

# Space Telescope Science Institute

## Baltimore, Maryland 21218

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This report covers the period October 1998 through September 1999.

### 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 spring 1990. ST ScI is also the home to an active science 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. Steven V. W. Beckwith continued his term as Director of ST ScI through this reporting period.

ST ScI ensures that *HST* observers use the science instruments to maximum effectiveness by providing direct technical advice in developing observations and interpreting data, and by calibrating and characterizing the scientific instruments *WFPC2*, *NICMOS*, *STIS*, and *FGS*.

*WFPC2* continued to operate flawlessly. Since it is now in its sixth year of operation, significant efforts to test for long-term changes in its performance were made. The long-term photometric stability appears to be excellent, with fluctuations of two percent or less in most filters between 1994 and 1998.

*NICMOS* has had a short, but productive life to date. Due to cryogen exhaustion, the last science observation was executed on 18 December 1998. The anticipated dewar warm-up started on 3 January 1999, and the instrument was placed into a safe configuration, where it will be held until the new mechanical cooling system is installed during servicing mission SM 3B (in late 2000 or early 2001). *NICMOS* was monitored closely during its warm-up period to learn what to expect when the detectors operate in the new temperature regime of the planned mechanical cooling system. It is expected to regain all basic science capabilities of the instrument.

*STIS* was successfully brought into routine operation as a mature instrument, guiding users through the first fully operational year of observing. The *STIS* performance has been excellent. It has good basic stability, including focus, flux repeatability, acquisition accuracy, flat fields, internal geometry, and mechanism reliability. After a period of lower usage while the *NICMOS* science program was expedited, the percentage of observations with *STIS* increased significantly in 1999.

The performance of the newly-refurbished *FGS IR* became outstanding as it stabilized after installation in the second servicing mission. It can resolve binary systems with separations as small as 7 milliseconds of arc, a dramatic improvement over *FGS 3*. Also, the stability of fringes is six times higher in *FGS IR* as compared with *FGS 3*. Conse-

quently, *FGS IR* was designated the astrometric science instrument for the Cycle 8 *HST* science program.

The most extensive observing campaign with *HST*, the Hubble Deep Field program, has been a beneficial undertaking from several perspectives, including the improved instrument understanding gained from the intensive efforts to release a data set of the highest possible quality. The Hubble Deep Field South data, obtained during October 1998 and released to the public in November 1998, included extensive imaging data of the prime and flanking fields and deep spectroscopic observations of the centered quasar. Newly developed techniques based on the experience gained from the Hubble Deep Field programs are applicable to the majority of the present and to future instruments as well, and will benefit all *HST* users in the form of improved algorithms, better data analysis software, and improved understanding of the instruments.

As part of the continuing effort to contribute to the promotion of scientific interaction, ST ScI hosted several scientific meetings during this reporting period. The topic of the annual May Symposium was *The Largest Explosions Since the Big Bang*. The meeting was held at ST ScI on May 3–6, 1999 and was attended by more than 110 participants. Works on all aspects of gamma-ray bursts and supernova explosions and their relevance to cosmology were extensively discussed, both in review talks and in poster presentations. Two workshops sponsored by the Journal Clubs were held. The workshop *When and How Do Bulges Form and Evolve?* took place on October 4–7, 1998. The workshop *Life Cycles of Radio Galaxies* was held on July 15–17, 1999. Both workshops were attended by more than 70 participants.

On 10 February 1999, Barry M. Lasker died following a heart attack. Barry was instrumental in several key areas at ST ScI, most notably in the creation of the Digitized Sky Survey. Just before his untimely death, he learned that the AAS had awarded him the 1999 Van Biesbroeck Prize in recognition of his long-term service to the scientific community.

Barry was one of the pioneering ST ScI scientists, arriving in Baltimore as early as 1981. In addition to being a brilliant and dedicated scientist, Barry will be remembered for his warm and selfless personality. He will be truly missed by his family, friends, and all ST ScI staff.

### 2. SOLAR SYSTEM

C. M. Lisse, collaborating with D. Christian (ST ScI), J. Truemper, K. Dennerl, J. Englhauser, M. Desch, F. E. Marshall, R. Petre, & S. Snowden (NASA/GSFC), is obtaining the first *AXAF* ACIS-BI images and low-resolution X-ray spectra of a comet. The goal is to detect line emission from charge exchange between solar wind minor ions and cometary gaseous species, as well as image the emission structure with unprecedented detail. This program has been delayed due to the *AXAF* launch rescheduling, and will be performed in the next year on a bright, new comet. A related

program, the *FUSE* Comet Study of H. Weaver, in collaboration with Lisse and Christian (ST ScI), will be obtaining the first *FUSE* high resolution far-EUV spectrum of the same comet. The goal of this program is to determine the presence or absence of far-EUV line emission from charge exchange between solar wind minor ions and cometary gaseous species. An extended series of *EUVE* observations (PI Lisse) will also be carried out, in order to obtain photometry at energies (20–300 eV) between *FUSE* and *AXAF*, as well as to allow comparison of the new comet to the *EUVE/ROSAT* X-ray photometry database of 15 comets. Analysis of this database to date has determined the following about this new phenomenon: the X-ray emission is confined to the cometary coma between the nucleus and the Sun in a region  $10^5$ – $10^6$  km in extent, is not correlated with extended dust or plasma tails, nor is it correlated in time with the solar X-ray flux or solar wind flux; the spectrum of the emission is very soft (kT  $\sim$  0.3 keV) with little C (0.28 keV) or O (0.53 keV) K-shell line emission, not due to scattering or resonance fluorescence or dust-dust impacts; roughly 25% of the time comets show luminosity outbursts correlated with increases in solar wind density and solar wind magnetic field; and that all comets within 2 AU of the Sun and brighter than  $V \sim 12$  have been detected in the X-ray.

Lisse, along with Y. Fernandez and M. F. A’Hearn (U. MD) and S. B. Peschke and E. Gruen (MPIE), has continued a campaign of optical and infrared (0.4–20.0  $\mu$ m) observations of cometary dust and nuclei. Twelve comets have been observed with high SNR that has allowed detailed modeling of the emitted dust, and 6 comets with high enough SNR and contrast between the nucleus and coma (i.e., either nearby comets or low activity comets) to obtain good estimates of the thermal emission from the nucleus alone and hence the nuclear size. Results so far include the detection of thermal infrared emission from the nuclei of comets C/Hyakutake 1996 B1 and P/Encke 1997, the probable detection of infrared emission from the nucleus of comet C/Hale-Bopp, and an analysis of the comets detected by *COBE* as compared to the IRAS comet database. We have demonstrated the unusual nature of comet Hyakutake, concerning its anomalously large activity and near breakup rotation rate; and shown that  $\sim$  40% of all comets have Halley-like dust emission, dominated by small particles easily detected in the optical, while the remaining 60% of comets emit the majority of their dust mass in large, dark grains. These very large grains are the origin of cometary dust trails, and are copious enough to supply the interplanetary dust cloud.

A. Storrs, in collaboration with J. Caldwell (York U.) and (in a separate project) with E. Barker (U. TX), made the first ever observations of the Moon’s surface with *HST*. The work with Caldwell was an attempt to get a good solar spectrum by observing Mare Imbrium. Parallel *WFPC2* observations of the region near the crater Copernicus were presented at the 30th Lunar and Planetary Sciences Conference (LPSC) in Houston this spring. The work with Barker was an attempt to observe an OH plume near the lunar limb, caused by the impact of the Lunar Prospector spacecraft into a permanently shadowed crater near the south pole of the Moon. No observatory, including *HST*, detected anything in relation to the

impact, and a paper on the upper limits is being presented at the DPS meeting.

Storrs has reduced *HST* images of asteroids. Many of these are extended sources, and careful image restoration can bring out the shape and some surface features of these objects. Archival data (from *WF/PC 1*) was published this spring (Storrs *et al.* 1999), and new data (from *WFPC2*) is the subject of a poster at this year’s Division for Planetary Science (DPS) meeting in Padova.

Storrs, in collaboration with D. Pascu (USNO) and E. Wells and J. Hershey (CSC/ST ScI), has reduced some high-resolution images of the Neptunian system in an attempt to get high-quality photometry of faint satellites. Preliminary analysis shows no brightening or reddening of Triton, and perhaps some blue reflection from the smaller satellites. These results are being presented at the DPS meeting.

### 3. STARS

D. Alves (ST ScI) continues work with I. Glass (SAAO) and the MACHO and ISOGAL collaborations (37 collaborators in 14 countries) on investigating the interplay of stellar pulsation and mass loss in asymptotic giant branch variable stars in the Galactic bulge. This is a data mining project, and Alves’ work is supported, in part, by an AAS Small Research Grant, awarded this year.

Alves, in collaboration with H. E. Bond (ST ScI) and summer student C. Onken, has derived a new color-magnitude diagram of the poorly studied Galactic globular cluster NGC 5986 from data obtained at *CTIO*. They derive the metallicity, reddening, and distance to this cluster. NGC 5986 has a metallicity similar to M13 and M3, yet a significantly different horizontal branch morphology, and is thus a new “second parameter” cluster. The relation between asymptotic giant branch bump color and horizontal branch morphology as a function of the second parameter is being investigated.

Alves, in collaboration with H. E. Bond and M. Livio (ST ScI), has searched for photometric variability in the central star of the unique planetary nebula, Kuestner 648, which is a member of the Galactic globular cluster M15. Although no evidence of variability was found, other arguments are made that this planetary nebula formed from a binary star system. It is suggested that no low mass stars form planetary nebulae unless they are descendents of a binary star system.

Alves continues his work with the MACHO Collaboration. Highlights include new calculations of the MACHO survey’s experimental sensitivity to detect microlensing in the Large Magellanic Cloud (LMC) and an analysis of 5.6 years of LMC survey data, yielding a new, higher precision estimate of the microlensing optical depth, with implications for the nature of the Galactic dark halo.

Alves, in collaboration with Bond, continues work on the search for post-asymptotic giant branch (pAGB) stars in the Galaxy and Local Group galaxies. Calibration of Landolt equatorial standards in the surface gravity-sensitive Gunn u-band, an integral part of the pAGB survey, is nearing completion. Observations of Landolt standards with uBVI filters obtained on nearly 50 different photometric nights at *CTIO* and *KPNO* have been reduced.

F. Boffi presented the results of her PhD Thesis on supernovae (SNe) of different types and their environments in a Dissertation Summary for PASP. In collaboration with D. Branch (OU), she studied the radio emission from SNe and showed how it can be used to test specific progenitor systems (in the case of SNe Ia) and how it can be useful to infer the pre-supernova system characteristics (for all SN types). In collaboration with W. B. Sparks (ST ScI) and F. D. Macchetto (ST ScI/ESA), she searched for SN light echoes and found a number of candidates for follow-on observations.

In the year under review, B. Espey made further studies of symbiotic stars using multi-wavelength data to study the Raman scattering of OVI emission. Using a combination of *HUT* and ground-based data, Espey and collaborators J. Birriel and R. Schulte-Ladbeck (U. Pitt.) obtained the first accurate determination of the Raman scattering efficiency in the symbiotic Z And. The unusual observed doublet ratio of 7:1 observed for the 1032–1038 Å lines of OVI was shown to be due to the effects of selective absorption by molecular hydrogen in the interstellar medium. After correction for this effect, a Raman scattering efficiency of  $\approx 5\text{--}7\%$  was obtained for the OVI lines. This result is similar to that determined previously by the same authors for RR Tel. The results of this work resulted in the publication of two papers (Birriel, Espey and Schulte-Ladbeck 1998, Birriel, Schulte-Ladbeck and Espey 1998). Further symbiotic star research is continuing with collaborators S. McCandliss (JHU), and summer student A. Brooks (Macalester) using a combination of ground-based, *HUT* and *HST* data in preparation for the arrival of Cycle 1 *FUSE* data to be obtained as part of Espey's Guest Investigator program.

Work by undergraduates S. Andreadis and P. Maksym (Yale) enabled the extension of Espey's QSO emission line work. With 150 objects and redshifts over the range  $0.3 < z < 5.0$  now represented in the database, preliminary results of this uniformly measured sample were presented at a QSO meeting in 1998 and published in the subsequent proceedings (Espey and Andreadis 1999). The inverse dependence of emission line equivalent width (the so-called 'Baldwin Effect') is clearly seen in the data for all but one lines examined, with the strongest effect seen for the OVI line. The careful deblending of the NV emission line shows that, unlike the other emission lines, its line strength actually increases with luminosity. One interpretation of this is that the ionization-dependent change of line strength with luminosity is more than compensated for by an increasing overabundance in nitrogen. The importance of a uniformly measured sample, independently verified, is vitally important where measurement errors may creep in to corrupt the underlying trends and the paper by Espey and Andreadis addresses the effects of possible errors on their emission line estimates. Further work on this topic is continuing with the aim of expanding and improving the database further to provide more stringent comparisons with theoretical models. The tantalizing possibility is the determination of limits to nitrogen abundance in the cores of QSO host galaxies to the highest redshifts.

M. Fall, M. Shara, and M. Rich (UCLA) continued their study of the rich star clusters in the Magellanic Clouds. They

discovered blue stragglers in one SMC cluster and evidence for two bursts of cluster formation in the SMC.

Fall and Q. Zhang (ST ScI & JHU) continued their calculations of the disruption of star clusters, including the effects of stellar mass loss, two-body relaxation, tidal shocks, and tidal limitation.

C. (Tony) Keyes, S. Kenyon (CfA), D. Proga (GSFC), R. Downes and W. Hack (ST ScI) are obtaining a *STIS* FUV and NUV spectroscopic snapshot survey of a large sample of symbiotic stars, many of which have never been observed in the ultraviolet. These spectra will be combined with nearly contemporaneous optical spectra obtained at Mt. Hopkins by Kenyon and in Argentina by collaborator M. Gomez. For the components of many systems, physical parameters such as Zanstra temperatures, emission line diagnostics, and limits on red giant wind velocity laws and mass-loss rates will be determined. Observation of a sufficient portion of the sample will permit establishing meaningful statistical limits on the nature of the hot component sources of ionization and fundamental wind parameters, which are vital steps toward understanding the accretion hydrodynamics and evolutionary status of symbiotic systems.

C. Leitherer, J. Chapman (Sydney), and B. Koribalski (Sydney) continued their stellar-wind study of southern hot stars with the *ATNF*. They performed a complete survey of a distance-limited sample of Wolf-Rayet stars to search for thermal and non-thermal emission at cm wavelengths. The high incidence rate of non-thermal emitters was explained as due to wind interaction in binary systems.

S. Lépine, with T. Eversberg (U. Montréal) and A. F. J. Moffat (U. Montréal), showed that the wind of Gamma Velorum, the brightest, and nearest Wolf-Rayet star in the sky, is pervaded by inhomogeneities on different scales. Spectroscopic variability indicates that the wind is clumped, as in many other Wolf-Rayet stars, but it also shows evidence for large-scale structures which must result from wind being non-spherically symmetric. The origin of this global and variable non-spherically symmetric structure is unknown.

Lépine, Shara, Livio, and D. Zurek, obtained *STIS* spectroscopic time-series of the recurrent nova U Scorpii, 8 and 15 days after it went into eruption on February 25th. An analysis of the data yielded the first direct measurement of acceleration in the outflow of a nova. The measured acceleration rate ( $10 \text{ m/s}^2$ ) was found to be comparable with the acceleration rates measured in the dense winds of Wolf-Rayet stars and O supergiants.

Lépine, in collaboration with Shara and B. McLean, initiated a systematic search for high proper-motion stars using multi-epoch, plate scans from the Digitized Sky Survey. So far, 420 square degrees have been "blinked" using software developed by Lépine. Over 200 new high proper-motion objects ( $> 0.2 \text{ arcsec/yr}$ ) have been discovered, with magnitudes between  $R = 11$  and  $R = 20$ .

M. Livio and L. Siess studied the problem of accretion of brown dwarfs and planets by giant stars, and showed that this process can explain a series of puzzling observations on rotation, Li abundance, and infrared excess in giants.

Livio, collaborating with G. Ogilvie and J. Pringle (Cam-

bridge), studied extraction of energy from spinning black holes. They showed that at least if standard disks are considered, the power obtained from the accretion disk always dominates over the power that can be extracted from the hole by the Blandford-Znajek mechanism.

Livio, in collaboration with C. Moran, P. Maxted, and T. Marsh (South Hampton) and R. Saffer (Villanova), determined the orbital parameters of three new subdwarf B binaries.

Livio, collaborating with T. Collins, A. Frank and J. Bjorkman (Rochester), showed that the properties of SN 1987A can be mapped into an evolutionary history of the system, involving a binary companion.

Livio and P. Godon studied the stability of vortices in protoplanetary disks, and their potential role in planet formation.

Livio, in collaboration with the *HST* gamma-ray bursts team, observed the fading optical counterpart of GRB 970228 and compared the observations to expectations from fireball models.

Livio, working with C. Tout and I. Bonnell (Cambridge) calculated evolutionary tracks for accreting pre-main-sequence stars, and discussed age uncertainties.

K. Long and R. Gilliland have completed 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 C. Knigge (Columbia U.) have continued to develop 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 are 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, B. Greeley (JHU), W. Blair (JHU) and J. Raymond (SAO) have completed the analysis of *HUT* spectra of the polar AM Her. They spectra are not well-modeled in terms of simple WD atmospheres, presumably because of the effect of radiation from the accretion column on the photosphere and/or the contribution of the accretion column to the continuum. Large (50%) variations in the flux on time scales of 10 s are observed, which poses significant challenges for models of the accretion flow in which blobs are thermalized well below the WD photosphere.

Long and Winkler (Middlebury) have continued their work on SN1006, using optical spectroscopy to identify 5 additional objects (4 stars and 1 quasar) which lie behind the SNR. *HST* UV spectroscopy is now scheduled to use these objects as probes of unshocked material in the ejecta of SN1006.

C. R. Proffitt, together with D. S. Leckrone (NASA/

GSFC), G. M. Wahlgren, J. Brandt (U. CO), and others continued working on radiative acceleration and non-LTE calculations for HgMn stars, especially the stars  $\chi$  Lupi and HR 7775 for which high resolution *Goddard High Resolution Spectrograph (GHRS)* data exist. An annotated atlas of the *GHRS* observations of  $\chi$  Lupi (Brandt *et al.* 1999) and a detailed summary of the scientific results derived from these data (Leckrone *et al.* 1999) were published. Proffitt has prepared an on-line version of the Brandt *et al.* (1999)  $\chi$  Lupi atlas, which is now available through the *HST* archive page at <http://archive.stsci.edu/>. Proffitt also initiated a new project on the radiative acceleration of very heavy elements in stellar envelopes in collaboration with F. Rogers and C. Iglesias (LLNL).

Proffitt, in collaboration with P. Jönsson (Lund), U. Litzén (Lund), J.-C. Pickering (Imperial Col. London), and G. Wahlgren (Catholic U. Lund) completed a study of the BIII resonance doublet in the early-B stars HD 35299 and HD 886, finding  $^{11}\text{B}/^{10}\text{B}$  isotope ratios consistent with the 4:1 ratio seen in the solar system. Work continues on a study of the BIII lines in *IUE* spectra of early-B stars. This latter work demonstrates that a substantial fraction of early-B main-sequence stars are depleted in boron.

D. Soderblom and B. Jones (UCSC) analyzed *Keck* HiRes spectra of solar-mass stars in the pre-main sequence open cluster NGC 2264. They showed that the age spread within NGC 2264 is likely to be no more than 5 Myr and that these stars appear not to have depleted any of the lithium they formed with. Further observations are being made at *Lick* and *Keck* to broaden the sample to the outer parts of the cluster. The next cluster to be examined is NGC 188, which is about 8 Gyr old.

D. Soderblom and J. King (UNLV) are completing the observations needed for a survey of activity in  $\sim 5,000$  G dwarfs within 50 pc. The sample has been defined using the *HIPPARCOS* catalog, and  $R = 2,000$  spectra are being obtained with the *Coude Feed Telescope* at *Kitt Peak*. The spectra are also being analyzed for metallicity and will go into the NStars database ([nstars.arc.nasa.gov](http://nstars.arc.nasa.gov)) on the nearby stars.

A. Suchkov and M. McMaster found evidence for a population of numerous binary stars with comparably bright components among the *HIPPARCOS* ‘‘single’’ F stars. The fraction of identified binary candidates was found to exceed the fraction of known binaries. The binary candidates were shown to severely impact the age-velocity relations, which also implies that all age-dependent relationships must be affected as well.

Suchkov has found a population of numerous F stars of anomalous brightness. At a given effective temperature, the absolute  $V$  magnitudes of these stars above the turnoff are too bright, hence the isochrone age too young, for their actually old age implied by high velocity dispersion. Also the stellar gravity is too high for the observed  $M_V$ . If these stars are mostly unresolved binaries, their anomalous brightness appears to be consistent with the fact discovered by Popper (1997) that the evolved primaries in late type eclipsing binaries look much younger than the unevolved secondaries—a result that has found no convincing explanation as yet.

