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This report covers the period 1 September 1999 to 31 August 2000.

1. PERSONNEL

During this time the departmental faculty consisted of Steven A. Balbus, Roger A. Chevalier, John F. Hawley, Philip A. Ianna, Zhi-Yun Li, Steven R. Majewski, Robert W. O'Connell, Richard J. Patterson, Mercedes T. Richards, Robert T. Rood, Craig L. Sarazin, William C. Saslaw, Trinh X. Thuan, Charles R. Tolbert, and D. Mark Whittle. Kiriaki Xilouris joined the faculty as Research Scientist in January. Emeritus faculty member Samuel J. Goldstein died on 13 June, 2000 a few days short of his 75th birthday.

Postdocs in residence included Márcio Catelan, Dana Dinescu, Richard deGrijs, Arunav Kundu, and Robert Link along with Franǫis LeBlanc and Catherine Tully from Robert Johnson's planetary astronomy group.

There were 17 enrolled graduate students at the end of this period. Franz Bauer, Ray Ohl, and Ronak Shah completed their Ph.D.s during the year.

The Virginia Institute for Theoretical Astronomy (VITA) continued operations during this period with support from the University of Virginia and NASA Astrophysical Theory Program grants and hosted a number of visitors for brief periods.

2. FACILITIES

The 26-in Leander McCormick refractor on Mount Jefferson and the 0.7-m and the 1-m reflectors on Fan Mountain were used during the year for education in both graduate and undergraduate courses. A new automated tail piece was installed and the mirror resilvered for the 1-m. In Australia, the 1-m reflector at Siding Spring Observatory has continued to be made available for the southern parallax program under a cooperative agreement with Mount Stromlo and Siding Spring Observatories.

Crane and Majewski built a speckle interferometry camera for the McCormick 26-in telescope which is now in regular use as part of the department's graduate observational astronomy course. Crane, Majewski and Sergueeva (undergraduate) have been designing and building a fiber-fed spectrograph for the Fan Mountain 1-m telescope to be used for spectroscopic work related to Majewski and Patterson's Grid Giant Star Survey.

In the summer of 2000 the Department received a major gift which will in part be used to initiate a program in optical/IR instrumentation and as a lead-in to a major telescope project.

3. RESEARCH

3.1 Stars and Stellar Evolution

Balbus, in collaboration with S. Fromang and C. Terquem (IAP, Université de Paris) has completed a study of the self-consistent ionization structure of protostellar disks. The ionization source was taken to be the X-rays from the central young stellar object (YSO). In contrast to previous studies which used disk models incompatible with steady accretion, the present investigation adopted density profiles taken from α disk calculations. A very broad radial range of ionized disk gas was found depending on the parameters adopted, but no model was fully ionized over the entire extent of the disk. Nevertheless, the study indicated that the distribution of the X-ray emissivity in disk-YSO systems (central source, distributed throughout a corona, etc.) is critical to understanding the MHD behavior of the disk.

Balbus and Hawley, along with graduate student Jeff Balsley, have carried out a numerical study of thermal transport in vertically stratified, MHD turbulent disks. The effect of MHD turbulence on heat transport in a convectively stable disk is to produce downward (i.e., toward the midplane) transport against the large scale temperature gradient. This is the analogue behavior of inward angular momentum transport found when convective turbulence is imposed in Rayleigh-stable disks.

Balbus has completed a study of the Hall Effect in astrophysical disks with C. Terquem (IAP, Université de Paris). By altering the process of self-induction in a fluid, the Hall Effect affects the stability of resistive, partially ionized disks in the presence of a magnetic field. Both stabilizing and destabilizing behavior is possible in the presence of Hall electromotive forces; the physics is rather complex. One simple conclusion however is that any type of differential law is potentially unstable, even profiles in which the angular velocity increases outward. The work bears upon understanding the extent of MHD turbulence in protostellar accretion disks, and the nature of angular momentum transport in the low states of dwarf novae. In collaboration with T. Sano and J. Stone (Maryland), Balbus is pursuing the nonlinear consequences of Hall-MHD turbulence with numerical methods.

During the past year Hawley has been performing a series global Keplerian accretion disk simulations on massively parallel supercomputers. These disks are strongly unstable to the magnetorotational instability. Turbulence is rapidly produced which drives angular momentum transport leading to mass accretion.

Hawley and Balbus continue to investigate the nature of the angular momentum transport mechanisms, MHD turbulence, and global dynamics of astrophysical disk systems including protoplanetary systems through combined analytical and numerical studies.

Hawley, in collaboration with J. Krolik (Johns Hopkins

University) has carried out a detailed three dimensional magnetohydrodynamic (MHD) simulation describing the inner region of a disk accreting onto a black hole with a particular focus on the inflow through the marginally stable orbit. They find that the Maxwell stress is continuous across the marginally stable orbit, in contradiction with the widely-held assumption that the stress should go to zero there. As a consequence, the specific angular momentum of the matter accreted into the hole is smaller than the specific angular momentum at the marginally stable orbit.

Along with graduate student Wayne Winters, Balbus and Hawley are carrying out three-dimensional global simulations of protostellar disks. They are modeling disks subject to MHD turbulence in which a planet is embedded to investigate the influence of the turbulence on gap formation and planet migration. They find that the planet can itself influence the turbulence, and hence the angular momentum transport in the disk. This is an important effect that cannot be captured by a standard viscous disk prescription.

Hawley and graduate student Marianne Vieira have been performing axisymmetric MHD simulations of non-radiative accretion flows into black holes. These two-dimensional flows provide an overview of inflow behavior and the influence of flow parameters in preparation for more demanding and realistic three dimensional simulations.

Catelan and F. Grundahl (Aarhus Univ.) are analyzing a large number of CMDs obtained in the Strömgren system. Catelan, M. Bellazzini (Bologna Obs.), W. B. Landsman (NASA/GSFC), F. R. Ferraro (Bologna Obs.), and F. Fusi Pecci (Staz. Astr. Cagliari) are studying recently obtained CMDs of the globular clusters NGC 288, NGC 362, and NGC 1851. Catelan, J. Borissova (Bulg. Acad. Sc.) and F. R. Ferraro are analyzing the CMD of M75 (NGC 6864).

Catelan is studying hot, UV-bright stars in GCs in collaboration with W.B. Landsman and F. Grundahl. The analysis includes ground-based and space-based (UIT and HST-STIS) data, as well as theoretical modelling.

