Pennsylvania State University
Astronomy and Astrophysics

University Park, Pennsylvania 16802-6305

[S0002-7537(93)02751-9]

This report covers the period from September 1, 2001 to August 31, 2002.

1. PERSONNEL

1.1 Faculty

The regular members of the faculty during the academic year 2001-2002 were Professors Peter Mészáros (Department Head and Distinguished Professor), Eric Feigelson, Gordon Garmire (Evan Pugh Professor), Pablo Laguna, Lawrence Ramsey, Mercedes Richards (formerly of the University of Virginia), Douglas Sampson (Emeritus), Donald Schneider, Peter Usher (Emeritus), and Alexander Wolszczan (Evan Pugh Professor); Associate Professors William Nielsen Brandt, Jane Charlton, Robin Ciardullo, and Richard Wade; Assistant Professors Tom Abel (formerly of the Institute of Astronomy, Cambridge, England), Michael Eracleous, Jian Ge, and Steinn Sigurdsson; Senior Scientist/Professors David Burrows, John Nousek and George Pavlov.

Jim Beatty and Lee Samuel Finn, Professors of Physics and Douglas Cowen, Associate Professors of Physics, and Stephane Coutu, Assistant Professor of Physics, all hold joint appointments in Astronomy & Astrophysics.

Senior Research Associates in the program were George Chartas and Leisa Townsley. Research Associates in the program were David Alexander, Franz Bauer, Abhijit Chakraborty, Margaret Chester, Christopher Churchill, Patrick Durrell, Audrey Garmire, Konstantin Getman, Valdimir Getman, Joanne Hill, Sally Hunsberger, Koji Mori, Christopher Palma, Sangwook Park, Gordon Richards, Peter Roming, Divas Sanwal, Nicholas Sessions, Hisa-aki Shinkai, Deirdre Shoemaker, Yohko Tsuboi, Cristian Vignali and Bing Zhang. Joining the department as Research Associates were Caryl Gronwall (formerly of Johns Hopkins University), Nina Jansen (formerly of the University of Copenhagen, Denmark), Shiho Kobayashi (formerly of Osaka University, Japan), Soebur Razzaque (formerly of the University of Kansas), Deqing Ren (formerly of the National Solar Observatory, New Mexico), Emanuele Ripamonti (formerly of the University Of Thessaloniki, Greece), and Marcus Teter (formerly of Montana State University).

Instructor Phillip Martell was joined by Scott Miller (formerly of the University of California-Santa Barbara) and Michael Weinstein (a recent Ph.D. graduate of the department).

Adjunct Associate Professor was Hans Kraus at the Oxford University Nuclear and Astrophysics Laboratory. Adjunct Assistant Professor was Matthew Bershady at the University of Wisconsin-Madison.

1.2 Visitors to the Department

Visitors to the department included Dr. Eli Waxman (from The Weizmann Institute of Science, Rehovot, Israel), Enrico Ramirez-Ruiz (from Wolfson College, England), Valdimir Kotcharvoski (from the Institute of Applied Physics, Russia) and Dr. Zigao Dai (from Nanjing University, China) working with Dr. Peter Mészáros. Alexei Koptsevich (from Ioffe Institute for Physics & Technology, Russia) working with Dr. George Pavlov. Tomasz Soltysinski (from Szczecin University, Poland) working with Dr. Alex Wolszczan. Dr. Warrick Lawson (from the Australian Defence Force Academy) working with Dr. Eric Feigelson. David Fiske (from The University of Maryland), Dario Nunez (from UNAM, Mexico), Pedro Marronetti (from the University of Illinois) and Adrian Gentle (from Los Alamos National Laboratory) working with Dr. Pablo Laguna. Stuart Barnes (from the University of Canterbury, New Zealand) working with Dr. Larry Ramsey. Naoki Yoshida (from Harvard University) and Aaron Sokasian (from Harvard University) working with Dr. Tom Abel.

2. ACADEMIC PROGRAM

Graduate and Undergraduate Majors

Twenty-two graduate and seventy undergraduate astronomy majors were enrolled during the academic year 2001-2002. During that time 12 B.S. degrees and five Ph.D. degrees were awarded in Astronomy & Astrophysics. Doctoral recipients were David Andersen, Sarah Gallagher, Rajib Ganguly, Ann Hornschemeier and Michael Weinstein.

