, C. M., Turner, T. J., Weaver, K. A., Maraschi, L., & Treves, A. 1997, ''An X-Ray Absorption Feature in the BL Lacertae Object H1426+428,'' ApJ, 483, 774

Sambruna, R. M., Madejski, G., Urry, C. M., Pesce, J. E., Maraschi, L., Stella, L., Tagliaferri, G., Celotti, A., Treves, A., Kollgaard, R. I., Kii, T., & Wehrle, A. E. 1997, ''XTE Observations of PKS2155−304,'' BAAS, 28, 1311

Sambruna, R. M., Urry, C. M., Maraschi, L., Ghisellini, G., Mukherjee, R., Pesce, J. E., Wagner, S. J., Wehrle, A. E., Hartman, R. C., Lin, Y. C., & von Montigny, C. 1997, ''The High-Energy Continuum Emission of the Gamma-Ray Blazar PKS 0528+134,'' ApJ, 474, 639

Scarpa, R., Urry, C. M., Pesce, J., Falomo, R., & Treves, A. 1997, ''HST Imaging of BL Lac Objects,'' in *All Colors of Astrophysics*, Mem. Della SAIt, in press

Schaefer, K. G., Fullton, L. K., Ciardullo, R., & Bond, H. E. 1998, ''HST Imagery of HD 44179, the 'Red Rectangle': The Disk Revealed?'' in preparation

Schaerer, D. 1997, ''Combined Stellar Structure and Atmosphere Models for Massive Stars: New Ionizing Fluxes and Their Impact on H II Regions,'' in *Luminous Blue Variables: Massive Stars in Transition*, eds. H. G. J. L. M. Lamers, & A. Nota, (San Francisco: Astronomical Society of the Pacific), p. 71

Schaerer, D. 1997, ''Models for Ionizing Fluxes of O Stars and their Implications on H II Regions and the Diffuse ISM,'' in *Boulder-Munich Workshop on Hot Stars*, ed. I. D. Howarth, (San Francisco: Astronomical Society of the Pacific), in press

Schaerer, D. 1997, ''New Models for Wolf-Rayet and O Star Populations in Young Starbursts,'' in *Galaxy Interactions at Low and High Redshift*, ed. D. Sanders, in press

Schaerer, D. 1997, ''On the Origin of Nebular HeII Emission in Young Starbursts,'' in *Dwarf Galaxies: Probes for Galaxy Formation and Evolution*, ed. J. Andersen, Highlights of Astronomy, in press

Schaerer, D., Contini, T., Kunth, D., & Meynet, G. 1997, ''Detection of Wolf-Rayet stars of WN and WC Subtype in Super Star Clusters of NGC 5253,'' ApJ, 481, L75

Schaerer, D., Schmutz, W., & Grenon, M. 1997, ''Fundamental Stellar Parameters of ζ Puppis and γ^2 Vel from HIPPARCOS Data,'' ApJ, 484, L153

Schaerer, D., & Vacca, W. D. W. 1996, ''WR Population in Starbursts: WN and WC Subtypes and the Role of Binaries,'' in *WR stars in the Framework of Stellar Evolution*, eds. J. M. Vreux *et al.*, p. 641

Schaerer, D., & Vacca, W. D. W. 1997, ''New Models for Wolf-Rayet and O Star Population in Young Starbursts,'' ApJ, in press

Scharf, C., Jones, L., Ebeling, H., Perlman, E., Malkan, M., & Wegner, G. 1997, ''The Wide-Angle ROSAT Pointed X-ray Survey of Galaxies, Groups and Clusters I: Methods and First Results,'' ApJ, 477, 79

Schmitt, H. R., Kinney, A. L., Calzetti, D., & Storchi-Bergmann, T. 1997, ''The Spectral Energy Distribution of Normal, Starburst and Active Galaxies,'' ApJ, in press

Schmutz, W., Schweickhardt, J., Stahl, O., Wolf, B., Dumm, T., Gäng, T., Jankovics, I., Kaufer, A., Lehmann, H., Mandel, H., Peitz, J., & Rivinius, T. 1997, ''The Orbital Motion of γ^2 Velorum,'' A&A, submitted

