This report covers the period 1 September 1994 to 31 August 1995.

I. PERSONNEL

During this time the departmental faculty consisted of Steven A. Balbus, Roger A. Chevalier, Laurence W. Fredrick, John F. Hawley, Philip A. Ianna, Shiv S. Kumar, 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. Fredrick retired with Emeritus status at the end of the 1994-1995 academic year, and the department sponsored a symposium entitled "Astrometry in the 20^{th} Century" in his honor. Steven Majewski was appointed Assistant Professor effective 1 September 1995. William W. Dalton served as a Lecturer during the year. Samuel J. Goldstein continued as Emeritus professor. Sarazin acted as Chairman until 1 August 1995, when O'Connell became Chairman.

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. Pamela Marcum was a postdoc during this period, while Carolyn Cox, Maxim Markevitch, Marina Murzina, and Duane Rosenberg arrived as postdocs at the end of the period.

Visitors under VITA auspices for the year included N. Chugai (Moscow), R. Dickens (RGO), A. Ferrera (Arcetri), R. Greenlaw (Leeds), Y. Isotov (Kiev), R. Kirshner (Harvard), R. Peterson (Lick), M. Shull (Colorado), J. Stone (Maryland), and T. Wilson (MPI).

Jonathan V. Brinkmann resigned as Research Scientist effective 30 September 1995. 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 and Cliff Mawyer continued as electronics technician and instrument maker, respectively. Virginia Bossong and Jacquelynn Harding continued as our secretaries. Willie J. (Nick) Nichols is the resident caretaker at the Fan Mountain Station.

There were 19 graduate students in residence at the end of this period. William Dalton, Gregory Hennessy, and Richard Patterson completed their Ph.D.s during the year.

II. FACILITIES

The 67 cm Leander McCormick refractor on Mount Jefferson and the 1 m reflector on Fan Mountain were used during the year for our astrometric programs, and for student research and training. A new RA drive system has been designed for the 1 m to include a stub axle bearing at the south end of the polar axis. The modifications are being carried out by DFM Engineering. In the southern hemisphere, the 66 cm Yale-Columbia refractor at Mount Stromlo Observatory continues to be available to the parallax program on a full time basis, although the observing emphasis has been on the CCD program on the 1 m at Siding Spring Observatory. During the year there were approximately 1940 visitors to the McCormick and Fan Mountain Observatories as part of our continuing public night programs.

The Perkin-Elmer PDS 1010GM microdensitometer was used for scanning parallax program plates. David Stokes and Shi Dan of the UVA Medical School (Physiology) also used the machine during the year.

III. RESEARCH

a. Stars and Stellar Evolution

G. Albright (graduate student) and Richards have extended their long-term observational program to obtain full-orbit Hα spectra of Algol-type binaries. In December 1994, they observed RZ Cas, TV Cas, TW Cas, U CrB, SW Cyg, RY Gem, TT Hya, AU Mon, β Per, RW Tau and TX UMa, as well as the RS CVn binary HR 1099. All observations were obtained during 7 nights with the 0.9 m Coudé Feed Telescope at Kitt Peak National Observatory (KPNO). They now have full-orbit coverage of 14 Algols with limited coverage of 4 others. As done previously, these spectra were converted to difference profiles by subtracting the theoretical absorption line profiles of the stars from the observed spectra. The Hα difference profiles contain evidence of double-peaked emission features at most phases outside of primary eclipse, and excess absorption at phases throughout primary eclipse. The strength of these absorption/emission features was typically within $\sim$ 30% of the quadrature continuum flux of each system. These profiles can be modeled in terms of accretion structures near the primary star which include the gas stream and transient circumprimary annuli. The spectra will be used to calculate the electron size, density and mass of the circumstellar gas and also the mass transfer rate.

Albright and Richards organized a multi-site, multi-wavelength observing campaign during their

December KPNO run. As in an earlier campaign in June 1994, the aim was to obtain simultaneous optical and radio continuum observations to discern the relative contributions of chromospheric emission associated with the magnetically-active secondary and the products of Roche-lobe overflow on the observed Hα line profile. Simultaneous Hα spectra of β Per were obtained with the help of P. Koubský at Ondřejov Observatory in the Czech Republic. The multi-site observations permitted coverage of the orbit of β Per within a much shorter time than is currently possible from one site. At the same time, E. Murphy (graduate student) searched for 8 GHz radio flaring activity from β Per and HR 1099 with the NRAO 140 ft. telescope at Green Bank Observatory. This was done during a time-shared cooperative observing effort with Rood, T. Bania (BU), and D. Balser (BU, NRAO).

J. Stone (U. Maryland) and Balbus carried out three-dimensional hydrodynamic simulations of convectively unstable sections of Keplerian accretion disks. Both their analytic and numerical studies indicate that convective instabilities do not, in general, lead to the outward transport of angular momentum in such disks. Convection therefore cannot be a source of anomalous viscosity in accretion disks.

Balbus, Hawley and Stone, through a combined analytical and numerical approach, have examined the hydrodynamic stability of shearing flows and accretion disks to finite amplitude perturbations. Although shearing flows are unstable to such perturbations, Keplerian disks are found to be nonlinearly stable. A simple analytic analysis shows that the key to nonlinear stability is the interaction of correlated velocity fluctuations with mean flow gradients. In accretion disks such fluctuations interact with the mean angular momentum gradient to act as a sink for angular momentum fluctuations, thereby damping out any turbulence present. This investigation extends the Stone and Balbus findings and rules out any kind of self-generated hydrodynamical turbulence as a source of anomalous viscosity in disks.

Balbus has carried through an extremely general study of the stability of magnetized stars and disks in which the rotation rate depends upon both radial and vertical coordinates. The analysis of a purely hydrodynamical, unmagnetized system leads to the classical Hoiland criteria for stability. When a magnetic field is included, however weak, the criteria changed abruptly. Instead of depending upon angular momentum gradients, the criteria instead depend upon angular velocity gradients; their form remains otherwise unchanged. Because of the ubiquity of magnetic fields, the classical Hoiland criteria are of very limited applicability.