Suchkov used *HIPPARCOS* *u*by F stars in the local Galactic disk to identify main epochs of star formation at different metallicities. It was found that stars with heavy elements abundance  $Z$  below  $0.5 Z_{\odot}$  essentially ceased to form  $\sim 6$  Gyr ago; similarly, the formation rate of stars with  $Z < 0.7 Z_{\odot}$  dropped dramatically  $\sim 3$  Gyr ago. The formation rate of stars at solar metallicity and above seems to have significantly declined since  $\sim 1$  Gyr ago. The data is unambiguous in showing a wide range of metallicity at any given age as well as a wide range of age at any given metallicity.

N. Walborn and E. Fitzpatrick (Villanova) completed an atlas of peculiar hot spectra including WN, Ofp, and LBV types, based on digital data from *CTIO*. Comprehensive literature surveys and spectral-line identifications are provided. Several new relationships among these objects emerged, perhaps most notably five cases of apparent spatial pairing between very similar, highly unusual spectra. This phenomenon may be revealing a particular mode of massive-star formation, in which two unbound components have masses so identical that even their rapid, late evolutionary phases are synchronized (“massive stellar twinning”).

Walborn and collaborators L. Drissen (Laval), J. Parker (SwRI), A. Saha (KPNO), J. MacKenty, and R. White completed studies of four very compact OB groups in the LMC, by means of *WF/PC I* and *WFPC2* photometry, and spatially resolved *FOS* spectroscopy. Two of these systems are in the 30 Doradus periphery, while the other two represent the initial, central and triggered, peripheral generations in the giant shell H II region N11. Uncontaminated spectrograms of three WR and two very early Of components were obtained for the first time. The spectra of numerous companions were observed separately; they provide information on the initial masses and ages of the peculiar objects, although several of the companions are also themselves of special interest.

#### 4. ISM

S. Beckwith, M. Meyer, A. Natta, and M. Robberto used *ISO* to search for thermal emission from circumstellar disks around stars between the ages of  $10^6$  and  $10^8$  years, the period during which planet-building is thought to occur. By the end of *ISO* operations, the observations were complete. The data have been analyzed with several different versions of the PIA reduction software. Early versions of this software produced results that were inconsistent with extant data on some of the objects (mainly from *IRAS*); in some cases, they were internally inconsistent. Calibration of the *ISOPHOT* data against ground-based observations (see next topic) suggests that *ISO* can deliver good quality results. A paper is currently in preparation describing the results.

Beckwith, Meyer, Natta, and Robberto also obtained observations of 16 stars in Chameleon to give spectral energy distributions from 3 to 200 mm (PHOT-S) from 3 to 13 mm for the first time. The scientific goal is to distinguish among the various geometrical models for circumstellar disks around these stars—for example, flared vs. flat disks. The spectra demonstrate that 10 mm silicate emission features from optically thin dust are commonly seen in these disks, so it is almost certain that the disks are heated externally, probably by the central objects. It has been difficult to calibrate

the data accurately enough to realize the scientific goals. There are inconsistencies with *IRAS* data on some of these stars as well as some internal inconsistencies in the *ISO* calibration. To check the calibration, the team got ground-based data at 10 mm on 6 of the stars and discovered that the *ISO* results match well, whereas the *IRAS* data are often inconsistent with the ground-based observations. Some stars are variable. The PIA data reduction program has undergone substantial changes to cure the internal inconsistencies in the data, so all data were re-reduced this year with the “final” version of PIA to ready the data for publication. A paper was submitted in August 1999.

Beckwith, T. Herbst, Meyer, and Robberto used the *MAX thermal infrared camera* to detect disks around young stars at unprecedented sensitivity at 10 mm. During 1997 and 1998, the team observed and detected essentially all of the disks in the Trapezium core that were discovered with *HST*—both the ionized and dark disks. Owing to the strong background emission from the nebula, background subtraction is difficult. By varying the spacing used for background subtraction, it is possible to eliminate most of the extended emission to get photometry on the unresolved disks. The results were presented at a meeting in Japan in June, 1999, and a paper should be submitted for publication late this year.

F. Boffi, in collaboration with W. B. Sparks (ST ScI) and F. D. Macchetto (ST ScI/ESA), reduced and analyzed ground-based B,V,R images of the environments of 64 SNe in 38 galaxies to search for light echoes from these SNe. The search for such echoes of SN light that is scattered by dust is justified by their possible use to determine distances geometrically (W. B. Sparks, *ApJ*, 433, 19, [1994]). They commonly find patches of optical emission at, or close to, the sites of the supernovae. The color distribution of these patches is broad, and generally agrees with stellar population colors, possibly with some reddening. However they note that patches with both unusually red and unusually blue colors are identified. They expect light echoes to be blue, and while none of the objects are quite as blue in V–R as the known light echo of SN 1991T, approximately 25% of all features are unusually blue and they identify these as candidate light echoes for follow-on observations. Another result is that in color/color plots indeed different SN Types are characterized by different environments.

Boffi contributed to a paper by W. B. Sparks (ST ScI), in collaboration with F. D. Macchetto (ST ScI/ESA), N. Panagia (ST ScI), D. Branch (OU), M. Hazen (CfA), and Della Valle (U. Padova). In this paper they presented photometry with the *Wide Field Camera 2* and high resolution imaging polarimetry and photometry with the *Faint Object Camera* on board the *HST* and were able to demonstrate that the late time optical emission of SN 1991T (B. P. Schmidt *et al.*, *ApJL*, 434, L19 [1994]) is indeed due to a light echo. In fact polarized emission is found at the center of the echo structure. From simple models of the polarized emission they also estimated a distance to the supernova, being 15 Mpc the upper allowable distance (with some caveats as the echo is still unresolved).

M. Donahue, with J. Mack, G. M. Voit, W. Sparks, P.

Malone (U. CO) and R. Elston (U. FL), discovered warm (2000–3000 K) molecular hydrogen filamentary nebula in the central galaxies of putative cluster “cooling flows” using narrow band imaging from *HST/NICMOS*. The molecular hydrogen nebula seem to be co-spatial with the filaments of the already known H-alpha nebulae. The brightness and line ratios of these nebula are consistent with the gas being heated by UV radiation from hot stars, although other heating mechanisms are also plausible.

J. English leads Canadian Galactic Plane Survey team members A. R. Taylor (U. Calgary), J. A. Irwin (Queen’s U.), S. Y. Mashchenko (U. Montréal), S. Basu (U. Western Ontario), and D. Johnstone (U. Toronto) in a study of the first resolved Galactic Worm (GW 123.4–1.5). The data acquired using the NRC’s *DRAO ST* shows that most of the neutral hydrogen gas ( $10^5$  solar masses) resides in this mushroom-shaped cloud’s “cap” rather than in its “stem.” Thus it appears unrelated to conventional theoretical super-shell or chimney structures previously identified with H I worms.

B. Espey continued his collaborative work with F. Keenan and others at the Queen’s University of Belfast, UK. This work centers on the development of new and improved emission line diagnostics which are applicable to nebular gas in astrophysical situations. A paper containing diagnostics obtainable from ratios of [NeIV] lines was published in the year under review which used *IUE* data to determine conditions in the hot gas of planetary nebulae. In addition, *HST/GHRS* spectra of the symbiotic system RR Tel were used to determine the wavelength separation of the doublet components of the 1601 Å line—the first time, to their knowledge, that this has been experimentally determined (Keenan *et al.* 1998). Another paper involving the application of [AlIII] diagnostics to *GHRS* spectra of RR Tel is in press (Keenan *et al.* 1999). These data may provide the first reliable detection of the forbidden line at 2661.06 Å.

P. Godon and M. Livio have carried out numerical simulations of the protoplanetary nebula using a time-dependent two-dimensional polytropic compressible code. They have shown that, contrary to what was previously believed, vortices can form in disks and are extremely stable (Godon & Livio 1999a,b). In addition, dust particles have been introduced in the simulations and it was obtained that the particles concentrate in the cores of anticyclonic vortices on a time scale of the order of a few orbital periods. The increased concentration of dust particles in the cores of the vortices accelerates the agglomeration process and can therefore trigger the formation of large planetesimals. The cores of vortices might therefore be preferred regions for the formation of the protoplanets. It was also obtained that the particles drift radially inward on a relatively short time scale, of the order of ten orbital periods when the drag parameter is of the order of the Keplerian frequency. (Godon & Livio 2000).

G. Kriss and B. Espey, in conjunction with J. Grimes (U. Chicago), published their results of spatially resolved observations of NGC 1068. The far-UV/UV spectra for this work were based mainly on *Hopkins Ultraviolet Telescope (HUT)* data taken as part of the Astro-2 space shuttle astronomy mission in 1995. Comparison is drawn with images obtained

during the Astro-2 mission by the *Ultraviolet Imaging Telescope (UIT)* and, additionally, *WFPC2* data from *HST*. Shortward of 1200 Å, the continuum emission is concentrated in a similar region as the line emission, consistent with being nuclear continuum light scattered by a combination of electrons and a dust cloud. The emission line strengths seen in the far-UV are consistent with a shock origin.

S. Lubow and G. Ogilvie have continued investigating the generation and propagation of waves in disks for which there is a vertical temperature variation. They found that an *f* mode is excited at Linblad resonances. The wave behaves compressibly near resonance, but becomes an incompressible surface gravity wave away from resonance. The waves grow in amplitude as they propagate and will likely shock in many cases. A disk atmosphere tends to suppress the effects of wave amplitude growth.

Lubow and Ogilvie have investigated the tilt stability of protostellar disks in young binary star systems. They found that disks which are large enough to be tidally truncated are stable to tilt perturbations. Therefore, such disks should evolve toward coplanarity with the binary. For smaller disks, tilts can sometime grow due to effects of tidal resonances.

Lubow, M. Seibert (JHU), and P. Artymowicz (Stockholm) have investigated the interactions between planets and protoplanetary gas disks. A tidally produced gap forms in the disk around the orbit of a Jupiter-mass planet. They found that a gas flow occurs through the gap and onto a young Jupiter-mass planet. The flow can substantially increase the planet’s mass. For conventional disk parameters, planets of 10 Jupiter masses can be formed by this process.

S. Oey, in collaboration with M. A. Dopita (ANU), J. C. Shields (Ohio U.), and R. C. Smith (CTIO), is investigating emission-line diagnostics of HII regions in the LMC. The ionizing stars in these nebulae have published spectral classifications, thus permitting a calibration of emission-line diagnostics for stellar effective temperature ( $T_{\star}$ ) and abundance. These objects also provide tests of stellar atmosphere models for O and WNE stars, generally showing agreement within 0.2 dex for major nebular line ratios. There is a peculiar situation in one object where the dominant WN3 stars are expected to produce He<sup>+</sup>-ionizing emission, yet no He II 4686 is found in the nebula. The team confirms that the widely-used  $\eta'$  parameter is insensitive to diagnosing  $T_{\star}$  for O stars having  $T_{\star} \geq 40,000$  K. The  $\eta'$  parameter is also shown to be sensitive to unresolved shocks, nebular morphology, and ionization parameter. In contrast, the [Ne III]/H  $\beta$  ratio is more robust to these effects and could be a useful discriminant of  $T_{\star}$ . In collaboration with J. C. Shields, Oey is continuing to investigate abundance diagnostics in a similar manner.

Oey is working with A. M. Watson (UNAM) on a study of the W3/W4 Galactic star forming region. The region is suggestive of star formation occurring in hierarchical shells. Oey and Watson are obtaining optical and NIR imaging and spectroscopy of the stellar populations in IC 1795 and W3. These data will yield a quantitative star formation history, testing the hypothesis of hierarchical star formation.

Through the ST ScI Summer Student Program, Oey is examining properties of H II region populations in spiral

galaxies with summer students J. S. Parker (Whitman Col.) and V. Mikles (JHU). They are testing models for evolution of the H II region luminosity function and size distributions with published data in the literature.

Inconsistent results have arisen from abundance determinations in nebulae from the forbidden lines and the recombination lines. Resolution of this dilemma requires an independent method of determining abundances. Together with M. Rosa (ESO/ECF) and E. Jenkins (Princeton), R. Williams has undertaken a program to observe resonance absorption in the exciting stars of nebulae so that ion column densities can be determined and compared with the abundances that are inferred from the emission-line fluxes. High resolution absorption-line data will be obtained during the coming year that should yield independent ion abundances in the nebular shells to compare with those determined from the forbidden line and the permitted recombination line fluxes.

## 5. GALAXIES

D. Alves continues work with C. Nelson (UC–Berkeley) on the rotation curve of the Large Magellanic Cloud (LMC) and the implications for microlensing in the LMC by LMC disk stars. Their analysis of archival carbon star radial velocity data shows declining rotation curve at large LMC radii, yielding new limits on the total LMC mass, and evidence that the LMC disk is flared (the vertical scale height of the disk increases with LMC radius). The implications of this LMC structure for LMC disk self-lensing are being investigated.

S. Beckwith, D. Thompson, and F. Mannucci continued their search for young, emission line galaxies at high redshift using narrow-band interference filters to look for emission-line objects (*MAGIC* and *Omega Prime* cameras on the *Calar Alto 3.5m Telescope* and the *CGS4 Spectrometer* on *UKIRT* and *NIRSPEC* on *Keck* for spectroscopic follow-up). More than a dozen new emission line galaxies have emerged from this work, most of which are irregular, spiral galaxies at redshifts  $\sim 1$  or greater. A paper describing the results of this second survey was submitted last year, and they are now using the *HST* to observe the additional candidates. It appears that damped Ly $_{\alpha}$  absorption systems pinpoint regions of vigorous star formation and will lead to a revision of the search strategies for young galaxies at high redshift.

T. Böker, together with the ST Sci *NICMOS* group, analyzed the data of a *NICMOS* snapshot survey of nearby galaxies. The survey, which was executed as a service for the astronomical community during two *NICMOS* camera 3 “campaigns,” observed about 100 galaxies in the light of both the near-infrared H-band continuum and the Pa-alpha emission line. A statistical analysis indicates that the average star formation in the central regions of spiral galaxies is strongest for early Hubble types.

Böker, R. van der Marel, and W. Vacca used the NASA *Infra-Red Telescope Facility (IRTF)* to observe the nuclear stellar cluster in the nearby, face-on, giant Scd spiral IC 342. High resolution ( $R = 21500$ ) spectra at the  $^{12}\text{CO}$  (2-0) bandhead at 2.3 micron yield a line-of-sight stellar velocity dispersion  $\sigma = (33 \pm 3)$  km/s. Dynamical models yield a K-band mass-to-light ratio  $M/L_K = 0.05$ , and a cluster mass

of  $6 \times 10^6 M_{\odot}$ . Comparison with stellar population synthesis models yields a best-fitting cluster age in the range 63–630 Myears. As a byproduct of the analysis it was found that IC 342 cannot have any central black hole more massive than 0.5 million solar masses. This is approximately 6 times less massive than the black hole inferred to exist in our Galaxy, consistent with the accumulating evidence that galaxies with less massive bulges harbor less massive black holes.

H. Bushouse, in collaboration with K. Borne (Raytheon STX), L. Colina (Inst. de Fisica de Cantabria), and R. Lucas (ST Sci), has performed an *HST* snapshot imaging survey of a large sample of Ultraluminous Infrared Galaxies (ULIRGs). *WFPC2* I-band images have been obtained for approximately 120 systems, and *NICMOS* H-band images have been obtained for 27 systems. Nearly 100% of the ULIRGs show evidence for interactions, collisions, or mergers with companion galaxies. In the majority of galaxies there is evidence for star formation on all scales. Evidence for an AGN-like nucleus, however, is seen in less than 10% of the ULIRGs, indicating that a starburst event is the dominant heating source for the majority of ULIRGs. In many instances there are a significant number of nearby small companion galaxies, suggesting that some of the ULIRGs should be reclassified as compact groups.

Bushouse, in collaboration with M. Zhu, E. Seaquist (U. Toronto), E. Davoust (Obs. Midi-Pyrénées), and D. Frayer (CalTech), has obtained CO (1-0) emission line observations for 80 interacting galaxies, as part of a program to study the role of interactions and mergers in triggering starbursts. Statistical analyses of the molecular properties of the interacting galaxies show that they have, on average, higher fractional molecular gas contents than isolated spiral galaxies, and that the fractional molecular gas content appears to increase with interaction strength.

D. Calzetti, with C. Conselice, J. Gallagher (U. WI), and A. Kinney (ST Sci) have analyzed the structure of the ionized gas emission in two local starburst galaxies: the dwarf NGC 5253 and the grand-design spiral M83, in order investigate the interplay between starbursts and ISM. They find that in NGC 5253 about 80–90% of the diffuse ionized gas is photo-excited, while only 10–20% is ‘shock’-excited. The ‘shocked’ gas is mostly concentrated along the major axis of the galaxy, contrary to what found in other galaxies. This suggests that the expanding gas will remain inside the galaxy, rather than being ejected outside.

Calzetti, L. Armus (SSC/IPAC), R. Bohlin, A. Kinney (ST Sci), J. Koornneef (KAI, U. Groningen), and T. Storchi-Bergmann (UFRGS) have investigated the far-infrared (up to 200  $\mu\text{m}$ ) emission from local starburst galaxies using *ISO* long-wavelength photometry. The far-infrared emission from the five galaxies in the sample is compatible with a combination of warm ( $T \sim 40$ –55 K) and cool dust ( $T \sim 20$ –25 K), with the latter component representing up to 60% of the total emission. The inferred dust masses produce gas-to-dust ratios similar to more quiescent galaxies (e.g., Milky Way). If the starburst galaxies in the sample are representative of high- $z$  star-forming (Lyman-break) galaxies, the extrapolated far-infrared fluxes are low enough that the high- $z$  galaxies will be generally undetected at sub-mm wavelengths.

Calzetti and T. Heckman (PHA/JHU) have investigated, from a theoretical point of view, the evolution of the dust opacity in galaxies as a function of redshift. Their results show that UV observations of high redshift galaxies can easily miss  $\sim 80\%$  of the star formation in early galaxies, because of the presence of dust. The missing energy is reprocessed by dust into far-infrared emission, thus accounting for the intensity and spectral shape of the Cosmic Infrared Background detected by *COBE*.

N. Cretton, T. de Zeeuw, R. van der Marel, and H. Rix developed an improved, practical method for constructing stellar dynamical galaxy models that match an arbitrary set of observational constraints, without prior assumptions about the phase-space distribution function. The method is an extension of Schwarzschild's orbit superposition technique. A key new element of this work is the ability to predict and match to the data the full line-of-sight velocity profile shapes. A dark component (such as a black hole and/or a dark halo) can easily be included in the models. The method was tested by using it to reconstruct the properties of a two-integral model built with independent software. Applications of the method to the galaxies M32 and NGC 4342 were already described elsewhere.

M. Dickinson, in collaboration with a team of investigators including H. Ferguson, A. Fruchter, M. Giavalisco, C. Hanley, R. Lucas, M. Postman (ST ScI) and others at other institutions, has obtained and analyzed a complete near-infrared map of the Hubble Deep Field North using *NICMOS* on board *HST*. These data provide deep, high angular resolution infrared (1.1 and 1.6 micron) images and photometry for nearly 2000 faint galaxies, extending the deep *WFPC2* HDF data by another octave in wavelength, and probing the rest-frame optical light from galaxies at  $1 < z < 3$ . Although spiral and elliptical galaxies are present out to  $z = 1$ , they find that few if any exist at  $z > 2$ , thus suggesting that the giant members of the Hubble Sequence assembled primarily at  $z < 2$ . The galaxy counterparts to submillimeter sources in the HDF are either unremarkable or completely invisible in the *NICMOS* data, and their nature remains puzzling. The combined *NICMOS* + *WFPC2* data is being used to study the spectral energy distributions of galaxies from  $1 < z < 3$ , to identify galaxy candidates at  $z > 5$ , and to improve photometric redshift estimates at all redshifts. Dickinson *et al.* have identified only one object which is readily detected in the *NICMOS* data but which is invisible at optical wavelengths. The nature of this extremely peculiar, so-called "J-band dropout," is unknown: it could be a dusty galaxy at  $z > 2$ , an "old" elliptical galaxy at  $z = 3$ , or (most speculatively) a bright, "primeval" galaxy at  $z = 12.5$ .

M. Fall and Y. Pei continued their study of the global evolution of stars, gas, metals, and dust in galaxies. Together with Hauser, they tested their models against recent measurements and upper limits on the cosmic infrared background radiation.

