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This report covers the period 1 September 1995 to 31 August 1996.

1. PERSONNEL

During this time the departmental faculty consisted of Steven A. Balbus, Roger A. Chevalier, John F. Hawley, Philip A. Ianna, Shiv S. Kumar, Steven R. Majewski Robert W. O'Connell, Mercedes T. Richards, Robert T. Rood, Craig L. Sarazin, William C. Saslaw, Trinh X. Thuan, Charles R. Tolbert, and D. Mark Whittle.

The Virginia Institute for Theoretical Astronomy (VITA) continued operations during this period with support from the University of Virginia and a NASA Astrophysical Theory Program Grant. Visitors under VITA auspices for the year included S. Bhavsar (UKy), J. Blondin (NCSU), N. Chugai (Moscow), D. Deeming (GSFC), A. Ferrara (Arcetri), A. Frank (UMn), Y. Izotov (Kiev), S. Mohler (STScI), S. Reynolds (NCSU), J. Stone (UMd), and J. Thorburn (Chicago). Postdocs in residence during this period included Carolyn Cox, Pamela Marcum, Maxim Markevitch, Marina Murzina, and Duane Rosenberg.

Eric W. Weisstein assumed a position as Research Scientist in July 1996. A full-time astrometric support position was held by Michael C. Begam who spends most of the year at Mount Stromlo Observatory. Richard J. Patterson held a part-time position at McCormick Observatory. James Barr continued as electronics technician. Cliff Mawyer, our instrument maker, retired after 20 years of service in May 1996. Virginia Bossong and Jacquelynn Harding continued as our secretaries. Willie J. (Nick) Nichols is the resident caretaker at the Fan Mountain Station.

There were 14 graduate students in residence at the end of this period. David Frayer, Jonathan Whitney, and Geary Albright completed their Ph.D.s during the year.

2. FACILITIES

The McCormick 67-cm refractor and the Fan Mountain 1-m and 0.7-m reflectors were used for student research and education in both undergraduate and graduate courses during the year. The 1-m is being prepared for installation of a new drive and control system by DFM Engineering in Fall 1996. Only limited astrometric observations were carried out with the refractor. The southern parallax program continues at Mount Stromlo and Siding Spring Observatories. A SITe 2K $\times$ 2K grade 1 CCD was purchased during the year. The CCD will be used on the Fan Mountain 1 m telescope with the San Diego State University controller boards. The system was delivered in July. A small CCD autoguider was developed for the refractor. The PDS 1010GM was in nearly continuous use scanning plates for our astrometric and galactic structure programs. It was also used on several occasions by other University researchers from biology and medicine.

3. RESEARCH

3.1 Stars and Stellar Evolution

G. Albright (graduate student) and Richards have completed their work on the morphology and physical properties of the accretion regions in Algol-type binaries. They obtained over 2000 full-orbit Hα spectra of 18 Algol-type binaries; characterized the orbital variations of the observed spectra; converted the spectra into difference spectra by subtracting a composite theoretical photospheric spectrum from the observed spectrum at each phase; used the enhanced spectrum of the circumstellar material to produce models of the gas distribution in the orbital plane; and compared the H α difference profiles of nine of these systems (some at multiple epochs) at eight critical phases in the orbit: $\phi =$ 0.0, 0.13, 0.25, 0.37, 0.5, 0.65, 0.75, 0.87, to illustrate the different morphologies within the group of Algols with orbital periods less than 7 days. In terms of their line profiles, these systems fall into two categories: 1) single-peaked emission systems, where the accreted gas was observed between the two stars and along the path of the gas stream, and 2) double-peaked emission systems where the accretion structure is a transient or classical accretion disk. Two systems (U Sge and U CrB) were observed to change from the single- to double-peaked emission type in less than 12 hours. Three other systems are suspected of displaying the same type of change in accretion structures (S Equ, RS Vul, and TX UMa). Richards has used the Hα difference spectra to produce Doppler tomograms of 12 of these binaries, some at multiple epochs.

Balbus is carrying through an analytic development of nonlinear fluctuation equations for MHD turbulence. Applications will be made to stellar convection zones as well as to accretion disks, with emphasis on understanding general properties of why solar differential rotation appears, and how the two systems differ in the role played by convective transport.

Balbus is also investigating the role of magnetic instabilities in the solar nebula. Current modeling shows that dissipational heating associated with the instability is hot enough to cause ionization of alkaline metals, and therefore to keep the nebula self-consistently magnetically coupled.

Balbus, Hawley, and Stone are continuing with their combined analytical and numerical examination of the purely hydrodynamic properties of shearing flows and accretion disks. A simple analytic analysis has shown that the key to nonlinear stability is the interaction of correlated velocity fluctuations with mean flow gradients. This investigation has ruled out any kind of self-generated hydrodynamical turbulence as a source of anomalous viscosity in disks.

Balbus and visiting graduate student M. Ricotti (Osservatorio Astrofisico Arcetri, Italy) are elucidating the mathematical and stability properties of magnetized analytic

structures in accretion disks. Their solutions are remarkable in that they rotate uniformly, even in the presence of differential rotation. If present in actual disks, such structures are likely to be of great importance in several situations, particularly those in which a disk is joining on to a magnetized star.

Chugai (Moscow) and Chevalier studied the late optical/ultraviolet spectrum in the supernova SN 1993J in M81. The spectrum shows line emission with broad, approximately rectangular profiles, which are the expected result of circumstellar interaction. The emission shows evidence for radiation from a cooling reverse shock front as well as from gas that is radiatively heated and ionized by emission from the hot interaction region. Although the emission is generally consistent with circumstellar interaction, the line profiles are not consistent with expectations of smooth supernova ejecta interacting with a smooth wind. The reverse shock emission appears to be from a fragmented shell, so there must be clumping in the ejecta and/or the circumstellar wind.

N. D'Cruz (graduate student), Rood, R. Dickens (Bristol), and D. Hatzidimitriou (Crete) are analyzing fiber spectra of 480 blue horizontal branch (BHB) stars in the globular cluster ω Centauri to obtain temperatures, gravities and Ca abundances for the stars. The objective is to identify the primary physical parameters which could cause the Oosterhoff dichotomy in globular clusters. Simulated HB distributions will be used to allow for evolution from the ZAHB. Effective temperatures are being obtained from existing B,V photometry, newer CCD V,I photometry and to a lesser extent from the Balmer line profiles. The Ca abundance is obtained from Ca K after correcting for the interstellar Ca K contribution. The initial analysis of the Ca abundances indicates that a large fraction of ω Cen's BHB stars have lower metallicity when compared to the abundance distribution of giants and RR Lyraes.

Hawley and Balbus continue to investigate the nature of astrophysical disk systems and the angular momentum transport mechanism. They are carrying out a study of the nonlinear behavior of magnetohydrodynamic (MHD) turbulence in accretion disks. Extensive simulations of the instability in a Keplerian shearing-sheet system using a three-dimensional MHD computer code demonstrate that the weak-field accretion disk instability, found earlier by Balbus and Hawley, constitutes a hydromagnetic dynamo. All aspects of the resulting flow, the dynamo mechanism, the turbulence, and the angular momentum transport depend upon the Lorentz force even if the field is weak by convectional standards. Details of the nonlinear saturation mechanism are currently under study, and several different mechanisms are being considered. Hawley and J. Stone (U. Maryland) are developing a three-dimensional MHD numerical code as the first step toward extending these investigations to more realistic global disks.