Catelan is involved in several studies of bright variable star population in globular clusters: (1) M75 (NGC 6864) in collaboration with T.M. Corwin (U. of North Carolina) and H.A. Smith (Michigan State). (2) the metal-rich GCs NGC 6388 and NGC 6441 in collaboration with B. Pritzl (NOAO), H.A. Smith, A.V. Sweigart (NASA/GSFC), and A. Layden (Bowling Green State). Their approach includes both ground-based and space-based (HST-WFPC2) data. (3) the outer-halo GC Palomar 3 in collaboration with J. Borissova, V.D. Ivanov (Steward Obs.), and S. Ortolani (Univ. Padova). (4) Arp 2 and NGC 6304 in collaboration with C. Cacciari (Bologna Obs.), C.E. Corsi (Rome Obs.), and A.V. Sweigart.

Chevalier is investigating pulsar wind nebulae in the context of models in which the relativistic wind from the central pulsar passes through a shock wave and builds up a synchrotron emitting nebula. Steady-state models of this type can account for the high energy emission (optical and above) from pulsar nebulae, but not for the radio emission. This problem is significant because the number of radio emitting particles in a nebula like the Crab is substantially larger than the number of high energy emitting particles. Chevalier found that the observational evidence supports a picture in which the radio emitting particles were injected into the nebula at early times through the pulsar wind shock. If the high early particle flux had the same Lorentz factor as the present wind in the Crab Nebula, the early nebula would be too luminous. The implication is that the large particle flux is in a lower Lorentz factor wind. J. Anderson (graduate student) and Chevalier are developing a numerical scheme to calculate the evolution of the relativistic particle spectrum.

Li started a new project investigating the origin of an emerging class of highly collimated bipolar molecular outflows in star formation. These outflows are mostly driven by very young, Class 0 protostars, and are characterized by an extremely high velocity (EHV) component that is absent from the ''classical'' outflows. He proposed that the EHV component is the dense axial part of a magneto-centrifugally launched wind from close to the central young star, rendered visible in CO by a combination of large wind mass flux and high degree of external collimation. The proposal was strengthened by a detailed calculation of the structure of an externally collimated magneto-centrifugal wind.

Li and Chevalier continued their investigation of modeling GRB (gamma-ray burst) afterglows in terms of interaction with a stellar wind, as would be expected if the progenitor were a massive star. They found that the observed radio evolution of GRB 991208 and GRB 000301C could be approximately reproduced in wind interaction models. These sources had previously been modeled as jets in a uniform density medium. The relatively steep decline and the fairly abrupt steepening of the R-band light curves of GRB 991208 and GRB 000301C could be accounted for with a non-standard, broken power-law distribution of electron energy. The wind model predicts a slower late decline for the radio flux than does the jet model.

Li, R. Krasnopolsky (University of Chicago) and R. Blandford (Caltech) continued their numerical studies of magneto-centrifugal jets/winds launched from accretion disks, with an emphasis on the large scale wind structure and properties of the dense jets formed around the rotation axis. They found that it is difficult to collimate more than half of the wind mass flux into the jet at observable distances from the launching surface, making the presence of a significant wide-angle component inevitable. This wide-angle wind component may play an important role in driving molecular outflows in star formation.

Li and V. Shematovich (Moscow) started a collaboration on the coupled dynamical-chemical models of star-forming molecular cloud cores. The dynamical part takes into account of magnetic support and ambipolar diffusion, and the chemical part includes an extensive chemical network as well as some effects of dust grains. Preliminary results in the simplest spherical geometry indicate that molecular species CCS and CS peak off-center in a shell while NH_3 at the center, in qualitative agreement with the ''onion ring-like'' chemical structure observed in the well studied star-less cores L1544 and L1498. The spherical models have difficulties reproducing the observations quantitatively, however, most likely due to the restrictive geometry assumed. Models in more complicated geometries are under construction.

Majewski's group has been using the three filter Wash-

ington + DDO51 photometric system to identify distant giant stars as a means to search for substructure in the Milky Way's halo. Two approaches are employed. The first is a systematic survey for giant stars in over 1300 evenly spaced fields, the Grid Giant Star Survey (GGSS), which is being used to search for tidal streams from accreted objects in the Galactic halo. More than half of the fields have been observed, and the spectroscopic phase of the GGSS has begun.

The second approach is a targeted search for extratidal stars associated with the present family of dwarf satellite galaxies and globular clusters. First results on the Carina dwarf spheroidal by Majewski, Ostheimer (grad student), Patterson, Frinchaboy (grad student), Kunkel (Las Campanas), and Johnston (Wesleyan) show an extended distribution of giant stars – now spectroscopically confirmed with HYDRA on the CTIO 4-m – beyond the nominal tidal radius for the galaxy. They are investigating whether the velocities of these stars imply they are unbound tidal debris (implying a substantial mass loss rate), or represent some kind of bound halo population.

Majewski, Dinescu, P. Frinchaboy, Patterson, Ostheimer, and Palma (graduate student) have been studying internal stellar population and bulk kinematical properties of the Galactic globular cluster ω Centauri. Together, the data lend support to the idea that this globular may actually be the nucleus of a massively disrupted dwarf galaxy.

Majewski and Siegel (graduate student) continued their work on the Selected Areas Starcounts Survey (SASSY), a systematic Galactic structure survey with the Swope telescope in collaboration with I.N. Reid (U. Penn) and I.B. Thompson (OCIW). They are completing their derivation of density laws using *RI* photometry in seven 2 deg^2 fields observed with the Swope 1-m, and exploring evidence for a gradient in the minimum metallicity of the disk populations as a function of height above the Galactic plane using BVI photometry in these same fields.

Crane (graduate student) and Majewski have been analyzing deep UBV photometric observations of Selected Area 57 as part of Majewski's ongoing studies of the structure of the Galactic halo.

Palma, W. Kunkel (Las Campanas), and Majewski completed a spectroscopic analysis of bright giant stars in the Pyxis globular cluster. This resulted in the first radial velocity for the cluster and a spectroscopic metallicity determination of $[\mathrm{Fe/H}] = -1.4$, consistent with photometric estimates. They explore the suggestion that Pyxis is a globular cluster captured from the Magellanic Clouds, and make a prediction for the cluster's proper motion under this scenario.