Chevalier continued to investigate steady neutron star accretion with neutrino losses. This can occur in a dense environment such as the interior of a supernova or inside a stellar envelope during a spiral-in phase. With spherical accretion, there is a critical accretion rate, $\dot{M}_{cn}$, below which steady flow is not possible because of radiative diffusion effects. When rotation of the gas is allowed, the centrifugal support lowers the flow pressure and keeps gas from directly reaching the neutron star surface. The value of $\dot{M}_{cn}$ is correspondingly raised, either because of radiative diffusion or because the shocked envelope around the neutron star reaches the characteristic accretion radius. Even if a disk does form and viscous angular momentum transport occurs, the value of α in a steady α-disk model must be small in order to allow a balance of neutrino cooling and viscous heating. For SN 1987A, these considerations reinforce the arguments that either a black hole is accreting dense gas or there has been mass loss from the envelope around a central neutron star. Neutrino cooling may aid the formation of a dense disk around a newly formed neutron star. For spiral-in of a neutron star through a massive star envelope, rotation may prevent rapid accretion for even a fairly compact envelope. The radius of the shocked region becomes greater than the radius of the sonic point in the accretion flow; the sonic radius depends on the relative importance of gas and radiation pressure in the stellar envelope. However, neutron star spiral in to a stellar core is likely to be accompanied by strong accretion, making it difficult to form stars with neutron star cores in this way.

Chevalier, with N. Chugai and R. Kirshner (Harvard), has modeled an HST spectrum of SN 1987A at an age of 8 years. They find that the expanding ejecta have cooled to a temperature of several hundred K, but excitation by radioactivity continues to give low ionization metal lines. The likely energy source is positrons and γ-rays from ^{44}Ti decays. The strength of the Fe lines suggests that the positrons are mostly trapped in clumps of Fe. The Hα emission is primarily from the recombination of previously ionized hydrogen. The ionized fraction in the iron-rich material is small (0.2–0.3) and the total net emission from Fe I should be comparable to that from Fe II. The intensity of the [O I] λ6300 doublet is consistent with that expected from the deposited energy of γ-rays from ^{44}Ti decays. There is no evidence for a power source associated with the central compact object at the level of $\sim 10^{37}\,\mathrm{ergs\,s^{-1}}$.

N. D'Cruz (graduate student), B. Dorman (NASA/Goddard), Rood and O'Connell are investigating the origin of extreme horizontal branch (EHB)

stars. It has been suggested that UV radiation from EHB stars and their progeny contributes greatly to the UVX phenomenon in spiral bulges and elliptical galaxies. EHB stars are believed to result from extreme mass loss during the red giant branch (RGB) phase. With the incorporation of mass loss into their stellar evolution code, they model mass loss in red giants over a large range in metallicity using Reimers' formula. Strong mass loss causes stars to peel-off the RGB. Some peel-off stars ignite helium at high temperatures and form a blue hook at the blue end of the zero-age horizontal branch (ZAHB). The blue hook extends about 0.15 mag below the ZAHB. Its stars are a part of the EHB population and evolve into AGB-manqué stars. This work shows that EHB stars can be easily produced at all metallicities. The range and values of the Reimers' mass loss efficiency parameter used to create EHB stars are comparable to those estimated for the normal HB and is roughly constant with composition. For solar metallicity and higher, the HB becomes bimodal and the population of mid-HB region decreases.

D'Cruz, Rood, R. Dickens (Bristol) and D. Hatzidimitriou (Crete) are analyzing spectra of 480 blue horizontal branch stars in the globular cluster ω Centauri to obtain temperatures, gravities and Ca abundance for the stars. The objective is to identify the primary physical parameters which cause the Oosterhoff dichotomy in globular clusters. Simulated HB distributions will be used to allow for evolution from the ZAHB.

Dalton and Sarazin 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. Dalton and Sarazin consider the possibility that the high luminosity MC X-ray sources contain high mass black holes radiating near their Eddington luminosity, and that such high mass black holes are more likely in the MCs because the lower metallicities result in lower stellar mass loss rates and more massive stellar remnants. They suggest that only the upper end of the HMXRB luminosity function has been identified in the Clouds, and that a number of the unidentified X-ray sources detected by the *Einstein* Observatory may in fact be intermediate

luminosity HMXRBs. The models for the population of HMXRBs, which are normalized by the observed star formation rates in these galaxies, are in good agreement with the detected numbers of HMXRBs, at least if the unidentified sources are indeed HMXRBs.

Dalton, Chevalier, and Sarazin are determining the effect which large supernova kick velocities can have on the properties of high mass X-ray binaries. The large kicks suggested by recent studies of radio pulsars can unbind HMXRBs and reduce their numbers.

Hawley, C. Gammie (CfA), and Balbus have continued their investigation of the nonlinear behavior of the weak field magnetohydrodynamic (MHD) instability present in accretion disks. They have done extensive simulations of the instability in a Keplerian shearing-sheet system using a three-dimensional MHD computer code developed by Hawley. These simulations demonstrate that the weak-field accretion disk instability, found earlier by Balbus and Hawley, constitutes a hydromagnetic dynamo. Because all aspects of the resulting flow, the dynamo mechanism, the turbulence, and the angular momentum transport depend upon the Lorentz force, their results imply that the kinematic dynamo approximation is always inappropriate for accretion disks.

J. Stone (U. Maryland), Hawley, Gammie and Balbus have carried out numerical simulations of stratified accretion disks. A variety of initial field topologies and strengths have been examined as well as disks with isothermal and adiabatic equations of state. Buoyancy does not affect the linear growth of the instability, nor does it seem to determine the saturation amplitudes.

M. Ratliff (graduate student) and Richards have performed hydrodynamical simulations of β Per, TT Hya, and AU Mon to study the structure of Hα emitting gas flows in Algol-type binaries as the orbital period is increased from 2.9 days to 11 days. In the closer binaries, the free fall trajectory of the gas stream intersects with the surface of the mass gainer, so the gas makes direct to grazing impact with the star. This event results in the formation of a structure which is distinct from the classical accretion disks seen in the long-period Algols or cataclysmic variables. Instead, an asymmetric circumprimary annulus forms close to the photosphere of the star. With increased separation between the stars, the annulus is transformed into a classical Keplerian accretion disk. For each binary, both spatial and velocity maps were made to permit direct comparison with the observationally generated Doppler tomograms.

Richards has used the technique of Doppler tomography to produce reconstructed images of Hα

emission sources in Algol binaries. With the help of R. Jones (Mitre Corp.) and M. Swain (UVa), Doppler images of β Per were obtained from Hα difference profiles collected on 1976/77 photographic plates. These images show gas flow predominantly along the predicted gravitational trajectory. However, when the data set was broken into two parts to exclude the influence of the gas stream, several other Hα emission sources were found. These include an unstable asymmetric accretion annulus containing a denser localized region. In addition chromospheric emission was detected in the Doppler image at the location of the magnetically active secondary star.