Hawley and Stone are performing numerical simulations of disk systems using a two-fluid (ion and neutral) version of their MHD code. They are studying the weak field two-fluid MHD instability in the local ''shearing box'' approximation in the presence of vertical and toroidal magnetic fields. This work bears on the issue of the importance of MHD turbulence as a transport mechanism in partially ionized disks, e.g., the protostellar nebula.

With W. Kunkel (Las Campanas Obs.), Majewski has been searching for giant stars correlated to the H I Magellanic Stream. The presence or lack of a stellar stream would delineate between tidal and ram pressure stripping models for the Magellanic Stream.

Majewski, N. Reid (Caltech), I. Thompson (OCIW), and M. Siegel (grad student) have continued their research into the classical starcount problem with a systematic survey of more than a dozen Kapteyn Selected Areas using the Swope 40'' at Las Campanas. Observations now include B,V,R and I band CCD frames of 2 square degrees in each Kapteyn field with better than 5% photometric accuracy to $V=21.5$. Additional deep ($V<22$) starcount data are being generated by Majewski and J. Ostheimer (undergraduate student) in collaboration with A. Sandage (OCIW). The latter data come from sky-limited Mayall 4 m photographic plates scanned on the UVa PDS microdensitometer. Majewski, Reid, and Thompson, with L. Yan and I. Smail (Caltech) have also recently analyzed deep V,R,I imaging data from the Keck 10 m telescope (to $R\sim25.5$) as well as the Hubble Deep Field (to two magnitudes fainter). They show that the contribution to the faint starcounts from halo subdwarfs is limited to $R-I<1.0$, with redder stars being contributed from the Galactic disk and Intermediate Population II (IPII). They conclude that the previously found large upturn in the halo luminosity function for $M(V)>10$ is an artifact of contamination of disk and IPII stars for the intrinsically fainter stars.

Marcum and O'Connell, along with collaborators D. Luttermoser (East Tennessee State University) and L. Jones (U. North Carolina) are collecting intermediate resolution (1 Å) data for a near infrared stellar spectral library. Some data has already been acquired using the Kitt Peak coudé-feed spectrograph and the NICMASS infrared detector. Once completed, the library will cover all spectral and luminosity types, and will cover a considerable range in metallicity ($-2.5<[\mathrm{Fe/H}]<0.5$).

With J. Munn (Yerkes Obs.) and S. Hawley (MSU), Majewski has continued to work on obtaining spetroscopy for radial velocities and abundances of his deep astrometric survey at the North Galactic Pole. The survey makes use of the WIYN 3.5 m telescope with the HYDRA multifiber spectrograph to obtain 2 Å resolution spectra. The survey is now almost complete to $V\sim19.5$ in two fields, and several additional fields have been begun. Early results on late type stars indicate a dearth of dMe stars past 250 pc above the Galactic plane whereas dM stars are observed to at least the 350 pc limit of the spectroscopic sample. Results on the three-dimensional velocities of the F-K stars in the Majewski (1992) sample (Majewski, Munn, & Hawley 1996) verify the existence of large-scale streaming motions in the Galactic halo. The latter appear to dominate the halo field star population, and suggest accretion of satellites as a primary source of halo stars.

O'Connell, Rood, and collaborators at GSFC and STScI are studying extremely hot stars in the globular cluster ω Centauri using HST WFPC2 and FOS observations. The

sample of six targets was identified on Ultraviolet Imaging Telescope/*Astro-1* far-UV images of the cluster. Far-UV images of all fields with WFPC2 confirm that the sources are indeed very hot and are unblended, non-variable stars. Two FOS spectra have been obtained to date, and analysis is proceeding.

M. Ratliff (graduate student) and Richards have performed two-dimensional hydrodynamical simulations of mass transfer in the Algol-type binaries using the numerical VH-1 code with radiative cooling. The simulations were performed to study the Hα emission from circumstellar gas in systems with orbital periods less than 7 days. Using observational evidence from the literature to constrain the gas stream properties, hydrodynamical maps of the Hα emissivity in the two systems β Per ($P = 2.87^d$) and TT Hya ($P = 6.95^d$) were made in both Cartesian and velocity coordinates from the simulation data. The velocity maps were then compared to Doppler tomograms constructed from observed Hα line emission in these systems. Since the tomograms cannot be directly transformed to maps of emission in spatial coordinates, the simulated Cartesian maps enabled them to interpret the dynamical processes which produce the features observed in the Doppler tomograms. Ratliff and Richards found that the simulations produce asymmetric accretion structures with many features similar to those found in the Doppler tomograms of Algol systems.

Richards has used the technique of Doppler tomography to produce reconstructed images of Hα emission sources in Algol binaries. A total of 18 Doppler tomograms have been constructed from the Hα difference spectra of 12 Algol binaries derived from observations collected by Albright and herself. Some systems were observed at several epochs and their Doppler maps illustrate variability with time. The tomograms of short-period Algols ($P < 5$ days) show that there are as many as seven sources of Hα emission in the binary, including a gas stream, an accretion annulus (a sub-Keplerian structure), at least two shock regions, an equatorial bulge on the mass gainer, as well as a contribution from the chromosphere of the magnetically active mass-losing star. The longer period Algols ($P > 5$ days) primarily display Keplerian-like accretion disks like those found in cataclysmic variables. Moreover, some of the short-period systems display prominent gas stream emission at some epochs, then switch to prominent accretion disk emission with weaker gas stream emission at other times. The Doppler map of HR 1099 also confirms the appearance of chromospheric emission in the Doppler maps of the Algols.

Richards and J. Blondin (NCSU) are continuing their 2-D and 3-D hydrodynamical study of Roche lobe overflow. Their work has focussed on the dynamics of mass loss, mass transfer and the process of accretion in a range of interacting binaries from the dynamic high mass transfer X-ray binaries to the slow mass transfer Algol systems in which the gas stream trajectory has been observed from Doppler tomograms.

Richards and L. Bowles (undergraduate student) compared the IUE spectra of the Algol binary U Sge collected by Richards in 1994 June with archival spectra of the RS CVn binary HR 1099. The purpose was to examine the magnetically-sensitive lines in the U Sge spectra. Since HR 1099 is a chromospherically active system with no mass transfer, the spectrum of HR 1099 provided a template to identify those U Sge lines which are due to chromospheric activity only. Several lines were identified in the spectra and then used to estimate an upper limit to the system temperatures. Richards and Bowles also cataloged the archival IUE observations of 17 other Algol binary systems, and calculated heliocentric Julian dates and orbital phases for every observation.