Palma, Majewski, Patterson and Siegel (grad student) have found an extended population of giants around the Ursa Minor dwarf galaxy, with a large area (4° along the major axis) survey using the KPNO 4-m and the MOSAIC camera. The large number of giant candidates beyond the nominal tidal radius is mirrored in the distribution of blue horizontal branch (BHB) stars. Similar results for both giant and BHB star candidates are found around the Sculptor dwarf galaxy by Westfall (undergraduate student), Ostheimer (graduate student), Patterson, and Majewski, in collaboration with W. Kunkel. However, a smaller amount of extratidal area has been surveyed for Sculptor. A large area survey around the Leo II dwarf hints at a tidal tail pulled out along the galaxy's major axis. Finally, the Majewski, Patterson, Ostheimer, Kunkel and Johnston survey around the Magellanic Clouds is being expanded (with the help of undergraduate Veronica Ponce) to map further the tidal streams previous previously identified. Spectroscopic follow-up of these various extratidal candidates is in progress.

Extratidal stars are also being sought around globular clusters. Majewski, Patterson and Siegel are exploring the distribution of giant stars around the globular cluster Arp 2 with the help of A. Johnson (undergraduate), around the Pyxis cluster with V. Ponce, and around the cluster N288 with undergraduate A. Forestell.

Siegel, Majewski, Catelan, Patterson and Grundahl (Aarhus) have examined the horizontal branches of several clusters in broadband U to see if the HB ''jump'' seen in Stromgren ultraviolet photometry is also present in the broadband photometry. The jump is clearly seen in several clusters.

Richards wrote a review paper on Doppler tomography of Algol-type binaries in which she described the diverse range of circumstellar structures seen in the tomograms obtained from Hα difference profiles of 11 Algols. These include a gas stream, accretion annulus, star-stream and disk-stream impact regions, a circumprimary bulge, as well as a transient accretion disk and/or chromospheric structure in the short-period Algols or a classical accretion disk in the long-period systems. The Hα tomograms of the short-period Algols also contain an absorption zone that may be associated with a region of hotter ($\sim 10^5$ K) gas. An ultraviolet tomogram generated from Si IV difference profiles of U Sge shows that the hotter gas and the Hα absorption zone overlap. Tomograms produced at multiple epochs demonstrate stability in systems like β Per and TX UMa but variability in others like U Sge, U CrB, and CX Dra. Some systems, like U CrB and U Sge, alternate between stream-like and disk-like states. Continuous monitoring of these systems should provide information about the cause of the variability.

Richards is also studying Doppler tomograms of the RS CVn binary, V711 Tau based on Mg II h & k and Hα spectra. The effects of interstellar absorption were first removed from the Mg II spectra in the standard manner. Mg II tomograms were produced for six epochs from 1978 August to 1994 September, and four of these epochs contained data collected over shorter periods of time from 4 – 23 days. The Hα tomogram was based on spectra collected in 1994 December and could be compared with the Mg II tomograms for 1994 September. Richards found that the distributions of Hα and Mg II gas are roughly centered on the magnetically active K star, but the Hα gas is more concentrated than the Mg II gas. In all cases, the Mg II k source was stronger than the Mg II h source.

Richards, Waltman (NRL), and Foster (NRL), and Ghigo (NRAO) are still monitoring radio flaring activity in β Per and V711 Tau with the Green Bank Interferometer. After 5 years of almost continuous monitoring, many strong flares have been observed and long-period flaring frequencies can now be calculated with greater confidence.

W. C. Saslaw and D. Valls-Gabaud (Toulouse, France) have been developing a new approach to the dynamics of star formation.

Kramer (Jodrell Bank), Xilouris and collaborators have been investigating, the emission properties of millisecond pulsars (MSPs). Their results have pointed out that MSP profiles are not much more complex than those of slower pulsars as previously thought. Additional pulse features are more common for MSPs. The frequent occurrence of such features poses the question whether they are of the same magnetospheric origin as the main pulse profiles or whether other sources of emission are responsible (e.g. outer magnetospheric gaps). The profile development with frequency of MSPs does not seem to follow the rules of slow pulsars. However, multifrequency timing observations do not seem to indicate deviations from a dipolar magnetic field structure prevailing their radio emitting magnetospheric regions. The percentage of polarization of the radio emission decays much more rapidly for MSPs than for normal ones. All these could be perceived as evidence of very compact but still dipolar magnetospheres. Furthermore, the authors have used polarization properties and statistical studies to determine the viewing geometry of a large sample of MSPs. Their results suggest that there is no preferential alignment of the magnetic and rotation axes. In collaboration with Lorimer (NAIC) Xilouris is investigating the emission properties of pulsars in globular clusters. Preliminary polarimetric profiles resulting from long integrations seem to indicate that the brightest of the pulsars in M15 exhibit very little polarization, unlike many normal pulsars but similar to the field MSPs.

In a joint STScI/NAIC effort Xilouris and collaborators have searched roughly 500^2deg of the sky visible with the Arecibo 300-m radio telescope discovering 9 new radio pulsars. Most of the pulsars in this survey are slow, low-luminosity objects with periods ranging between 0.4 and 2.2 sec. However, one of them has a rare rotational period of 25 msec, and is most likely a recycled millisecond pulsar in a three year orbit with a white dwarf. Two of the slow pulsars were found to exhibit integrated profile mode-changes while another one appears to be in a nulling phase for a significant amount of the time observed. Follow up, high precision timing observations are regularly performed aiming at establishing the spin and astrometric parameters as well as the flux densities and emission properties of these sources. In a targeted search around the area of the soft gamma ray repeater SGR 1900+14 Xilouris and Lorimer (NAIC) discovered PSR J1907+0819, among the top 20 youngest known radio pulsars in our galaxy. A phase-coherent timing solution was recently obtained indicating that the pulsar is located only two arc-minutes away from the magnetar, SGR 1900+14, with a characteristic age of only 38,000 yr. The authors suggested that the SNR associated with this pulsar is G42.8+06, thought by many to be associated with the magnetar. A test of association would be a measurement of proper motion direction of either star using VLBI techniques. Xilouris participated in multifrequency timing observations of the planet pulsar PSR B1257+12 led by Wolszczan (Penn State) and collaborators using the Arecibo telescope. The observations demonstrated clearly that the timing residuals of this pulsar are frequency independent. This strongly suggests that the 25.3 day periodicity in the pulsar's timing residuals is explained in terms of the orbital motion of a Moon-mass planet orbiting the pulsar, rather than propagation effects induced in the interplanetary space by the solar rotation.