Schweizer, F., Miller, B. W., Whitmore, B. C., & Fall, S. M. 1996, ''Hubble Space Telescope Observations of Candidate Young Globular Clusters and Stellar Associations in the Recent Merger Remnant NGC 3921,'' AJ, 112, 1839

Shahbaz, T., Livio, M., Southwell, K. A. & Charles, P. A. 1997, ''T Pyxidis: The First Short-Period CV with a Collimated Jet,'' ApJ, 484, L59

Shara, M. M., Fall, S. M., Rich, R. M., & Zurek, D. 1997, ''HST Observations of NGC 121: First Detection of Blue Stragglers in an Extragalactic Globular Cluster,'' ApJ, submitted

Shara, M. M., Zurek, D. R., Williams, R. E., Prialnik, D., Gilmozzi, R., & Moffat, A. F. J. 1997, ''HST Imagery of the Non-Expanding, Clumped Shell of the Recurrent Nova T Pyxidis,'' AJ, 114, 258

Smith, D. A., Neff, S. G., Bothun, G. D., Fanelli, M. N., Offenberg, J. D., Waller, W. H., Bohlin, R. C., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1996, ''UV Imaging of NGC3310: A Merger-Driven Global Starburst,'' ApJL, 473, L21

Smith, E. P., Bohlin, R. C., Bothun, G. D., O'Connell, R. W., Roberts, M. S., Neff, S. G., Smith, A. M., & Stecher, T. P. 1997, ''UV Imaging Observations of the cD Galaxy in Abell 1795: Further Evidence for Massive Star Formation in a Cooling Flow,'' ApJ, 478, 516

Smith, E. P., Pica, A. J., Bohlin, R. C., Cornett, R. H., Fanelli, M. N., Landsman, W. B., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1996, ''UIT: Near-UV Bright Object Catalog,'' ApJS, 104, 287

Soderblom, D. R. 1996, ''Rotation, Activity, and Lithium in Young Clusters,'' in *Ninth Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun*, eds. R. Pallavicini & A. K. Dupree (San Francisco: Astronomical Society of the Pacific), p. 315

Soderblom, D. R. 1996, ''Target Selection for Planet

Searches,'' in *Planets Beyond the Solar System and the Next Generation of Space Missions*, ed. D. R. Soderblom (San Francisco: Astronomical Society of the Pacific), p. 29

Soderblom, D. R., *et al.* 1997, ''HD 98800: A Unique Stellar System of Post-T Tauri Stars,'' ApJ, submitted

Sodroski, T. J., Odegard, N., Arendt, R. G., Dwek, E., Weiland, J. L., Hauser, M. G., & Kelsall, T. 1997, ''A Three-Dimensional Decomposition of the Infrared Emission from Dust in the Milky Way,'' ApJ, 480, 173

Sonneborn, G., Fransson, C., Lundqvist, P., Cassatella, A., Gilmozzi, R., Kirshner, R., Panagia, N., & Wamsteker, W. 1997, ''The Evolution of Ultraviolet Emission Lines from Circumstellar Material Surrounding SN 1987A,'' ApJ, 477, 848

Stanghellini, C., Bondi, M., Dallacasa, D., O'Dea, C. P., Baum, S. A., Fanti, R., & Fanti, C. 1997, ''The Radio Source OQ208: Parsec Scale Morphology and Spectral Properties,'' A&A, 318, 376

Stecher, T. P., Cornett, R. H., Greason, M. R., Landsman, W. B., Hill, J. K., Hill, R. S., Bohlin, R. C., Chen, P. C., Collins, N. R., Fanelli, M. N., Hollis, J. I., Neff, S. G., O'Connell, R. W., Offenberg, J. D., Parise, R. A., Parker, J. W., Roberts, M. S., Smith, A. M., & Walker, W. H. 1997, ''The Ultraviolet Imaging Telescope: Instrument and Data Characteristics,'' PASP, 109, 584 (cover issue)

Stiavelli, M., Panagia, N., Carollo, C. M., Romaniello, M., Heyer, H., & Gonzaga, S. 1997, ''WFPC2 Observations of NGC 454: An Interacting Pair of Galaxies,'' ApJL, in press

Stiavelli, M., Peletier, R. F., & Carollo, C. M. 1997, ''M87 in the Near-Infrared: the Jet and the Counter-jet Region,'' MNRAS, 285, 181