Richards also used Hα CCD spectra obtained at KPNO and NSO from 1992–1994 by G. Albright (graduate student) and herself to produce Doppler images of eleven Algols as well as the RS CVn binary HR 1099. This work has demonstrated the existence of gas streams and unstable sub-Keplerian accretion annuli in the short-period Algols with $P < 3$ days (e.g., β Per, TX UMa); a combination of gas streams and quasi-stable accretion disks for systems with $P \sim 3$–5 days (e.g., U Sge, U CrB, SW Cyg); and much more stable accretion disks when $P > 6$ days (e.g., TT Hya). There was also evidence of chromospheric emission in the systems with $P < 6$ days, where the strength of that emission was comparable to other emission sources. Further analysis of the Doppler images is in progress.

Richards, M. Arevallo (Teide Observatory, Tenerife) and C. Lazaro (Astrophysical Institute of the Canaries) are continuing their long term monitoring of JHK infrared photometry of Algol binaries with the aim of obtaining star spot models.

Richards and J. Blondin (NCSU) are continuing their 2-D and 3-D hydrodynamical study of Roche lobe overflow. Their work will concentrate 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 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 have obtained IUE time during 1996 ESA shifts to observe NEAs and will continue their long-term project to obtain simultaneous Hα and ultraviolet spectra of NEAs and classical eclipsing Algols.

Richards has collaborated with E. Waltman (NRL), R. Foster (NRL), and F. Ghigo (NRAO) to

monitor the 2 GHz and 8 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 has been monitoring flare activity since 1995 January. Several strong flares with strengths up to 0.8 Jy at 8 GHz were detected from β Per and HR 1099, but no flares have been confirmed from δ Lib.

Rood, R. Peterson (Lick), and D. Crocker (U. Alabama) continue their investigation of rotation, abundances, and diffusion in blue horizontal branch (BHB) stars. They have found that the distribution of rotation differs significantly among the clusters M13, M3, and NGC 288. Further data has been obtained for ω Cen and NGC 6752.

J. Whitney (graduate student), O'Connell, and Rood have developed a new method of translating theoretical evolutionary tracks to the color-magnitude diagram using image processing techniques to predict stellar densities. An image of a CMD begins as a blank array, with counts placed corresponding to the amount of time evolving stars stay in a portion of the diagram. Areas with highest array count levels represent the expected highest stellar densities. Results have been compared with the observed data sets of the globular clusters M3, M5, and M13. Stellar counts in various portions of the CMD agree well with those predicted by theory.

Whitney, O'Connell, and Rood are continuing to analyze far-UV photometry of the globular cluster ω Cen, obtained with the UIT/Astro-1 instrument. Radial distributions of stars with different colors are being derived. The preliminary result is that the blue objects are not concentrated in the cluster core, which is not necessarily surprising since ω Cen is not very evolved dynamically. The cooler HB stars ($T_e < 15,000$ K) fit theoretical tracks very well, but there is a conspicuous break in the density of HB stars at $T_e \sim 16,000$ K. Bluer than this many stars are fainter than the predicted location of the HB at [Fe/H] $= -1.5$. Many stars are near to or hotter than the locus of zero envelope HB and post-HB tracks. Some of these could be on the white-dwarf cooling curve; for others, the unusual colors could be produced by strong line emission. Imaging simulations currently being conducted for ω Cen's CMD explicitly including the known metallicity dispersion will determine the expected numbers of stars and the statistical importance of the break in the HB.

A number of the UV-bright stars in ω Cen are being pursued spectroscopically. With W. Landsman and T. Stecher (GSFC) and A. Crotts (Columbia U.), Whitney, O'Connell, and Rood are studying

spectra obtained with the CTIO 4 m and/or IUE of eleven of the brightest of these stars. Three have $T_e \sim 60,000$ K and show only Balmer lines and He II lines. These appear to be in the post-asymptotic giant branch phase and are the hottest stars ever found in a globular cluster. An analysis of the He lines in an attempt to directly measure the primordial He abundance is being made. A separate HST program involving UV spectroscopy of 6 extreme UV stars is under way. Two fields have been observed in the far-UV and V bands with WFPC2 in order to measure offsets and to perform more accurate UV photometry than possible with the UIT data.

b. Interstellar Medium

V. Dwarkadas (graduate student), Chevalier, and J. Blondin (NCSU) have modeled planetary nebulae (PNe) in the context of the interacting stellar winds model. If the two interacting winds have constant properties, the velocity of the PN shell tends towards a constant with time and the shape becomes self-similar. Additionally, if the fast wind velocity is much higher than the expansion velocity of the shell, the interior of the hot shocked bubble becomes isobaric. They have calculated shapes of PN in the self-similar stage, both analytically and using hydrodynamic simulations. An asymmetric density profile was assumed for the outer "slow" wind, with the asymmetry modelled by different functions. They have included the effects of the ambient wind velocity, which have not received much attention since the work of Kahn & West (MNRAS, 212, 837, 1985). They find that the morphological appearance of the PN is a consequence of three factors—the density contrast from equator to pole, steepness of the density profile and velocity of the ambient medium. Classification based only on the former two factors can be misleading. The ambient wind velocity plays a large part in determining the shape of the nebula. In particular, the ambient wind velocity is effective in determining whether the nebula shows a bulge or a cusp at the equator. The effects of the other parameters have also been studied in detail. In addition, they have investigated shapes of PNe resulting from an asymmetric velocity profile being present. Their numerical simulations revealed that PN shells are corrugated because of Kelvin-Helmholtz instabilities. A ratio of interior sound speed to shell velocity ≥ 10 yields nebulae whose shapes match those given by the isobaric approximation.

Dwarkadas and Chevalier are studying the interaction of supernova shock waves with a high density shell. Type II supernovae usually arise from massive

($> 8\,M_\odot$) progenitor stars. Mass loss from these stars in the pre-explosion stage can lead to matter accumulating around the star in the form of a shell of dense material. Some Wolf-Rayet stars in particular are surrounded by thick, dense shells. If the star explodes as a supernova, the resulting supernova shock wave will eventually interact with this circumstellar shell. They are studying this interaction numerically using the Zeus-2D code. Comparisons will be made to the analytical work of Chevalier & Liang (ApJ, 344, 332, 1989). Special attention is being paid to the cases of SN 1987A, Cas A, and W44.