3.2 Interstellar Medium

C.-Y. Wang (graduate student) and Chevalier carried out two-dimensional numerical simulations of the interaction of Type Ia supernovae with the interstellar medium. The freely expanding ejecta were assumed to have an exponential density profile. The deceleration of the ejecta gave rise to hydrodynamic instabilities near the contact discontinuity. Provided the simulation was initiated early in the evolution, with a perturbation $>1\%$, the instability reached its fully developed nonlinear strength within 5 doubling times. The further nonlinear evolution did not depend on the initial conditions. Based on observations of X-ray knots and the protrusion in the southeast outline of Tycho's supernova remnant, clumping was included in the ejecta because these features could not be explained by instabilities growing from small perturbations. In order to survive crushing and to have a bulging effect on the forward shock, the clump's initial density ratio to the surrounding ejecta must be at least 100 for the conditions in Tycho's remnant. The ^{56}Ni bubble effect may be important for the development of clumpiness in the ejecta. The model predicts that Si line emission in the outer parts of Tycho's remnant should be very clumpy. Wang and Chevalier are following up this work by studying the apparent ''bullets'' around the Vela supernova remnant.

3.3 Galaxies and Active Galactic Nuclei

E. Blanton (post doc), Sarazin, and J. Irwin (U. Michigan) observed the X-ray faint S0 galaxy NGC 1553 in X-rays with Chandra. The majority (70%) of the emission in the 0.3−10.0 keV band is diffuse, and the remaining 30% is resolved into 49 discrete sources. There is a bright source at the projected position of the nucleus of the galaxy; its X-ray properties indicate that it is an AGN. The diffuse emission exhibits significant substructure with an intriguing spiral feature passing through the center of the galaxy. The X-ray spectrum and surface brightness of the spiral feature are consistent with adiabatic or shock compression of ambient gas, but not with cooling. This feature may be due to compression of the hot interstellar gas by radio lobes or jets associated with the AGN.

de Grijs, O'Connell, and J. Gallagher (UWisc) completed their study of optical and near-IR HST imaging of M82 ''B,'' a region in the disk of M82 about 1 kpc from the present-day starburst core. This region has been suspected to be a fossil starburst site in which an intense episode of star formation occurred over 100 Myr ago, and the new observations confirm this interpretation.

They find a large (over 110) system of evolved super star clusters in M82 B. Using a two-color *BVI* diagram and evolutionary spectral synthesis models to separately estimate the extinction and age of each cluster, they find the clusters

range in absolute magnitude from $M_V^0 = -6$ to -10, with a peak at -7.5. The derived age distribution suggests steady, continuing cluster formation at a modest rate at early times (>2 Gyr ago), followed by a concentrated formation episode ~ 600 Myr ago and more recent suppression of cluster formation. The peak episode coincides with independent dynamical estimates for the last tidal encounter with M81, which presumably induced the starburst. de Grijs *et al.* also resolve the bright giant population in M82's disk for the first time. Star formation evidently continued in M82 B until about 20 – 30 Myr ago, but none is found associated with the youngest generations in the nuclear starburst (age $\lesssim 15$ Myr). After correcting the cluster luminosity function to a fiducial age of 50 Myr, they find that the bright end is characterized by a power-law slope with $\alpha = -1.2 \pm 0.3$, similar to that of other young cluster systems in interacting galaxies.

Majewski, Siegel, Gallart (Yale) and Braun (NFRA) have been imaging fields centered on compact high velocity clouds (CHVCs) in order to search for evidence of associated stars as a test of the hypothesis that CHVCs are protogalaxies.

Crane and Ostheimer have begun a systematic search for local group dwarf galaxies in the vicinity of the Andromeda Galaxy using the Digital Sky Survey.

Steve Crawford (undergraduate), Majewski and M. Bershady (Wisconsin) have been investigating the influence of large-scale structure on faint galaxy count/color surveys.

Ostheimer, Majewski and Patterson continued their study of M31's halo. They are using their photometric giant identification technique in conjunction with a wide field survey to determine M31's extent, flattening, and density law. Additionally, they are also searching for tidal debris around M31's satellite galaxies with the help of undergraduate Jennifer Alltop.

Palma, Majewski, Kundu (Yale), and de Grijs have begun to search nearby, edge-on, late-type, warped spiral galaxies for evidence of luminous halos and/or rings reminiscent of dwarf galaxy disruption such as are seen in the halo of the Milky Way (e.g., the Sagittarius dwarf) and NGC 5907. Wide field, deep imaging in the BATC intermediate red filter was obtained for four galaxies with the KPNO 0.9-m and MOSAIC camera.

O'Connell, with collaborative groups led by P. Marcum (TCU) and L. Kuchinski (IPAC), completed two papers which constitute a ''UV-Optical Atlas of Bright Galaxies,'' based on vacuum UV images obtained by the Ultraviolet Imaging Telescope during the Astro-1 and Astro-2 missions. The studies compare wide field ($40'$), moderate resolution ($3''$) UV images at 1500 and 2500 Å with ground-based CCD images in *U,B,V,R,I* and Hα and provide multicolor surface photometry. There are 78 galaxies in the published sample. UV galaxy morphologies are usually significantly different from visible band morphologies as a consequence of spatially inhomogeneous stellar populations. Differences are quite pronounced for systems in the middle range of Hubble types, Sa through Sc, but less so for ellipticals or late-type disks. Normal ellipticals and large spiral bulges are fainter and more compact in the UV. However, they typically exhibit smooth UV profiles with far-UV/optical color gradients which are larger than any at optical/IR wavelengths. A number of systems have unusual UV-bright structures in their inner disks, including rings, compact knots, and starburst nuclei, which could easily dominate the UV light in high redshift analogs.

The multiband comparisons show that dust in normal spiral disks does not control UV morphologies, even in some edge-on spirals. The heaviest extinction is apparently confined to thin layers and the immediate vicinity of young HII complexes; the UV light emerges from thicker star distributions, regions evacuated of dust by photodestruction or winds, or by virtue of strong dust clumpiness. Only in cases where the dust layers are disturbed does dust appear to be a major factor in UV morphology.