Richards and P. Koubský (Ondřejov Observatory, Czech Republic) have begun a project to study both eclipsing and non-eclipsing Algol (NEA) candidates with the aim of obtaining the 3-D structure of the accretion regions in these systems. They observed NEA's and classical eclipsing Algols with the IUE satellite during ESA shifts in 1996 February, and simultaneously obtained Hα and He I spectra from KPNO. Richards and Koubský are participants in an international exchange sponsored by the NSF and the Czech Academy of Sciences. Over the next three years, Koubský will spend 6 months at the U. Virginia.

Richards and E. Rosolowsky (undergraduate student, Swarthmore College) used archival IUE spectra of the RS CVn binary, HR 1099, from 1978−1994 to obtain reconstructed Doppler images of the sources of emission in the binary. Doppler tomograms were made from the Mg h+k, C II, He II and Lyα lines. These results are consistent with chromospheric emission in the case where the gas is tidally enhanced. The tomograms show the gas centered on and around the velocity of the more magnetically active K star with a concentration at the velocity of the L1 point.

Richards and S. Russell (undergraduate student) studied the 2.7 GHz and 8.1 GHz radio flare observations of four binaries to determine whether strong flares occurred at specific orbital phases. The 1972−1975 observations of two Algols (β Per and b Per) and two RS CVn binaries (AR Lac and UX Ari) were obtained at the NRAO Green Bank Observatory by D. Gibson. There was the expectation that tidal effects would enhance the flaring activity near phase 0.5 and 0.0, but the data showed no correlation with orbital phase.

Richards has collaborated with E. Waltman (NRL), R. Foster (NRL), and F. Ghigo (NRAO) to monitor the 2.3 GHz and 8.3 GHz radio continuum flux of magnetically active systems β Per, HR 1099, and δ Lib with the NRL radio interferometer at Green Bank Observatory. This project monitored flare activity continuously from 1995 January to 1996 April when the Green Bank Interferometer officially closed its operations. The campaign was successful in detecting several strong flares with continuum fluxes as high as 1 Jy at 8.3 GHz in β Per and up to 1.5 Jy at 8.3 GHz in HR 1099. The time scale of these flares is 1 – 2 months. These flaring times scales may provide a clue to the processes which result in the extreme variability of the Hα emission in systems like U CrB and U Sge, or those which influence the gas stream trajectory in TX UMa.

Rood, B. Dorman (GSFC), F. Pecci, F. Ferraro, and others in Bologna continue their project on HST observations of globular cluster stars. Photometric reductions in M3 are almost complete and will supplement ground based photom-

etry of the outer parts of the cluster. The resulting sample of unprecedented size will allow direct observational tests of the so-called canonical assumptions of stellar evolution which might introduce systematic error into the stellar age scale calibration. Clusters with long blue extensions to the horizontal branch are being observed in the visible and UV. HST Cycle 5 data for M13 show a very extended blue HB with 2 gaps. It is hoped that study of these stars will lead to increased understanding of the stellar mass loss problem.

Sarazin and W. Dalton (former graduate student) are constructing models for the high mass X-ray binary (HMXRB) populations in the Large Magellanic Cloud (LMC) and Small Magellanic Cloud (SMC). In particular, they investigate the effects which the lower stellar metallicities of the Magellanic Clouds (MCs) have on the evolution and properties of HMXRBs. From the observed properties of the relatively small number of identified HMXRBs in the MCs, it has been suggested that MC sources have very high X-ray luminosities, and may contain a higher proportion of black holes than HMXRBs in our Galaxy.

R. Shah (graduate student), O'Connell, Rood, and Dorman (GSFC) are analyzing far-UV images obtained by the Ultraviolet Imaging Telescope of the globular clusters NGC 362 and 47 Tuc. Both are well known for having strong red horizontal branches. Blue HB stars and supra-HB stars were detected in both clusters. In NGC 362 the blue stars constitute about 10% of the HB population. The red giant mass loss process in these clusters is evidently bimodal. In 47 Tuc, the UIT detected a diffuse far-UV source which is measurable to at a radius of 400″; the source less concentrated than the optical-band light in the cluster.

3.2 Interstellar Medium

V. Dwarkadas (graduate student) and Chevalier investigated the interaction of realistic models for Type Ia supernovae with their surroundings. An exponential density profile gives an approximate fit to a number of profiles computed by Khokhlov and Höflich, but some of the models show substantial deviations at low velocities. Dwarkadas and Chevalier computed the detailed properties of the exponential profile case and found an approximate analytic description of the evolution. However, this interaction model is not compatible with X-ray observations of Tycho's supernova remnant, which is thought to be the result of a Type Ia supernova. Models with regions of higher density, which do occur in some of the Type Ia supernova models, are more consistent with the observations.

Murzina and Chevalier are investigating shock wave breakout in a number of supernova models, based on progenitor structures from K. Nomoto. They are using the TITAN radiation gasdynamics code to follow the supernova shock front from the optically thick interior to the optically thin stellar wind. A model for SN 1993J was followed for 30 years of shock evolution. A viscous shock formed when the initial supernova radius expanded by about 40%. At the same time, a cooling reverse shock formed, beginning the build-up of a dense shell.

Rood, T. Bania (BU), D. Balser (NRAO), and T. Wilson (MPIfR) are continuing their project to determine the cosmic abundance of ^{3}He. A paper reporting their Effelsberg 100 m telescope observations of planetary nebulae is nearly ready for submission. The PNe abundances of ^{3}He are 10 times or more than in HII regions. This result is consistent with standard stellar model predictions. However, when stellar ^{3}He production is included in Galactic chemical evolution models, results are obtained which are in conflict with their observations of HII regions as well as other ^{3}He abundance determinations. Several investigators have recently reexamined the stellar synthesis of ^{3}He and if their hypotheses are correct, the PNe sample must be highly atypical. Observations of HII regions continue at the Green Bank 140 Foot Telescope. These are now focused on determining higher precision line parameters for a few sources which are easy to model (a necessary step in getting the abundances) and low density ''simple'' extensions of previously observed giant H II regions.

Rosenberg and Chevalier computed time-dependent axisymmetric numerical models of bipolar planetary nebulae, incorporating the effects of a photoionizing stellar radiation field. This project was motivated by a desire to understand the precursor nebular environment of SN 1987a, in order to elucidate the apparent interaction of the supernova ejecta with dense material inside of the famous circumstellar ring. To produce bipolar structures, the models rely on the standard interacting winds scenario, in which a fast stellar wind creates a nebula in a slow wind from a previous evolutionary stage. A density enhancement in the equatorial plane of the slow, dense wind helps create the bipolar nebula. Indeed, the ring in the SN 1987a precursor is thought to be dense red supergiant gas that has been swept up by fast blue supergiant wind in the equatorial plane. The dense region with which the ejecta may be interacting may be caused by the photoionizing radiation from the progenitor, which photoionizes the swept-up red supergiant wind, and creates a dense H II region inside the equatorial ring. The models demonstrate this effect, and also show that an ionization front may break out of the shell, in agreement with previous research. This work demonstrates that if the H II region becomes geometrically thick before ionization front break-out, it may be an important factor in shaping planetary nebulae; a variety of morphologies may be observed depending on the strength of the photoionizing source. The results also illustrate the importance of the photoionizing source as a mechanism for driving the equatorial ring in such bipolar nebulae outward, when conditions are such that the dynamics are radiation-dominated. The results of this work are in preparation.