Rood, T. Bania (BU), D. Balser (BU, NRAO) & T. Wilson (MPIfR) are continuing their project to determine the cosmic abundance of ^{3}He. The abundances range from $^3\mathrm{He/H} = 1\text{–}5 \times 10^{-5}$. The observed distribution of ^{3}He in the Galaxy is in conflict with the predictions of chemical evolution models. This has spurred further observations of the stellar ^{3}He "source term"—planetary nebulae. Additional observations of PNe have been obtained with the 100 m Effelsberg radio telescope. Selecting only the highest quality data, the ^{3}He line in NGC 3242 now appears to have the non-gaussian line shape expected for an expanding shell. Other PNe show indications of ^{3}He as well. Observations of H II regions continue at the Green Bank 140 ft. telescope. These are now focused on outer Galaxy sources where little ^{3}He enhancement is expected and on sources morphologically similar to previously detected "high abundance" sources.

Sarazin, K. Borkowski (GSFC), A. Szymkowiak (GSFC), and J. Blondin (NCSU) have undertaken a comprehensive effort to model the Cas A SNR, through one- and two-dimensional hydrodynamical simulations coupled with nonequilibrium X-ray emission calculations. They model Cas A in the framework of the circumstellar shell interaction model. In this model, it is assumed that a slow red supergiant wind of the SN progenitor was swept into a dense shell by a fast stellar wind in the subsequent blue supergiant stage of the progenitor star. The supernova blast wave propagates quickly (~ 100 yr) through the wind-blown bubble located within this shell, and then slows down in the dense ($n_H \sim 10\,\mathrm{cm}^{-3}$) CSM shell. During the subsequent interaction, the shell is accelerated to $2000\,\mathrm{km\,s}^{-1}$, the currently observed expansion rate. The comparison of these X-ray emission calculations with the ASCA spectrum suggest that about $5\,M_\odot$ of X-ray emitting material is present in Cas A, and more than half of this mass is located in the CSM shell and in the outlying red supergiant wind. The remainder belongs to the SN ejecta; this is where the strong Si and S lines must be produced.

Sarazin, Borkowski, and R. McCray (Colorado) are calculating detailed models for the X-ray emission to be expected from SN 1987A when the blast wave hits the dense shell around the remnant.

c. Galaxies and Active Galactic Nuclei

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 the 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.

O'Connell and R. Grant (undergraduate student) have made a study of the starburst wind-driven plume emerging from M82 using broad-band UBVR and Hα interference filter images. They have traced Hα emission to a distance of 6 kpc from the main body and are mapping the equivalent width of Hα and fine structure in the plume. As expected from earlier spectroscopy, there are anomalously few H II regions found in the main body of the galaxy at radii larger than 1 kpc.

O'Connell and Marcum are analyzing high precision 3300–10000 Å spectrophotometry of two regions in M82 using a linear programming optimizing synthesis technique. They extract information on both extinction by dust (internal and external) and the history of star formation. The central region (M82 A) is found to have considerable internal as well as external extinction and a population including recently-formed OB stars, while the disk region (B) has much less extinction, none internal, and had its last significant burst of star formation $\sim$ 100 Myr ago.

With B. Dorman (GSFC), O'Connell is investigating the utility of mid-UV (2000–3200 Å) spectra of galaxies as diagnostics of age and abundance. The work is based on Dorman's grid of isochrones for systems older than 1 Gyr with a range of metallicities; it employs Kurucz (1992) atmospheres. The mid-UV is found to be quite sensitive to age and abundance; preliminary evidence is that the infamous "age-abundance degeneracy" can be readily broken using UV observations.

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 3C 171. 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. Based on the I-band and X-ray images, 3C 171 does not appear to be associated with a rich cluster of galaxies, although association with a poor cluster or group has not been excluded. These and other observations support the conclusion that strong radio-optical alignments can occur at low redshifts in relatively isolated FR II radio galaxies, as well as in the cores of nearby rich clusters along weaker, FR I radio sources. The data do not constrain definitively the emission mechanism for the aligned blue continuum in 3C 171. The radio and blue-lobe morphologies suggest nuclear radiation that is collimated along the jet axis and scattered into the line of sight, or star formation as strong candidates. The absence of detectable X-ray emission may favor dust scattering rather than electron scattering. The V-band light from the radio galaxy is, however, unpolarized, although dilution of a polarized component by stellar continuum and emission lines may be occurring to some degree. On the other hand, the kinematic evidence for entrained gas along the lobes and the absence of polarized light are consistent with radio-triggered star formation.

R. Spiker (graduate student) continued his study of the dynamical origins of the correlation of the luminosity function of H II regions with galactic Hubble type, with particular emphasis upon the dynamics of the spiral arm–ISM interaaction. This work will comprise Spiker's PhD thesis.

Whittle and A. Wilson (U. Maryland) have continued their study of the Seyfert galaxy Markarian 78 using the HST. Following their earlier work using narrow band images, they were awarded time to take UV and optical spectra at a number of locations across the extended emission line region. These are intended to probe the velocity field and ionization structure of the emission region. Since there is a relatively strong jet-like radio source present, these observations should highlight the role played by the jet in its interaction with the emission line region.

Whittle and C. Nelson (STScI) have continued their study of the nuclear stellar velocity dispersions of Seyfert and radio galaxies. These measurements, perhaps more than any other, characterize the depth of the near nuclear gravitational potential. They have

found that many of the properties associated with nuclear activity are related to this nuclear potential. In particular, their recent work has focused on how the radio source properties depend on the bulge mass. There is good evidence for a single continuous relation between galactic scale radio luminosity and the bulge potential, spanning a factor 10^7 in radio luminosity, thereby connecting radio quiet and radio loud AGN populations. Thus, the often cited tendency for Seyferts to be spirals and radio galaxies to be ellipticals is seen to be a more fundamental dependence of radio luminosity on bulge mass. Further continuity between Seyferts and radio galaxies is found in their Faber-Jackson relation. Both Seyferts and radio galaxies show a tight correlation between stellar velocity dispersion and bulge luminosity, but the locus is offset from the relation for normal galaxies. Thus, active galaxies seem to have systematically lower mass to light ratios, suggesting that their recent histories have included more star formation than normal galaxies. The work has been submitted for publication in the ApJ.