Fall, B. Whitmore, F. Schweizer (DTM), and B. Miller (Leiden) continued their study of the young star clusters in merging galaxies, particularly NGC 4038/4039 (the "Antennae"). They find that the luminosity function of these clus-

ters has power-law form, very different from the lognormal form of the luminosity function of old globular clusters in normal galaxies such as the Milky Way.

P. Goudfrooij has assembled a unique library of absorption-line template spectra, covering 3650–7300 Å, that can be used to synthesize the stellar absorption-line component in spectra of emission-line galaxies. The library is a hybrid of spectra of galaxies and stars of different spectral type. The galaxy spectra and G-K giant stars were observed by Goudfrooij at the *ESO* and *La Palma* observatories, whereas the earlier-type stars were inherited from existing stellar libraries. The library can be adapted to spectra of any given spectral resolution  $\geq 4.5$  Å. Along with this library, Goudfrooij and E. Emsellem (Obs. de Lyon) have developed a  $\chi^2$ -minimization routine which uses the library of template spectra to derive the best fit to the absorption-line continua of emission-line objects. Given two input tables containing spectra (one containing the spectra of emission-line objects, and one containing the template spectra, along with their respective velocities and velocity dispersions) and a list of wavelength intervals to be used for fitting the spectra (i.e., excluding the wavelength regions in which emission lines occur at zero redshift), the program first applies velocity shifts and line broadenings (by convolving with a Gaussian with the appropriate  $\sigma$ ) to the templates, after which it solves for the relative contributions of the different templates, as well as the global continuum shape. The continuum shape is fit by adding a featureless polynomial continuum during the evaluation of the relative contributions of the different templates. This is necessary to correct for the effect of extinction by dust intrinsic to galaxies, and the fact that (relative) absorption-line strengths do not uniquely define the continuum shape of spectra of galaxies or stars.

Goudfrooij, G. Meylan (ESO), and J. Mack (ST ScI) have used the *ESONTT* in MOS mode to obtain radial velocity measurements of globular cluster candidates in the giant elliptical galaxy NGC 1316 (Fornax A). The globular cluster candidates were chosen to cover a suitable range in  $V - I$  color in order to study the nature of globular clusters of different colors in NGC 1316 as well as obtain dynamical information on the outer parts of early-type galaxies that are not in the center of clusters. Some candidate young star clusters were also observed to reveal whether or not they are indeed part of the globular cluster system. From the radial velocities, the candidate young star clusters turn out to be foreground halo stars or background galaxies. From the bona fide globular clusters, 23 targets had sufficient signal to measure their radial velocities. For this cluster sample we measure a mean velocity of  $v_{\text{rad}} = 1707 \pm 50 \text{ km s}^{-1}$ , and a velocity dispersion of  $\sigma = 239 \pm 56 \text{ km s}^{-1}$ . Using different mass estimators, these measurements are currently being used to constrain the  $M/L$  ratio at large radii from the center of NGC 1316. Preliminary estimates show the  $M/L$  ratio to be in the range 30–100 at a radius of 15 kpc. This result constitutes a rising  $M/L$  with radius, i.e., important evidence for the presence of dark matter in the outer regions. This is the first time that such evidence has been found in an elliptical galaxy that is *NOT* in the center of a cluster of galaxies.

Goudfrooij and E. Emsellem (Obs. de Lyon) have been working on *HST/WFPC2* data of the central region of the radio-quiet elliptical galaxy NGC 2974 in order to build detailed (photometric and dynamical) models to reproduce the observed surface brightness of the stellar light, the flux distribution of the gas, and the kinematics of the stars and gas. Ground-based spectroscopy of NGC 2974, obtained with the 4.2-m *WHT* on La Palma, reveals broad *forbidden* emission lines in its center, which may hint for the presence of either highly turbulent gas motions or a central dark mass. In order to distinguish between these two possibilities, they obtained *WFPC2* V- and I-band images as well as narrow-band images centered on the  $H\alpha + [N\ II]$  emission lines. They also have *CFHT/TIGER* 3-D spectroscopy covering both the stellar absorption lines and the nebular emission lines. They combined *HST/WFPC2* and ground-based I-band images to build a detailed model of the stellar light distribution by means of the Multi-Gaussian Expansion (MGE) method, which permits an analytical derivation of the spatial luminosity distribution for any assumed triaxial shape and an arbitrary line of sight. Such a treatment turns out to be necessary in the case of NGC 2974 since their *HST* images reveal the presence of a  $m = 2$  spiral structure in the central regions, suggestive of triaxiality. Given this model of the three-dimensional density distribution, the gravitational potential has been parameterized. Using the *WFPC2* broad- and narrow-band images, they made a map of the apparent optical depth of the dust as a function of wavelength, as well as a map of the distribution of ionized gas in the central regions of NGC 2974. Those maps provided viewing angles of the equatorial plane of the galaxy. Combined with the luminosity distribution they then proceeded to derive a 2-D map of the percentage of light emitted in front of the dusty structures, enabling them to fully correct for the effect of dust absorption on the stellar light as well as on the gaseous emission. This is the first time such a detailed model for the stellar and gas distribution in the central regions of an elliptical galaxy has been derived.

T. Herbst, D. Thompson, and S. Beckwith searched for dark matter in galaxies that might be in the form of underluminous stars such as brown dwarfs. Evidence for luminous matter was reported by Sackett *et al.* (1994, *Nature*), who looked at the edge-on Sc galaxy NGC 5907 for faint R-band light, and subsequently by Rudy *et al.* (1997, *Nature*), who observed near infrared emission at K. They reported the detection of excesses in the halo well above and below the disk plane. The group led by Herbst observed several edge-on spirals, including NGC 5907, with the *MAGIC* and *Omega Prime* cameras, reaching limits of 26th and 25th mag/sq. arcsec in J and K bands, respectively, and do not see the emission claimed by Rudy *et al.* The group believes the initially reported results are in error. The intensity profiles above and below the disk plane are inconsistent with a luminous component of the dark matter needed to produce the observed rotation curves. This work is currently being prepared for publication in 2000.

C. Leitherer, in collaboration with Johnson (Boulder), P. Conti (Boulder), and W. Vacca (Honolulu), carried out a multi-instrument *HST* study of several Wolf-Rayet galaxies.

A key result was the detection of a large-scale outflow of the cool interstellar medium in He2–10. The outflow velocity significantly exceeds the escape velocity, suggesting that the material is lost to the intergalactic medium.

Leitherer, collaborating with V. Luridiana (Mexico City) and M. Peimbert (Mexico City), applied photo-ionization and population synthesis models to the starburst cluster NGC 2363. This study emphasized the importance of Wolf-Rayet stars for the ionizing radiation field and the uncertainties associated with current models.

Leitherer, R. Gonzalez Delgado (Granada), and T. Heckman (JHU) developed synthetic spectral models for the higher Balmer lines in starburst and post-starburst systems. The models were made available to the public and will be used at ST ScI as well. It is planned to apply the models to evolved starburst systems in groups selected from the CfA2 survey (in collaboration with Barton, Victoria).

Leitherer, D. de Mello, and Heckman (JHU) performed a detailed investigation of the UV spectral region of starburst galaxies, discussing the contributions of stars and interstellar gas to the line spectrum. From a comparison of the synthetic and observed spectrum of the distant star-forming galaxy cB58 they were able to constrain the star-formation history in this galaxy.

Leitherer, D. Schaerer (Toulouse), J. Goldader (Philadelphia), R. Gonzalez Delgado (Granada), C. Robert (Québec City), D. Foo Kune (St. Paul), de Mello, Devost, and Heckman (JHU) built an extensive database of synthetic galaxy properties and made it available on a dedicated server. This tool allows users to run their own tailored starburst models.

Leitherer and L. Origlia (Bologna) continued their investigation of the near-IR spectral region of star-forming galaxies. They found that current stellar evolution models are inadequate to describe red supergiant dominated starburst population at low metallicity. They also derived transformation relations between various photometric systems of *HST*.

K. Long, G. Dubus (Amsterdam), and P. Charles (Oxford) have completed the analysis of *HST* imaging of the nucleus of M33 in an attempt to identify the counterpart to the brightest X-ray source in the Local Group. The observations show that the nucleus is bluer than expected from the A–F spectrum seen in the visible. More than half of the UV luminosity arises from the inner 0.1" of the nucleus. However, an identification of the X-ray source requires *HST* spectroscopy. These observations are scheduled for late 1999.

R. Lucas and P. Goudfrooij participated in the *HST* service observations of the GRB 990123, a Director's Discretionary program under the direction of the ST ScI Director, S. Beckwith. The observations were made immediately public for the benefit of the astronomical community so that this remarkable GRB and its environment could be studied in more detail and at fainter magnitudes via these *HSTSTIS* images.

Lucas continued his work in the collaboration with K. Borne *et al.* on two SNAPshot survey programs on Ultraluminous Infrared Galaxies (ULIRGs), one a *WFPC2* I-band (F814W) survey for which images of  $\sim 130$  out of 160 galaxies were obtained, and a *NICMOS* F160W survey of 50 QDOT ULIRGs (all with *WFPC2* SNAPshot images already

obtained), for which images of  $\sim 30$  galaxies were obtained. Results thus far support the views that nearly all ULIRGs are the result of interactions and/or mergers, and that many are also likely the result of multiple mergers. A very small number still appear as AGN with stellar-like nuclei, and some also appear to be possible groups or small clusters of galaxies which were within the *IRAS* beam. While it is impossible to know without spectroscopy of the members of these groups, there is some reason to speculate that some of these groups may represent the early stages of the multiple merger scenario. A nuclear photometry paper and *WFPC2* and *NICMOS* Atlas papers are currently in the final stages of preparation, and several other smaller papers are in preparation or have already been submitted and/or accepted, including papers on the multiple merger scenario, on the QSO ULIRG IR10026+4347 and its rich environment, the prototypical QSO ULIRG IR1334+246 and its environment, the X-ray companion to Markarian 273 (a possible cluster at  $z = 0.46$ ), and several others on some more notable individual galaxies in the sample. Relationships between ULIRGs, LIRGs, and the HDF-N and HDF-S populations of galaxies are also being explored as a part of this collaboration.

R. van der Marel studied models for the surface brightness profiles of early-type galaxies. *HST* observations show that two types of profiles are generally observed: ‘core’ profiles have a break at a resolved radius and logarithmic cusp slope  $\gamma < 0.3$  inside that radius; ‘power-law’ profiles have no clear break and  $\gamma > 0.3$ . With few exceptions, galaxies with  $M_V < -22$  have core profiles, and galaxies with  $M_V > -20.5$  have power-law profiles. Both profile types occur in galaxies with  $-22 < M_V < -20.5$ . van der Marel showed that these results are consistent with models in which all early-type galaxies have black holes that grew adiabatically in homogeneous isothermal cores that followed scaling relations similar to those of the fundamental plane. Application to individual galaxies with *HST* photometry yields a roughly linear correlation between black hole mass and V-band galaxy luminosity,  $\log M_{\text{bh}} = -1.83 + \log L$  (in solar units), in agreement with kinematical studies and predictions from quasar statistics.

H. Schmitt, T. Storchi-Bergmann (UFRGS) and R. Cid Fernandes (UFSC) analyzed the nuclear stellar population of 20 Seyfert 2s and 4 Radio Galaxies, using a base of stellar population templates of different ages and metallicities and a power-law continuum. The comparison with the stellar population of elliptical galaxies showed that Seyfert 2s usually have a smaller contribution from old metal rich stars (10 Gyr,  $Z \geq Z_{\odot}$ ), and a larger contribution from stars with 100 Myr. The contribution from stars with age  $\leq 10$  Myr and from a power law continuum are small, rarely exceeding 5% of the light at  $\lambda 5870 \text{ \AA}$ . These results show that the general assumption of elliptical galaxies as stellar population templates for these objects is incorrect, also implying that the excess blue continuum frequently found in their nuclear spectra is probably due to this template mismatch. They also found a considerable contribution from 100 Myr stars ( $\approx 5\%$ ), which indicates a connection between Starbursts and nuclear activity.

M. Stiavelli, T. Treu, and S. Casertano in collaboration

with P. Miller (ESO) and G. Bertin (Scuola Normale Superiore), are continuing their study of the evolution of field elliptical galaxies with redshift by means of diagnostic tools such as the Fundamental Plane (FP) and the Kormendy Relation (KR). Their sample of intermediate redshift ellipticals ( $z = 0.2-0.4$ ) is drawn from the *HST* Medium Deep Survey and they are obtaining follow-up spectroscopy with the spectrograph *EFOSC2* at the *ESO-3.6m* telescope, in order to measure velocity dispersion. The results from the first set of data indicate that the FP and the KR are well defined in the field at intermediate redshift. The galaxies show an average brightening with respect to local samples, consistent with the evolution of stellar populations formed at relatively high redshift. They started also a program aimed at measuring the FP in two clusters at  $z = 0.58$ , in collaboration with M. Carollo (Columbia) and P. Rosati (ESO). Images and spectra are obtained with *WFPC2* and the spectrograph *FORS* at the *ESO Very Large Telescope (VLT)*. The comparison of the results in the cluster and field environment will allow the investigator to test the predictions of the hierarchical cluster models, i.e., that the cluster ellipticals were formed very early in the first overdensity peaks, while the field ellipticals have experienced a relatively recent major merger ( $z < 1$ ).

Stiavelli and Treu are investigating the evolution of elliptical galaxies with the help of *NICMOS* high resolution images. They have defined a color-morphology selection criterion to select high redshift elliptical galaxies candidates (HizECs; like the one they identified in the Hubble Deep Field South, with a photometric redshift  $z = 1.8$ ) and they have applied it to a dataset of *NICMOS* images, with deep optical counterparts taken at different telescopes (*CTIO-4m*, *ESO-NTT*, *HST-WFPC2*) covering a total of 13.74 square arcmin. From this first survey there is evidence for a substantial population of HizECs, that is inconsistent with a scenario where all field ellipticals are assembled at  $z < 1$ . However, the observed density is smaller than what is predicted by a simple model where all E/S0 galaxies form in a single burst of star formation at high redshift ( $z = 3-5$ ) and evolve passively (10–66% depending on cosmology and the redshift of formation). Possible explanations for this lack of objects include: *i*) a small amount of delayed star formation is sufficient to make these galaxies significantly bluer than an high redshift old elliptical galaxy; *ii*) tidal interactions or accretion of satellites are distorting the morphology; *iii*) part of the E/S0s are not yet assembled.

D. Thompson, S. Beckwith and several collaborators have found many extremely red galaxies (EROs for Extremely Red Objects) in the fields of the Calar Alto Deep Imaging Survey (CADIS). These objects have R–K colors exceeding 6 magnitudes. All of these objects are seen in the *K* band but not the *R* band; most are a few seconds of arc in extent, indicating galaxies at redshifts greater than about 0.2. Objects of this type have been seen in early surveys, but only a few were known. The one CADIS field completely reduced revealed 20 EROs. A paper describing EROs was accepted for publication in June 1999. A second finding is that there are more quasars at high redshift discovered using the multi-filter CADIS technique than have previously been discovered with more traditional methods. Two papers describing these

results have been submitted, and a more extensive paper will be submitted making use of better statistics on the quasars as the survey observations are finished next year.

B. Whitmore, collaborating with Q. Zhang, (ST ScI & JHU), C. Leitherer, S. M. Fall, F. Schweizer, (CIW/DTM) and B. Miller (Leiden), obtained high-resolution *WFPC2* images of NGC 4038/4039 (the “Antennae” galaxies) that go roughly 3 magnitudes deeper in *V* than their previous observations made during Cycle 2. To first order the luminosity function of the young star clusters formed by this prototypical merger is a power law, with exponent  $\alpha = -2.12 \pm 0.04$ . However, using a variety of different techniques to decouple the cluster and stellar luminosity functions, they find an apparent bend in the young cluster luminosity function at approximately  $M_V = -10.4$ . Brightward of this magnitude the luminosity function has a power law exponent  $\alpha = -2.6 \pm 0.2$  while faintward the slope is  $\alpha = -1.7 \pm 0.2$ . The bend corresponds to a mass  $\sim 1 \times 10^5 M_\odot$ , only slightly lower than the characteristic mass of globular clusters in the Milky Way ( $\sim 2 \times 10^5 M_\odot$ ). The star clusters of the Antennae appear slightly resolved, with median effective radii of  $4 \pm 1$  pc, similar to or perhaps slightly larger than those of globular clusters in our Galaxy. The UBVI colors have been used to show the presence of four generations of star clusters in the Antennae. Effective gas-outflow velocities for two of the youngest clusters are estimated to be about 25–30 km/s, while measured widths of the interstellar absorption lines suggest dispersion velocities of  $\sim 400$  km/s along the lines of sight.

Together with the HDF-S team, Williams helped coordinate the data reduction, creation of the source catalogues, and the data release of the southern Deep Fields.

## 6. CLUSTERS AND COSMOLOGY

M. Donahue has finished ASCA observations of the most distant X-ray luminous clusters in the Extended Medium Sensitivity Survey. Because these clusters are hot and distant, their redshifts and temperatures provide a sensitive measure to the mean density of matter in the Universe. G. M. Voit provided the theoretical foundations for the comparing the theory of gravitational formation of clusters of galaxies to the observations, including appropriate modifications to the Press-Schechter theory and the cluster mass-temperature relation. Donahue and Voit and their collaborators, I. Gioia (IfA, Hawaii & Bologna), C. Mullis (Ifa), J. Hughes (Rutgers), C. Scharf (ST ScI), published the compiled results in the ApJ. Donahue and Voit derive an allowed 1- $\sigma$  range for  $\Omega_{\text{matter}}$  of 0.2–0.4 (flat universe) or 0.35–0.55 (open universe), and exclude  $\Omega_{\text{matter}} = 1$  models with over 99.97% confidence. With Sunyaev-Zel’dovich observations of two of these distant clusters, the University of Chicago group (E. Reese, J. Carlstrom and many collaborators, including Donahue) inferred that  $H_0 = 63 \pm 12 \pm 20$  km/s/Mpc if  $\Omega_{\text{matter}} = 0.3$  and  $\Omega_\lambda = 0.7$ .

M. Fall, P. Miller (ESO/Garching), S. Warren (Imperial Col.), and P. Jakobsen (ESA/ESTEC) continued their search with *STIS* and *NICMOS* on *HST* for starlight from high-redshift damped Lyman- $\alpha$  absorption systems. They have detected optical counterparts of several absorbers.

M. Hauser and Y. C. Pei, in collaboration with colleagues on the *COBE* science team, completed a search for the cosmic infrared background (CIB) radiation using data from the *COBE* Diffuse Infrared Background Experiment (DIRBE). In a series of four papers, the team reported detection of the CIB at 140 and 240 microns, and upper limits from 1.25 to 100 microns. Detailed models of foreground infrared radiation from interplanetary dust and stars and dust in the Milky Way Galaxy were developed and described. The large CIB brightness detected implies that much of the radiation from star formation at high redshift was absorbed by dust. Y. Pei, M. Fall, and M. Hauser used the *COBE* infrared background data, together with data from quasar absorption line surveys, optical imaging and redshift surveys, to develop a cosmic chemical evolution model for the histories of stars, interstellar gas, heavy elements, dust, and radiation from stars and dust.

M. Livio examined the question of how rare is intelligent life in the universe, and when is the most likely epoch in the universe’s lifetime for intelligent life to appear.

Livio and Stiavelli examined a recent claim that the fine structure constant varies with redshift, and showed that the claimed result is at variance with experimental verifications of the equivalence principle.

Livio has written a popular book, *The Accelerating Universe*, about the beauty of physical theories of the universe. The book will appear in February 2000.

P. Padovani, in collaboration with H. Landt (ST ScI), E. Perlman (ST ScI) and P. Giommi (SAX/SDC), has continued his work on the Deep X-ray/Radio Blazar Survey (DXRBS). By correlating the *ROSAT* WGACAT database with several radio catalogs, and restricting the candidate list to serendipitous flat spectrum radio sources ( $\alpha_r < 0.70$ ), DXRBS is sampling the faint end of the blazar population with high efficiency (90%). The sample identification is now 85% complete and work has started on the evolutionary properties of the sample. A study is also underway of the previously unknown population of flat-spectrum radio quasars with relatively strong X-ray emission.

C. Scharf, working with the *ROSAT* X-ray Optical (ROX) survey team M. Donahue, M. Postman, M. Dickinson, J. Mack, P. Lee (ST ScI) and P. Rosati (ESA) discovered an intergalactic X-ray/optical filament. If confirmed, this filament will be the first confirmation of the idea suggested by hydrodynamic simulations that many of the baryons in the universe reside in hot gaseous intergalactic filaments.