2.1 Educational Initiatives

Once again, the Department offered summer graduate classes for high-school teachers interested in learning more about astronomy and its potential as a medium for physical science education in secondary schools. The 2002 program entitled, Penn State Inservice Workshops in Astronomy (PSIWA), consisted of two 1-week courses on Space Astronomy for Science Teachers and Galaxies and Cosmology for Science Teachers. Both courses were offered at Penn State's main campus and included a variety of classroom, laboratory and computer activities. Funding was received from the PA Space Grant Consortium and NASA. Feigelson and Brandt were the workshop instructors. Numerous department faculty, research associates and graduate students also participated in the programs.

2.2 Outreach

The department outreach effort continued to provide stimulating and educational programs for the general public in 2002. This year the department hosted the Friedman Lecture Series; a set of five, free public lectures sponsored by the Ronald and Susan Friedman Fund and NASA's PA Space Grant Consortium. Guest speakers Dr. Marc Millis of NASA Glenn Research Center and Professor Lawrence Krauss of Case Western Reserve University, along with several faculty members and graduate students from the department presented talks on black holes and time machines. Once again this summer, members from the department teamed up with Astronomy Club members to produce AstroFest: a program featuring numerous astronomical activities held during the Central Pennsylvania Festival of the Arts. More than 1,600 people visited the department over the four-day event. Additional public service programs, i.e., planetarium shows, observing with telescopes, and public lectures were held throughout the year. A complete listing of outreach programs offered by the department may be viewed at http://www.astro.psu.edu/outreach/outreach.html. Between all events, we have served upwards of 6,000 people over the year.

2.3 Astronomy Club

The Astronomy Club continued to conduct monthly public observing sessions, uninterruptedly since 1973. These Open Houses attracted hundreds of visitors to the roof of Davey Laboratory to view selected celestial objects through various telescopes. Members also participated in outreach programs for school children, making use of the department's planetarium. Club officers are: President, Christa Hasenkopf; Vice President, Brandon Aldinger; Treasurer, Eric Rotthoff; Secretary, David Kiger. Eracleous is the Club's faculty advisor.

3. RESEARCH ACTIVITIES

3.1 Instrumentation for Observing

3.1.1 Optical

3.1.1.1 The Hobby-Eberly Telescope The HET is nearing completion of its third year of early operations. During this last year about 2/3s of the HET time was scheduled for science observations in the queue mode. The remainder of the time is taken up by instrument commissioning and telescope engineering and facility improvements. Synoptic observations are also obtained on many of the nights that were scheduled for instrument commissioning and telescope engineering. The facility instruments in service this period remain the Low Resolution Spectrograph (LRS) and the High Resolution Spectrograph (HRS). The average shutter open on sky efficiency of the HET during science operations has improved from 30% to about 45%. Spectra were delivered to all five collaborating institutions: UT Austin, Penn State University, Stanford University, Georg August Universitaet Goettingen, Ludwig Maximilians Universitaet Muenchen, and to the US national community through NOAO. The Pennsylvania State University accounted for roughly 30% of the time.

The HET has benefited substantially from the HET Completion Project in the past nine months. The HET Completion Project (HETCP) was begun in June 2001 to finish critical aspects of the HET which were not supported in the original very constrained construction budget and deficiencies that became apparent in the commissioning and early operations. Phase I consisted of four major elements: The Segment Alignment Maintenance System (SAMS), the Dome Ventilation System (DVS), and the Mirror Alignment Recovery System (MARS), and the Differential Image Motion Monitors (DIMM).

SAMS, which is the primary mirror array edge sensor retrofit to eliminate segment misalignment after stacking, was installed in October 2001 and has greatly benefitted telescope performance. Average time between segment alignment, called ''stacking,'' has increased from 1 hour pre-SAMS to about 4 hours with SAMS. Delivered telescope image quality improved about 0.3 arcsec under SAMS operation. SAMS does not yet meet specifications, and an in-house effort was begun in summer 2002 to improve SAMS performance.