Whittle and K. Plett (undergraduate student) have looked for factors which influence the velocity field of the broad line region in Seyfert galaxies. They measured Hβ line widths for a large sample of Seyfert 1 galaxies, and gathered data on narrow line region properties and properties of the host galaxy. In a correlation study, they were able to identify moderately strong correlations between the broad Hβ line width and tracers of the bugle gravitational field; specifically, the [O III] line width, the bulge luminosity, and the stellar velocity dispersion. While other factors are clearly at work, it does seem that a significant portion of the ionized gas velocity field on highly nuclear scales is linked, directly or indirectly, to the depth of the gravitational potential on much larger scales. This highlights the importance of the bulge potential in setting the stage for the manifestation of nuclear activity from kpc scales down to sub-pc scales.

Whittle and C. Moss (Cambridge) have continued their study of star formation in cluster spirals. Using the JKT in La Palma, they imaged over 100 spiral galaxies in Hα and R. The galaxies were selected from their objective prism survey of 6 rich Abell clusters, and were therefore known to be strong Hα emitters. In the present study, the spatial distribution of Hα is ascertained. This provides a calibration of their objective prism estimates of Hα distribution, but more importantly it provides insight into the triggering mechanism for the star formation. Their previous objective prism work established that, relative to the field, the cluster environment can trigger significant

star formation in early type galaxies, but can suppress star formation in late type galaxies. By obtaining more detailed information on the star formation within individual galaxies, they hope to establish the nature of the triggering mechanisms and thereby gain insight into why it seems to be dependent on Hubble type.

d. Clusters of Galaxies

Z. Huang (graduate student) and Sarazin have observed the well-studied, irregular Hercules cluster of galaxies (Abell 2151) in X-rays with the ROSAT HRI. They find that the X-ray emission is concentrated towards the central subcluster of the system, in agreement with previous *Einstein* and ROSAT PSPC observations. The X-ray emission in this subcluster divides into two components, which correspond to two groups of galaxies in the region. The center of the brightest (western) X-ray component coincides with the brightest cluster galaxy (BCG) NGC 6041A, while there is an X-ray peak near the center of the poorer eastern component which agrees with the position of an elliptical radio galaxy NGC 6047. The X-ray emission is fairly irregular, and there are separate X-ray features associated with individual galaxies including the BCG NGC 6041A. There are two X-ray clumps associated with an interacting peculiar galaxy pair NGC 6040A/B.

J. Irwin (graduate student) and Sarazin are analyzing the distribution of the hot gas, dark matter, and cold gas in the cooling flow cluster 2A0335+096 using PSPC data from ROSAT. Spatially resolved X-ray spectra show a decrease in the ambient temperature of the X-ray emitting gas in the inner regions of the cluster, indicative of a cooling flow. The spectra also confirm the presence of an absorbing column density in excess of the measured Galactic value towards the cooling flow region which must be intrinsic to the cluster. The mass of this absorbing matter is $7.4 \times 10^{11}\,M_\odot$ within 170 kpc of the center of the cluster. A cooling rate of $400^{+90}_{-65} M_\odot$ yr^{-1} is found within the cooling radius of 166^{+28}_{-18} kpc. This value is consistent with the cooling rate obtained by fitting a cooling flow model to the spectrum of the central 166 kpc. Although the cooling rate is proportional to radius for the inner 60 kpc, it is essentially constant beyond this point, which suggests that the gas cools homogeneously in this region.

O'Connell, Sarazin, and B. McNamara (CfA) are comparing multicolor optical CCD images of the central region of NGC 1275 in the Perseus cluster to previous Hα, ROSAT HRI X-ray, and radio images.

Using difference maps formed by modeling and subtracting the elliptical galaxy background, they find blue central structures which are spatially coincident with the bright Hα and X-ray emitting filaments. The unusually blue colors extend to $\sim$ 20 kpc in radius. The colors indicate a young population with ages ranging from 10^{7-9} yr. The brightest and bluest regions lie along the edges of the radio source and/or in regions with bright X-ray emission. The most recent episode of star formation may have resulted from an interaction between the radio source and the ambient medium.

Sarazin and J. Breen (graduate student) are analyzing the structure of the hot gas in the cooling flow cluster A1795. They have a deep ROSAT observation of this system.

Sarazin and D. Christodoulou (LSU) have numerically simulated nonmagnetic and magnetized cluster cooling flows in a cylindrical geometry. After about 4 Gyr, radiative cooling causes a catastrophic collapse of the gas in the inner core, irrespective of the presence of the magnetic field. If a weak field exists in the core initially, it begins to build up substantially at the center after the cooling catastrophe. Outside of the inner 50 kpc, the magnetic field quickly approaches the steady–state profiles determined by the conservation laws of mass and magnetic flux, i.e. $B_\phi \propto \rho r$ and $B_z \propto \rho$, where r denotes the cylindrical radius and ρ denotes the density. They have also studied linear and nonlinear $m = 2$ perturbations in three dimensions under the same initial conditions but at modest numerical resolution. No additional nonaxisymmetric structure develops during inflow. The original perturbations are carried homologously into the inner core without growth.

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

Sarazin and S. Pistinner (Negev U.) have shown that it is very difficult for highly tangled magnetic fields to effectively suppress thermal conduction in cluster cooling flows. In the limit where the field is highly tangled but simply connected, they have derived the transport coefficients by expanding the Boltzmann equation in drift variable. The alternative possibility that the magnetic field lines consist of a large number of very small loops is shown to be inconsistent with the observed Faraday rotation toward radio sources in many cooling flows. Sarazin and Pistinner have applied a complete kinetic, nonlocal treatment to heat conduction in cluster cooling flows. They find that

nonlocal saturation effects cause the gas to be more thermally unstable than had previously been thought.

Sarazin and M. Wise (CfA) 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 measuring the X-ray spectra of the A2029 and 2A0335+096 clusters of galaxies with cooling flows using ASCA. They are particularly interested in studying the spectrum of the cooling gas, and the possible spectral effects of cold gas in these systems.

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.

Sarazin, S. Baum (STScI), and C. O'Dea (STScI) have made high dynamic range VLA radio observations of the cooling flow cluster 2A0335+096. They have found radio emission associated with the central D galaxies, with the companion nucleus of the central D galaxies, with a cluster galaxy projected near the nucleus, with the very long NAT radio galaxy, and with several other sources. The central radio emission has an unusual disrupted jet structure with filaments of radio emission which coincide with filaments of X-ray and optical line emission which were discovered by Sarazin, O'Connell, and McNamara.