Scharf has continued work on X-ray galaxy clusters and large-scale structure. An analysis of the Mass-Temperature relationship for X-ray clusters with Horner and Mushotzky (GSFC) was completed and provided evidence of non-gravitational energy input to intra-cluster gas. Two related works on the nature of anisotropies in the all-sky hard X-ray background were completed. In one the power spectrum of mass fluctuations was constrained on scales of several hundred mega-parsecs (intermediate to the scales probed by the CMB and galaxy surveys) and in the other the dipole anisotropy was related to bulk motions of the sources. This data was also used to constrain the fractal correlation dimension of structure and strongly suggests that the Universe is homo-

geneous on scales larger than 600 mega-parsecs. A work on the role of gas entropy in galaxy cluster formation was completed with Tozzi (JHU) and Norman (ST ScI/JHU) and provided a prediction for the observation of a cluster virial shock using XMM. Results from the ongoing WARPS project were presented; the discovery of a luminous X-ray cluster at redshift 0.83 and a new measurement of the evolution of the luminosity-temperature relationship for clusters, both of which suggest a low-density cosmology. Using data from Donahues (ST ScI) ROX survey an extremely low surface-brightness, filamentary X-ray structure was discovered. The system is at least 6 mega-parsecs in length and exhibits many of the properties expected for large-scale, inter-cluster structures. Simulations suggest these filaments may contain much of the currently unseen baryonic component of the Universe. Plans are underway for detailed follow-up observations of this discovery.

## 7. AGN

L. Dressel completed spectroscopic observations of 8 Liner galaxies with radio-bright nuclei. With co-investigators H. Ford, Z. Tsvetanov (JHU), G. Kriss (ST ScI), and R. O’Connell (U. VA), she made a pattern of long-slit observations with *STIS* of several emission lines, to map the kinematics of the circumnuclear gas and study the excitation and gas density as a function of distance from the nucleus. The brightest gaseous disk, in NGC 3998, is seen to be in regular rotation well beyond the sphere of influence of the central supermassive black hole. The velocities indicate a black hole of  $10^8$  solar masses embedded in a density of 2000 solar masses per cubic parsec.

A. Kinney and H. Schmitt, in collaboration with J. Pringle and C. Clarke (Cambridge), R. Antonucci (UCSB) and J. Ulvestad (NRAO-VLA), studied the orientation of radio jets relative to the host galaxy disk in a sample of Seyfert galaxies selected from a mostly isotropic property, the flux at 60  $\mu\text{m}$ . They used *VLA* A-array 3.6 cm data and ground based *B* and *I* images to determine, for each one of the galaxies with extended radio emission, a pair of points ( $i$ ,  $\delta$ ), which are the inclination of the galaxy relative to the line of sight and the angle between the jet projected into the plane of the sky and the host galaxy major axis, respectively. This data was combined with a statistical technique to determine the distribution of angles  $\beta$ , the angle between the jet and the host galaxy plane axis. The analysis of the data showed that the observed distribution of  $i$  and  $\delta$  values can be well represented either by a homogeneous  $\beta$  – distribution in the range  $0^\circ \leq \beta \leq 90^\circ$ , or  $0^\circ \leq \beta \leq 65^\circ$ , but not by an equatorial ring. Kinney *et al.* (2000) explored several explanations for this misalignment. Their analysis also showed that the inclusion of viewing angle restrictions for Seyfert 1s, namely, that a galaxy can only be recognized as a Seyfert 1 if the angle between the jet and the line of sight ( $|\phi|$ ) is smaller than a given angle  $\phi_c$  and that the galaxy inclination  $i$  is smaller than an angle  $i_c$ , improved the acceptability of the models and is an independent confirmation to the Unified Model.

G. Kriss, Z. Tsvetanov (JHU) and R. Telfer (JHU) are studying indicators of the orientation and geometry of broad absorption line QSOs (BALQSOs). *HST* and *HUT* observa-

tions of the QSO SBS1542+541 reveal broad absorption lines that are only apparent in the most highly ionized atomic species, e.g., Ne VIII, Mg X, Si XII. The broad lines only partially cover the continuum source, and there is a correlation between covered fraction and ionization state, with the most highly ionized species covering more of the continuum source. This suggests either a model in which a highly stratified wind, with low ionization gas at its base and more highly ionized gas at larger radii, is viewed by the observer at high inclination, or one in which small, high density, low ionization clumps are embedded in a larger, more tenuous wind.

In an *HST* snapshot program, Kriss, Tsvetanov, and Telfer obtained narrow-band images of BALQSOs using *NICMOS* in an attempt to detect extended emission line regions. These are to be expected if BALQSOs have geometries similar to Seyfert 2 galaxies in which the obscuring BAL material lies in an equatorial lane and they view it at high inclination (as suggested by spectropolarimetry). Thus, by analogy to Seyfert 2s like NGC 1068, one should see extended ‘‘ionization cones’’ in BALQSOs. None were detected in observations of sample of a dozen objects, however. This suggests that either little surrounding material is present to be illuminated by the central continuum source, or that the geometry of BALQSOs is even more complex than thought.

Kriss, in collaboration with R. Green (NOAO), other members of the *FUSE* team, W. Zheng (JHU), A. Koratkar (ST ScI), and M. Brotherton (NOAO), is performing a comprehensive survey of the far-ultraviolet through optical spectral energy distribution of the  $\sim 100$  UV-brightest AGN on the sky. *FUSE* spectra of the sample will cover the 912–1150  $\text{\AA}$  wavelength region. Contemporaneous *HST/STIS* spectra in a snapshot program will obtain G140L and G230L spectra covering the longer UV wavelengths from 1150–3200  $\text{\AA}$ . Ground-based spectra obtained at *KPNO* and at *APO* will provide coverage from the atmospheric limit to  $\sim 1$  micron. The full data set on each object will span the continuum across the peak of the ‘‘blue bump.’’ They will also measure emission lines, absorption lines, and line profiles over a wide range of ionization states, providing a comprehensive data set for understanding the central engine and its environs in the lowest redshift AGN ( $z < 0.3$ ).

M. Livio, in collaboration with C. Xu and S. Baum, showed from a large database that the radio power as a function of the UV luminosity is linear for both radio-loud and radio-quiet AGN, and suggested a theoretical explanation for this relation in terms of jet formation by accretion disks.

R. van der Marel and F. van den Bosch used *HST* to study the nuclear region of the E4 radio galaxy NGC 7052, which has a nuclear disk of dust and gas. The *WFPC2* was used to obtain *B*, *V* and *I* broad-band images and an  $\text{H}_{\alpha+[\text{NII}]}$  narrow-band image. The *FOS* was used to obtain  $\text{H}_{\alpha+[\text{NII}]}$  spectra along the major axis, using a 0.26 arcsec diameter circular aperture. The observed rotation velocity of the ionized gas is  $V = 155 \pm 17$  km/s at  $r = 0.2$  arcsec from the nucleus. The Gaussian dispersion of the emission lines increases from  $\sigma = 70$  km/s at  $r = 1$  arcsec, to  $\sigma = 400$  km/s on the nucleus. Axisymmetric dynamical models for the observations imply the presence of a black hole in the

center of the galaxy with a mass of  $3.3_{-1.3}^{+2.3} \times 10^8 M_{\odot}$ .

R. McLure, J. Dunlop, M. Kukula, D. Hughes (Edinburgh) and C. O’Dea and S. Baum (ST ScI) are using *HST/WFPC2* in an imaging study aimed at providing the first statistically meaningful comparison of the morphologies, luminosities, scale-lengths and colors of the host galaxies of radio-quiet quasars, radio-loud quasars, and radio galaxies. They find that the underlying hosts of all three classes of luminous AGN are massive elliptical galaxies, with scale-lengths about 10 kpc, and  $R - K$  colors consistent with old stellar populations. Most importantly this is the first unambiguous evidence that, just like radio-loud quasars, essentially all radio-quiet quasars brighter than  $M_R = -24$  reside in massive ellipticals. This result removes the possibility that radio ‘loudness’ is an inevitable outcome of the host galaxy having an elliptical morphology, but is however in excellent accord with the black-hole/spheroid mass correlation recently highlighted by Magorrian *et al.* (1998). They apply the spheroid luminosity/spheroid mass/black-hole mass relations given by Magorrian *et al.* to infer the expected Eddington luminosity (and hence maximum expected nuclear R-band luminosity) of the putative black hole at the center of each of the spheroidal host galaxies they have uncovered. Comparison of the predicted Eddington luminosities with the actual nuclear R-band luminosities produces a clear relationship, and suggests that the black holes in most of these galaxies are radiating at a few percent of the Eddington luminosity (although a few appear to radiating close to the Eddington limit); the brightest host galaxies in the low-redshift sample are capable of hosting quasars with  $M_R - 28$ , comparable to the most luminous quasars at  $z \sim 3$ , if fueled at the Eddington rate.

P. Padovani, with a large number of investigators, has continued his work on various *BeppoSAX* projects on AGN, including radio-selected BL Lacs, X-ray elected BL Lacs, lobe-dominated broad-lined radio sources, flat-spectrum radio quasars, and radio galaxies. In particular, with Trussoni *et al.* he has studied the hard X-ray properties of a sample of Fanaroff-Riley I radio galaxies and with Giommi *et al.* he has analyzed the synchrotron and inverse Compton variability of the BL Lacertae object S5 0716+714. Work is also in progress on the X-ray spectra of the 1 Jy BL Lacs and of some of the newly discovered flat-spectrum radio quasars with relatively strong X-ray emission.

R. Scarpa is continuing his study of BL Lacertae objects and radio galaxies in collaboration with C. M. Urry, R. Falomo (Padua Obs.) and A. Treves (Milan U.). The *HST* survey of BL Lac objects is finally completed and results published. Follow-up *NICMOS* IR observation of 12 BL Lac objects have been obtained; preliminary results shows that the  $R - H$  color of the host galaxy is indistinguishable from that of normal, non-active elliptical galaxies. Similar results were found analyzing ground based observations of a large sample of radio galaxies, which, in turn, are found to be indistinguishable from both BL Lac hosts and non-active ellipticals. A new optical synchrotron jet has been discovered in a *WFPC2HST* image of the BL Lac object PKS 2201+044, a result which led Scarpa to investigate the physical properties of all known optical jets in AGN thoroughly.

Urry, Scarpa, O’Dowd, Pesce, Falomo, Treves, and Giavalisco are finishing their *HST* imaging survey of BL Lac objects, investigating the properties of their host galaxies and environments (Falomo *et al.* 1999; Urry 1999c,d; Urry *et al.* 1999a,c-f; Pesce *et al.* 1999; Scarpa & Urry 1999a,b; Scarpa *et al.* 1999a-e; O’Dowd *et al.* 1998). *WFPC2* observations of 110 BL Lacs yield detected host galaxies in most objects with  $z < 0.5$ , and about 1/4 of those with  $z > 0.5$ . The host galaxies are luminous ellipticals, comparable to FRI radio galaxies, thus confirming the standard unification scenario. Apart from their luminous BL Lac nuclei, these galaxies are indistinguishable from other ellipticals, following the same  $\mu_e - r_e$  relation. There is no evidence that the galaxy luminosity correlates with nuclear luminosity. Serendipitous discoveries during this survey include several new optical jets; together with the radio data, the optical surface brightness strongly constrains the jet power, bulk relativistic motion, and electron lifetimes (Scarpa & Urry 1999a,b; Scarpa *et al.* 1999a,d; Urry 1999c). Several gravitational lens candidates were also found, including a possible Einstein ring (Scarpa *et al.* 1999b-d; Urry *et al.* 1999c). Follow-up observations on these lens candidates are underway.

Urry has continued multiwavelength monitoring of blazars (Urry 1998, 1999a,c,d; Urry *et al.* 1998,1999b; Chiappetti *et al.* 1999; Kataoka *et al.* 1999; Mantegazza *et al.* 1999; Maraschi *et al.* 1999; Pian *et al.* 1998,1999a,c; Sambruna *et al.* 1999b,c; Treves *et al.* 1999; Wehrle *et al.* 1998a,b; Zhang *et al.* 1999), with Chiappetti, Kataoka, Mantegazza, Maraschi, Pian, Sambruna, Treves, Wehrle, and Zhang, and collaborators carrying out radio-through-gamma-ray campaigns on the blazars Mrk 421, Mrk 501, PKS 2155–304, and 3C 279, among others. The multiwavelength light curves of Mrk 421 show strongly correlated variability at UV through TeV energies, with amplitude increasing with wavelength. The flaring is rapid and complex in the synchrotron component, with both soft and hard lags observed, suggesting a complicated interplay of electron injection, acceleration, and cooling. For 3C 279, 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 (Wehrle *et al.* 1998a,b). A re-analysis of archival *IUE* spectra of 3C 279 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 (Koratkar *et al.* 1998). This interpretation is supported by the discovery that 3C 279, in its lowest UV state, shows evidence of the thermal component required for external Comptonization (Pian *et al.* 1999b,d).

Urry, Grandi, Haardt, Padovani, Wolter, and collaborators have used the *BeppoSAX* satellite to survey the X-ray properties of BL Lac objects, quasars, and radio galaxies (Grandi *et al.* 1998, 1999a-c; Haardt *et al.* 1998; Padovani *et al.* 1999; Wolter *et al.* 1998). The blazars show a range of X-ray spectral shapes, from steep (synchrotron) tails for the lower luminosity BL Lacs to flat (possibly Compton-scattered) spectra for the high-luminosity BL Lacs and radio-loud quasars. A study of radio-loud quasars with the *ASCA* satellite

confirms this blazar paradigm, finding the usual flat spectra in the medium X-ray band but much steeper (synchrotron) emission in the soft X-ray band (Sambruna *et al.* 1999). Seyferts and radio-quiet quasars have thermal emission, as evidenced by iron lines and hard reflection X-ray spectra. Radio galaxies are a mix of blazar plus Seyfert-like X-ray spectra: the iron lines and reflection components are systematically weaker, and a blazar component is present at varying levels from one galaxy to the next.

## 8. INSTRUMENTS AND SOFTWARE

T. Böker, R. Allen, and J. Rajagopal continued their work on simulations of the imaging performance of the Space Interferometer Mission (SIM). Using the anticipated instrumental parameters for SIM, they predicted the signals from various types of astronomical sources, and analyzed the image quality of reconstructed images. The results of such simulations allow conclusions about the feasibility of synthesis imaging observations with SIM.

B. Espey and G. Kriss also contributed to the paper containing the comprehensive final calibration results for the *Hopkins Ultraviolet Telescope (HUT)* as flown on the *Astro-2* space astronomy mission in March 1995. Final sensitivity results using hot DA white dwarf standards show consistency with laboratory sensitivity measurements at the 3% level over the entire wavelength 910–1840 Å wavelength range of the detector. The instrumental linewidth varies from 1.8–4.5 Å over the same range. For complete details see Kruk *et al.* (1999). Observations from *HUT* for both the *Astro-1* and *Astro-2* missions are now available in the MAST archive at ST ScI.

D. Figer, in collaboration with a team led by I. S. McLean (UCLA), commissioned *NIRSPEC*, the facility near-infrared spectrometer on the *Keck II Telescope*. Figer co-authored the original proposal and served as Local Project Scientist and Principle Optical Engineer for the 5-year project. He was responsible for optical system testing and integration to the *Keck Telescope* during the commissioning period. During the 15 commissioning nights, he led the Galactic Center science program to determine the nature of the stars swirling about the supermassive black hole in the center, measure radial velocities in the center to within 500 m/s, determine the metallicity in the center, study the gas dynamics of the minispiral, and fix the mass-magnitude relationship for stars in the Arches and Quintuplet clusters. In addition, the commissioning science included observations of: planets, comets, colliding galaxies, brown dwarfs, AGN, starburst galaxies, J-band dropouts, and Kuiper-belt objects. Figer led another team in identifying the Quintuplet and Arches clusters as the most massive young clusters in the Galaxy using *HST/NICMOS* images (ST ScI-PRC99-30).

B. Whitmore, I. Heyer, and S. Casertano have used observations of Omega Cen to characterize the Charge Transfer Efficiency (CTE) of the *Wide Field and Planetary Camera 2 (WFPC2)* on board the *HST*. A set of formulae has been developed to correct aperture photometry for CTE loss with dependencies on the X and Y positions, the background counts, the brightness of the star, and the time of the observation. The observations indicate that for very faint stars on

a very faint background, the CTE loss from the top to the bottom of a chip has increased from about 3% shortly after the cool-down of *WFPC2* (April 23, 1994) to roughly 40% in February 1999. In general, typical *WFPC2* exposures are much longer than these short calibration images, resulting in higher background which significantly reduces the CTE loss and minimizes the CTE problem for most science exposures.

## PUBLICATIONS

*This list includes papers published or submitted between October 1998 and September 1999 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., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “Binary Microlensing Events from the MACHO Project,” *ApJ*, submitted
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “Calibration of the MACHO Project Photometry Database,” *PASP*, in press
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “Difference Image Analysis of Galactic Microlensing. I. Data Analysis,” *ApJ*, 521, 603
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “Difference Image Analysis of Galactic Microlensing. II. Microlensing Events,” *ApJS*, submitted
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “Discovery and Characterization of a Caustic Crossing Microlensing Event in the Small Magellanic Cloud,” *ApJ*, 518, 44
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The Blazhko Effect in RR Lyrae Stars: Strong Evidence for the Oblique Pulsator Model,” *ApJ*, submitted
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The MACHO Project 9 Million Star Color-Magnitude Diagram of the Large Magellanic Cloud,” *AJ*, submitted
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The MACHO Project LMC Variable Star Inventory. VI. The Second Overtone Mode of Cepheid Pulsation from First/Second Overtone Beat Cepheids,” *ApJ*, 511, 185
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The MACHO Project LMC Variable Star Inventory. VIII. The Recent Star Formation History of the Large Magellanic Cloud from the Cepheid Period Distribution,” 1999, *AJ*, 117, 920
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The MACHO Project SMC Variable Star Inventory. I. The Second Overtone Mode of Cepheid Pulsation from First/Second Overtone Beat Cepheids,” *AJ*, submitted
- Alcock, C., Allsman, R. A., Alves, D. R., *et al.* (The MACHO Collaboration) 1999, “The MACHO Project