S. Randall (graduate student), Sarazin, Irwin, J. Bregman (U. Michigan), M. Wise (MIT), and B. McNamara (U. Ohio) are analyzing the Chandra observations of the X-ray bright elliptical galaxy NGC 4649. This galaxy has extended emission line filaments and dust, and the X-ray data be used to study the interaction between the hot, X-ray emitting gas and cooler interstellar material. They will determine whether heat conduction into the cooler gas or energy losses to grains affect the thermal state of the gas. The elemental abundances and gradients in the hot gas will be derived and compared to the stellar values.

Sarazin, Blanton, Randall, and Irwin are using Chandra X-ray observations to resolve the X-ray binary population in the X-ray faint early-type galaxies NGC 4365 and NGC 4382. They will determine the luminosity functions of the LMXBs, which provide direct evidence of the history of massive star formation, and a measure of the relative numbers of NS and BH binaries.

Sarazin, Irwin, and Bregman observed the nearby X-ray faint elliptical galaxy NGC 4697 with Chandra. This observation resolves much of the X-ray emission (61% within one effective radius) into ~ 80 point sources, of which most are low mass X-ray binaries (LMXBs). Of the remaining unresolved emission, it is likely that about half is from fainter LMXBs, while the other half ($\sim 23\%$ of the total emission) is from interstellar gas. Three of the resolved sources are super-soft sources. In the outer regions of NGC 4697, eight of the LMXBs (about 25%) are coincident with candidate globular clusters, which indicates that globulars have a high probability of containing X-ray binaries compared to the normal stellar population. The luminosity function of the LMXBs has a ''knee'' at 3.2×10^{38} ergs s^{-1}, which is roughly the Eddington luminosity of a 1.4 $M_\odot$ neutron star (NS); this knee might be useful as a distance indicator. The highest luminosity source has the Eddington luminosity of a ~ 20 $M_\odot$ black hole (BH). The presence of this large population of NS and massive BH stellar remnants in this elliptical galaxy shows that it (or its progenitors) once contained a large population of massive main sequence stars.

Sarazin, Irwin, and Bregman also analyzed ASCA and ROSAT images and spectra of the X-ray-faint elliptical galaxy NGC 4697. The aim was to understand the origin of the hard and soft emission in these systems.

Sarazin, Irwin, and Bregman are analyzing a Chandra X-ray observation of the nearby, bulge-dominated Sa galaxy

NGC 1291. Much like the Chandra observation of the X-ray faint elliptical galaxy NGC 4697, our observation of NGC 1291 reveals that a majority of the X-ray emission is resolved into discrete point sources down to a limiting luminosity of about 2×10^{37} ergs/s. These appear to be low-mass X-ray binaries. Some of the emission is truly diffuse and gaseous.

Sarazin, Irwin, and Bregman are observing the very X-ray faint S0 galaxy NGC 3115 to determine the nature of its LMXB population, and to try to understand why it is fainter than similar elliptical galaxies.

Sarazin, Kempner, Irwin, and Wise are also observing NGC 4649 and and NGC 5846 (another X-ray bright elliptical with optical emission line and dust filaments) with XMM-Newton.

W. C. Saslaw and W. Cotton (NRAO) have used the VLBA to observe a case of a Milky Way star superimposed on the nucleus of an extragalactic radio source to see if it produces a gravitational lens. If so, it would have a number of implications for the nature of the star, the structure of the Milky Way, and the nature of the radio galaxy's nucleus.

Thuan and graduate student Bauer, in collaboration with J. Condon (NRAO) have cross-identified the ROSAT Bright Source Catalogue (RBSC) and the NRAO VLA Sky Survey (NVSS) to construct the RBSC-NVSS sample of the brightest X-ray sources ($\geqslant 10^{-12}$ ergs cm^{-2} s^{-1} in the 0.1–2.4 keV band) that are also radio sources ($S \geqslant 2.5$ mJy at 1.4 GHz). The resulting X-ray/radio sample is unique in its size (1556 objects), composition (a mixture of normal galaxies, Seyfert galaxies, quasars and clusters), and low average redshift (~ 0.1). The local X-ray and radio luminosity functions for Seyfert galaxies have been derived. Seyfert 1 galaxies produce the bulk of the X-ray emission in the local Universe. A break in the X-ray luminosity function is seen at $10^{41.5}$ ergs s^{-1}, indicating the transition from bright Seyferts to less luminous ones (LINERs). Most of the properties of active galactic nuclei in the sample can be explained by a range in orientation, black hole mass and accretion rate.

Thuan in collaboration with Pustilnik (SAO), Brinks (Guanajuato), Lipovetsky (SAO) and Izotov (Kiev) has done VLA HI mapping of SBS 0335–052. A large HI complex associated with this object was detected, with an overall size of about 64 by 21 kpc and elongated in the East–West direction. There are two prominent, slightly resolved peaks visible in the integrated HI map, separated in the East–West direction by 22 kpc. The eastern peak is nearly coincident with the position of the optical galaxy SBS 0335–052. The western peak is about a factor of 1.3 brighter in the HI line and is identified with a faint blue compact dwarf galaxy, SBS 0335–052W, with $m_V = 19$, and a metallicity close to the lowest values known for BCDs, about 1/50 that of the Sun. The radial velocities of both systems are similar, suggesting that the two BCDs SBS 0335–052 and SBS 0335–052W constitute a pair of dwarf galaxies embedded in a common HI envelope. Alternatively, the BCDs can be the nuclei of two distinct interacting primordial HI clouds. The estimated total dynamical mass, assuming the BCDs form a bound system, is larger than $\sim 6\times10^9\,M_\odot$. This is to be compared to a total gaseous mass $M_{gas}=2.0\times10^9\,M_\odot$, and a total stellar mass $M_{star}\leqslant 10^8\,M_\odot$. Hence, the mass of the SBS 0335–052 system is dominated by dark matter. Because of the disturbed HI velocity field and the presence of what might be tidal tails at either end of the system, we favor the hypothesis of tidal triggering of the star formation in this system. It can be due to either the nearby giant galaxy NGC 1376 or the mutual gravitational interaction of the two HI clouds.