DVS this year consisted of designing, fabricating, and installing large ring wall louvers in the HET enclosure. This effort, begun in June 2001, was completed on schedule and on budget in May 2002. While it is difficult to quantify the improvement in image quality due to the installation of the louvers, there is little doubt that the benefit is significant. An effort underway this year to minimize the effect of dome supercooling on image quality by covering the dome with low emmissivity aluminum foil and insulating the interior surface of the dome. A complete Facility Thermal Management project was also started in the summer of 2002 to address remaining heat sources within the enclosure and other thermal issues.

MARS, a prototype Shack-Hartmann-based segment alignment system for the primary mirror array, replace the original failed Center of Curvature Alignment System (CCAS) in October 2001. CCAS and MARS performance is measured in the size of the stack image at the Center of Curvature. CCAS averaged 1.2 arcsec, and MARS has averaged a significantly better 0.9 arcsec stack image. A MARS II final instrument is under design and construction by the McDonald engineering staff in Austin and Mt. Locke, and should become operational in early 2003.

Two DIMM telescopes were set up and put into regular operation in July 2001, and have now provided the first complete and quantitative site seeing data set at the Observatory for an entire year. Average zenith seeing during the summer months is 0.9 arcsec FWHM, average seeing during the winter months is 1.2 arcsec, and the average over the year is 1.0 arcsec. DIMM operation has aided HET operation by providing realtime feedback on seeing conditions, which is important for science operations decision-making and for deciding when to realign the primary mirror array. Construction of a permanent DIMM tower to eliminate the effects of the surface boundary layer has begun, and plans are in place to modify the DIMM control system to provide fully remote operation from the HET control room.

At the end of this reporting period the Medium Resolution Spectrograph (MRS), the third HET facility instrument for the HET, was installed and had first light. MRS is a versatile, fiber-fed echelle spectrograph. This instrument is designed for a wide range of scientific investigations and includes single-fiber inputs for the study of point-like sources, synthetic slits of fibers for long slit spectroscopy, 9 independently positionable probes for multi-object spectroscopy, and a circular fiber integral field unit. The MRS consists of two beams. The visible beam has wavelength coverage from 450 - 900 nm in a single exposure with resolving power between 5,300 and 20,000 depending on the fibers configuration selected. This beam also has capability in the ranges 380 - 950 nm by altering the angles of the cross-disperser gratings. A second beam (NIR beam) operating in the near-infrared has coverage of 900 - 1300 nm with resolving power between 5,300 and 10,000. Both beams can be used simultaneously and are fed by the HET Fiber Instrument Feed (FIF) which is mounted at the prime focus of the telescope and positions the fibers feeding the MRS . Both the visible beam and the NIR beam began initial testing on the HET this last year. Basic modes for the visible beam are expected to be available in early 2003 and the NIR beam in the second quarter of 2003. Full commissioning of all modes will continue throughout 2003. The MRS team this last year working consists of engineers Leland Engel and Nicholas Sessions as well as undergraduate students Chris DeFilippo and Michelle Graver and PI L. Ramsey

3.1.2 X-ray

3.1.2.1 Overview of CCD Imaging Spectrometer on Chandra The ACIS instrument on the Chandra X-ray Observatory continues to operate well. During this past year with the observation of a pulsar, George Pavlov determined that the intensity of the pulsar was low by nearly a factor of two. Since the spectrum of the pulsar was very soft and steady, this indicated that there might be an increase in the absorbing layer in the ACIS instrument. Catherine Grant at MIT measured the ratio of the Mn L lines and an iron fluorescence line from the onboard calibration source, relative to the Mn Kalpha line. This ratio showed a steady decrease, indicating that the low energy efficiency of the instrument was suffering a decrease. The amount of the decrease was substantially greater (10x) expected, based on models of the spacecraft outgassing supplied by TRW prior to launch. Observations conducted with the objective gratings of sources with power law spectra, such as BLAZARS, also indicated an excess of absorption, especially near the carbon edge, when compared to observations of the same BLAZAR using the HRC camera on Chandra. Using the data collected by Catherine Grant, George Chartas developed a computer code to include the absorption in the model of the ACIS instrument that is used for spectral analysis (see http://asc.harvard.edu/cgi-gen/cont-soft/soft-list.cgi). The instrument can be warmed to room temperature which may drive off the layer of material that is acting as an absorber, but warming the instrument has some potential negative aspects, such as increasing the charge transfer inefficiency, so this option is under review at this time.