Sarazin, Baum, O'Dea, and F. Owen (NRAO) are studying the quasar B2 1028+313, which is located at the center of the Abell cluster A1030. They hope to use the quasar to detect cooler components in the intergalactic medium through UV or X-ray absorption.

Sarazin, H. Ford (JHU), Baum, and O'Dea are using HST UV spectra of the nucleus and jet knots in M87 to search for absorption lines from cold gas in the Virgo cluster. This technique should reveal the nature of the cold gas which has been observed in X-ray absorption in this and other cooling flows clusters.

Sarazin, W. Jaffe (Leiden), M. Bremer (Leiden), B. McNamara (CfA), C. O'Dea (STScI), S. Baum (STScI), 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 (Hughes STX), 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 and B. McNamara (CfA) 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, B. Jannuzi (IAS), 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.

Thuan, in collaboration with Yu. Izotov (Kiev Observatory, Ukraine) and V. Lipovetsky (Special Astrophysical Observatory, Russia) have obtained HST WFPC2 V and I images and FOS UV and optical spectrophotometry of the unusual blue compact dwarf galaxy Mrk 996. They found Mrk 996 to have a disk structure with a small scale-length ($\sim$ 0.4 kpc) and a two-arm spiral-like pattern confined to the inner 160 pc in radius. Nearly all the star-forming activity occurs in an extremely compact nuclear H II region of radius $\sim$ 315 pc. A central density greater than $10^6\,\mathrm{cm}^{-3}$ together with a density gradient are needed to explain the emission-line intensities. The density gradient may be caused by a mass outflow which would also account for the much broader line widths (FWHM $\sim 900\,\mathrm{km\,s}^{-1}$) of the high-excitation lines originating in the inner region as compared to the low-excitation lines originating in the outer region. There is a large population of WR stars which may drive the mass outflow and heavily pollute the central region with nitrogen, producing a nitrogen abundance gradient

from the inner to outer parts. The nitrogen abundance in the center is about 25 times larger than that derived for other blue compact galaxies. It decreases by a factor of about 6 from the inner high-excitation zone to the outer low-excitation zone. The number ratio of WNL stars to O stars is $\geq$ 0.1, larger by a factor of $\geq$ 5 than predictions by evolutionary synthesis models. The ratio of the number of WC stars to the total number of WR stars is $\sim$ 0.11. The oxygen abundance of Mrk 996 is $\sim$ 1/10 that of the Sun, its C/O ratio is 0.25 and its helium mass fraction $Y = 0.26$. There is a system of old ($\sim 10^{10}$ yr) globular clusters distributed asymmetrically around Mrk 996, mainly to the South of the galaxy, an asymmetry probably related to the one seen in the outer isophotes of Mrk 996. The globular cluster luminosity function in Mrk 996 is very similar to that of the Milky Way, with a suggestion of a slightly larger number of clusters at the bright end, in the M_V range between -9 and -10.4.

Thuan, in collaboration with N. Guseva and Yu. Izotov (Kiev Observatory, Ukraine) is studying the kinematics of the ionized gas in blue compact galaxies from the First and Second Byurakan Surveys with long slit spectra. They find that the strong emission lines possess broad (200 $\mathrm{km\,s^{-1}}$) and very broad ($\sim$ 1000–2000 $\mathrm{km\,s^{-1}}$) low-intensity components, due to motions of shells of matter blown out by stellar winds from young stellar clusters. In addition, the strong narrow emission components of these lines show velocity jumps of 20 to 200 $\mathrm{km\,s^{-1}}$ on a scale of 50 to 300 pc, probably due to shocks caused by the interaction of stellar winds from massive stars and of supernovae with the ambient interstellar medium.

Thuan, in collaboration with P. Papaderos, H.-H. Loose, and K. Fricke (University of Gottingen, Germany) has studied the optical structure of blue compact galaxies. They have obtained surface brightness profiles for a dozen BCGs and performed a 3-component decomposition scheme, a Gaussian and a modified exponential distribution describing the starburst component and an exponential distribution describing the underlying low-surface-brightness (LSB) component. They find that the extent of the starburst component is linearly related to the total luminosity and the size of the older LSB stellar component. In addition, the fractional area of a BCG within which star formation takes place, tends to increase with decreasing luminosity of the LSB component. These results imply that global star formation in BCGs is partly dependent on the structural properties of the older stellar population on which it is superimposed. The LSB component differs systematically in its structure from the one in other types of dwarf galaxies

such as dwarf irregulars (dIs) and dwarf ellipticals, being $\sim 1.5\,\mathrm{mag arcsec}^{-2}$ brighter in its central surface brightness and a factor of $\sim$ 2 smaller in its scale length. Consequently, BCDs cannot originate from dIs, unless the latter can change their structural properties in a dynamical process.

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

Whittle, Sarazin, and R. Gelderman (GSFC) are using long slit spectra and narrow band image 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 origin of the X-ray–radio–optical filaments in this system.

e. Cosmology

F. Fang (graduate student) and Saslaw have shown that some statistical distribution functions, such as the negative binomial, which are used to model the spatial distribution of galaxies do not satisfy the second law of thermodynamics in the expanding universe. This makes their physical basis rather uncertain, and provides a new constraint on theories of galaxy clustering.

Fang and Saslaw are examining a variety of models for the possible distribution of dark matter in our universe, to see if they are compatible with the observed spatial and velocity distributions of the galaxies. It appears that the observations provide considerably more powerful constraints on these models than thought previously.

Saslaw and S. Raychaudhury (Cambridge) have completed the first determination of the observed peculiar velocity distribution function for a representative sample of galaxies. This is a new fundamental astronomical quantity (analogous to the Maxwell-Boltzmann velocity distribution of a perfect gas). The larger scale bulk motions are superimposed on this average velocity distribution. This observed galaxy velocity distribution is non-Maxwellian. It is consistent with an earlier prediction of gravitational clustering, over the entire range of peculiar velocities from field galaxies to rich clusters, on scales up to about 50 Mpc. The effects of uncertainties in sampling and distance measurements have been explored in detail. In the simplest consistent model, most of the inhomogeneous dark matter in the Universe is in galaxies or their halos. This result provides new tests for all models of galaxy clustering.

Saslaw and Raychaudhury have estimated the "Mach number" for the bulk flow within about

$50h^{-1}$ Mpc from us to be $M \simeq 0.8$. This subsonic result includes the contributions of the high velocity dispersion galaxies in clusters.