Thuan in collaboration with L. Vanzi (ESO), L. Hunt (Arcetri) and Y. Izotov (Kiev) has obtained near-infrared spectra and deep JHK images of SBS 0335–052, the second most-metal deficient blue compact dwarf (BCD) galaxy known ($Z_\odot/40$). The idea was to test Izotov & Thuan's proposition that all BCDs with a metallicity less than 1/20 solar should be young, with stellar populations not older than about 100 Myr. The near-infrared spectrum of SBS 0335-052 is representative of an extreme and young starburst galaxy. The $Br\gamma$ equivalent width indicates a very young age, and is one of the largest ever observed in an extragalactic object. The He I recombination lines support the presence of young massive stars. Recombination and H_2 lines are strong, [FeII] and stellar absorption bands are absent, which also implies a strong UV field and a young stellar population; there is no spectroscopic evidence for stars older than 5–6 Myr. Modeling the $Br\gamma$ and K continuum leads to a burst age $\leqslant 5$ Myr and a star formation rate that can be as high as 10 $M_\odot$/yr. The optical and NIR colors are unusual, and after correction for the nebular emission from the ionized gas, can be only understood as due to a stellar population not older than 4 Myr, together with hot dust at 670 K. Thus the NIR colors are consistent with SBS 0335–052 being a young galaxy. The possible contribution from an evolved stellar population cannot exceed 15%.

Whittle prepared the phase II submission for a cycle 8 HST project to study in detailed two Seyfert galaxies with exceptionally strong blue wing asymmetries. The aim is to find out whether the blue wings originate from outflowing gas or inflowing gas. The ambiguity in direction of flow has been recognised but not solved for nearly 15 years. It is hoped that this study will finally solve the flow direction ambiguity. The WFPC data have been taken and analysed, including broad band and emission line images. The spectroscopic data have just been taken and need to be analysed in conjunction with the image data.

Whittle completed a 10,000 word invited review article on ''Seyfert Galaxies'' for the upcoming ''Encyclopedia of Astrophysics'' published by the Institute of Physics (IoP). The review is written at the advanced undergraduate, graduate and professional non-specialist level and considers a number of themes: discovery, classification, detection, structure and geometry, relation to other AGNs, black holes, continuum emission, broad line region, narrow line region, hosts, environment, triggering, and future prospects.

Whittle and Nelson (U. Nevada) completed work on the stellar populations in the nuclei of Seyfert galaxies. Previously, it has been assumed that the reason optical stellar absorption lines are weak in Seyfert galaxies is because they are diluted by a featureless power law AGN continuum. Combining measurements of Mgb (optical) and CaII triplet (near IR) features, they have shown that this model does not

work for a significant number of Seyferts including many Seyfert 2s. Instead, they find that evolved circumnuclear starbursts fit the linestrength data better. Combined with off nuclear data and IRAS colors, they conclude that nuclear star formation is common in many Seyfert nuclei and can cominate the optical continuum, rather than emission from an AGN.

Whittle (PI), Silverman (graduate student), Nelson (U. Nevada), and Wilson (U. Maryland) have continued to work on their cycle 7 HST STIS data on the Seyfert 2 galaxy Markarian 78. STIS spectral images from four slits each with four spectral ranges were re-reduced and calibrated, improving on the pipeline reduction. [OIII] λ5007 line profile parameters have been measured for all spectra as well as line strengths and reddening corrections for all optical and red lines (blue and UV lines have yet to be measured). Together, these have yielded the kinetic energy distribution in the emission region, and provided a preliminary understanding of the dynamical evolution of the jet gas interaction. The dynamical study completed Silverman's Masters Thesis work.

This same group (Whittle, PI) prepared the phase II submission for a related cycle 8 HST project to study a further 8 Seyfert galaxies thought to have strong jet-gas interactions in their narrow line regions. Data for 7 of the eight have now been taken and the initial recalibration of the pipeline data is underway. Our aim is to extend the detailed case study of Markarian 78 with a simpler kinematic analysis of these other galaxies, establishing the full range of jet-gas interactions.

3.4 Clusters of Galaxies

Blanton, along with M. D. Gregg (LLNL/IGPP, UC Davis), D. J. Helfand (Columbia U.), R. H. Becker (LLNL/IGPP, UC Davis), K. Leighly (U. of Oklahoma), and R. L. White (STScI) studied the environments of a complete sample of moderate-redshift bent-double radio sources selected from the VLA *FIRST* survey, using optical images and spectroscopy. More than half of the 40 radio galaxies in the sample were found to be associated with Abell richness class 0 or greater clusters at $z<0.4$. Most of the remaining objects are associated with groups, although a few appear to be hosted by nearly isolated elliptical galaxies. For the bent doubles appearing in poor environments, either dense gas must be associated with the systems to provide the ram pressure to bend the lobes, or alternative bending mechanisms will have to be invoked to explain the radio morphologies. Correlation with the *ROSAT* All Sky Survey Bright and Faint Source Catalogs revealed that the majority of the $z<0.2$ objects in the sample that were optically classified as clusters are also X-ray sources.

Blanton, Sarazin, Z. Huang (GSFC), McNamara, and Wise are using a Chandra image to study the interaction of the central radio galaxy with the cooling flow gas in the cluster Abell 2052. The X-ray image shows that the radio source is blowing bubbles in the X-ray gas.

N. D'Cruz (U. Sidney) and Sarazin have determined the predicted luminosities, surface brightness profiles, and spectral line profiles for the 3.071 mm hyperfine line from Li-like ^{57}Fe in cooling flow and non-cooling flow clusters.

J. Kempner (graduate student) and Sarazin used the WENSS survey to discover 7 new cluster radio halos and relics in Abell clusters. These diffuse radio sources are believed to arise from a population of relativistic electrons accelerated in cluster merger shocks. The low frequency (327 MHz) covered by WENSS is ideal for observing radio halos and relics since they characteristically have very steep spectra.

Kempner and Sarazin are studying Abell 85 using Cycle 1 observations from the Chandra X-ray Observatory. The cluster has a significant cooling flow, but also shows interesting structure associated with the merger of two small subclusters with the main cluster, one of which also has a radio relic. The observations will provide information about thermal and nonthermal effects in the merger process and about the effect of mergers on cooling flows.

Kempner, Sarazin, Blanton, M. Markevitch (CfA), and P. Ricker (U. Chicago) are observing the cluster Abell 2034 in X-rays with Chandra. This is a merging cluster with a radio relic newly discovered by Kempner and Sarazin. The analysis of this cluster will be similar to both Abell 85 and Abell 133.

Kempner, Sarazin, Markevitch, and Ricker are observing the three merging clusters Abell 3395, Abell 1644, and Abell 2034 in X-rays with XMM-Newton. They will obtain high resolution temperature and entropy maps of the clusters, as well as providing kinematic information about the mergers. Abell 3395 is a well behaved off-center merger which will be compared in detail to hydrodynamic simulations by Ricker.