3.1.2.2 The Swift Gamma Ray Burst Explorer The flight versions of the X-ray Telescope and UV-Optical Telescope for Swift were completed this year. Science calibrations will be performed during Fall '02, followed by integration with the Burst Alert Telescope (NASA/Goddard Space Flight Center) and the spacecraft. After launch in Fall 2003, Swift will be operated by PSU; the mission operations team includes the XRT and UVOT scientists.

3.2 Observational Research

3.2.1 Stellar Astronomy

3.2.1.1 Star Formation The Chandra star formation group (Feigelson,Townsley, Getman, Broos, and Garmire) pursued a variety of studies during the year. A Chandra observation of the NGC 1333 star forming cloud revealed over a hundred young cluster members. One result is that young stellar X-ray emission appears to be independent of the presence or absence of a bipolar outflow. Soft X-ray emission from the bow shock of a Herbig-Haro outflow was seen in the Orion cloud. Two major studies on the Orion Nebula region emerged with a variety of findings: an unexpected rapid X-ray flare in a 30 $M_\odot$ O star; low X-ray emission in intermediate-mass stars consistent with binarity; hot plasma temperatures in some T Tauri stars of all luminosities; and the largest sample to date of X-ray detected young brown dwarfs indicating that magnetic activity in brown dwarfs declines as their atmospheres cool. Analogs of the pre-main sequence Sun were found to have X-ray flares 30 times stronger and 300 times more frequently than the most powerful flares on the Sun today. MeV particle fluences are expected to be elevated 10^5 over contemporary levels, which is sufficient to explain several puzzling isotopic anomalies of short-lived radionuclides in ancient meteorites. The Chandra data thus supports a local irradiation spallation model, rather than external seeding by a supernova remnant, for these isotopic anomalies.

Townsley, Feigelson, Broos, Garmire, Getman, and colleagues obtained the first high-spatial-resolution X-ray images and spectra of M 17, the Omega Nebula, in a 40-ksec observation with the Advanced CCD Imaging Spectrometer (ACIS) aboard the Chandra X-ray Observatory in March 2002. This rich high-mass star-forming region reveals a complex mix of point source and diffuse X-ray emission. The OB association is resolved at the arcsecond level into more than 900 sources. Soft diffuse X-ray emission pervades the H II region and is resolved from the point source population. This extended emission is most likely from the fast O-star winds that thermalize and shock the surrounding media.

The same group obtained an 80-ksec ACIS observation of the very young, high-mass star-forming region W 51 in June 2002. This region is much farther away than M 17 and contains many very early O stars, masers, and other indicators of recent and ongoing star formation. The ACIS image reveals over a hundred point sources and hard diffuse emission. The diffuse component must consist partially of unresolved pre-main sequence stars, but may also come from other components of this very young complex, such as interactions between the O star winds.

Townsley continues to lead an effort to analyze the ACIS data on 30 Doradus in the Large Magellanic Cloud, the archetype giant extragalactic H II region. The group has presented spatially-resolved ACIS spectra of the 30 Dor superbubbles and N157B, the plerion SNR containing a 16-msec pulsar (2002 HEAD meeting poster #B17.061). The superbubbles were seen to contain a variety of thermal plasmas, with temperatures ranging between 1 and 9 million degrees. The SNR shows clear evolution from purely nonthermal close to the pulsar to completely thermal in its outer regions. See the image release at chandra.harvard.edu/photo/2002/0057/index.html.