Saslaw and L. Krzewina (graduate student) have developed three useful new statistical methods, and a smoothing procedure, for objectively examining large scale structure with minimal spanning trees. They applied these statistics to three illustrative data sets: the Southern Sky Redshift Survey, a gravitationally evolved model for the galaxy distribution, and a Poisson distribution. The observations are clearly different from the Poisson case, and are consistent with the gravitational model to within uncertainties of about five percent.

Saslaw and F. Fang (graduate student) have re-examined the physical basis of the gravitational quasi-equilibrium theory of galaxy clustering, which agrees well with observations of the spatial distribution of the galaxies and also with their observed peculiar velocity distribution function. The results clarify the basis of the quasi-equilibrium approximation and its applicability for non-Poisson initial distributions. They have also derived the complete functional form of the equation of state from the pairwise nature of the gravitational interaction. This functional form also follows from a principle of minimal clustering. These new derivations confirm an earlier derivation based on an assumption for the form of the thermodynamic dependence of the ratio of gravitational correlation energy to thermal energy.

Thuan, in collaboration with Yu. Izotov (Kiev Observatory, Ukraine) and V. Lipovetsky (Special Astrophysical Observatory, Russia), have continued their program of determination of the primordial helium abundance Y_p using blue compact galaxies (BCGs) from the Second Byurakan Survey, which contains significantly more low-metallicity BCGs than previous surveys. They have now obtained very high-quality spectrophotometric observations of 25 low-metallicity BCGs. They obtain $Y_p = 0.029 \pm 0.003$, a result which has not changed although the sample has doubled in size. The enlarged sample allowed them not only to reduce the formal error in Y_p, but also to start looking for systematic errors in its determination, such as those due to the atomic data. All the previously quoted values of Y_p were derived using HeI emissitivities from Brocklehurst (1972) and correction factors for collisional enhancement of the He I lines from Clegg (1987). They found that the use of the above set of atomic parameters leads to a large scatter of the data points in the Y–O/H and Y–N/H planes, and to a systematic underestimate of Y_p. They believe the correct set of atomic parameters to use is Smits (1995)

He I emissivities and Kingdon and Ferland (1995) correction factors because it minimizes the scatter in the data. The new value $Y_p = 0.241 \pm 0.003$ is more consistent with the lower limit of 0.236 given by standard big bang nucleosynthesis theory.

Thuan, Izotov and Lipovetsky have obtained HST WFPC2 V and I images of the most metal-deficient BCG in the SBS, SBS 0335-052 which has a metallicity of $Z_\odot/41$ and is the second most metal-deficient BCG known, after I Zw18 ($Z_\odot/50$). The central part of the galaxy consists of 6 very bright and blue clusters of massive stars with absolute V magnitudes ranging between -15 and -13 mag, and surrounded by large bright HII regions. There is a large hole in the interstellar medium of the BCG, presumably carved out by supernova explosions. They have also detected a more extended low-surface-brightness underlying component with a radius of 3.5 kpc down to a V surface-brightness level of 26 magarcsec^{-2}. The $V - I$ color of this low surface-brightness component is very blue ($\sim$ 0.1 to 0.2), excluding the possibility that the light of this component can come from a population of low-mass old stars. The $V - I$ color is consistent with that of a population consisting mainly of A0–A5 stars. In this case, the age of SBS 0335-052 would not exceed 10^8 yr, significantly lower than the Hubble time. However, the irregular and filamentary structure of this outer component argues against a stellar origin for the emission. They believe that the hypothesis of its emission being produced by ionized gas to be more reasonable. In this case, the BCG is a young galaxy undergoing its first burst of star formation, with the stars in the blue young stellar clusters being less than 10^7 yr old. BCGs without an underlying low-surface-brightness old stellar population are extremely rare. The BCG I Zw18 may be such a case, and SBS 0335-052 is the second such known case. They also obtained a HST HRS spectrum of SBS 0335-052. A striking feature is the absence of Lyα emission, reminiscent of the situation for I Zw18. It is not clear at present why Lyα emission is not seen in the two best candidates for young galaxies, but this absence can explain the unsuccessful searches for high-redshift primeval galaxies in deep Ly α surveys.

Thuan, in collaboration with R. Dominguez-Tenreiro (University of Madrid, Spain) J.-M. Alimi and A. Serna (Observatoire de Meudon, France) has used the scaling formalism to analyze the spatial distribution of dwarf and low-surface-brightness galaxies as compared to that of bright galaxies. The analysis was based on a dwarf statistical sample of $\sim$ 1000 dwarfs assembled by Thuan and S. Schneider (University of Massachusetts) a few years ago. The scaling formalism allows for a separate analysis of regions with different

galaxian densities. They find, at a 95% confidence level, that dwarf and LSB galaxies are less clustered 5% than bright galaxies, in both high and low density regions.

f. Solar System

Goldstein and R. Goldstein (JPL) continue their studies of millimetric space debris (AJ, 110, 1329; see also AJ, 107, 367). From 21.4 hrs of zenith radar observations at the Goldstone observatory at 8510 MHz, they evaluate the flux of the debris as a function of altitude. The particles have radar cross sections between 0.02 and 260 mm^2. (If they are conducting spheres, their diameters lie between 2 and 18 mm.) A maximum in flux, 3.3 particles km^{-2} day^{-1}, occurs at 950 km altitude. The population is not well mixed. An attempt to detect evolution of the orbits failed.

Goldstein and K. Jacobs (Hollins College) returned to the study of the Galilean satellites of Jupiter. They completed a new analysis of the acceleration of the mean motion of Io from comparison of seventeenth century eclipse observations and twentieth century eclipse observations. They find from these observations (AJ, in press Dec. 1995) that $\dot{n}/n = (+4.5 \pm 1.0) \times 10^{-10}\,\mathrm{yr}^{-1}$.

From the theory of Sampson based on observations between 1878-1903 and the E-2 ephemeris of Lieske (1982) Goldstein and Jacobs calculated accelerations for all four Galilean satellites and the tidal torque of Jupiter on Io (submitted to AJ July 1995). The three inner satellites are accelerating and consequently their orbits are shrinking. Callisto is decelerating and its orbit is expanding. The torque on Io opposes its motion. If so, the tidal bulge on Jupiter lags the satellite that induces it, and the natural resonant frequency of Jupiter's tidal medium (presumably the outer atmosphere) is less than the frequency of Io's motion with respect to the tidal medium.