Kempner, Sarazin, and L. Rudnick (U. Minnesota) have proposed to do follow-up observations of three newly discovered radio relics using the VLA. The proposal to get high resolution total intensity maps of the relics at multiple frequencies would enable measurements of the cluster magnetic fields and the spectral aging of this population of cosmic ray particles, while polarization maps would provide details about the magnetic field structure and shock amplification of the field. Comparison with X-ray observations would also provide an opportunity to study the efficiency of shock acceleration of relativistic electrons and the contributions of nonthermal effects to pressure support in the ICM.

O'Connell, Sarazin, McNamara, C. O'Dea, S. Baum, M. Donahue, M. Voit, A. Koekemoer (STScI), J. Houck (MIT), and Wise are analyzing a Chandra observations of the cooling flow cluster Abell 2597. This system shows evidence for interaction between the X-ray emitting gas, the radio source, and cooler interstellar gas.

Randall and Sarazin calculated the effect of extreme ultraviolet emission from clusters of galaxies on the diffuse ionizing radiation field in the universe.

Randall and Sarazin are using merger trees to determine the effects of cluster mergers on the thermal and nonthermal properties of clusters of galaxies.

Sarazin, Blanton, Kempner, Wise, and McNamara will use Chandra observations to study the interaction of the radio source and cooling flow in the clusters of galaxies Abell 262 and Abell 3112.

Sarazin, P. Goldoni, A. Goldwurm, P. Laurent, J. Paul (Saclay), and M. Cassé (IAP) have calculated models for the hard X-ray and soft gamma-ray fluxes, spectra, and images of clusters of galaxies. These have been used to simulate INTEGRAL observations of clusters; the simulations show that INTEGRAL should provide key information about the nonthermal content of clusters.

Sarazin, Kempner, Blanton, H. Andernach (U. de Guanajuato), M. Ehle (XMM-Newton SOC), A. Roy (MPIfR), Rudnick, and B. Slee (ATNF) are analyzing a Chandra X-ray observation of Abell 133, a merging cluster which has a filamentary radio relic. The data from Chandra will be used to determine changes in temperature and entropy of the ICM in merger shocks and kinematics of the merger. It will also be combined with radio observations to study local variations in the magnetic field, particle acceleration efficiency of the shocks, and the contribution of nonthermal pressures to pressure support of the ICM.

Sarazin, E. Lufkin, and R. White (UA) used 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, McNamara, Wise, P. Nulsen (U. Wolongong), and L. David (CfA) will observe the moderate redshift cluster MS0839.9+2938, which may be a cooling flow cluster in formation.

Sarazin and P. Ricker (U. Chicago) are simulating offset mergers between virialized clusters of galaxies, using the Eulerian hydrodynamics/*N*-body code COSMOS. They find that the cluster X-ray luminosity and temperature can increase significantly during the merger. They study the development of turbulent flows during mergers, and compare the survival of distinct pressure peaks in the different simulations. They also study the generation and redistribution of entropy by merger shocks, finding that turbulent mixing and fluid instabilities play a significant role in raising the core entropy of the intracluster medium over a period of several Gyr following a merger.

Sarazin and Wise calculated 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 effects the X-ray surface brightness profiles, from which the local rates of gas cooling have been derived.

Sarazin, Wise, McNamara, Houck, and D. Davis (MIT) are using the Chandra spectrum of the distant cooling flow cluster MS2137.3-2353 to study the origin of excess soft X-ray absorption in the spectra of cooling flows.

Whittle, and Moss (John Moors University, Liverpool) have completed their Objective Prism Survey of Hα emitting galaxies in 8 nearby Abell clusters, submitting the work for publication in MNRAS as paper IV in their series. In the current work, they have investigated how the environmental influence on star formation itself depends on the cluster richness. For clusters spanning a significant range from loose (e.g. Abell 262) to dense (e.g. Coma) there is a very significant increase in the incidence of triggering star formation. This dependence is distinct from the relation between triggered star formation and local galaxy surface density.

3.5 Cosmology

W. C. Saslaw is developing an analytic theory for the effects of a cosmological constant and of exotic dark matter on the observable rate of galaxy clustering at modest redshifts.

W. C. Saslaw and I. Odisharia (Tbilisi State Univ., Georgia) are developing new methods for the recognition of spatial patterns in galaxy clustering and their relation to many-body gravitational physics.

Thuan has started a collaboration with F. Hammer (Meudon), N. Gruel (Meudon) and H. Flores (Saclay) to study luminous ($M_{AB}(B) \leqslant -20$) compact ($r_{1/2} \leqslant 5\ h_{50}^{-1}$ kpc) galaxies (LCG) in the redshift range from 0.45 to 0.8. VLT spectra of 14 LCGs selected from two galaxy fields in the Canada-France redshift survey reveal strong metallic absorption line sytems as well as narrow and intense emission lines. Their gas extinction is found to be large ($A_V \sim 2$ mag) leading to an upward revision of their star formation rate (SFR) to a median value of $\sim 50\ M_\odot\ \mathrm{yr}^{-1}$. Gas metal abundances in LCGs have about half the solar value. LCG absorption spectra can be synthesized with a mix of a few Gyr old and relatively metal-rich (generally solar to over-solar values) stellar population and a younger stellar population ($< 5\times10^8$ years) having a metal abundance similar to that of the gas. It is argued that LCGs are the progenitors of present-day spiral bulges because they have masses, light concentrations and abundances similar to those of present-day bulges. Because LCGs are 10 to 100 times more massive than dwarf galaxies, they cannot be the progenitors of local spheroidal or irregular systems through fading, as proposed before. The gas needed to feed the observed star formation is likely to be falling in from the outskirts of the galaxy, being tidally pulled out from interacting companion galaxies. At least for the strongest star-forming LCGs, there is clear imaging evidence for the presence of such companions. Some LCGs also show evidence for the beginning of a disk formation. If the above scenario holds for all LCGs, they estimate that at least 20% of present-day spiral galaxies have formed the bulk of their stars at relatively recent epochs, during the last 8–9 Gyr, at redshifts less than ~ 1. Since they are heavily extincted, they predict their IR luminosities to be relatively large, around $L_{IR}=10^{11}\ L_\odot$, i.e. near or slightly below the luminosities of the galaxies detected by ISO in the same redshift range. Taking into account the integrated IR luminosity of the LCG galaxy population can lead to a significant upward revision of the cosmic SFR density in the redshift range from 0.5 to 1.