Sarazin and C. Wu (CSC), D. Crenshaw (CSC), A. Hamilton (U. Colorado), R. Fesen (Dartmouth), and M. Leventhal (U. Maryland) used the Hubble Space Telescope to observe the far UV spectrum of the Schweizer-Middleditch star behind the remnant of Supernova 1006. They find absorption features due to silicon, sulfur, oxygen, and iron which are almost certainly caused by supernova ejecta in SN1006. Sarazin and Hamilton, Fesen, Wu, and Crenshaw have developed a consistent theoretical interpretation of the broad silicon and iron ultraviolet absorptions as due to both shocked and unshocked ejecta from the supernova.

3.3 Galaxies and Active Galactic Nuclei

Balbus and J. Sellwood (Rutgers) are collaborating on a project to explain the presence of large gaseous velocity dispersions in disk galaxies in regions devoid of stars. Coupling to the differential rotation of the galaxies via magnetic fields and the Balbus-Hawley (1991) instability are the focus of this investigation.

Cox and Sarazin are analyzing the ROSAT HRI image of the Virgo elliptical galaxy NGC 4636.

D. Frayer (graduate student) and R. Brown (NRAO) computed chemical evolutionary models to estimate the abundance of molecular gas and dust in galaxies as a function of metallicity and cosmological epoch. This work was motivated by the recent detections of CO and dust at high redshift. Over a wide range of input parameters, the models suggest that (1) the total mass in gaseous metals peaks at early epochs when approximately half the total baryonic mass is in stars and half is in gas, (2) at its extreme, the mass of gaseous metals ranges from a few to more than ten times larger than the mass of gaseous metals at the current epoch, (3) the O/C ratios are expected to be significantly larger in chemically young systems, which may enhance the O_2/CO ratio within dark molecular clouds at early cosmological epochs (Frayer & Brown 1996).

J. Irwin (graduate student) and Sarazin are analyzing the ROSAT High Resolution Imager X-ray image of the bright elliptical galaxy NGC 4472. They find that the galaxy is interacting with ambient group and/or Virgo cluster gas. A region of reduced soft X-ray emission is seen at the location of the H I cloud, which is believed to have been stripped from a nearby irregular dwarf galaxy. If the reduction is due to soft X-ray absorption, the cloud must be in front of the galaxy, and must contain a significant amount of molecular material.

Irwin, Sarazin, and Frayer are analyzing observations of the H I cloud in NGC 4472 in CO made with the NRAO 12 m Telescope at Kitt Peak. Models for the X-ray hole suggested that the cloud might have a substantial molecular content.

Irwin and Sarazin are studying the ASCA X-ray spectrum of the elliptical galaxy NGC 499.

Majewski, S. Anderson (U. Washington), and C. Palma (graduate student) are analyzing three color CCD images of several fields taken repeatedly at the Palomar 200'' over more than a decade. Photometry of the several epochs is nearly complete. The objective is to identify a sample of QSO candidates to $g\sim 24$ on the basis of colors and variability.

Majewski and M. Bershady (Penn State) have begun a systematic search of very luminous high redshift galaxies in their 4 m plate fields covering over a square degree. Majewski and Bershady are pushing another magnitude deeper ($B\sim 23$) with A. Soroka (undergraduate student) by analyzing large format CCD frames in the U,B and V bands. An upcoming observing run at KPNO will be devoted to spectroscopic confirmation of redshifts, but already they have constrained the shape of the bright end of the $z>3$ luminosity function, based on the number of candidates found. A critical aspect of this study is the prediction of the colors of high redshift galaxies. Detailed modeling of the statistical distribution of high redshift galaxy colors is underway with J. Geoffroy, J. Charlton, and Bershady at Penn State.

Marcum and O'Connell are analyzing spectrophotometry of two bright regions in the starburst prototype galaxy M82. They use an automatic optimizing spectral synthesis algorithm to simultaneously deduce the star formation history and extinction properties.

Marcum and O'Connell, together with members of the UIT team at Goddard, are preparing an Atlas which compares UV and optical-band morphologies for nearby galaxies, using UIT data accumulated during the *Astro-1* and 2 missions. The image fields are up to $40'$ in diameter. About 25 objects will be included in the first edition of the Atlas. The atlas will include ground-based optical (UBVRI) as well as Hα data for comparison. Both images and surface photometry will be presented. The Atlas will help interpret the morphology of very distant galaxies (e.g. those in the Hubble Deep Field), which are often observed in the rest-frame UV. As part of this effort, O'Connell and G. Becker (undergraduate student) developed an improved color-mapping procedure to explore differences in surface brightness in the far-UV and Hα (sensitive to stellar populations with mean ages of 50 Myr and 5 Myr, respectively) in the face-on spiral M51 and the active spiral NGC 4258.

Using infrared and optical imaging, Marcum is exploring the nature of galaxies belonging to loose groups and the effects of local environment on galaxy evolution.

O'Connell and R. Ohl (graduate student) have analyzed the far-UV surface brightness distributions of 8 elliptical galaxies observed with the Ultraviolet Imaging Telescope during the *Astro-2* mission. All objects show significant gradients in UV/optical band colors. The ''reversed'' gradient—i.e. where the UV-optical color becomes bluer rather than redder with increasing radius— in the Local Group dwarf M32 has been confirmed, and several other cases of such reversals have been identified. The far-UV light is probably produced by a population of the same EHB and post-EHB stars being studied on UIT frames of globular clusters by O'Connell and collaborators here and at GSFC. The dependence of this ''UVX'' population on mean abundance and age parameters will be studied in the galaxies by comparing local UV properties to optical-band line strengths.

Patterson and Thuan have derived CCD B and I surface brightness and color profiles for a sample of 51 dwarf and low-surface-brightness (LSB) galaxies. The galaxies were drawn mainly from the sample of UGC dwarf and LSB galaxies detected in H I by Schneider *et al.* (1990, 1992). They focus their attention on extreme dwarf irregulars (dIs), where turbulent motions are as or more important than rotational motions, so that the majority of the dwarfs were chosen to have narrow H I line widths ($V_{20}<100$ km s^{-1}), in addition to being nearby ($v<1500$ km s^{-1}). For each dI galaxy, they derive structural parameters for the underlying low-surface-brightness disk component on which are superimposed the star-forming regions. They found that the central surface brightness of the underlying exponential component of dIs is similar to that of dwarf ellipticals (dEs) but ~ 1.5 mag fainter than that of blue compact dwarf (BCDs). As for the scale

lengths, the dIs divide into 2 groups, one where, for a given B luminosity, the scale length of the underlying exponential component is comparable to that of dEs and a factor of ~ 2 larger than that of BCDs, and one group where the scale length of the dIs is comparable to that of BCDs but a factor of ~ 2 smaller than that of dEs. These differences in structural parameters put strong constraints on evolutionary scenarios between the 3 types of dwarfs. Patterson and Thuan use the CCD images to set up a tentative morphological classification scheme for LSB dIs based on the shape of the underlying low-surface-brightness component and the morphology and location of the star-forming regions on top of it. The division of the dIs into two groups appears to be correlated with morphology. There are a few dwarf spirals in their sample, showing fragments of low-surface-brightness spiral arms. They found that Nilson and Zwicky magnitudes are systematically too faint for dwarfs and LSB galaxies by 1 to 2 magnitudes. The underlying disks in dIs have $(B-I)$ colors ~ 1.5, corresponding to a stellar population of G and K main-sequence or giant stars, and are redder than those of BCDs. The color profiles of the galaxies in the sample are generally flat, with no strong gradient.