Stockman, H. S. (ed.) 1997, *Next Generation Space Telescope: Visiting a Time When Galaxies Were Young*, Space Telescope Science Institute

Stockman, H. S., & Mather, J. 1997, ''The Next Generation Space Telescope: Beyond the Hubble Deep Field,'' in *The Hubble Deep Field*, ed. M. Livio, ST ScI Symposium Series, in preparation

Stockman, H. S., Stiavelli, M., & Im, M. 1997, ''The NGST Science Mission,'' in *Science with NGST*, ed. E. Smith, (San Francisco: Astronomical Society of the Pacific), in press

Storchi-Bergmann, T., Eracleous, M., Ruiz, M. T., Livio, M., Wilson, A. S., & Filippenko, A. V. 1997, ''Evidence for a Precessing Accretion Disk in the Nucleus of NGC 1097,'' ApJ, 489, 87

Storrs, A., Zellner, B., Wells, E., Buratti, B., Currie, D. G., Seidelmann, P. K., & Pascue, D. 1996, ''Spectrophotometry of Small Uranian Satellites,'' BAAS, 28, 1072

Szkody, P., Vennes, S., Sion, E. M., Long, K. S., & Howell, S. B. 1997, ''Extreme Ultraviolet Photometry and Spectroscopy of BL Hydri,'' ApJ, 487, 916

Thomas, P. C., Binzel, R. P., Gaffey, M. J., Zellner, B. H., Storrs, A. D., & Wells, E. N. 1997, ''Vesta: Spin Pole, Size, and Shape from HST Images,'' Icarus, 128, 88

Ulrich, M.-H., Maraschi, L., & Urry, C. M. 1997, ''Variability of Active Galactic Nuclei,'' ARA&A, 35, 445

Urry, C. M. 1996, ''Blazars, the Most Violent Active Galaxies,'' in *AAAS Annual Meeting and Science Innovation Exposition, 162nd National Meeting of the AAAS*, eds. M. S. Strauss *et al.*, p. S-48

Urry, C. M. 1996, ''An Overview of Blazar Variability,'' in *Blazar Variability*, eds. H. R. Miller, J. R. Webb, & J. C. Noble (San Francisco: Astronomical Society of the Pacific), p. 391

Urry, C. M. 1997, ''Multiwavelength Properties of Blazars,'' Adv. Space Res., in press

Urry, C. M., Falomo, R., Scarpa, R., Pesce, J., O'Dowd, M., Treves, A., & Giavalisco, M. 1997, ''An HST Survey of BL Lac Objects: Host Galaxies and Environments,'' in *Proc. Eighth Marcel Grossman Meeting*, (Jerusalem, June 1997), in press

Urry, C. M., Treves, A., Maraschi, L., Marshall, H., Kii, T., Madejski, G., Penton, S., Pesce, J. E., Pian, E., Celotti, A., Fujimoto, R., Makino, F., Otani, C., Sambruna, R. M., Sasaki, K., Shull, J. M., Smith, P., Takahashi, T., & Tashiro, M. 1997, ''Multiwavelength Monitoring of the BL Lacertae Object PKS2155–304 in May 1994. III. Probing the Inner Jet through Multiwavelength Correlations,'' ApJ, 486, 799

Van Dyk, S. D., Montes, M. J., Weiler, K. W., Sramek, R. A., & Panagia, N. 1997, ''Radio Detection of SN 1985L in NGC 5033,'' ApJ, submitted

Van Dyk, S. D., Sramek, R. A., Weiler, K. W., Montes, M. J., & Panagia, N. 1997, ''An Update on Radio Supernovae,'' in press

van Gorkom, J., Carilli, C., Stocke, J., Perlman, E., & Shull, J. M. 1996, ''The HI Environment of Nearby Lyman-alpha Absorbers,'' AJ, 112, 1397

von Montigny, C., *et al.* 1997, ''Multi-Wavelength Observations of 3C273 in 1993–1995,'' ApJ, 483, 161

Walborn, N. R. 1997, ''Optical Spectral Morphology of LBVs,'' in *Luminous Blue Variables: Massive Stars in Transition*, eds. A. Nota & H. J. G. L. M. Lamers (San Francisco: Astronomical Society of the Pacific), p. 8