3.6 Astrometry

Dinescu, Majewski, Girard (Yale), and Cudworth (Yerkes) have completed a study of the absolute proper motion of Palomar 12 and its orbit. From the analysis of its orbit in combination with a tidal disruption model of the Sagittarius dSph, they find that Pal 12 was most likely torn from Sgr rather than the Large Magellanic Cloud (LMC), as had been previously hypothesized. Dinescu and Majewski have also started a proper-motion study of NGC 7006, which has similar plate material to that of Pal 12. Two of the three epochs of data have been scanned.

Dinescu, Majewski and Keeney (undergraduate student) have started a project to measure the absolute proper motion of the Fornax dwarf spheroidal, using HST archived data as the modern epoch, and earlier epochs of photographic plates spanning more than 40 years. To date all the HST data have been reduced, and the measurement of the oldest (Hale 5m) plates with the UVa PDS has begun. In a similar study, Siegel and Majewski have continued their efforts to measure the absolute proper motion of the Leo II dsph with a combination of archival $200''$ plates and a new epoch of HST snapshot data. Scanning of the plates on the UVa PDS is proceeding. Siegel, Majewski, Cudworth and Dinescu are working to improve the proper motion of the Sculptor dwarf with the addition of background QSO's to the extra-galactic reference frame.

Dinescu and Majewski, in collaboration with A. Sandage (OCIW) are continuing their deep proper motion survey of five Kapteyn Selected Area fields with the UVa PDS microdensitometer. Preliminary scans have provided catalogues of photographic photometry, which are being calibrated with CCD data, as well as object classification down to $V=22$.

Ianna and Begam are continuing the CCD parallax program at the Mount Stromlo and Siding Spring Observatories using the 1 m reflector at a reduced rate. Ianna, T. Henry (GSU), and R. Mendez (ESO) are into the second year of a parallax program at CTIO on the 0.9m and 1.5m telescopes through a NOAO Survey award. The observing, about six nights per month, began in August 1999. The aims of this program are similar to the Australian program: to identify new nearby star candidates in new southern proper motion catalogs through photometry as well as other sources and to obtain parallaxes of those objects likely to be within 20 pc.

Patterson, Xilouris and Dinescu have upgraded the UVa PDS microdensitometer and it is now controlled by a SUN workstation, replacing the much older VAX system. The new system has proved very reliable, and from comparisons with scans from the Yale PDS, it is found that a precision of the order of 0.9 micron can be obtained for well-measured objects.

Siegel, Majewski, Cudworth (Yerkes) and Takamiya (Gemini) have completed a comprehensive astrometric and photometric survey of the outer halo globular cluster Palomar 13. The color-magnitude diagram, proper motion, blue straggler fraction and radial density profile are all consistent with Pal 13 having undergone substantial mass loss in the past. The cluster is unlikely to survive many more perigalactic passages.

4. MISCELLANY

Balbus was a visitor at Institut d'Astrophysique de Paris in June 2000.

Balbus and Hawley were participants in the astrophysical turbulence workshop held at the Institute for Theoretical Physics in Santa Barbara in May 2000.

Chevalier served on the NRC/NAS Committee on Astronomy and Astrophysics, the AURA/NOAO Observatories Visiting Committee, and began a term on the USRA Board of Trustees.

Dinescu received the Dirk Brower Memorial Prize from Yale University.

Hawley served on the National Computational Science Alliance User Advisory Panel.

Ianna serves as a technical consultant to CSICOP, a member of the Executive Board of the International Dark-Sky Association, Chair of the Virginia Section of IDA, on the Scientific Working Group of the NASA NStars Project, and the IAU Working Group on Extrasolar Planets.

The Grid Giant Star Survey of Majewski and Patterson has been selected as a primary source of Astrometric Grid stars for NASA's Space interferometry Mission.

O'Connell is chair of the Scientific Oversight Committee for the Hubble Space Telescope Wide Field Camera 3, a two-channel UV-visible-infrared imager scheduled for installation during the 2003 servicing mission. He also served as a member of the stellar populations panel for the Giant Segmented Mirror Telescope project (NOAO) and of the UV/Optical Detector Working Group (NASA HQ).

Palma served as the President of the Graduate School of Arts & Sciences Graduate Student Council and was appointed to the panel to interview and select finalists for the student member of the UVa Board of Visitors. He was elected to the university's Raven Honor Society.

Palma (graduate student) and Kempner (graduate student) organized and ran the ''First Annual University of Virginia Graduate Student Research Exhibition.'' A total of 32 graduate students from many departments in Arts & Sciences presented poster displays and gave talks on their research, competing for $4000 in prize money contributed by the Graduate School.

Richards wrote the report on the ''The Status of the Algols,'' for the IAU Triennial Report of Commission 42 which was published in *Reports on Astronomy* (*Transactions of the International Astronomical Union*), Vol. XXIVA. This review described the need for southern hemisphere surveys of the Algols, enhanced searches for more non-eclipsing Algols, as well as monitoring with the proposed Space Interferometer to resolve some of these binaries. Richards presented an invited review lecture on Doppler tomography of eclipsing and non-eclipsing Algol-type binaries at the conference on Astro Tomography: An International Workshop on Indirect Imaging that was held in Brussels, in July 2000. Richards continued to serve as a member of the AAS Committee on Minorities in Astronomy.

Sarazin was chair of the Chandra Users' Committee, and a member of the ASCA Users' Committee, the Astro-E Users' Committee, the High Energy Astrophysics Panel for National Academy of Sciences Decadal Report, the Astronomy

and Space Physics Council of Universities for Space Research Association, and the scientific organizing committee for the Chandra Science Symposium and the IAP 2000 Conference on Constructing the Universe with Clusters of Galaxies.

W. C. Saslaw's book The Distribution of the Galaxies: Gravitational Clustering in Cosmology has been published by Cambridge University Press.

Thuan was on sabbatical leave in France at the Observatoire de Meudon and the Institut d'Astrophysique de Paris. He gave an invited 1-week series of lectures in Astrophysics at the University of Hanoi (Vietnam).

During the year there were about 4000 visitors to the McCormick and Fan Mountain Observatories as part of our continuing public outreach program.

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