Sarazin, B. McNamara (CfA), and B. Jannuzi (IAS) have discovered aligned radio and blue optical lobes in the powerful, FR II, $z = 0.2384$ radio galaxy 3C171. They obtained U-band, I-band and X-ray images of the galaxy with the KPNO 4 m telescope, the 2.5 m Isaac Newton telescope, and the ROSAT High Resolution Imager. The U-band image shows lobe-like continuum features projected 11 arcsec in length straddling a bright, unresolved, central continuum source. At the redshift of 3C 171, the optical lobes have a linear extent of 55 kpc. The radio jets and emission-line gas appear to be nearly coincident with the blue continuum lobes.

R. Spiker (graduate student) and Balbus worked on relating the properties of extragalactic H II regions to the large scale morphology of their host galaxy.

C.-Y. Wang (graduate student) and Sarazin are analyzing the ROSAT HRI observation of the elliptical galaxy NGC 1404 in the Fornax cluster.

Whittle and R. Gelderman (WKU) have continued their study of Compact Steep Spectrum radio galaxies. Following their spectroscopic study, they have pursued an imaging study (KPNO 2.1 m) to focus on host galaxy properties. Having established the presence of strong jet-gas interactions in these galaxies using high dispersion spectroscopy, their present aim is to see whether the galaxies show more general evidence for a gaseous component, such as bluer continuum colors or distortions resulting from mergers. These images also provide a more general characterization of the SSC host galaxies, allowing their placement into the growing taxonomy of radio galaxy hosts.

Whittle, C. Mullis (U. Hawaii), Gelderman (WKU), and A. Wilson (U. Maryland) have continued their imaging and spectroscopic study of the Extended Narrow Line Region (ENLR) of Markarian 78. This Seyfert galaxy presents one of the few clear conically shaped ENLRs, thought to be produced by a partly hidden nuclear ionizing source. By combining emission line imaging (KPNO 2.1 m) and long slit spectroscopy (KPNO 4 m) we have attempted to reconstruct the angular dependence of the ionizing radiation field emerging from the nucleus. There are some clear observational results. The nuclear obscuring zone is apparent both in continuum images (redder nucleus) and in the Balmer decrement (peak in $H\alpha/H\beta$ ratio). This accounts for the apparently high nuclear ionization since, for example, [O III]λ5007/[O II] λ3727 is artificially amplified by reddening. After reddening corrections are applied, we find that the radiation parameter remains high even beyond the limits of the ENLR cone, suggesting that the nuclear source of opacity is thick but patchy. There are also a number of lines of evidence which point to a relatively recent merger in the history of this galaxy.

Whittle and Wilson have continued their study of the Seyfert galaxy Markarian 78 using the HST. Following their earlier work using narrow band images, they have obtained UV and optical spectra at a number of locations across the extended emission line region using FOS. Analysis has been complicated by the fact that the location of the apertures was offset by a larger than expected slew error. Nevertheless, they have been able to reconstruct the major velocity components and their ionization conditions. In particular, it seems that the overall velocity field of the jet perturbed gas increases along the radio source, supporting the scenario of ISM entrainment and ablation, with ram pressure acceleration. The ionization conditions in the gas are under current investigation.

Whittle, Wilson, G. Ferland (U. Kentucky), and J. Mulchaey (Carnegie) have pursued their project to study the contribution of shock ionization to Narrow Line Region gas in Seyfert galaxies which harbor relatively prominent nuclear radio sources. The expectation is that the radio source shocks and accelerates the gas, and that this is a significant contribution to the ionization processes. This would be an important modification to the prevailing view that photoionization is the principal ionization mechanism in AGN. The project makes use of the UV capabilities of HST FOS to obtain spectra of NGC 2110 and NGC 5529 — two Seyferts with clear evidence for jet-gas interactions in the Narrow Line Region. So far observations have only been taken for NGC 2110. A preliminary analysis suggests that the UV line strengths are significantly weaker than expected for shock ionization.

3.4 Clusters of Galaxies

F. Bauer (graduate student) and Sarazin are analyzing a new ASCA observation and an archival ROSAT PSPC observation of the X-ray cluster Abell 644.

J. Breen (graduate student) analyzed the ROSAT PSPC spectra of the central regions of a sample of cooling flow clusters. He did not confirm the general presence of large columns of intrinsic X-ray absorption which had been seen in *Einstein* data.

D'Cruz, Sarazin and J. Dubau (Meudon) are working on calculating the expected emission from the Li-like ^{57}Fe hyperfine line in cooling flows. This line has a wavelength of 3.071 mm. If observable in the cooling flow regions of clusters of galaxies, velocity information of the cooling gas could be obtained, and the chemical history of the gas could

be inferred by comparing the abundance of ^{57}Fe to ^{56}Fe derived from X-ray observations. Improved calculations of the electron collision cross-section for directly exciting the hyperfine levels will help in computing the expected emission.

Z. Huang (graduate student) and Sarazin are studying the X-ray structure of Abell 4059 using ROSAT data. They find that the X-ray emission is anti-correlated with the radio emission, suggesting that the radio lobes have displaced the thermal X-ray–emitting gas.

Markevitch, Sarazin, and M. Henriksen (U. North Dakota) produced an atlas of temperature profiles of clusters using ASCA and ROSAT X-ray spectra.

Markevitch, Sarazin, and Irwin used ASCA and ROSAT observations of the nearby, X-ray bright Triangulum Australis cluster to show that the cluster has probably undergone a recent merger. They show that images in the gas temperature, pressure, and specific entropy provide powerful diagnostics for understanding its dynamical history.

Markevitch and A. Vikhlinin (CfA) showed that ASCA and ROSAT give consistent temperature determinations for clusters when the errors are treated properly.

O'Connell, with E. Smith (GSFC) and other members of the UIT team, studied far-UV images of the luminous cD galaxy in the cooling flow cluster A1795. The far-UV continuum indicates the presence of an OB star component consistent with a current star formation rate of $\sim 5-10 M_{\odot}\mathrm{yr}^{-1}$ (much smaller than the estimated X-ray inflow rate) and that the internal extinction is modest and matches the Galactic reddening law.