Goldstein and H. Bailey (Rose-Hulman Institute) have used numerical methods to study the orbits of hypothetical satellites of Jupiter well outside the satellite with the largest semi-major axis, Sinope. They found five stable orbits with distances to Jupiter between 0.47 and 2.82 au that endure more than a million years. These orbits have epicycles, directed away from Jupiter with random amplitudes. All have retrograde motion, and do not obey Kepler's first and third laws. These calculations are planar, three-body integrations with Jupiter in a fixed elliptical orbit. The addition to one of these cases of a "planar Saturn," affects the positions and sizes of the epicycles but not the long term stability.

Goldstein has analyzed the evolution of magnetic fields in space on the assumption that the field is produced by a circular current loop. The analysis leads to a family of first order ordinary differential equations, which are easily solved numerically. There are two possible solutions: one where the radius of the conductor grows as the loop expands and a second where the conductor shrinks as the loop expands. The Klein-Burlaga "magnetized clouds" in the solar wind fit the theory with decreasing conductor radius as the field expands beyond 1 au. If the radius of the loop is 1.0 au, its conductor radius = 0.125 au and the temperature of the conducting electrons and protons is 105 K; after 26 days the radius of the loop will be 7.1 au, the conductor radius 0.025 au, and the temperature 2600 K.

g. Astrometry

Ianna and Patterson have brought up to date data reductions for McCormick fields measured in recent years, and a parallax list has been submitted for publication. The list contains twenty-one Vyssotsky K and M dwarfs, eighteen having no previously published parallaxes; all the Vyssotsky stars have been observed by HIPPARCOS and we have discontinued observations of them. The list also has an X-ray luminous M dwarf, a rapidly rotating spotted flare star, and two astrometric binaries. One of the latter is Gl 105 (BD+6°398) which has a companion recently detected by coronographic camera. It is likely the astrometric companion, currently near periastron and occulted by their mask, was not seen, but rather an additional companion.

Ianna has been measuring regions observed photographically at Mount Stromlo Observatory on the Virginia PDS. Some fields have fewer than ideal numbers of observations, but the deletion of the IIa-O emulsion makes it difficult and unlikely he can extend their series. A paper reporting on these stars is in the final stages of preparation to bring this work up-to-date. Most of the stars are white dwarfs, but the list contains a number of M dwarfs and subdwarfs as well. One M dwarf is CoD−46°11540, a star within 5 pc with no modern astrometric investigations. The final residuals do not show any trends indicative of an astrometric companion. Of special note is the star LHS 1565 for which he finds a parallax of 0.270 ± 0.005 (3.7 pc). This is the first object measured to be within 5 pc in many years.

Ianna and J. Martin (undergraduate student) began a program to empirically measure the binary blending parameter, β, for the McCormick refractor

for a range of Δm. A number of visual binaries were observed with an objective grating to artificially create photographically blended images. Knowledge of the image blending properties of the telescope is crucial to the correct evaluation of mass ratios in astrometric binary analyses. Preliminary results show little or no deviations from the theoretical relationship.

Ianna and Begam are continuing the CCD parallax program at the Mount Stromlo and Siding Spring Observatories using the 1 m reflector. Recent 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 show they can reach precisions of 1–2 mas at this telescope. They have preliminary first parallax determinations for fourteen stars; ten are within 25 pc, and two are within 10 pc (LHS 22 and LHS 337). Observations are also continuing for the faint very red Hawkins-Bessell sample, a collection of stars all lying near the substellar boundary.

Ianna is collaborating with T. Henry (STScI) and D. Kirkpatrick (IPAC) to identify new nearby star candidates in the southern hemisphere by means of JHK photometry and near IR spectroscopy. An initial observing run has confirmed several likely nearby stars and revealed several new very late M dwarfs in the Wroblewski and Torres proper motion survey. The result of these fundamental observations will be the establishment of a comprehensive database for southern nearby stars and the reddest objects known.

h. Space Astronomy

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. R. Shah (graduate student), O'Connell, and colleagues at Goddard SFC are analyzing the FUV images of globular clusters NGC 362 and 47 Tuc, known to have red horizontal branches. Both clusters contain unexpectedly UV-bright hot stars, and in 47 Tuc there is evidence for a diffuse UV component. R. Ohl (graduate student) and O'Connell are analyzing UV images of elliptical, S0, and related galaxies obtained during both UIT missions. There are large differences in the UV–V color profiles in the UIT sample, which they will correlate with available information on age and abundance. In the case of the starburst systems NGC 1510 and 5253, they find predominantly exponential

UV surface brightness distributions, with a strong outward bluing in UV–V for 1510. Marcum, O'Connell, and graduate student C. Palma are combining UIT *Astro-1* UIT images of galaxies with ground-based CCD data to produce a UV Atlas of Galaxies. As well as UV and visual-band images and a discussion of UV morphologies, this will contain photometry intended to facilitate interpretation of high redshift galaxies observed in the rest-frame UV.

IV. MISCELLANY

Chevalier co-edited the proceedings of the Jubilee Gamow Seminar in St. Petersburg. Hawley was appointed to the review panel for the NASA Origins of Solar Systems program. Ianna was elected Chair of the AAS Division on Dynamical Astronomy, and he is serving as Vice-President of IAU Commission 24 (Photographic Astrometry). O'Connell served as a member of the NASA Astrophysics Science Operations and Data Analysis working group, as chair of the search committee for the Director of Kitt Peak National Observatory, as an external reviewer for the STEDI program for USRA, and as a reviewer for the NASA Astrophysics Theory Program. Richards served as a panel reviewer for the National Science Foundation. Sarazin was a member of the NASA Working Group on X-ray Astronomy, the ASCA Users' Committee, the AXAF Users' Committee, the NASA Long Term Space Astrophysics Review Panel, the Heineman Prize Committee of the American Astronomical Society, the scientific organizing committee of the Tokyo Conference on X-ray Imaging and Spectroscopy of Cosmic Hot Plasmas, the scientific organizing committee of the Israel Conference on Cluster Cooling Flows, and the NOAO Time Allocation Committee. Together with Daniel Kunth (Institut d'Astrophysique, Paris), Thuan organized an international meeting on Interplay Between Massive Star Formation, the ISM and Galaxy Evolution held July 3–8, 1995 at the Institut d'Astrophysique in Paris.

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