Walborn, N. R., & Barbá, R. H. 1998, ''A New Stellar Generation in 30 Doradus,'' in *Boulder-Munich II: Properties of Hot, Luminous Stars*, ed. I. D. Howarth (San Francisco: Astronomical Society of the Pacific), in press

Walborn, N. R., & Blades, J. C. 1997, ''Spectral Classification of the 30 Doradus Stellar Populations,'' ApJS, 112, in press

Walborn, N. R., Danks, A. C., Sembach, K. R., Bohlin, R. C., Jenkins, E. B., Gull, T. R., Lindler, D. J., Feggans, J. K., Hulbert, S. J., Linsky, J., Hutchings, J. B., & Joseph, C. L. 1997, ''Space Telescope Imaging Spectrograph Observations of the Interstellar Velocity Structure and Chemical Composition Toward the Carina Nebula,'' ApJL, in press

Waller, W. H., Bohlin, R. C., Cornett, R. H., Fanelli, M. N., Freedman, W. L., Hill, J. K., Madore, B. F., Neff, S. G., Offenberg, J. D., O'Connell, R. W., Roberts, M. S., Smith, A. M., & Stecher, T. P. 1997, ''UV Signatures of Tidal Interaction in the Giant Spiral Galaxy M101,'' ApJ, 481, 169

Wehrle, A. E., Pian, E., Urry, C. M., *et al.* 1997, ''Multi-

wavelength Observations of a Dramatic High Energy Flare in the Blazar 3C279,'' ApJ, submitted

Wehrle, A., Urry, C. M., *et al.* 1997, ''Multiwavelength Flaring of the Quasar 3C279,'' in *Proc. 4th Compton Symposium*, (Williamsburg, April 1997), in press

Weiler, K. W., Montes, M. J., Van Dyk, S. D., Sramek, R. A., & Panagia, N. 1997, ''Type II Radio Supernovae and SN 1987A,'' in *SN 1987A: Ten Years After*, eds. M. Phillips & N. Suntzeff, (San Francisco: Astronomical Society of the Pacific), in press

Weiler, K. W., Van Dyk, S. D., Panagia, N., Sramek, R. A., Montes, M. J. 1997, ''On the Possible Use of Radio Supernovae for Distance Determinations,'' in *Cosmological Distance Scale*, eds. M. Livio, M. Donahue, & N. Panagia (Cambridge: Cambridge University Press), p. 212

Whitmore, B. C., Miller, B. W., Schweizer, F., & Fall, S. M. 1997, ''Hubble Space Telescope Observations of Two Dynamically Young Elliptical Galaxies,'' AJ, in press

Whitney, J. H., Rood, R. T., O'Connell, R. W., D'Cruz, N. L., Dorman, B., Landsman, W. B., Bohlin, R. C., Roberts, M. S., Smith, A. M., Stecher, T. P. 1997, ''Analysis of the Hot Stellar Population of the Globular Cluster Omega Centauri,'' submitted

Williams, R. E., Blacker, B., Dickinson, M., Dixon, W. V. D., Ferguson, H. C., Fruchter, A. S., Giavalisco, M., Gilliland, R. L., Heyer, I., Katsanis, R., Levay, Z., Lucas, R. A., McElroy, D. B., Petro, L., Postman, M., Adorf, H.-M., & Hook, R. N. 1996, ''The Hubble Deep Field: Observations, Data Reduction, and Galaxy Photometry,'' AJ, 112, 1335

Winkler, P. F., & Long, K. S. 1997, ''A Second UV Light Bulb Behind the SN1006 Remnant,'' ApJ, 486, 137

Yungelson, L. Livio, M. & Tutukov, A. V. 1997, ''On the Rate of Novae in Galaxies of Different Types,'' ApJ, 481, 127

Zellner, B. H., Albrecht, R., Binzel, R. P., Gaffey, M. J., Thomas, P. C., Storrs, A. D., & Wells, E. N. 1997, ''Hubble Space Telescope Images of Asteroid 4 Vesta in 1994,'' Icarus, 128, 83

Zellner, B. H., Binzel, R. P., Gaffey, M. J., Thomas, P. C., Storrs, A. D., & Wells, E. N. 1996, ''HST Images of Vesta Near Perihelion,'' BAAS, 28, 1100

M. Livio, R. A. González, S. Toolan