Rosenberg and Sarazin computed time-dependent magnetohydrodynamic models of cooling cluster flows. These results are a continuing effort to understand the role of magnetic fields in the dynamics of such flows. So far, one- and two-dimensional homogeneous models have been computed in cylindrical coordinates to check the approach to steady state. The results are in good agreement with those from previous work. Work is continuing on models using a variety of magnetic field configurations, both symmetric and perturbed, that should shed light on the contribution of magnetic fields to turbulent motions within the cluster core, and on the fate of the magnetic flux near the center.

With a collaboration of Japanese X-ray astronomers, Sarazin is determining the gas temperature and abundance distributions in a number of clusters of galaxies using ASCA and ROSAT X-ray observations.

Sarazin, S. Baum (STScI), C. O'Dea (STScI), and F. Owen (NRAO) are studying the quasar B2 1028+313, which is located at the center of the Abell cluster A1030. They have acquired HST UV spectra, ROSAT PSPC and HRI X-ray images, and ASCA X-ray spectra of this system. They hope to use the quasar to detect cooler components in the intergalactic medium through UV or X-ray absorption.

Sarazin, W. Jaffe (Leiden), M. Bremer (Leiden), B. McNamara, O'Dea, Baum, and M. Wise (MIT) are using ISO to search for infrared line and continuum emission from cold gas and dust in cluster cooling flows with evidence for excess X-ray absorption.

Sarazin, E. Lufkin, and R. White (U. Alabama) are using hydrodynamical models to determine the time-dependence of the mass accretion rate and cooling rate in cluster cooling flows. Detailed agreement is found between previous steady-state models and time-dependent models at fixed times in the simulations. The mass accretion rate $\dot{M}$ is found either to increase or remain nearly constant once the flows reach a steady state.

Sarazin, Markevitch, and Wise are using ASCA X-ray observations of the cluster A2029 to determine the radial variation of the gas temperature and the properties of the cooling flow.

Sarazin and McNamara have analyzed the ROSAT PSPC X-ray image and spectrum of the cooling flow cluster A2597. They find that this bright cooling flow cluster has no evidence for excess soft X-ray absorption. Recently observations have suggested that such excess absorption is a characteristic feature of cooling flow clusters.

Sarazin, McNamara, Jannuzi, R. Elston (CTIO), and Wise have obtained *U*-band polarimetry of the blue optical lobes that are located along the radio lobes of the FR I radio source in the Abell 1795 cluster central galaxy. They find an upper limit to the degree of polarization of the light emitted from the lobes to be $<7\%$. This limit renders improbable lobes composed primarily of light that originated in an obscured, anisotropically radiating nucleus that has been scattered into the line of sight by dust or electrons. These limits are at variance with the recent detections of scattered light in the radio-aligned lobes in high redshift, FR II radio galaxies.

Sarazin and Wise are calculating the effects of optical depth and radiative transfer on X-ray emission from cluster cooling flows. Previous studies of X-ray emission from clusters have assumed the cluster to be optically thin; however, Sarazin and Wise find that resonance lines in clusters may be significantly optically thick. This opacity significantly affects the emergent spectrum.

Sarazin and Wise are calculating models for the X-ray emission in cluster cooling flows in which a fraction of the cooled gas is stored as cold, X-ray absorbing gas. The spectra of these models agree with recent observations of excess X-ray absorption in cluster cooling flows. Sarazin and Wise find that the spectra are distinguishable from foreground absorption in ways that should be detectable in ASCA spectra. Also, the absorption affects the X-ray surface brightness profiles, from which the local rates of gas cooling have been derived.

Whittle, Sarazin, and R. Gelderman (GSFC) are using long slit spectra and narrow band images to map out the distribution and kinematics of the optical line emitting gas in the cooling flow cluster 2A0335+096. Hopefully, this may lead to an understanding of the origin of the X-ray–radio–optical filaments in this system. Sarazin and Wise are measuring ASCA X-ray spectra of this system.

3.5 Cosmology

F. Fang (graduate student) and Saslaw have shown that by combining observations of both the luminosity and the spatial distributions of galaxies, it is possible to put strong constraints on galaxy merging evolution from moderate redshifts to the present. The method employs a master equation de-

scription for both the changes of galaxy mass and of the counts in cells resulting from merging. With additional assumptions about the effects of merging on the mass/light ratio, the results can be compared with evolution of the luminosity function in, say, the Autofib survey. To obtain agreement, galaxies fainter than L* must ultimately dim more than brighter galaxies after they merge. This also constrains models of merger induced starbursts. Examination of a range of models shows that agreement with observations becomes increasingly difficult if more than about 1/4 the galaxies have undergone major mergers since $z \lesssim 0.7$.

Saslaw and visiting graduate student S. Haque-Copilah (U. West Indies) analyzed the spatial and velocity distributions of about 4500 galaxies in the Pisces-Perseus supercluster. Preliminary results appear consistent with the supercluster forming gravitationally as an accumulation of smaller clusters. The best-fit values of b, representing the ratio of gravitational correlation energy to the kinetic energy of peculiar motions, is $b = 0.8$. This is close to the value obtained from larger, more statistically homogeneous catalogs.

Saslaw, S. Maharaj (U. Natal, South Africa), and N. Dadhich (IUCAA) have derived a new solution of the Einstein field equations which represents a class of isothermal inhomogeneous universes. Unlike the Tolman-Bondi models, these models have a non-zero pressure which balances gravity in a spherical, static metric. They are relatively stable to mechanical perturbations, and to perturbations of the density distribution and of the isothermal equation of state. It is possible that this may represent the asymptotic state of galaxy clustering in an $\Omega = 1$ Einstein-deSitter universe as if large inhomogeneities do not enter the horizon. These isothermal universes with nonzero pressure cannot be matched to the pressure-free Einstein-deSitter model across any specific $r =$ constant hypersurface. This implies that the global metric may undergo a discontinuous phase transition from uniform Robertson-Walker to spherical isothermal, driven by the changing equation of state.

Saslaw and R. Sheth (MPI) have extended the statistical thermodynamic theory of gravitational clustering in an expanding universe to include the volume scale dependence of the ratio, b, of gravitational correlation energy to thermal energy. The resulting form of the gravitational quasi-equilibrium distribution function is unchanged by this scale dependence. However the value of b is now determined self-consistently and this generalized theory contains no free parameters. The results explain the improved agreement between simulations, observations and theory, previously found empirically, when b was allowed to depend on scale. They also explain the relation between the three-dimensional volume distribution functions and the two-dimensional projected spatial distributions.

Sheth and Saslaw have tested the extended statistical thermodynamic theory more precisely against N-body simulations. Theory and simulations now agree to an accuracy of about 98%. At this level of comparison it is important to include the effects of softening the gravitational potential on the simulation.