- Sample of Galactic Bulge High-Amplitude Delta-Scuti Stars: Pulsation Behavior and Stellar Properties,” AJ, submitted
- Alves, D. R. & Sarajedini, A. 1999, “The Age-dependent Luminosities of the Red Giant Branch Bump, Asymptotic Giant Branch Bump, and Horizontal Branch Red Clump,” ApJ, 511, 225
- Alves, D. R., Bond, H. E. & Zurek, D.R. 1999 “Hubble Space Telescope Observations of the Planetary Nebula K 648 in the Globular Cluster M15,” BAAS, 194, 8518
- Alves, D. R., *et al.* 1998, “The MACHO Project 9 Million Star Color-Magnitude Diagram of the Large Magellanic Cloud: Probing the LMC Disk,” 1998, BAAS, 193, 10801
- Arendt, R. G., Odegard, N., Weiland, J. L., Sodroski, T. J., Hauser, M. G., Dwek, E., Kelsall, T., Moseley, S. H., Silverberg, R. F., Leisawitz, D., Mitchell, K., & Reach, W. T. 1998, “The COBE Diffuse Infrared Background Experiment Search for the Cosmic Infrared Background. III. Separation of the Galactic Emission from the Infrared Sky Brightness,” ApJ, 508, 74
- Baptista, R., Horne, K., Wade, R. A., Hubeny, I., Long, K. S., & Rutten, R. G. 1998, “HST spatially resolved spectra of the accretion disk and gas stream of the nova-like variable UX Ursae Majoris,” MNRAS, 298, 1079
- Beckwith, S. V. W., Henning, Th., & Nakagawa, Y. 2000, “Dust Properties and Assembly of Large Particles in Protoplanetary Disks,” in *Protostars and Planets III*, eds. V. Mannings, A. P. Boss, & S. S. Russell (University of Arizona Press), in press
- Beckwith, S. V. W. 1999, “Circumstellar Disks,” in *The Origin of Stars and Planetary Systems NATO Science Series*, eds. C. J. Lada & N. D. Kylafis, 540, 579 (Kluwer Academic Press)
- Bennett, J., Donahue, M., Schneider, N., Voit, G. M. 1998, “The Cosmic Perspective,” (Addison-Wesley Longman)
- Bennett, J., Donahue, M., Schneider, N., Voit, G. M. 1999, “The Cosmic Perspective: The Short Edition,” (Addison-Wesley Longman)
- Bertero, M., Boccacci, P., & Robberto, M. 1999, “An inversion method for the restoration of chopped and noded images,” *Inverse Problems*, 15, 345
- Bertero, M., Boccacci, P., & Robberto, M. 1999, “Image restoration in thermal infrared astronomy,” in *Proc. Second Workshop on Large-Scale Scientific Computations*, in press
- Bertero, M., Boccacci, P., & Robberto, M. 1999, “Wide-Field Imaging at Mid-IR Wavelengths: Reconstruction of Chopped and Noded Data,” PASP
- Birriel, J. J., Espey, B. R., & Schulte-Ladbeck, R. S. 1998, “Near-Simultaneous Observations of Direct and Raman Scattered Lines in the Symbiotic Star Z Andromedae,” ApJL, 507, 75
- Birriel, J. J., Schulte-Ladbeck, R. E., & Espey, B. R. 1998 “Raman Scattering in Symbiotic Stars: Ultraviolet and Optical Observation,” Bull. American Physical Society 43, 1185
- Boffi, F. R. 1999, “Circumstellar and Interstellar Environments of Supernovae of Different Types and Astrophysical Applications,” PASP, 111, 649
- Boffi, F. R., Sparks, W. B., & Macchetto, F. D. 1999, “A search for candidate light echoes: photometry of supernova environments,” A&A, Supplement Series, 138, 253
- Böker, T. & Allen, R. J. 1999, “Imaging and Nulling with the Space Interferometer Mission,” ApJS, in press
- Böker, T., Allen, R. J., & Rajagopal, J. 1999, “Imaging stellar proper motions in the nucleus of M31 with SIM,” in *Working on the fringe*, eds. S. Unwin & R. Stachnik, ASP Conference Series, p. 72
- Böker, T., Calzetti, D., Sparks, W., Axon, D., Bergeron, L. E., Bushouse, H., Colina, L., Daou, D., Gilmore, D., Holfeltz, S., MacKenty, J., Mazzuca, L., Monroe, B., Najita, J., Noll, K., Nota, A., Ritchie, C., Schultz, A., Sosey, M., Storrs, A., & Suchkov, A. 1999, “The NICMOS Snapshot Survey of Nearby Galaxies,” ApJS, in press
- Böker, T., van der Marel, R. P., & Vacca W. 1999, “CO-bandhead spectroscopy of IC 342: mass and age of the nuclear star cluster,” AJ, 118, 831
- Borne, K. D., Bushouse, H., Colina, L., & Lucas, R. A. 1998, “Evidence for Multiple Mergers Among Ultraluminous IR Galaxies,” in *After the Dark Ages: When Galaxies Were Young*, eds. S. Holt & E. Smith (Woodbury: AIP), p. 220
- Borne, K. D., Bushouse, H., Colina, L., & Lucas, R. A. 1999, “Evidence for Multiple Mergers among Ultraluminous IR Galaxies (ULIRGs): Remnants of Compact Groups?” ApJL, submitted
- Borne, K. D., Bushouse, H., Colina, L., Lucas, R. A., Baker, A., Clements, D., Lawrence, A., Oliver, S., & Rowan-Robinson, M. 1998, “A Morphological Classification Scheme for Ultraluminous Galaxies: Evidence for Multiple Mergers,” Ap&SS, in press
- Borne, K. D., Bushouse, H., Colina, L., Lucas, R. A., Baker, A., Clements, D., Lawrence, A., Oliver, S., & Rowan-Robinson, M. 1998, “Dynamics of Ultraluminous Galaxies,” in *Galaxy Dynamics*, p. 461
- Borne, K. D., Bushouse, H., Colina, L., Lucas, R. A., Baker, A., Clements, D., Lawrence, A., Oliver, S., & Rowan-Robinson, M. 1998, “NICMOS and WFPC2 Imaging of Ultraluminous Galaxies,” in *Astrophysics with Infrared Surveys: A Prelude to SIRTf*, in press
- Borne, K. D., Colina, L., Bushouse, H., & Lucas, R. A. 1999, “HST Observations of the Serendipitous X-ray Companion to Mrk 273: Cluster at  $z=0.46$ ?” ApJ, in press
- Borne, K. D., Colina, L., Bushouse, H., & Lucas, R. A. 1999, “HST Observations of the Ultraluminous IR Galaxy IRAS 10026+4347: The QSO, its Host Galaxy, and its Rich Environment,” AJ, submitted
- Borne, K. D., Lucas, R., Appleton, P., Struck, C., Schultz, A., & Spight, L., 2000, “HST Imaging Observations of the ‘Cartwheel’ Ring Galaxy,” in preparation
- Borne, K., Bushouse, H., Lucas, R., & Colina, L. 1999, “Evidence for Multiple Mergers Among Ultraluminous IR Galaxies (ULIRGs): Remnants of Compact Groups?” ApJ, submitted
- Borne, K., Colina, L., Bushouse, H., & Lucas, R. 1999, “HST Observations of the Serendipitous X-ray Companion

- ion to Mrk 273: Cluster at  $z = 0.46$ ?" ApJ, in press
- Borne, K., Colina, L., Bushouse, H., & Lucas, R. 1999, "HST Observations of the Ultraluminous IR Galaxy IRAS 10026+4347: The Environment and Host Galaxy of a Strong FeII QSO," AJ, submitted
- Brage, T., Proffitt, C. R., & Leckrone, D. S. 1999, "Theoretical Oscillator Strengths and Hyperfine Structure in Hg II," ApJ, 513, 524
- Brandt, J. C., Heap, S. R., Beaver, E. A., Boggess, A., Carpenter, K. G., Ebbets, D. C., Hutchings, J. B., Jura, M., Leckrone, D. S., Linsky, J. L., Maran, S. P., Savage, B. D., Smith, A. M., Trafton, L. M., Walter, F. M., Weymann, R. J., Proffitt, C. R., Wahlgren, G. M., Johansson, S. G., Nilsson, H., Brage, T., Snow, M., & Ake T. B. 1999, "A GHRS Atlas of Echelle Observations of the HgMn Star  $\chi$  Lupi," AJ, 117, 1505
- Budavari, T., Szalay, A. S., Connolly, A. J., Csabai, I., & Dickinson, M., 1999, "Creating Spectral Templates from Multicolor Redshift Surveys," in *Photometric Redshifts and High Redshift Galaxies*, eds. R. Weymann, L. Storrie-Lombardi, M. Sawicki & R. Brunner, (ASP), in press
- Bushouse, H. A., Borne, K. D., Colina, L., & Lucas, R. A., 1998, "HST Reveals the Core Properties of Ultraluminous IR Galaxies," BAAS, 193, 76.09
- Calzetti, D. & Heckman, T. M. 1999, "The Evolution of Dust Opacity in Galaxies," ApJ, 519, 27
- Calzetti, D., Armus, L., Bohlin, R. C., Kinney, A. L., Koornneef, J., & Storchi-Bergmann, T. 1999, "The Dust Content and Opacity of Actively Star-Forming Galaxies," ApJ, submitted
- Calzetti, D., Conselice, C. J., Gallagher, J. S. III, & Kinney, A. L. 1999, "The Structure and Morphology of the Ionized Gas in Starburst Galaxies: NGC 5253/5236," AJ, in press
- Casertano, S., De Mello, D., Ferguson, H. C., Fruchter, A. S., Heyer, I., Hook, R. N., Lucas, R. A., Makidon, R., Mutchler, M., Stiavelli, M., Wiggs, M. S., & Williams, R., 1998, "HDF-S: A WFPC2 Deep Image of a Field near QSO J2233-60," BAAS, 193, 75.05
- Cesaroni, R., Felli, M., Jennes, T., Neri, R., Olmi, L., Robertto, M., Testi L., & Walmsley, C. M. 1999, "Unveiling the disk-jet system in the massive (proto)star IRAS 20126+4104," A&A, 345, 949
- Chapman, J. M., Leitherer, C., Koribalski, B., Bouter, R., & Storey, M. 1999, "Radio Continuum Measurements of Southern Early-Type Stars. III. Nonthermal Emission from Wolf-Rayet Stars," ApJ, 518, 590
- Chapman, S. C., Scott, D., Steidel, C. C., Borys, C., Halpern, M., Morris, S. L., Adelberger, K. L., Dickinson, M., Giavalisco, M., & Pettini, M. 1999, "A Search for the Submillimetre Counterparts to Lyman Break Galaxies," MNRAS, submitted
- Chiappetti, L., Maraschi, L., Tavecchio, F., Celotti, A., Fosfati, G., Ghisellini, G., Giommi, P., Pian, E., Tagliaferri, G., Treves, A., Urry, C. M., Zhang, Y. H. 1999, "Spectral Evolution of PKS 2155-304 observed with BeppoSAX during an Active Gamma-ray Phase," ApJ, 521, 552
- Collins, T., Frank, A., Bjorkman, J., & Livio, M. 1999, "SN1987A: Rotation and a Binary Companion," ApJ, 512, 322
- Conselice, C., Bershad, M. A., Dickinson, M., Ferguson, H. C., Fruchter, A. S., Hanley, C., Lucas, R. A., Mack, J., Madau, P., Postman, M., Connolly, A., Papovich, C., Szalay, A., Eisenhardt, P., Elston, R. J., Giavalisco, M., Hook, R. N., Stanford, S. A., & Steidel, C. C., 1998, "Quantitative Morphology of the NICMOS Hubble Deep Field," BAAS, 193, 75.12
- Cretton, N., de Zeeuw, P. T., van der Marel, R. P., & Rix, H. W. 1999, "Axisymmetric three-integral models for galaxies," 1999, ApJS, in press
- DePropris, R., Stanford, S. A., Eisenhardt, P. R., & Dickinson, M. 1999, "The K-Band Luminosity Function in Galaxy Clusters to  $z \sim 1$ ," AJ, in press
- Dickinson, M., 1999, "A Complete NICMOS Map of the Hubble Deep Field North," in *After the Dark Ages: When Galaxies were Young*, eds. S. Holt & E. Smith, AIP, 122
- Dickinson, M., 1999, "Surveys for Galaxies at  $z > 2$ , and an Introduction to the HDF-South," in *Looking Deep in the Southern Sky*, eds. R. Morganti & W. J. Couch (Springer: Berlin), p. 262
- Dickinson, M., Ferguson, H. C., Fruchter, A. S., Hanley, C., Lucas, R. A., Mack, J., Madau, P., Postman, M., Connolly, A., Papovich, C., Szalay, A., Bershad, M. A., Conselice, C., Eisenhardt, P., Elston, R. J., Giavalisco, M., Hook, R. N., Stanford, S. A., & Steidel, C. C., 1998, "A Complete NICMOS Map of the Hubble Deep Field (North)," BAAS, 193, 75.11
- Dickinson, M., Hanley, C., Elston, R., Eisenhardt, P. R., Stanford, S. A., Adelberger, K. L., Shapley, A., Steidel, C. C., Papovich, C., Szalay, A. S., Bershad, M. A., Conselice, C. J., Ferguson, H. C., & Fruchter, A. S., 1999, "The Unusual Infrared Object HDF-N J123656.3+621322," ApJ, in press
- Donahue, M. & Mack, J. 1999, "Warm Molecular Hydrogen in Cluster Cooling Flows," ST Sci Radio Galaxy Workshop proceedings
- Donahue, M. & Voit, G. M. 1999, "Estimation of the Mass Density of the Universe from the EMSS Cluster Temperature Redshift Distribution," in *Large Scale Structure in the X-ray Universe*
- Donahue, M. 1999, "Distant Massive Clusters and Cosmology," ASP Conf. Series, in press
- Donahue, M. 2000, "Clusters of Galaxies and the Fate of the Universe or How to Be a Cosmologist without Really Trying," in *Our Universe*, ed. A. Stern (Cambridge University Press)
- Donahue, M. & Voit, G. M. 1999, " $\Omega_m$  from the Temperature-Redshift Distribution of EMSS Clusters of Galaxies," ApJL, in press, Oct 1
- Donahue, M., Voit, G. M., Gioia, I. M., Luppino, G., Hughes, J. A., & Stocke, J. T. 1998, "A Hot Massive Cluster at Redshift 0.8: More Trouble for  $\Omega_0 = 1$ ?" ApJ, 502, 550
- Donahue, M., Voit, G. M., Scharf, C. A., Gioia, I. M., Mullis, C. R., Hughes, J. P., & Stocke, J. T. 1999, "The Second Most Distant Cluster of Galaxies in the EMSS," ApJ, in press, Dec 20.

- Dubus, G., Charles, P. A., Long, K. S., & Kuulkers, E. 1999, "The Eclipsing X-ray Pulsar X-7 in M33," *MNRAS*, 302, 731
- Dubus, G., Long, K. S. & Charles, P. A. 1999, "The Compact UV Nucleus of M33," *ApJ*, 519, L135
- Dwek, E., Arendt, R. G., Hauser, M. G., Fixsen, D., Kelsall, T., Leisawitz, D., Pei, Y. C., Wright, E. L., Mather, J. C., Moseley, S. H., Odegard, N., Shafer, R., Silverberg, R. F., & Weiland, J. L. 1998, "The COBE Diffuse Infrared Background Experiment Search for the Cosmic Infrared Background. IV. Cosmological Implications," *ApJ*, 508, 106
- Ebeling, H., Jones, L. R., Perlman, E., Scharf, C. A., Horner, D., Wegner, G., Malkan, M., Fairley, B., Mullis, C. R. 1999, "The WARPS survey: III. The discovery of an X-ray luminous galaxy cluster at  $z = 0.833$  and the evolution of X-ray luminous clusters at  $z < 1$ ," *ApJ*, submitted
- Emsellem, E. & Goudfrooij, P., 1999, "Gas and stellar 2-D kinematics in early-type galaxies," in *Galaxy Dynamics: from the Early Universe to the Present*, eds. F. Combes, G. A. Mamon & V. Charmandaris, (ASP), in press (astro-ph/9910006)
- English, J. & Freeman, K. C. 1999, "Giant H II regions in the Merging System NGC 3256: Are they the birthplaces of globular clusters?" *AJ*, submitted
- English, J., Taylor, A. R., Mashchenko, S. Y., Irwin, J. A., Basu, S., & Johnstone, D. 1999 "Galactic Worm 123.4-1.5: A Mushroom-shaped HI Cloud," *ApJL*, submitted
- English, J., Norris, R. P., Freeman, K. C., & Booth R. S. 1999, "NGC 3256: Kinematic Anatomy of a Merger," *AJ*, submitted
- Espey, B. R. 1999, "Observations of NGC 4151 from the Astro-2 and ORFEUS-SPAS-II Missions," in *Structure and Kinematics of Quasar Broad Line Regions*, ed. M. Gaskell, ASP Conf. Series 175, 351
- Espey, B. R. & Andreadis, S. J. 1999, "Observational Evidence for an Ionization-Dependent Baldwin Effect," in *Quasars and Cosmology*, eds. G. Ferland & J. Baldwin, ASP Conf. Series 162, 351
- Fairley, B. W., Jones, L. R., Scharf, C. A., Ebeling, H., Perlman, E., Horner D., Wegner, G., Malkan, M. 1999, "The WARPS survey IV: the X-ray Luminosity-Temperature relation of high redshift galaxy clusters," *MNRAS*, submitted
- Fall, S. M. 1998, "Global Evolution of the Stellar and Interstellar Contents of Galaxies," in *The Hubble Deep Field* (ST ScI Symposium 11), eds. M. Livio, S. M. Fall, & P. Madau (Cambridge University Press), p. 163
- Fall, S. M. 1999, "Global Evolution of the Stars, Gas, Metals, and Dust in Galaxies," in *Cosmic Chemical Evolution* (IAU Symposium 187), eds. K. Nomoto & J. Truran (Kluwer), in press
- Falomo, R., Pesce, J., Scarpa, R., Treves, A. & Urry, C. M. 1999, "The HST Snapshot Imaging of BL Lacs," in *Proc. BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 389
- Fernandez, Y. R., A'Hearn, M. F., Lisse, C. M., Hoffmann, W. F., Dayal, A., Hanner, M. S., Ressler, M. E., Deutsch, L. K., Fazio, G. G., Hora, J.L., Meech, K. J., Bauer, J. M. 1998, "Survey of the Physical Properties of Cometary Nuclei: Progress Report," *IAU Colloquium #168*, ASP Conf. Series, Volume 145, ed. M. F. A'Hearn, in press
- Fernandez, Y. R., Wellnitz, D. D., Buie, M. W., Dunham, E. W., Millis, R. L., Nye, R. A., A'Hearn, M. F., Lisse, C. M., Golden, M. E., Person, M. J., Howell, R. R., Marcialis, R. L., Spitalre, J. N. 1999, "The Inner Coma and Nucleus of Comet Hale-Bopp: Results From a Stellar Occultation," *Icarus*, 140, 205
- Figer, D. F., *et al.* 1999, "K-band Spectroscopy within 0.3 arcseconds of Sgr A\*," *ApJL*, in preparation
- Figer, D. F., *et al.* 1999, "NIRSPEC Observations of the Galactic Center," in *Discoveries and Research Prospects from 8-10-Meter-Class Telescopes*, ed. A. Ardeberg (SPIE), in preparation
- Figer, D. F. 1999, "Super-star clusters in the Galactic Center as revealed by HST/NICMOS," in *Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies*, Proc. IAU Symposium No. 193, eds. K. A. van der Hucht, G. Koenigsberger & P. R. J. Eenens, (ASP), 459
- Figer, D. F., Kim, S. S., Morris, M., Serabyn, E., Rich, R. M., & McLean, I. S. 1999, "HST/NICMOS Observations of Massive Stellar Clusters Near the Galactic Center," *ApJ*, 525, in press
- Figer, D. F., McLean, I. S., & Morris, M. 1999, "Massive Stars in the Quintuplet Cluster," *ApJ*, 514, 202
- Figer, D. F., Morris, M., Geballe, T. R., Rich, R. M., McLean, I. S., Serabyn, E., Puetter, R., & Yahil, A. 1999, "High Resolution Infrared Imaging and Spectroscopy of the Pistol Nebula: Evidence for Ejection," *ApJ*, 525, in press
- Figer, D. F., Morris, M., Kim, S., & Serabyn, E. 1999, "HST/NICMOS Imaging of the Quintuplet and Arches Clusters," in *The Central Parsecs: Galactic Center Workshop '98*, ASP Conf. Series, Vol. 186, 329
- Figer, D. F., Najarro, F., Langer, N. 1999, "The Pistol Star and Massive Stars in the Galactic Center," in *Unsolved Problems in Stellar Evolution*, ed. M. Livio, Cambridge University Press, in press
- Fratzare, L., Urry, C. M. 1999, "Behind the Scenes, Behind the Screens," January STATUS (ST ScI), p. 15
- Fruchter, A. S., Pian, E., Thorsett, S. E., Bergeron, L. E.; González, R. A., Metzger, M., Goudfrooij, P., Sahu, K. C.; Ferguson, H. C., Livio, M., Mutchler, M., Petro, L., Frontera, F., Galama, T., Groot, P., Hook, R., Kouveliotou, C., Macchetto, D. F., van Paradijs, J., Palazzi, E., Pedersen, H., Sparks, W. B., Tavani, M., 1999, "The Fading Optical Counterpart of GRB 970228, 6 Months and 1 Year Later," *ApJ*, 516, 683
- Gardner, J. P., Baum, S. A., Brown, T. A., Carollo, C. M., Christensen, J., Dashevsky, I., Dickinson, M., Espey, B. R., Ferguson, H. C., Fruchter, A. S., Gonnella, A. M., Gonzalez-Lopezlira, R. A., Hook, R. N., Kaiser, M. E., Martin, C. L., Sahu, K. C., Savaglio, S., Smith, T. E., Teplitz, H. I., Williams, R. E., & Wilson, J. 1999, "The Hubble Deep Field South—STIS Imaging," *AJ*, submitted
- Geballe, T. R., Figer, D. F., & Najarro, F. 1999, "A Second