Getman, Feigelson, Townsley and colleagues studied X-rays from the young stellar population in the NGC 1333, highly active star-forming region. Colleagues include John Bally (Univ. of Colorado), Charles Lada (SAO), and Bo Reipurth (Univ. of Hawaii). Ninety five *Chandra* ACIS sources are identified with known cluster members, including seven of the 20 known YSOs in NGC 1333 producing jets or molecular outflows as well as one deeply imbedded protostellar object. Comparison with K-band source counts indicates that all of the known cluster members with $K<12$ and about half of the members with $K>12$ are detected in X-ray. Most of the sources have plasma energies between 0.6 and 3 keV, a typical range for the X-ray active T Tauri stars, but a few sources show higher energies up to 7 keV. No systematic difference in X-ray luminosity distributions between two complete subsamples of CTTs and WTTs is found. There is also no evident difference in X-ray emission of young stars with and without outflows. The spectral analysis for the X-ray counterpart of the famous SVS 16 shows that the column density is much lower than that expected from near-IR photometry and thus its X-ray luminosity is not anomalously high, as has been previously suggested.

3.2.1.2 Variability-Induced Movers and the SIM Astrometric Grid The term ‘‘variability-induced mover’’ (VIM) denotes a binary star whose photocenter shows an astrometric shift that is caused by a temporary change in the luminosity ratio of the component stars. It has been suggested that the VIM phenomenon may be detrimental to the Space Interferometry Mission (SIM), by destroying the astrometric stability of the Grid Star network that will be used by to establish SIM's reference frame. The Grid will be composed of about 1300 halo giant stars with typical distances of a few kpc. In some cases, late-type main sequence companions orbiting these giants with periods of 10^2–10^3 yr will survive screening for radial velocity variations and other duplicity tests. The angular separations of these binaries will be $\approx 10^4 \mu$as. A fraction of the ‘‘certified’’ Grid stars will then be VIMs, owing either to mmag variations of the halo giant itself or to variations of its companion star. Wade and graduate student Michele Stark carried out an investigation to determine if VIMs will be present in the Grid with sufficient amplitudes (jitter greater than a few μas), varying on relevant timescales and in sufficiently many cases, to undermine the robustness of the Grid as a whole. Present understanding of the problem suggests there is little danger to the Grid.

3.2.1.3 Hot Subdwarf Star Membership in Visual Binaries Wade and Michele Stark, with collaborators J. Orosz (SDSU) and G. B. Berriman (IPAC), continued their study of hot subdwarf stars (sdB or sdO stars) that, on a statistical basis, appear to be members of wide binaries (common-proper-motion pairs). These c.p.m. candidates make up several percent of the approximately 1300 catalogued subdwarfs. Current information about these pairs from literature and new investigations includes magnitude differences and colors, distribution of angular separation vs. magnitude, 2MASS colors, spectra, etc. Confirmation of these candidate binary systems awaits radial velocity and proper motion studies. Radial velocity collection for a portion of the sample is underway at the Hobby-Eberly Telescope; classification spectra are being obtained at McDonald Observatory and KPNO. This sample cannot be regarded as complete in any rigorous way, and is certainly biased in the selection process. It nevertheless shows promise that a purified sample can be used to learn about the luminosities, ages, and original metallicities of the hot subdwarf stars.

3.2.1.4 An RR Lyrae Star in a Binary System Wade and graduating senior J. Donley, along with R. Fried and C. Jones of Flagstaff, AZ, obtained additional photometry of TU UMa. This RR Lyrae star is a probable member of a $\sim$23 year binary system, made manifest by light-time variations in the epochs of maximum light. A model combining a quadratic pulsation ephemeris with a light-time binary orbit of high eccentricity is quite successful at describing the collected timing data. Periastron passage is predicted to occur in about 2011 (depending on what specific model is used), near which time there should be an excursion in the center-of-mass radial velocity of TU UMa. The elements of the $\sim$23 y binary orbit are still rather uncertain, as is the quadratic coefficient of the pulsation ephemeris. It is therefore useful to continue to collect epochs of light maximum, in order to test and refine the orbital/pulsational model. The team obtained differential light curves of TU UMa through Johnson B and V filters at Braeside Observatory and determined five epochs of maximum light in V, using a template light curve technique. The scatter of these observations, obtained over several months in early 2002, is satisfyingly small. The mean $O-C$ of 21.3 minutes from a standard linear test ephemeris is in line with models previously published by Wade *et al.*, indicating there is not yet a need to update the model.