Thuan, in collaboration with Y. Izotov (Kiev Observatory) and V. Lipovetsky (Special Astrophysical Observatory, Russia), have continued their work on the determination of the primordial helium abundance Y_p, using blue compact galaxies (BCGs). They find that the most metal-deficient BCG known, IZw18, cannot be used for this purpose because of its abnormally low He I line intensities. They have examined critically the systematic effects which may influence the determination of Y_p, and find that the effects of the corrections for neutral helium and for underlying stellar absorption of the He I lines, possible deviations from case B recombination theory, fluorescent enhancement of the He I line intensities, temperature fluctuations in H II regions, Wolf-Rayet stellar winds and supernova shock waves to be small. The main effect comes from the particular set of atomic data used. The best set of atomic data for use in the determination of Y_p is composed of Smits' (1995) He I emissivities and Kingdon & Ferland (1995) data in the $Y-$ O/H and $Y-$ N/H planes and corrects best the data for collisional enhancement effects. By extrapolating the Y vs. O/H and Y vs. N/H linear regressions to O/H = N/H = 0, they obtain $Y_p = 0.243 \pm 0.003$ for both regressions, considerably larger than the values derived before. In the framework of the standard hot big bang nucleosynthesis model with a number of neutrino families $N_\mu = 3$ and a neutron half-lifetime $\tau_n = 887$ s, the new Y_p gives a baryon-to-photon number ratio, or a baryonic mass fraction. This Y_p determination is fully consistent with measurements of the primordial ^{7}Li in Galactic halo stars and of (D + ^{3}He) in the local ISM and the solar system, and consistent at the 2σ level with the primordial D abundance derived in a quasar absorption system by Tytler, Fan, & Burles (1996). They derive a slope of $dY/dZ = 1.7 \pm 0.9$, considerably smaller than the slopes obtained before and consistent with chemical evolution models for star-forming dwarf galaxies with an outflow of well-mixed material. Extrapolation to solar metallicity with such a slope gives the correct solar helium mass fraction within the errors.

Thuan, Izotov, and Lipovetsky have obtained HST WFPC2 V and I images and GHRS UV spectrophotometry of the spectral regions around Lyα and O I 1302 of the extremely metal-deficient ($Z \sim Z_\odot/41$) blue compact dwarf (BCD) galaxy SBS 0335-052. All the star formation in the BCD occurs in six super-star clusters (SSC) with ages 25 Myr, within a region of ~ 2 arcsec or 520 pc in size. Dust is clearly present and mixed spatially with the SSCs. The SSCs are roughly aligned in the SE–NW direction, and there is a systematic increase in reddening of the clusters away from the brightest one. The observed color dependence on position may be the combined effects of differential extinction by dust and color evolution with time due to sequential propagating star formation. There is a supershell of radius ~ 380 pc, delineating a large supernova cavity. The instantaneous star formation rate is $\sim 0.4 M_\odot$ yr^{-1}. Strong narrow Lyα emission is not observed. Rather there is low intensity broad (FWZI = 20 Å) Lyα emission superposed on even broader Lyα absorption by the H I envelope. This broad low-intensity emission is caused by resonant scattering of Lyα photons. The absence of strong Lyα emission may be due partly to dust absorption, but mainly to multiple scattering which removes Lyα photons from the small HST aperture.

As the H I cloud is seen nearly edge-on, geometrical effects may also play a role as photons escape more easily in a direction perpendicular to the plane than along it. The BCD appears to be a young galaxy, undergoing one of its very first bursts of star formation. This conclusion is based on the following evidence: 1) the underlying extended low-surface-brightness component is irregular and filamentary, suggesting that a significant part of the emission comes from ionized gas. Any underlying stellar population must be younger than $\sim$108 Myr. 2) the underlying component has very blue colors ($-0.34 \lesssim (V-I)_0 \lesssim 0.16$), consistent with gaseous emission colors; 3) the O I 1302 line is not detected in absorption in the GHRS spectrum, setting an upper limit for N(O)/N(H) in the H I envelope of the BCD of more than 3000 times smaller than the value in Orion.

3.6 Solar System

T. Encrenaz (DESPA, Observatoire de Paris), E. Serabyn (Caltech), and Weisstein obtained spectra of Uranus and Neptune in the 190–310 GHz frequency range (i.e., $6.3-10.3$ cm^{-1}, wavelength range $1.0-1.5$ mm) with the FTS. The data had a spectral resolution of 7.2 GHz and were analyzed in a search for CO and PH_3. Encrenaz *et al.* detected neither the CO 2–1 transition at 230 GHz nor the PH_3 1–0 transition at 267 GHz. The absence of a detectable absorption feature at the position of the CO 2–1 line favors a CO tropospheric mixing ratio lower than 5×10^{-7} in Uranus and 1.0×10^{-6} in Neptune (3σ limits). In the case of Neptune, a tropospheric mixing ratio of 6×10^{-7} seems to be in best agreement with all extant low-resolution data for CO. In the case of Uranus, a PH_3 enrichment stronger than a factor 4 can be excluded. Encrenaz *et al.* found no evidence for a strong PH_3 supersaturation in either Uranus or Neptune.

Goldstein and H. Bailey (Rose-Hulman Institute) have used numerical integration to study hypothetical satellites of Jupiter whose sidereal periods range from 19 to 200 years. The outermost known satellites have sidereal periods near two years. The hypothetical satellites all have orbits in the synodic reference frame with Jupiter at the center, and the side facing the Sun is flattened relative to that opposite the Sun. A diameter perpendicular to the Jupiter-Sun line is about twice that on the line. Each synodic cycle differs randomly from the others. We found five non-critical orbits (all retrograde) that are stable for more than a million years. Similar calculations were made by Benest (1971) of the Observatoire de Nice over about a hundred years. Goldstein developed methods of searching for real satellites in these distant orbits, based on a telescope that can track accurately at Jupiter's known angular rate. The satellites would have very nearly Jupiter's rate and would thus form seeing-disk images. Background stars or minor planets would form trails, one of whose dimensions would be larger than the seeing disk.

Goldstein and K. Jacobs (Hollins College) recalculated the acceleration of Io from longitude and mean-motion comparisons between the 17th century observations of Picard and Roemer and the 20th century observations of Innes (Goldstein & Jacobs 1995). Goldstein is engaged in the analysis of the accelerations of all four Galilean satellites, considering tidal coupling on Io and magnetic drag on Ganymede.

Weisstein and Serabyn (Caltech) used a Fourier transform spectrometer (FTS) at the Caltech Submillimeter Observatory to search for the rotational transitions of a number of molecular species in the atmospheres of Jupiter and Saturn in all available submillimeter atmospheric windows between 300 and 1000 GHz (1000 and 300 μm). The molecules searched for include the saturated molecules PH_3 and H_2S, the hydrogen halides HCl and HBr, the alkali hydrides LiH and NaH, as well as HCN and HCP. Weisstein and Serabyn detected a strong absorption feature at 800.5 GHz corresponding to the $J=3-2$ transition of PH_3 in both Jupiter and Saturn. They also tentatively observed a feature coincident with the $J=1-0$ transition of HCl in Saturn. They did not detect any other molecules in either planet, setting stringent limits on most of the species listed above. The FTS measurements set an upper limit of 0.3 ppb on the HCN mole fraction in Jupiter if HCN is distributed with a constant mixing ratio. This concentration is significantly lower than the purported infrared detection of Tokunaga *et al.* (1981). A conservative upper limit of 0.4 ppb is obtained for Saturn, although the molecule may actually be present in Saturn with that abundance. If condensation of HCN is included, the deep tropospheric HCN limits are increased to 2 ppb for Jupiter and $\sim$15 ppb for Saturn. Weisstein and Serabyn set a tropospheric HCl upper limit of 5 ppb in Jupiter, and have tentatively detected this molecule at a mole fraction of 1.1 ppb in Saturn. Weisstein and Serabyn also set HBr upper limits of 7 ppb in Jupiter and 1.1 ppb in Saturn, indicating that Cl is strongly depleted relative to the solar abundance in the upper troposphere of Jupiter and Saturn, but the tentative detection of HCl in Saturn suggests that vertical transport is rapid compared to the chemical lifetime of HCl.