- Luminous Blue Variable Candidate in the Quintuplet Cluster,” *ApJ*, in preparation
- Gilbert, A. M., Graham, J. R., McLean, I. S., Becklin, E. E., Figer, D. F., Larkin, J., Levenson, N. A., Teplitz, H. I., & Wilcox, M. 1999, “Infrared Spectroscopy of a Massive Obscured Star Cluster in NGC 4038/4039 with NIR-SPEC,” in *SOFIA-Star Formation Workshop*, in press
- Gilliland, R. L., Goudfrooij, P., & Kimble, R. A., 1999, “Linearity and High Signal-to-Noise Performance of the STIS CCD,” *PASP*, 111, 1009
- Giommi, P., Massaro, E., Chiappetti, L., Ferrara, E. C., Ghisellini, G., Minhwang Jang, Maesano, M., Miller, H. R., Montagni, F., Nesci, R., Padovani, P., Perlman, E., Raiteri, C. M., Sclavi, S., Tagliaferri, G., Tosti, G., Villata, M., 1999, “Synchrotron and Inverse Compton Variability in the BL Lacertae object S5 0716+714,” *A&A*, in press
- Giommi, P., Menna, M. T., & Padovani, P., 1999, “The Sedentary Multi-Frequency Survey. I. Statistical Identification and Cosmological Properties of HBL BL Lac,” *MNRAS*, in press
- Giommi, P., Menna, M. T., Padovani, P., 1999, “The Sedentary Multi-Frequency Survey,” in *BL Lac Phenomenon*, ASP Conf. Series, Vol. 159, p. 517
- Giommi, P., Padovani, P., & Perlman, E., 1999, “Detection of Exceptional X-ray Spectral Variability in the TeV BL Lac 1ES 2344+514,” *MNRAS*, in press
- Godon, P. & Livio, M. 1999a, “On the Hydrodynamic Stability of Thin Keplerian Disks,” *ApJ*, 521, 319
- Godon, P. & Livio, M. 1999b, “Vortices in Protoplanetary Disks,” *ApJ*, 523, 350
- Godon, P. & Livio, M., 2000, “The Formation and Role of Vortices in Protoplanetary Disks,” *ApJ*, submitted
- Gonzalez Delgado, R. M. & Leitherer, C. 1999, “Synthetic Spectra of H Balmer and He I Absorption Lines. I. Stellar Library,” *ApJS*, in press
- Gonzalez Delgado, R. M., Garcia-Vargas, M. L., Goldader, J., Leitherer, C., & Pasquali, A. 1999, “Multiwavelength Study of the Starburst Galaxy NGC 7714: I. Ultraviolet-Optical Spectroscopy,” *ApJ*, 513, 707
- Gonzalez Delgado, R. M., Leitherer, C., & Heckman, T. M. 1999, “Synthetic Spectra of H Balmer and He I Absorption Lines. II. Evolutionary Synthesis Models for Starburst and Post-Starburst Galaxies,” *ApJS*, in press
- Gordon, S. M., Kirshner, R. P., Long, K. S., Blair, W. P., Duric, N., & Smith, R. C. 1998, “A New Optical Sample of Supernova Remnants in M33,” *ApJS*, 117, 89
- Goudfrooij, P. & Trinchieri, G., 1998, “The Nature of the Dusty Ionized Gas in NGC 5846,” in *IAU Symposium No. 186, Galaxy Interactions at Low and High Redshift*, eds. D. B. Sanders & J. Barnes (Kluwer), p. 199
- Goudfrooij, P. 1999, “The Nature of Ionized Gas in Giant Elliptical Galaxies,” in *Star Formation in Early-Type Galaxies*, eds. P. Carral & J. Cepa, ASP Conf. Series No. 63, (ASP), p. 55
- Goudfrooij, P., Alonso, M. V., & Minniti, D., 1998, “The Globular Cluster System of NGC 1399,” in *IAU Symposium No. 186, Galaxy Interactions at Low and High Redshift*, eds. D. B. Sanders & J. Barnes (Kluwer), p. 198
- Goudfrooij, P., Jablonka, P., & Gorgas, J. 1998, “Bulges of Spiral Galaxies: The Radial Distribution of their Stellar Population,” *BAAS*, 193, in press
- Goudfrooij, P., Jablonka, P., & Gorgas, J. 1999, “Line Strengths and Line Strength Gradients of Bulges along the Hubble Sequence,” in *Galaxy Morphology in the new Millennium*, eds. D. L. Block, I. Puerari, A. Stockton & D. Ferreira (Kluwer), in press (astro-ph/9910020)
- Govoni, F., Falomo, R., Fasano, G., & Scarpa, R. 1999, “Optical Surface Photometry of Radio Galaxies: II.—Observations and Data Analysis,” *A&A*, in press
- Govoni, F., Falomo, R., Fasano, G., & Scarpa, R. 1999, “The Optical Properties of Low Redshift Radio Galaxies” *A&A*, in press
- Grandi, P., Guainazzi, M., Cimatti, A., Giommi, P., Maraschi, L., Massaro, E., Matt, G., Padovani, P., C. G. Perola, L. Piro, D. Ricci, & Urry, C. M. 1999, “BeppoSAX Observations of the Radio Galaxy Centaurus A,” *COSPAR Meeting on Broad Band X-Ray Spectra of Cosmic Sources*, in press
- Grandi, P., Guainazzi, M., Haardt, F., Maraschi, L., Massaro, E., Matt, G., Piro, L., & Urry, C. M. 1999, “Reprocessing and Variable Cold Absorption in the Broad-Line Radio Galaxy 3C 390.3,” *A&A*, 343, 33
- Grandi, P., Haardt, F., Ghisellini, G., Grove, E. J., Maraschi, L., & Urry, C. M. 1998, “High Energy Break and Reflection Features in the Seyfert Galaxy MCG+8-11-11,” *ApJ*, 498, 220
- Grandi, P., Maraschi, L., Guainazzi, M., Haardt, F., Matt, G., Massaro, E., Urry, C. M., Bassani, L., & Giommi, P. 1999, “Bright Radio Galaxies with BeppoSAX,” in *The Extreme Universe (3rd INTEGRAL Workshop)*, in press (astro-ph/9811468)
- Greeley, B. W., Blair, W. P., Long, K. S., & Raymond, J. C. 1999, “Rapid Variability in the FUV Spectrum of AM Her, in ASP Conf. Ser. 157 Annapolis Workshop on Magnetic Cataclysmic Variables, ed. by C. Hellier & K. Mukai, 169
- Greeley, B. W., Blair, W. P., Long, K. S., & Raymond, J. C. 1999, “The Far-Ultraviolet Spectrum and Short-Timescale Variability of AM Herculis from Observations with the Hopkins Ultraviolet Telescope,” *ApJ*, 513, 491
- Grimes, J. P., Kriss, G. A., & Espey, B. R. 1999, “Spatially Resolved Hopkins Ultraviolet Telescope Spectra of NGC 1068,” *ApJ*, in press
- Gruen, E., (and 22 authors, including C. M. Lisse), 1999, “ISOPHOT Observations of Comet Hale-Bopp: Initial Data Reduction,” *Proceedings of the ISO Conference, The Universe as seen by ISO*, ESA SP-427, 181
- Haardt, F., Fossati, G., Grandi, P., Celotti, A., Pian, E., Ghisellini, G., Malizia, A., Maraschi, L., Paciesas, W., Raiteri, C. M., Tagliaferri, G., Treves, A., Urry, C. M., Villata, M., & Wagner, S. 1998, “The Hidden X-Ray Seyfert Nucleus in 3C 273: BeppoSAX Results,” *A&A*, in press (astro-ph/9806229)
- Hansen, L., Jørgensen, H. E., Nørgaard-Nielsen, H. U., Pedersen, K., Goudfrooij, P., Linden-Vørnle, M. J. D., 1999, “ISO far-infrared observations of rich galaxy clusters. I. Abell 2670,” *A&A*, 349, 406
- Hauser, M. G., Arendt, R. G., Kelsall, T., Dwek, E., Ode-

- gard, N., Weiland, J. L., Freudenreich, H. T., Reach, W. T., Silverberg, R. F., Moseley, S. H., Pei, Y. C., Lubin, P., Mather, J. C., Shafer, R. A., Smoot, G. F., Weiss, R., Wilkinson, D. T., & Wright, E. L. 1998, "The COBE Diffuse Infrared Background Experiment Search for the Cosmic Infrared Background. I. Limits and Detections," *ApJ*, 508, 25
- Horner, D. J., Mushotzky, R. F., & Scharf, C. A. 1999, "Observational Tests of the Mass-Temperature Relation for Galaxy Clusters," *ApJ*, 520, 78
- Howell, S. B., Ciardi, D. R., Szkody, P., Van Paradijs, J., Kuulkers, E., Cash, J., Sirk, M., & Long, K. S. 1999, "Multiwavelength Superoutburst Observations of T Leonis," *PASP*, 111, 342
- Imhoff, C., Abney, F., Christian, D., Donahue, M., Hanisch, R., Kimball, T., Levay, K., Padovani, P., Postman, M., Smith, M., & Thompson, R., "Resources Available through the Multimission Archive at Space Telescope (MAST)," 1999, *BAAS*, 194, 8302
- Irwin, J. A., Saikia, D. J., & English, J. 1999 "High Resolution Radio Continuum Observations of Edge-On Spiral Galaxies," *AJ*, submitted
- Irwin, J. A., English, J., & Sorathia, B. 1999 "High-latitude radio emission in a sample of edge-on spiral galaxies," *AJ*, 117, 2102
- Irwin, J. A., Widrow, L. M., & English, J. 1999 "Constraints on cold H I in the halo of NGC 3079 from absorption measurements of QSO0957+561," *Publications of the Astronomical Society of Australia*, 16, 89
- Irwin, J. A., Widrow, L. M., & English, J. 1999, "An Observational Test of Dark Matter as Cold Fractal Clouds," *ApJ*, in press
- Johnson, K. E., Vacca, W. D., Leitherer, C., Conti, P. S., & Lipsy, S. J. 1999, "The Very Young Starburst Merger System NGC 1741," *AJ*, 117, 1708
- Jones, B. F., Fischer, D., & Soderblom, D. R. 1999, "The Evolution of the Lithium Abundances of Solar-Type Stars. VIII. M67 (NGC 2682)," *AJ*, 117, 330
- Joy, M., Carlstrom, J. E., Reese, E. D., Holder, G. P., Mohr, J., Patel, S. K., Grego, L., Holzapfel, W. L., Donahue, M., Hughes, J. P., Neumann, D. 1999, "Distance Estimates for High Redshift Clusters from SZ and X-ray Measurements," *BAAS*, 194, 5806.
- Kantharia, N. G., Anantharamaiah, K. R., & Payne, H. E. 1998 "Carbon Recombination Lines Between 34.5 and 770 MHz Toward Cassiopeia A," *ApJ*, 506, 758
- Kataoka, J., Takahashi, T., Makino, F., Inoue, S., Madejski, G. M., Tashiro, M., Urry, C. M., & Kubo, H. 1999, "Variability Pattern and the Spectral Evolution of the BL Lacertae Object PKS 2155-304," *ApJ*, 528, in press (astro-ph/9908090)
- Keenan, F. P., Espey, B. R., Aggarwal, K. M., Crawford, F. L., Feibelman, W. A., & McKenna, F. C. 1999, "[AlII] in the Ultraviolet Spectrum of the Symbiotic Star RR Telescopii," *MNRAS*, in press
- Kelsall, T., Weiland, J. L., Franz, B. A., Reach, W. T., Arendt, R. G., Dwek, E., Freudenreich, H. T., Hauser, M. G., Moseley, S. H., Odegard, N. P., Silverberg, R. F., & Wright, E. L. 1998, "The COBE Diffuse Infrared Background Experiment Search for the Cosmic Infrared Background. II. Model of the Interplanetary Dust Cloud," *ApJ*, 508, 44
- Kim, S. S., Morris, M., & Figer, D. F. 1999, "N-body Simulations and the Eventual Fate of the Arches and Quintuplet clusters," *ApJ*, in preparation
- King, J. R., Soderblom, D. R., Fischer, D., & Jones, B. F. 1999, "Spectroscopic Abundances in Cool Pleiades Dwarfs and NGC 2264," *ApJ*, submitted
- Kinney, A. L., Schmitt, H. R., Clarke, C. J., Pringle, J. E., Ulvestad, J. S., & Antonucci, R. R. J. 2000, "Jet Directions in Seyfert Galaxies," *ApJ*, submitted
- Kissler-Patig, M., Grillmair, C. J., Meylan, G., Brodie, J. P., Minniti, D., Goudfrooij, P., 1999, "Toward an Understanding of the Globular Cluster Overabundance around the Central Giant Elliptical Galaxy NGC 1399," *AJ*, 177, 1206
- Knapp, G. R., Binette, L., Bower, R. G., Brinks, E., Goudfrooij, P., Hau, G. K. T., Pogge, R. W., Young, L. M. 1999, "Panel Discussion: Star Formation in Early-Type Galaxies," in *Star Formation in Early-Type Galaxies*, eds. P. Carral & J. Cepa, ASP Conf. Series No. 63, (ASP), p. 142
- Knigge, C., Drake, N., Long, K. S., Horne, K., Wade, R. A., & Baptista, R., 1998 "Recovering 29-s Oscillations in HST Eclipse Observations of UX UMA," in *AIP Conf. Proc. 431 Accretion Process in Astrophysical Systems: Some Like It Hot*, eds. S. S. Holt & T. Kallman, p. 463
- Knigge, C., Drake, N., Long, K. S., Wade, R. A., Horne, K., & Baptista, R. 1998, "Recovery of 29 Second Oscillations in Hubble Space Telescope Eclipse Observations of the Cataclysmic Variable UX Ursae Majoris," *ApJ*, 499, 429
- Knigge, C., Long, K. S., Wade, R. A., Baptista, R., Horne, K., Hubeny, I., & Rutten, R. G. M. 1998, "Hubble Space Telescope Eclipse Observations of the Nova-like Cataclysmic Variable UX Ursae Majoris," *ApJ*, 499, 414
- Koekemoer, A. M., O'Dea, C. P., Baum, S. A., Sarazin, C. L., Owen, F. N., & Ledlow, M. J., 1998, "A Study of UV Absorption in the Intra-Cluster Medium of Abell 1030," *ApJ*, 508, 608
- Koekemoer, A. M., O'Dea, C. P., Sarazin, C. L., McNamara, B. R., Donahue, M., Voit, G. M., Baum, S. A., & Gallimore, J. F. 1999, "Resolving the Extended Blue Continuum and Line Emission around the Central Radio Galaxy in the Cooling-Flow Cluster Abell 2597," *ApJ*, in press
- Koratkar, A., Pesce, J. E., Urry, C. M., & Pian, E. 1998, "Monitoring Ly $\alpha$  Emission from the Blazar 3C 279," *ApJ*, 492, 173
- Kruk, J. W., Brown, T. M., Davidsen, A. F., Espey, B. R., Finley, D. S., & Kriss, G. A. 1999, "Final Astro-2 Calibration of the Hopkins Ultraviolet Telescope," *ApJS*, 122, 299
- Lang, C. C., Figer, D. F., Goss, W. M., & Morris, M. 1999, "Radio Detections of Stellar Winds from the Pistol Star and from other Stars in the Galactic Center Quintuplet Cluster," *AJ*, in press
- Lara, L., Feretti, L., Giovannini, G., Baum, S., Cotton, W.

- D., O’Dea, C. P., & Venturi, T. 1999, “The Radio-Optical Jet in NGC 3862 from Parsec to Sub-Kpc Scales,” *ApJ*, 513, 197
- Larkin, *et al.* 1999, “Discovery of an Obscured Broad Line Region in the High Redshift Radio Galaxy MRC 2025–218,” *ApJL*, in preparation
- Larkin, J. E., McLean, I. S., Graham, J. R., Becklin, E. E., Figer, D. F., Gilbert, A. M., Glassman, T. M., Levenson, N. A., Teplitz, H., & Wilcox, M. K. 1999, “Infrared Spectroscopy of the High Redshift Radio Galaxy MRC 2025–218 and a Neighboring Extremely Red Galaxy,” in proceedings of *The Hy-Redshift Universe: Galaxy Formation and Evolution at High Redshift*, eds. A. J. Bunker & W. J. M. van Breugel, submitted
- Leckrone, D. S., Proffitt, C. R., Wahlgren, G. M., Johansson, S. G., & Brage, T. 1999, “Very High Resolution UV Spectroscopy of a Chemically Peculiar Star: Results of the  $\chi$  Lupi Pathfinder Project,” *AJ*, 117, 1454
- Leitherer, C. 1998, “The Initial Mass Function in Starburst Galaxies,” in 38th Herstmonceux Conference, *The Stellar Initial Mass Function*, eds. G. Gilmore & D. Howell (ASP), p. 61
- Leitherer, C. 1999, “Synthesis Models for Starburst Populations with Wolf-Rayet Stars,” in IAU Symp. 193, *Wolf-Rayet Phenomena in Stars and Starburst Galaxies*, eds. P. Eenens, G. Koenigsberger, & K. A. van Hucht (ASP), p. 526
- Leitherer, C. 1999, “The Initial Mass Function in Starburst Galaxies,” in IAU Symp. 186 *Interacting Galaxies at Low and High Redshift*, eds. J. E. Barnes & D. B. Sanders (ASP), p. 243
- Leitherer, C. 2000, “Age-Dating of Young Stars and Stellar Systems,” in *Spectrophotometric Dating of Stars and Galaxies*, eds. I. Hubeny, S. Heap, R. Cornett (ASP), in press
- Leitherer, C. 2000, “Photon and Metal Production in Starburst Galaxies,” in *Building the Galaxies: From the Primordial Universe to the Present*, eds. F. Hammer, T. X. Thuan, V. Cayatte, B. Guiderdoni, & J. T. T. Van (Editions Frontieres), in press
- Leitherer, C. 2000, “The Chemical Composition of Star-Forming Galaxies at High Redshift,” in *Chemical Evolution from Zero to High Redshift*, eds. J. Walsh & M. Rosa (Springer), in press
- Leitherer, C. 2000, “The Initial Mass Function in Local Dwarf Galaxies,” in *Dwarf Galaxies and Cosmology*, eds. T. X. Thuan, C. Balkowski, V. Cayatte, & J. T. T. Van (Editions Frontieres), in press
- Leitherer, C., Schaerer, D., Goldader, J. D., González-Delgado, R. M., Robert, C., Foo Kune, D., de Mello, D. F., Devost, D., & Heckman, T. M. 1999, “Starburst99: Synthesis Models for Galaxies with Active Star Formation,” *ApJS*, 123, 3
- Lépine, S. & Moffat, A. F. J. 1999, “Inhomogeneous Winds: The Nature of Emission-Line Profile Variations in Wolf-Rayet Spectra,” in Proceedings of the IAU symposium #193, *Wolf-Rayet Stars Phenomena in Massive Stars and Starburst Galaxies*, eds. K. A. van der Hucht, G. Koenigsberger, & P. R. J. Eenens, p. 250
- Lépine, S. & Moffat, A. F. J. 1999, “Wind Inhomogeneities in Wolf-Rayet Stars. II. Investigation of Emission-Line Profile Variations” *ApJ*, 514, 909
- Lépine, S., Eversberg, T., & Moffat, A. F. J. 1999, “Wind Inhomogeneities in Wolf-Rayet Stars. III. Unusual Emission-Line Profile Variations in  $\gamma^2$  Velorum,” *AJ*, 117, 1441
- Lépine, S., Shara, M. M., Livio, M., & Zurek, D. 1999, “First Direct Measurement of Acceleration in the Outflow of a Nova: U Scorpii (1999),” *ApJL*, 522, 121
- Levine, D., Morris, M., & Figer, D. F. 1999, “Blowing a Carbon-rich Bubble in the Galactic Center Medium around the Quintuplet Cluster,” in *The Universe as seen by ISO*, eds. P. Cox & M. F. Kessler, (ESA-SP 427), in press
- Ligori, S., Robberto, M., & Herbst, T. M. 1999, “Mid-IR Images of W51,” in *Star Formation 1999*, in press
- Lisse, C. M., A’Hearn, M. F., Dayal, A., Deutsch, L. K., Fazio, G. G., Fernandez, Y. R., Hora, J. L., Kundu, A., & Hoffmann, W. F., 1999, “The Nucleus of Comet C/1996 B2 (Hyakutake),” *Icarus*, 140, 1, 189
- Lisse, C. M., Bingham, B., Dennerl, K., Englhauser, J., Kellett, B., Marshall, F. E., Petre, R., Truemper, J., & Valita, A., 1999, “X-Ray Emission From Comet Hale-Bopp,” *Earth, Moon, and Planets*, 77, 3, 283
- Lisse, C. M., Christian, D., Dennerl, K., Desch, M., Englhauser, J., Marshall, F. E., Petre, R., Snowden, S., & Truemper, J., 1999, “X-ray and Extreme Ultraviolet Emission from Comet 2P/Encke 1997,” *Icarus*, 141, 2, 316
- Lisse, C. M., Fernandez, Y. R., A’Hearn, M. F., Kostiuik, T., Livengood, T. A., Kaufl, H. U., Hoffmann, W. F., Dayal, A., Ressler, M. E., Hanner, M. S., Fazio, G. G., Hora, J. L., Peschke, S., Grun, E., & Deutsch, L. K. 1999, “Infrared Observations of the Dust Emitted By Comet Hale-Bopp,” *Earth, Moon, and Planets*, in press
- Livio, M., Ogilvie, G. ., & Pringle, J. 1999, “Extracting Energy from Black Holes,” *ApJ*, 512, 100
- Livio, M. 1999 “How Rare Are Extraterrestrial Civilizations?” *ApJ*, 511, 429
- Livio, M. & Stiavelli, M., 1999, “Does the Fine Structure Constant Really Vary in Time?” *ApJL*, 507, 13
- Livio, M. 1999, “The Accelerating Universe,” (John Wiley & Sons), in press
- Long, K. S. & Gilliland, R. L., 1999, “GHRs Observations of the White Dwarf in U Geminorum,” *ApJ*, 511, 916
- Long, K. S. & Knigge, C. 1998 “Modeling the Spectral Signatures of Accretion Disk Winds in Cataclysmic Variables,” in AIP Conf. Proc. 431, *Accretion Process in Astrophysical Systems: Some Like It Hot*, eds. S. S. Holt & T. Kallman, p. 467
- Lubow, S. H. & Artymowicz, P. 1999, “Interactions of Young Binaries with Disks,” in *Protostars and Planets IV*, eds. V. Mannings, A. P. Boss & S. S. Russell (University of Arizona Press), in press
- Lubow, S. H. & Ogilvie, G. I. 1999, “On the tilting of protostellar disks by tidal resonance effects,” *ApJ*, submitted
- Lubow, S. H., Seibert, M., & Artymowicz, P. 1999, “Disk accretion onto high mass planets,” *ApJ*, in press