3.2.1.5 An Accretion Disk Devoid of Hydrogen Wade and Eracleous obtained HST/STIS observations of AM CVn, an ultra-short-period interacting binary star composed of two white dwarfs. The less massive star is transferring H-depleted matter to an accretion disk around the more massive star. Understanding the spectrum and structure of this disk will assist in determining the mass transfer rate and thus the lifetimes and space density of such double-degenerate objects, which will provide a significant background source of gravitational waves to experiments such as LISA. Previous analyses of the disk have been based on spectra from the visual band. Preliminary analysis of the time-tagged STIS ultraviolet spectra has already shown that the UV flux is variable on many different timescales, and the P Cyg-like profiles of resonance lines are also variable in time.

3.2.1.6 Radio Flares from RS CVn and Algol Binaries Richards, Waltman (Naval Research Lab), and Ghigo (NRAO) continued their study of radio flares from binary systems. They analyzed 2.3 GHz (S band) and 8.3 GHz (X band) radio continuum observations collected with the NRAO–Green Bank Interferometer nearly continuously over 2096 days (5.7 years). Two RS CVn binaries (V711 Tau and UX Ari) and two Algol-type binaries (β Per and δ Lib) were studied. Flare events were unique. Most began with a strong initial rise, with weaker peaks along the exponential tail of the event. Other flares had the weaker peaks at nearly constant flux. The intensity dips in the flare profile can be explained either by the eclipse of the flare region or by the intermittent production of nonthermal particles as the flare decayed. For the four systems, flares took (20 – 50) hours to rise and decayed over (10 – 40) days. On the Sun, flare eruptions occur within 100 seconds and decay over a few hours. The duration of the flares in the four systems was correlated with the total energy output during the flare event. The spectral index was positive during flares for all four systems, which suggests that the flares arise from a partially opaque gyrosynchrotron source. The flaring behavior of UX Ari was similar to that of V711 Tau, but its flares were weaker than those of V711 Tau. More flares were detected from β Per than from V711 Tau over the same time interval, but the flares on V711 Tau were typically stronger than those on β Per. Flare strength at 8.3 GHz was as high as 1.17 Jy in β Per, 1.44 Jy in V711 Tau, and 0.82 Jy in UX Ari. Only two flares were detected from δ Lib during the survey, with maximum 8.3 GHz flux of only 0.034 Jy. A preliminary analysis suggests that the strongest flares in the RS CVn binaries tend to occur near $\phi = 0.5$ or 1.0, with more flares visible near $\phi = 0.5$ when the more active K star is toward the observer. The strongest flares in the Algols were seen near $\phi = 0.0$ when the active cooler star was toward the observer.

Richards, Waltman, and Ghigo found that β Per, V711 Tau, and UX Ari have predictable flaring cycles. They used Power Spectrum analysis and the Phase Dispersion Minimization technique to determine the periodicity of flaring activity from data collected continuously over a total of 4.6 years. From 1995 January to 2000 October, flares on β Per had a periodicity of (48.9 $\pm$ 1.7) days. In the RS CVn group, the significant periodicities were (120.7 $\pm$ 3.4) days and (80.8 $\pm$ 2.5) days for V711 Tau, with (141.4 $\pm$ 4.5) days and (52.6 $\pm$ 0.7) days for UX Ari. So strong flares occurred roughly every 17 orbital cycles on β Per, every 28.5 and 42.5 orbits on V711 Tau, and every 8 and 22 orbits on UX Ari. No periodicities were found from the δ Lib data. Both V711 Tau and β Per display long-term cycles of apparently alternating active and quiescent flaring activity which seem to last for more than 500 days. However, the survey was not long enough for the period-search analysis to confirm these long-term cycles to any level of confidence. These results were presented at the AAS Meeting in June 2002. A press release was issued at that meeting (see http://www.aoc.nrao.edu/epo/pr/2002/algol/).