Weisstein and Serabyn detected the $J=3-2$ transition of PH_3 at 800.5 GHz (375 μm) in Jupiter, and observed it to be a deep ($\sim$20%), strongly pressure-broadened absorption line with a full-width at half-maximum of 9.6 GHz. The lineshape of this transition is quite sensitive to the distribution of PH_3 in the upper troposphere of Jupiter. Using a radiative transfer model which constrains the PH_3 vertical profile to approach a constant mixing ratio in the ''deep'' ($\geq$0.6 bar) atmosphere, Weisstein, Serabyn, and M. Allen (Caltech) derived a PH_3 mole fraction which falls off with increasing height. The best-fit deep PH_3 mole fraction of 0.6 ± 0.2 ppm is consistent with infrared results, but the slope of the PH_3 falloff in the upper troposphere is steeper than that inferred from both infrared measurements and previous photochemical models. Using a simplified photochemical model with updated photodissociation cross-sections for PH_3, Weisstein *et al.* found that an upper tropospheric eddy diffusion coefficient of $K=10^4-10^6$ cm^2 s^{-1} and a deep tropospheric value of $K\geq10^8$ cm^2 s^{-1} are required to match the derived PH_3 profile. Weisstein *et al.* interpreted the transition region between these two eddy diffusion regimes as Jupiter's radiative-convective boundary.

3.7 Astrometry

The recently published parallax list from the McCormick refractor marks the end of an era as the last such list likely to be published. Parallax observations have now ceased with the McCormick refractor owing to the discontinuance by Kodak of the 103a-G emulsion and the coverage of the majority of the program stars by HIPPARCOS.

Ianna, Patterson, and Begam are continuing the CCD parallax program at the Mount Stromlo and Siding Spring Observatories using the 1 m reflector. Emphasis has been placed on brighter stars ($m \sim 13$) from the Catalog of Nearby Stars. These objects are easily observed with very good S/N, and we have been achieving precisions of $1-2$ mas at this telescope (focal plane scale of 25.4 arcsec mm^{-1}). Patterson and Ianna plan to begin a limited program to obtain parallaxes for a small sample of very low luminosity objects in the infrared in collaboration with H. Jones and M. Hawkins (ROE).

Ianna continues to collaborate with T. Henry (STScI) and D. Kirkpatrick (UCLA) to identify new nearby star candidates in the southern hemisphere by means of *JHK* photometry and IR spectroscopy. Two observing runs have confirmed several likely nearby stars and revealed several new very late M dwarfs in the Wroblewski and Torres proper motion survey. A number of the new objects have been added to the southern parallax program.

Majewski and K. Cudworth (Yerkes Obs.) have continued their program to derive absolute proper motions with respect to galaxies for a sample of distant (>20 kpc) halo globular clusters and dwarf spheroidals. In the past year, in collaboration with A Schweitzer (U. Wisconsin), they have derived proper motions for the Sculptor (Schweitzer et al. 1995) and Ursa Minor (Schweitzer, Cudworth, & Majewski, in preparation) dwarf spheroidals. They are now beginning work on the Draco dwarf spheroidal galaxy and the globular cluster Pal 15.

Majewski has just begun a program on the DuPont 100-in telescope at Las Campanas to repeat photographic observations of the mid-declination (-15 to +15 degree) Kapteyn Selected Areas. The goal is to match the original plates taken by Seares, Kapteyn and van Rhijn at the turn of the century on the Mt. Wilson 60-in telescope, for proper motions of exquisite (<0.1 arcsec/century) precision to $V \sim 19$, tied to the extragalactic absolute reference frame. The 55 Selected Areas with $|b|>20$ degrees will allow an assessment of the halo two point correlation function in phase space as a means to search for and map large scale streaming motions in the halo.

3.8 Space Astronomy

Fredrick continues as a member of the HST Astrometry Team.

R. Goldstein (JPL) and Goldstein completed a study of 831 particles observed with bistatic 3.5 cm radar at the Goldstone Observatory. These objects have altitudes between 177 km and 1662 km and radar cross sections between 0.02 mm^2 and 260 mm^2. All are potentially destructive to spacecraft. Their flux has a maximum value of 3.3 particles km^{-2} day^{-1}. Goldstein and Goldstein's paper gives a table that allows orbit designers to minimize the probability of impacts with debris. Observations continue with a new ranging system that detects debris with altitudes up to 3000 km.

O'Connell continues as a Co-Investigator for the Ultraviolet Imaging Telescope of the *Astro-2* Spacelab payload, which successfully flew on a 16-day Space Shuttle mission during March 1995. UIT obtained a total of 757 far-UV (1500Å) images of 193 different targets, ranging from the Moon to distant quasar fields. He is also a Co-Investigator on the Hopkins Ultraviolet Background Explorer project, which was selected as an alternate to MAP as a NASA MIDEX mission, and a Co-Investigator on the IRIS tuneable, wide-field, UV imaging project, which is under conceptual study for a new NASA mission.

4. MISCELLANY

Chevalier was elected to the National Academy of Sciences and was awarded the 1996 Dannie Heineman Prize for Astrophysics by the American Astronomical society. Fang received the Gwathmey Award for the best graduate student research in science and engineering at U.Va. for his thesis ''Nonlinear Gravitational Galaxy Clustering.'' He also received the Physics Award of Sigma Xi for this work. Hawley served on the review panel for the NASA Origins of Solar Systems program, and the review panel for the NASA Astrophysical Theory Program. Ianna served as Chair of the Division on Dynamical Astronomy, Vice-President of IAU Commission 24 (Photographic Astrometry), and as a technical consultant to CSICOP, and was appointed to the Board of Directors of the International Dark-Sky Association. O'Connell served as a member of the NASA Astrophysics Science Operations and Data Analysis working group, as a member of the American Astronomical Society Investments Advisory Committee, and on the scientific organizing committee of the Crete conference on applications of stellar physics to stellar populations. Richards served as a panel reviewer for the National Science Foundation Graduate Fellowship Program. Sarazin was a member of the ASCA Users' Committee, the AXAF Users' Committee, the Heineman Prize Committee of the American Astronomical Society, the Kitt Peak Dark Time Allocation Committee, and the scientific organizing committees of the Tokyo Conference on X-ray Imaging and Spectroscopy of Cosmic Hot Plasmas and of the Israel Conference on Cluster Cooling Flows.

As part of our public outreach program, approximately 2060 visitors toured the McCormick and Fan Mountain Observatories during the year.

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