- Lucas, R. A., Bushouse, H., Colina, L., & Borne, K. D., 1999, "The Archival Study of Tidal Tails in NGST Observations," *BAAS*, 194, 91.03
- Lucas, R. A., Baum, S. A., Brown, T. M., Casertano, S., De Mello, D., Dickinson, M., Ferguson, H. C., Fruchter, A. S., Gardner, J. P., Gilmore, D., Gonzalez-Lopezlira, R., Heyer, I., Hook, R. N., Kaiser, M. E., Mack, J., Makidon, R., Martin, C. L., Mutchler, M., Smith, T. E., Stiavelli, M., Teplitz, H. I., Wiggs, M. S., Williams, R. E., Zurek, D., 1999, "The Hubble Deep Field South Flanking Fields," *AJ*, in preparation.
- Lucas, R. A., Baum, S. A., Casertano, S., De Mello, D., Dickinson, M., Ferguson, H. C., Fruchter, A. S., Gonzalez-Lopezlira, R., Heyer, I., Mack, J., Makidon, R., Martin, C. L., Mutchler, M., Smith, T. E., Stiavelli, M., Teplitz, H. I., Wiggs, M. S., Williams, R. E., Zurek, D., Brown, T. M., Gardner, J. P., Kaiser, M. E., & Hook, R. N., 1998, "The Hubble Deep Field South: Flanking Fields," *BAAS*, 193, 75.06
- Luridiana, L., Peimbert, M., & Leitherer, C. 1999, "Photoionization Models of NGC 2363 and Their Implications for the Ionizing Star Cluster," *ApJ*, in press
- Mantegazza, L., Poretti, E., Pian, E., Scarpa, R., O'Dowd, M., Treves, A., Zhang, Y. H., Paltani, S., Courvoisier, T. J.-L., Urry, C. M., Celotti, A., Ghisellini, G., & Gialisco, M. 1999, "Fast Optical Photometry of the BL Lac Object PKS 2155-304," in *Proc. BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 137
- Maraschi, L., Fossati, G., Tavecchio, F., Chiappetti, L., Celotti, A., Ghisellini, G., Grandi, P., Pian, E., Tagliaferri, G., Treves, A., Zhang, Y., Weekes, T. C., Breslin, A. C., Buckley, J. H., Carter-Lewis, D. A., Catanese, M., Cawley, M. F., Fegan, D. J., Fegan, S., Finley, J., Gaidos, J., Hall, T., Hillas, A. M., Krennrich, F., Lessard, R. W., Masterson, C., Moriarty, P., Quinn, J., Rose, J., Samuelson, F., Urry, C. M., & Takahashi, T. 1999, "Correlated Variability of Mkn 421 at X-ray and TeV Wavelengths on Timescales of Hours," *ApJ*, in press
- van der Marel, R. P. 1999, "Active Galaxies," in *Astronomy at the Cutting Edge* (American Museum of Natural History), in press
- van der Marel, R. P. 1999, "Black holes and central surface brightness cusps," in *Galaxy Dynamics*, eds. D. Merritt, J. Sellwood, & M. Valluri, ASP Conf. Series, p. 65
- van der Marel, R. P. 1999, "Research on black holes," in *Space Telescope Science Institute Annual Report over 1998*, p. 17
- van der Marel, R. P. 1999, "The black hole mass distribution in early-type galaxies: cusps in HST photometry interpreted through adiabatic black hole growth," *AJ*, 117, 744
- van der Marel, R. P. & van den Bosch, F. 1998, "Evidence for a  $3 \times 10^8$  solar mass black hole in NGC 7052 from HST observations of the nuclear gas disk," *AJ*, 116, 2220
- Mason, B. D., Henry, T. J., Hartkopf, W. I., Brummelaar, T., & Soderblom, D. R. 1998, "A Multiplicity Survey of Chromospherically Active and Inactive Stars," *AJ*, 116, 2975
- de Mello, D. F., Leitherer, C., & Heckman, T. M. 2000, "B Stars as a Diagnostic of Star Formation at Low and High Redshift," *ApJ*, in press
- de Mello, D., Schaerer, D., Heldmann, J., & Leitherer, C. 1998, "Searching for WR Stars in I Zw 18—the Origin of He II Emission," *ApJ*, 507, 199
- McCarthy, P. J., Yan, L., Freudling, W., Teplitz, H. I., Malumuth, E. M., Weymann, R. J., Malkan, M. A., Fosbury, R. A. E., Gardner, J. P., Storrie-Lombardi, L. J., Thompson, R. I., Williams, R. E., & Heap, S. R. 1999, "Emission-Line Galaxies from the NICMOS/Hubble Space Telescope Grism Parallel Survey," *ApJ*, 520, 548
- McLean, *et al.* 1999, "New J-band Infrared Spectroscopy of a Sample of Brown Dwarfs Using NIRSPEC on Keck II," *ApJL*, in preparation
- McLure, R. J., Dunlop, J. S., Kukula, M. J., Baum, S. A., O'Dea, C. P., & Hughes, D. H. 1999, "A Comparative HST Imaging Study of the Host Galaxies of Radio-Quiet Quasars, Radio-Loud Quasars and Radio Galaxies: Paper I," *MNRAS*, 308, 377
- Moneti, A., Blommaert, J., Najarro, F., Figer, D. F., & Stolovy, S. 1999, "Spectroscopy of the Pistol and Quintuplet Stars in the Galactic Centre," in *The Universe as seen by ISO*, eds. P. Cox & M. F. Kessler (ESA-SP 427), p. 723
- Moran, C., Maxted, P., Marsh, T., Saffer, R., & Livio, M. 1999 "The Orbital Parameters of Three New Subdwarf B Binaries," *MNRAS*, 304, 535.
- Najarro, F., Hillier, D. J., & Figer, D. F. 1999, "Metal Abundances in the Galactic Center," in *Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies*, Proc. IAU Symposium No. 193, eds. K. A. van der Hucht, G. Koenigsberger & P. R. J. Eenens, (ASP), p. 491
- Najarro, F., Hillier, D. J., Figer, D. F., & Geballe, T. R. 1999, "Theoretical Modelling of Hot Stars," in proceedings of *The Central Parsecs: Galactic Center Workshop '98*, ASP Conf. Series, 186, p. 340
- Natta, A., Meyer, M. R., & Beckwith, S. V. W. 2000, "Silicate Emission in T Tauri Stars: Evidence for Disk Atmospheres?" *ApJ*, in press
- O'Brien, P. T., Dietrich, M., Leighly, K., Alloin, D., Clavel, J., Crenshaw, D. M., Horne, K., Kriss, G. A., *et al.* 1998, "Steps toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. XIII. Ultraviolet Observations of the Broad-Line Radio Galaxy 3C 390.3," *ApJ*, 509, 163
- O'Dea, C. P., De Vries, W., Biretta, J. A., & Baum, S. A. 1999, "HST and VLA Observations of Two Optical Continuum Knots in the Jet in 3C380," *AJ*, 117, 1143
- O'Dowd, M., Urry, C. M., Scarpa, R., & Pesce, J. E. 1998, "Finding AGN Host Galaxies with HST, and the Joint Analysis with Ground Based Images," *BAAS*, 29, 1373 (191, 103.08)
- Odehwan, S. C., Djorgovski, S. G., Kulkarni, S. R., Dickinson, M., Frail, D. A., Ramaprakash, A. N., Bloom, J. S., Adelberger, K. L., Halpern, J., Helfand, D. J., Bahcall, J., Goodrich, R., Frontera, F., Feroci, M., Piro, L., & Costa, E. 1998, "The Host Galaxy of the Gamma-Ray Burst 971214," *ApJL*, 509, 5
- Oey, M. S., Dopita, M. A., Shields, J. C., & Smith, R. C.

- 1999, "Calibration of Nebular Emission-line Diagnostics: I. Stellar Effective Temperatures," ApJ, in preparation
- Oey, M. S. 1999, "The Influence of Massive Stars on the Interstellar Medium," in *Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies*, IAU Symp. 193, eds. K. A. van der Hucht, G. Koenigsberger, & P. R. J. Eensens, (ASP), p. 627
- Oey, M. S. 1999, "Superbubbles in the Magellanic Clouds," in *New Views of the Magellanic Clouds*, IAU Symp. 190, eds. Y.-H. Chu, N. Suntzeff, J. Hesser, & D. Bohlender, (ASP), in press
- Ogilvie, G. I. & Lubow, S. H. 1998, "The Effect of an Isothermal Atmosphere on the Propagation of Three-Dimensional Waves in a Thermally Stratified Disk," ApJ, 515, 767
- Origlia, L. & Leitherer, C. 2000, "Transformations between the Theoretical and Observational Planes in the HST-NICMOS and WFPC2 Photometric Systems," AJ, submitted
- Origlia, L., Goldader, J. D., Leitherer, C., Schaerer, D., & Oliva, E. 1999, "Evolutionary Synthesis Modeling of Red Supergiant Absorption Features in H and K Band Spectra of Starbursts," ApJ, 514, 96
- Outram, P. J., Boyle, B. J., Carswell, R. F., Hewett, P. C., & Williams, R. E. 1999, "Echelle Spectrograph Observations of the Hubble Deep Field South QSO J2233-606," MNRAS, 305, 685
- Padovani, P., Perlman, E., Giommi, P., Sambruna, R., Jones, L., Tzioumis, A., & Reynolds, J. 1998, "The Deep X-ray Radio Blazar Survey," in *Looking Deep in the Southern Sky*, eds. R. Morganti & W. Couch, (Springer-Verlag), p. 187
- Padovani, P. 1999, "The Two Classes of BL Lacs and Unified Schemes," in *BL Lac Phenomenon*, ASP Conf. Series, Vol. 159, p. 339
- Padovani, P., Giommi, P., Comastri, A., Wolter, A., Ghisellini, G., Maccacaro, T., Maraschi, L., Tagliaferri, G., Mantovani, F., Stanghellini, C., & Urry, C. M. 1999, "BeppoSAX Observations of 1 Jy BL Lacs," in *BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 188
- Padovani, P., Morganti, R., Siebert, J., Vagnetti, F., & Ciomatti, A. 1998, "BeppoSAX Observations of 2 Jy Lobe-dominated Broad-line Sources. I. The Discovery of a Hard X-ray Component," MNRAS, 304, 829
- Padovani, P., Perlman, E., Giommi, P., & Sambruna, R. 1998, "New Constraints on the Spectral Energy Distribution of Blazars from the Deep X-ray Radio Blazar Survey (DXRBS)," BAAS, 193.107.16
- Papovich, C., Dickinson, M., Ferguson, H. C., Fruchter, A. S., Hanley, C., Lucas, R. A., Mack, J., Madau, P., Postman, M., Connolly, A., Szalay, A., Bershady, M. A., Conselice, C., Eisenhardt, P., Elston, R. J., Giavalisco, M., Hook, R. N., Stanford, S. A., & Steidel, C. C. 1998, "Galaxy Photometry in the HDF-North from Combined NICMOS, WFPC2, and Ground-based data," BAAS, 193, 75.13
- Papovich, C., Dickinson, M., Hanley, C., & the NICMOS HDF-N GO Team, 1999, "Near-Infrared Properties of Galaxies in the HDF-N," in *The Hy-Redshift Universe: Galaxy Formation and Evolution at High Redshift*, eds. A. Bunker & W. van Breugel, (ASP), in press
- Pei, Y. C., Fall, S. M., & Hauser, M. G. 1999, "Cosmic Histories of Stars, Gas, Heavy Elements, and Dust in Galaxies," ApJ, 522, 604
- Pesce, J. E., Urry, C. M., O'Dowd, M., Scarpa, R., Falomo, R., Treves, A. 1999, "HST Observations of BL Lacertae Environments," in *Life Cycles of Radio Galaxies*, New Astronomy Reviews, in press (astro-ph/9908344)
- Peschke, S. B., Gruen, E., Bohnhardt, H., Campins, H., Osip, D. J., Hanner, M. S., Heinrichsen, I., Knacke, R., Leinert, Ch., Lemke, D., Lisse, C. M., Syckel, M., Sykes, M., Vanysek, V., & Zarnecki, J. 1999, "ISOPHOT Observations of Comet Hale-Bopp," Earth, Moon, and Planets, in press
- Peschke, S. B., Stickel, M., Heinrichsen, I., Lisse, C. M., Gruen, E. & Osip, D. J. 1999, "First Maps of Comet Hale-Bopp in the Far-Infrared, in Relation to Radial Profiles at Other Wavelengths," in the Proceedings of the ISO Conference *The Universe As Seen by ISO*, ESA SP-427, 185
- Petr, M. G., Beckwith, S. V. W., Coudé di Foresto, V., Richichi, A., McCaughrean, M. J., & Zinnecker, H. 2000, "Pre-main sequence binaries in the Trapezium Cluster," in *The Orion Complex Revisited*, ed. M. J. McCaughrean, ASP Conf. Series
- Pettini, M., Kellogg, M., Steidel, C. C., Dickinson, M., Adelberger, K. L., & Giavalisco, M. 1998, "Infrared Observations of Nebular Emission Lines from Galaxies at  $z \approx 3$ ," ApJ, 508, 539
- Pettini, M., Steidel, C. C., Adelberger, K. L., Dickinson, M., & Giavalisco, M. 1999, "The Ultraviolet Spectrum of MS1512-cB58: An Insight into Lyman Break Galaxies," ApJ, in press
- Pian, E., Chiappetti, L., Giommi, P., Maraschi, L., Palazzi, E., Aharonian, F., Catanese, M., Celotti, A., Degrange, B., Djannati-Atai, A., Fossati, G., Ghisellini, G., Krawczynski, H., Raiteri, C. M., Sambruna, R. M., Smith, D., Tagliaferri, G., Tavecchio, F., Tosti, G., Treves, A., Urry, C. M., & Villata, M. 1999, "BeppoSAX Observations of Markarian 501 in June 1999," in *Proc. X-Ray Astronomy '99: Stellar Endpoints, AGN and the Diffuse X-Ray Background*, in press
- Pian, E., Koratkar, A., Maraschi, L., Urry, C. M., Madejski, G., McHardy, I. M., Pesce, J. E., Treves, A., Grandi, P., & Leach, C. M. 1999, "Ultraviolet Isotropic Emission from the Blazar 3C 279," in *Ultraviolet Astrophysics Beyond the IUE Final Archive*, ed. R. Harris (ESA-SP-413), in press (astro-ph/9805005)
- Pian, E., Palazzi, E., Chiappetti, L., Maraschi, L., Tavecchio, F., Ghisellini, G., Tagliaferri, G., Fossati, G., Treves, A., Urry, C. M., & Vacanti, G. 1999, "BeppoSAX Observations of the BL Lac Object Mkn 501 in an Intermediate State," in *BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 180
- Pian, E., Urry, C. M., Maraschi, L., Madejski, G., McHardy, I. M., Koratkar, A., Treves, A., Chiappetti, L., Grandi, P., Hartman, R. C., Kubo, H., Leach, C. M., Pesce, J. E.,

- Imhoff, C., Thompson, R., & Wehrle, A. E. 1999, "Ultraviolet and Multiwavelength Variability of the Blazar 3C 279: Evidence for Thermal Emission," *ApJ*, 521, 112
- 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. 1998, "BeppoSAX Observations of Unprecedented Synchrotron Activity in the BL Lac Object Mkn 501," *ApJL*, 492, 17
- Pringle, J. E., Antonucci, R. R. J., Clarke, C. J., Kinney, A. L., Schmitt, H. R., & Ulvestad, J. S. 1999, "Direct Measurement of the Jet Geometry in Seyfert Galaxies," *ApJ*, 526, in press
- Proffitt, C. R., Brage, T., Leckrone, D. S., Brandt, J. C., Wahlgren, G. M., Sansonetti, C. J., Reader, J., & Johansson, S. G. 1999, "Mercury in the HgMn Stars  $\chi$  Lupi and HR 7775," *ApJ*, 512, 942
- Proffitt, C. R., Jönsson, P., Litzén, U., Pickering, J. C., & Wahlgren, G. M. 1999, "Goddard High-Resolution Spectrograph Observations of the B III Resonance Doublet in Early B Stars: Abundances and Isotope Ratios," *ApJ*, 516, 342
- Raymond, J. C., Blair, W. P., & Long, K. S. 1998, "Ultraviolet H<sub>2</sub> Emission from HH2," *Revista Mexicana de Astronomia y Astrofisica Conf. Ser.* 7, 7
- Reese, E., Mohr, J. J., Carlstrom, J. C., Joy, M., Grego, L., Holder, G. I., Holzappel, W. L., Hughes, J. P., Patel, S. K., & Donahue, M. 2000, "Sunyaev-Zel'dovich Effect—Derived Distance to the High Redshift Clusters MS 0451.6-0305 and CL 0016+16," *ApJ*, submitted
- Rich, R. M., Shara, M., Fall, S. M., & Zurek, D. 1999, "Two Groups of Nearly Coeval Star Clusters in the Small Magellanic Cloud," *AJ*, in press
- Robberto, M., Beckwith, S. V. W., & Herbst, T. M. 1999, "Circumstellar Disks in Orion: First Results from a Mid-IR survey," in *Star Formation 1999*, in press
- Robberto, M., Beckwith, S. V. W., Meyer, M. R., & Natta, A. 1999, "ISO-PHOT Observations of Circumstellar Disks around Young-Stellar-Objects," in *The Universe as seen by ISO*, eds. P. Cox & M. Kessler, ESA SP-427, p. 195
- Rubio, M., Barbá, R. H., Walborn, N. R., Probst, R. G., Garcia, J., & Roth, M. R. 1998, "Infrared Observations of Ongoing Star Formation in the 30 Doradus Nebula and a Comparison with Hubble Space Telescope WFPC2 Images," *AJ*, 116, 1708
- Salgado, J. F., Altschuler, D. R., Ghosh, T., Dennison, B. K., Mitchell, K. J., & Payne, H. E. 1999, "14-Year Program Monitoring the Flux Densities of 33 Radio Sources at Low Frequencies," *ApJS*, 120, 77
- Sambruna, R. M., Chou, L. L., Urry, C. M. 1999, "ASCA Observations of FSRQs with Steep Soft X-Ray Spectra: Testing the Blazar Paradigm," *ApJ*, submitted
- Sambruna, R. M., Ghisellini, G., Hooper, E., Kollgaard, R. I., Pesce, J. E., Urry, C. M. 1999, "ASCA & Contemporaneous Ground-Based Observations of the BL Lacertae Objects 1749+096 and 2200+420 (BL Lac)," *ApJ*, 515, 140
- Sambruna, R. M., Urry, C. M., Chou, L., Aharonian, F. A., Krawczynski, H. 1999, "High-Energy Monitoring of Mrk 501," in *Proc. X-Ray Astronomy '99: Stellar Endpoints, AGN and the Diffuse X-Ray Background*, in press
- Sarazin, C. L., Koekemoer, A. M., Baum, S. A., O'Dea, C. P., Owen, F. N., & Wise, M. W. 1999, "X-ray Properties of B2 1028+313: A Quasar at the center of the Abell Cluster A1030," *ApJ*, 510, 90
- Savaglio, S., Ferguson, H. C., Brown, T. M., Espey, B. R., Sahu, K. C., Baum, S. A., Carollo, C. M., Kaiser, M. E., Stiavelli, M., Williams, R. E., & Wilson, J. 1999, "The Lyman-alpha Forest of the Quasar in the Hubble Deep Field-South," *ApJL*, 515, 5
- Scarpa, R. & Urry, C. M. 1999, "On the Physical Conditions in AGN Optical Jets," in *Life Cycles of Radio Galaxies*, *New Astronomy Reviews*, in press
- Scarpa, R. & Urry, C. M. 1999, "On the Physical Conditions in AGN Optical Synchrotron Jets," *BAAS*, 31, 857, 20.05
- Scarpa, R., Urry, C. M., Falomo, R., & Treves, A. 1999, "HST Observation of the Optical Jets of PKS 0521-365, 3C371, and PKS 2201+044" *ApJ*, 526, in press
- Scarpa, R., Urry, C. M., Falomo, R., Pesce, J. E., & Treves, A. 1999, "The HST Survey of BL Lacertae Objects. I. Surface Brightness Profiles, Magnitudes, and Radii of Host Galaxies," *ApJ*, in press
- Scarpa, R., Urry, C. M., Falomo, R., Pesce, J. E., Webster, R., O'Dowd, M., & Treves, A. 1999, "The HST Survey of BL Lac Objects: Gravitational Lens Candidates and Other Unusual Sources," *ApJ*, 521, 134
- Scarpa, R., Urry, C. M., Falomo, R., & Treves, A. 1999, "HST Observations of the Optical Jets of PKS 0521-365, 3C 371, and PKS 2201+044," *ApJ*, in press (astro-ph/9906462, ST Sci preprint 1365)
- Scarpa, R., Urry, C. M., Falomo, R., Treves, A., & Pesce, J. E. 1999, "Four Gravitational Lens Candidates in the HST Snapshot Survey of BL Lac Objects," in *BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 413
- Scarpa, R., Urry, C. M., O'Dowd, M., Falomo, R., Pesce, J. E., Treves, A., Giavalisco, M. 1999, "The HST Survey of BL Lacertae Objects. II. Analysis," *ApJS*, submitted
- Scarpa, R., Urry, C. M., Padovani, P., O'Dowd, M., Calzetti, D. 1999, "NICMOS Observations of BL Lacertae Objects," *BAAS*, 30, 1252 (193, 6.01)
- Scharf, C. A., Donahue, M., Voit, M., Rosati, P., Postman, M. 1999, "Evidence for X-ray emission from a large-scale filament of galaxies?" *ApJ*, submitted
- Scharf, C. A., Jahoda, K., Treyer, M., Lahav, O., Boldt, E., Piran, T. 1999, "The 2-10 KeV XRB dipole and its cosmological implications," *ApJ*, submitted
- Scharf, C., Donahue, M., Voit, G. M., Rosati, P., Postman, M. 1999, "A Candidate X-ray Filament of Large Scale Structure," in *Large Scale Structure in the X-ray Universe*
- Scharf, C., Donahue, M., Voit, G. M., Rosati, P., Postman, M. 1999, "Evidence for X-ray emission from a large-scale filament of galaxies," *ApJL*, submitted.
- Schmitt, H. R. 1999, "The Spectral Energy Distribution of Spiral Galaxies," in *Building Galaxies: from the primordial universe to the present*, eds. F. Hammer, T. X.

- Thuan, V. Cayatte, B. Guiderdoni & J. T. T. Van (Frontiers), in press
- Schmitt, H. R., Storchi-Bergmann, T., & Cid Fernandes, R. 1998, "Star formation and Nuclear Activity in AGN," *BAAS*, 193, 0608
- Schmitt, H. R., Storchi-Bergmann, T., & Cid Fernandes, R. 1999, "Spectral Synthesis of the Nuclear Region of Seyfert 2 and Radio Galaxies," *MNRAS*, 303, 173
- Schmitt, H. R. & Kinney, A. L. 1999, "The Relative Orientation of the Accretion Disk and Host Galaxy Disk in Seyferts," in *Lifecycles of Radio Galaxies*, ed. J. Biretta, (New Astronomy Reviews), in press
- Serabyn, E., Figer, D. F., Rich, R. M., & Morris, M. 1999, "The Star Formation History in the Galactic Center," *ApJ*, in preparation
- Serabyn, E., Shupe, D., & Figer, D. F. 1999, "Massive Star Formation in the Arches Cluster," in proceedings of *The Central Parsecs: Galactic Center Workshop '98*, ASP Conf. Series, Vol. 186, 320
- Shara, M. M., Fall, S. M., Rich, R. M., & Zurek, D. 1998, "Hubble Space Telescope Observations of NGC 121: First Detection of Blue Stragglers in an Extragalactic Globular Cluster," *ApJ*, 508, 570
- Siess, L. & Livio, M. 1999, "The Accretion of Brown Dwarfs and Planets by Giant Stars I," *MNRAS*, 304, 925
- Simpson, C., Eisenhardt, P., Armus, L., Chokshi, A., Dickinson, M., Djorgovski, S. G., Elston, R., Jannuzi, B. T., McCarthy, P. J., Pahre, M. A., & Soifer, B. T. 1999, "Young Stars and Non-Stellar Emission in the Aligned Radio Galaxy 3C 256," *ApJ*, in press
- Sirianni, M., Nota, A., Leitherer, C., De Marchi, G., & Clampin, M. 2000, "The Low End of the Initial Mass Function in Young LMC Clusters. I. The Case of R136," *ApJ*, submitted
- Soderblom, D. R. 1999, "Activity and Ages," in *Nearby Stars Workshop Proceedings*, ed. D. Backman, (NASA), in press
- Soderblom, D. R., 1999, "Rotation on the Main Sequence," in *Encyclopedia of Astronomy and Astrophysics*, Institute of Physics, in press.
- Soderblom, D. R., King, J. R., Siess, L., Jones, B. F., & Fischer, D. 1999, "The Evolution of the Lithium Abundances of Solar-Type Stars. IX. High-Resolution Spectroscopy of Low-Mass Stars in NGC 2264," *AJ*, in press.
- Sparks, W. B., Macchetto, F. D., Panagia, N., Boffi, F. R., Branch, D., Hazen, M. L., & Della Valle, M. 1999, "Evolution of the Light Echo of SN1991T," *ApJ*, 523, 585
- Stanghellini, C., O'Dea, C. P., & Murphy, D. W. 1999, "A VLBI study of GHz-Peaked-Spectrum radio sources. II. Additional VLBI images at 6 cm," *A&A Supplement Series*, 134, 309
- Steidel, C. C., Adelberger, K. L., Giavalisco, M., Dickinson, M., & Pettini, M. 1999, "Lyman Break Galaxies at  $z \geq 4$  and the Evolution of the Ultraviolet Luminosity Density at High Redshift," *ApJ*, 519, 1
- Stern, D., Dey, A., Spinrad, H., Maxfield, L., Dickinson, M., Schlegel, D., & González, R. A. 1999, "New High-Redshift Radio Galaxies from the MIT-Green Bank Catalog," *AJ*, 117, 1112
- Stiavelli, M., Treu, T., Carollo, C.M., Rosati, P., Viezzer, R., Casertano, S., Dickinson, M., Ferguson, H., Fruchter, A., Madau, P., Martin, C., & Teplitz, H. 1999, "VLT and HST Observations of a Candidate High Redshift Elliptical Galaxy in the Hubble Deep Field South," *A&A*, 343, L25.
- Storrs, A. D., Caldwell, J. J., Hawke, B. R., Bell, J. F., & Smith, G. A. 1999, "Imaging Observations of the Moon with the Hubble Space Telescope," *Proc. 30th Lunar and Planetary Sciences Conf.*, p. 28
- Storrs, A. D., Weiss, B., Zellner, B., Burlinson, W., Sichertiu, R., Wells, E., Kowal, C., & Tholen, D. 1999, "Imaging Observations of Asteroids with Hubble Space Telescope," *Icarus*, 137, 260
- Storrs, A. D., Wells, E., Zellner, B., Stern, A., & Durda, D. 1999, "Imaging Observations of Asteroids from HST," in *BAAS*, 31, in press
- Suchkov, A. A. & McMaster, M. 1999, "Evidence for a Population of Numerous Binaries with Comparably Bright Components Among *HIPPARCOS* "Single" F Stars," *ApJL*, 524, October 20 issue
- Suchkov, A. A. 1999, "Age-Velocity Relation for *HIPPARCOS* Stars," *BAAS*, 40, 1346
- Suchkov, A. A. 1999, "Unidentified Binaries Among Local F Stars," *BAAS*, 41, in press
- Suntzeff, N. B., *et al.* 1999, "Optical Light Curve of the Type IA Supernova 1998BU in M96 and the Supernova Calibration of the Hubble Constant," *AJ*, 117, 1175
- Taylor, G. B., O'Dea, C. P., Peck, A. B., Koekemoer, A. M. 1999, "HI Absorption toward the Nucleus of the Radio Galaxy PKS 2322-123 in A2597," *ApJ*, 512, 27
- Telfer, R. C., Kriss, G. A., Zheng, W., Davidsen, A. F., & Green, R. F. 1998, "The Very Highly Ionized Broad Absorption Line System of the QSO SBS1542+541," *ApJ*, 509, 132
- Teplitz, *et al.* 1999, "The Rest-Frame Optical Spectrum of MS 1512-cB58," *ApJL*, in preparation
- Thompson, D., Beckwith, S. V. W., Fockenbrock, R., Fried, J., Hippelein, H., Hopp, U., Huang, J.-S., Leinert, Ch., Meisenheimer, K., Phleps, Röser, H.-J., Thommes, E., & Wolf, C., 1999, "The Surface Density of Extremely Red Objects," *ApJ*, 523, 100
- Tout, C., Livio, M., & Bonnell, I. 1999 "The Ages of Pre-Main-Sequence Stars," *MNRAS*, in press
- Tozzi, P., Scharf, C. A., Norman, C. 1999, "Detection of the Entropy of the Intergalactic Medium: Accretion Shocks in Clusters, Adiabatic Cores in Groups," *ApJ*, submitted
- Treu, T. & Stiavelli, M. 1999, "A NICMOS search for high redshift elliptical galaxy candidates," *ApJ*, 524, L27
- Treu, T., Stiavelli, M., Casertano, S., Møller, P., & Bertin, G. 1999, "The properties of field elliptical galaxies at intermediate redshift. I: empirical scaling laws," *MNRAS*, in press, (astro-ph/9904327)
- Treu, T., Stiavelli, M., Walker, A. R., Williams, R. E., Baum, S. A., Bernstein, G., Blacker, B. S.; Carollo, C. M., Casertano, S., Dickinson, M. E., De Mello, D. F., Ferguson, H. C., Fruchter, A. S., Lucas, R. A., Mackenty, J., Madau, P., & Postman, M. 1998, "An extremely red

- R<sup>(1/4)</sup> galaxy in the test image of the Hubble Deep Field South,” *A&A*, 340, L10
- Treves, A., Zhang, Y. H., Celotti, A., Tavecchio, F., Maraschi, L., Ghisellini, G., Tagliaferri, G., Chiappetti, L., Pian, E., Urry, C. M. 1999, “Fast X-Ray Variability of PKS 2155–304: A Cross Correlation Analysis,” in *BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 184
- Treyer, M., Scharf, C. A., Lahav, O., Jahoda, J., Boldt, E., Piran, T. 1998, “Large-Scale Fluctuations in the X-Ray Background,” *ApJ*, 509, 531
- Trussoni, E., Vagnetti, F., Massaglia, S., Feretti, L., Parma, P., Morganti, R., Fanti, R., & Padovani, P. 1999, “X-ray Observations of Low-power FR I Radio Galaxies,” *A&A*, 348, 437
- Urry, C. M. 1998, “Multiwavelength Properties of Blazars,” *Adv. Space Res.*, 21, 89; in *Space Based Astronomy: ISO, AGN, Radiopulsars and the Sun*, eds. H. J. Walker, W. F. Welsh, P. A. Caraveo & A. Gabriel (Pergamon, Elsevier)
- Urry, C. M. 1999, “BL Lac Objects and Blazars: Past, Present, and Future,” in *BL Lac Phenomenon*, eds. L. Takalo & A. Sillanpää (ASP), p. 3
- Urry, C. M. 1999, “Jets in Active Galactic Nuclei,” *BAAS*, 31, 725 (HEAD, 24.01)
- Urry, C. M. 1999, “Multiwavelength Properties of Blazars,” in *TeV Astrophysics of Extragalactic Objects*, eds. T. Weekes & M. Catanese (Elsevier), *Astroparticle Physics*, 11, 159
- Urry, C. M. 1999, “The Baltimore Charter and Women in Astronomy,” *June STATUS (ST ScI)*, p. 6
- Urry, C. M., Falomo, R., Scarpa, R., Pesce, J. E., Treves, A., Giavalisco, M. 1999, “HST Observations of the Host Galaxies of BL Lacertae Objects,” *ApJ*, 512, 88
- Urry, C. M., Frattare, L. 1999, “The Status of STATUS,” *January STATUS (ST ScI)*, p. 1
- Urry, C. M., Remillard, R., Aharonian, F. A. 1999, “X-Ray and TeV Emission from Blazars,” in *Proc. X-Ray Astronomy '99: Stellar Endpoints, AGN and the Diffuse X-Ray Background*, in press
- Urry, C. M., Sambruna, R. M., Brinkmann, W. P., & Marshall, H. L. 1998, “RXTE Monitoring of the Blazar PKS 2155–304,” in *The Active X-Ray Sky. Results from BeppoSAX and RossiXTE*, *Nucl. Phys. B (Proc. Suppl.)* 69, 1-3, 419
- Urry, C. M., Scarpa, R., O’Dowd, M., Broadhurst, T., Falomo, R., Treves, A., Webster, R., Sillanpää, A., Takalo, L., Heidt, J. 1999, “Unusual Morphologies from the HST Snapshot Survey of BL Lac Objects: Three Optical Jets and A Possible Einstein Ring,” *BAAS*, 31, 951 (73.08)
- Urry, C. M., Scarpa, R., O’Dowd, M., Falomo, R., Giavalisco, M., Pesce, J. E., Treves, A. 1999, “Host Galaxies and the Unification of Radio-Loud AGN,” in *Life Cycles of Radio Galaxies*, *New Astronomy Reviews*, in press
- Urry, C. M., Scarpa, R., O’Dowd, M., Falomo, R., Giavalisco, M., Pesce, J. E., Treves, A. 1999, “The HST Survey of BL Lacertae Objects. I. Host Galaxies,” *ApJ*, submitted
- Urry, C. M., Scarpa, R., O’Dowd, M., Falomo, R., Pesce, J. E., & Treves, A. 1999, “The HST Survey of BL Lacertae Objects. II. Host Galaxies,” *ApJ*, in press
- Urry, C. M., Scarpa, R., O’Dowd, M., Giavalisco, M., Falomo, R., Pesce, J. E., Treves, A. 1999, “The Host Galaxies of Radio-Loud AGN,” in *The Formation of Bulges*, eds. M. Carollo, H. Ferguson, & R. Wyse (CUP), in press
- Voit, G. M. & Donahue, M. 1998, “On the Evolution of the Temperature Virial Mass Relation for Clusters of Galaxies,” *ApJL*, 500, 111.
- Walborn, N. R., Barbá, R. H., Brandner, W., Rubio, M., Grebel, E. K., & Probst, R. G. 1999, “Some Characteristics of Current Star Formation in the 30 Doradus Nebula Revealed by HST/NICMOS,” *AJ*, 117, 225
- Walborn, N. R., Drissen, L., Parker, J. Wm., Saha, A., MacKenty, J. W., & White, R. L. 1999, “HST/FOS Spatially Resolved Spectral Classification of Compact OB Groups in the Large Magellanic Cloud,” *AJ*, 118, in press
- Walborn, N. R. & Fitzpatrick, E. L. 1999, “The OB Zoo: A Digital Atlas of Peculiar Spectra,” *PASP*, in press
- Wegmann, R., Schmidt, H. U., Lisse, C. M., Dennerl, K., & Englhauser, J. 1998, “X-rays From Comets Generated by Energetic Solar Wind Particles,” *Planet. Space Sci.*, 46, 603
- Wehrle, A. E., Pian, E., Urry, C. M., and the Multiwavelength Blazar Consortium, 1998, “Multiwavelength Observations of a Dramatic High Energy Flare in the Blazar 3C 279,” *BAAS*, 29, 1304 (191, 56.05)
- Wehrle, A. E., Pian, E., Urry, C. M., *et al.* 1998, “Multiwavelength Observations of a Dramatic High Energy Flare in the Blazar 3C 279,” *ApJ*, 497, 178
- Whitmore, B. C., Heyer, I., & Casertano, S. 1999 “Charge Transfer Efficiency of the Wide Field and Planetary Camera 2,” *PASP*, in press
- Whitmore, B. C., Zhang, Q., Leitherer, C., Fall, S. M., Schweizer, F., & Miller, B. W. 1999, “The Luminosity Function of Young Star Clusters in “The Antennae Galaxies,” (NGC 4038/4039),” *AJ*, 118, in press
- Williams, R. E. 1998, “The Hubble Deep Field,” in *Highlights of Astronomy*, Vol. 11A, ed. J. Andersen (Kluwer), p. 3
- Williams, R., Baum, S. A., Bergeron, L. E., Blacker, B., Boyle, B. J., Brown, T. M., Bernstein, N., Carollo, C. M., Casertano, S.; De Mello, D., Dickinson, M., Espey, B. R., Ferguson, H. C., Fruchter, A. S., Gardner, J. P., Gonnella, A., Gonzalez, R., Hayes, J., Hewett, P., Heyer, I., Hook, R. N., Jones, D., Kaiser, M. E., Lubenow, A., Lucas, R. A., Mack, J., Mackenty, J. W., Madau, P., Makidon, R., Martin, C. L., Mazzuca, L., Mutchler, M., Norris, R. P., Perriello, B., Postman, M., Royle, P., Sahu, K. C., Savaglio, S., Sherwin, A., Smith, T. E., Stiavelli, M., Teplitz, H. I., van der Marel, R., Weymann, R. J., Wiggs, M. S., Williger, G. M., Wilson, J., & Zurek, D. 1998, “The Southern Hubble Deep Field: HDF-S,” *BAAS*, 193, 75.01
- Wolf, C., Mundt, R., Thompson, D., Chaffee, F., Beckwith, S. V. W., Fockenbrock, R., Fried, J., Hippelein, Huang, J.-S., von Kuhlmann, B., Leinert, Ch., Meisenheimer, K., Phleps, S., Röser, H.-J., & Thommes, E. 1998, “Discov-

- ery of three very distant L and M dwarfs,” *A&A*, 338, 127
- Wolf, C., Meisenheimer, K., Beckwith, S. V. W., Fockenbrock, R., Hippelein, H., von Kuhlmann, B., Phleps, S., & Thommes, E. 1999, “Did Most High-Redshift Quasars Escape Detection?” *A&A*, 343, 399
- Wolf, C., Meisenheimer, K., Röser, H.-J., Beckwith, S. V. W., Fockenbrock, R., Hippelein, H., von Kuhlmann, B., Phleps, S., & Thommes, E. 2000, “Have most high-redshift quasars been overlooked?” in *Imaging the Universe in Three Dimensions: Astrophysics with Advanced Multi-wavelength Imaging Devices*, eds. W. van Breugel & J. Bland-Hawthorn (ASP Conf. Series), in press
- Wolter, A., Comastri, A., Ghisellini, G., Giommi, P., Guainazzi, M., Maccacaro, T., Maraschi, L., Padovani, P., Raiteri, C. M., Tagliaferri, G., Urry, C. M., & Villata, M. 1998, “BeppoSAX Spectral Survey of Soft X-Ray Selected BL Lacertae Objects,” *A&A*, 335, 899
- Xu, C., Livio, M., & Baum, S. 1999, “Radio Loud and Radio Quiet AGN,” *AJ*, in press
- Xu, C., O’Dea, C. P., Biretta, J. A. 1999, “VLBI Observations of Symmetric Parsec-Scale Twin Jets in the Narrow-Angle-Tail Radio Galaxy NGC 1265 (3C83.1B),” *AJ*, 117, 2626
- Zepf, S. E., Ashman, K. M., English, J., Freeman, K. C., & Sharples, R. M. 1999 “The Formation & Evolution of Candidate Young Globular Clusters in NGC 3256,” *AJ*, in press
- Zhang, Y. H., Celotti, A., Treves, A., Chiappetti, L., Ghisellini, G., Maraschi, L., Pian, E., Tagliaferri, G., Tavecchio, F., Urry, C. M. 1999, “Rapid X-Ray Variability of the BL Lacertae Object PKS 2155–304,” *ApJ*, in press (astro-ph/9907325)
- Zhu, M., Seaquist, E., Davoust, E., Frayer, D., & Bushouse, H. 1999, “Molecular Gas in Strongly Interacting Galaxies. I. CO (1–0) Observations,” *AJ*, 118, 145
- Zirm, A., Dey, A., Dickinson, M., McCarthy, P. J., Eisenhardt, P., Djorgovski, S. G., Spinrad, H., Stanford, S. A., & van Breugel, W. 1999, “NICMOS Imaging of High-Redshift Radio Galaxies,” in *The Hy-Redshift Universe: Galaxy Formation and Evolution at High Redshift*, eds. A. Bunker & W. van Breugel, (ASP), in press

C. Leitherer, S. Lépine, M. Livio, S. Toolan