Tiffany Soinski (undergraduate student, U. Virginia) and Richards used the 5-year database of radio flares from V711 Tau, UX Ari, and β Per. They studied the profiles of individual radio flares and discovered that no two were exactly alike. While the timescales of flaring activing may be predictable, the shape of the flare is quite variable. These results were presented at the AAS Meeting in June 2002.

3.2.1.7 Cataclysmic Variables Eracleous and Hasenkopf (Penn State) have been studying the X-ray spectra of non-magnetic cataclysmic variables observed with the *ASCA* X-ray observatory. Two-temperature, thermal plasma models are found to provide the best description of the observed spectra. The resulting temperatures lie mostly between 4 and 10 keV, which is somewhat higher than what was found in previous such "surveys" with the Einstein and ROSAT X-ray observatories, but in reasonable agreement with older, EXOSAT observations.

3.2.1.8 Stellar Clusters Feigelson continued his studies of older phases of young stellar evolution with Warrick Lawson (UNSW) and Eric Mamajek (Arizona). Having previously discovered a nearby cluster of coeval stars born 9 ± 1 Myr ago around η Chamaeleontis, they now report the presence of a fully accreting classical T Tauri star in the cluster. An *JHKL* infrared study further demonstrates that many of the cluster members still retain weak circumstellar disks, even at this great age. The cluster is probably only part of a population of $10-20$ Myr stars surrounding the Sco-Cen Association, the nearest OB association to the Sun.

3.2.1.9 Neutron Stars, Pulsars, and Central Compact Objects in Supernova Remnants Rutledge (CalTech), Bildsten (UCSB), Brown (Univ. Chicago), Pavlov, and Zavlin (MPE, Germany) analyzed four Chandra/ACIS-S observations beginning 2 weeks after the end of the 2000 November outburst of the neutron star (NS) transient Aql X-1. Over the 5 month span in quiescence, the X-ray spectra are consistent with thermal emission from a NS with a pure hydrogen photosphere and a radius of 15.9(+0.8,-2.9) (d/5 kpc) km at the optically implied X-ray column density. A hard power-law tail was detected during two of the four observations. The intensity of Aql X-1 first decreased by $50\% \pm 4\%$ over 3 months, then increased by $35\% \pm 5\%$ in 1 month, and then remained constant ($<6\%$ change) over the last month. These variations in the first two observations cannot be explained by a change in either the power-law spectral component or the X-ray column density. Presuming a pure hydrogen atmosphere and that the radius is not variable, the long-term changes can only be explained by variations in the NS effective temperature, from $kT_{\rm eff}^{\infty} = 130(+3,-5)$ eV, down to $113(+3,-4)$ eV, and finally increasing to $118(+9,-4)$ eV for the final two observations. During one of these observations, we observe two phenomena that were previously suggested as indicators of quiescent accretion onto the NS: short-timescale (<104 s) variability [at 32(+8,-6)% rms] and a possible absorption feature near 0.5 keV. Such a feature has not been detected previously from a NS and, if confirmed and identified, can be exploited for simultaneous measurements of the photospheric redshift and NS radius.

Rutledge (CalTech), Bildsten (UCSB), Brown (Univ. Chicago), Pavlov, and Zavlin (MPE, Germany) identified an X-ray source (CXOU 132619.7–472910.8) with a thermal spectrum consistent with that observed from transiently accreting neutron stars in quiescence at the distance of the globular cluster NGC 5139 (ω Cen). The absence of intensity variability on timescales as short as 4 s (less than 25% rms variability) and as long as 5 yr (less than 50% variability) supports the identification of this source as a neutron star, most likely maintained at a high effective temperature ($\sim 10^6$ K) by transient accretion from a binary companion. An alternative hypothesis –that the source is an isolated neutron star accreting from the intracluster medium– could be excluded or confirmed by identifying the X-ray source's optical counterpart. The ability to spectrally identify quiescent neutron stars in globular clusters (where the distance and interstellar column densities are known) opens up new opportunities for precision neutron star radius measurements.

Pavlov, Zavlin (MPE, Germany), Sanwal, and Trümper (MPE, Germany) observed 1E 1207.4−5209, a neutron star in the center of the supernova remnant PKS 1209−51/52, with the ACIS detector aboard the Chandra X-Ray Observatory and confirmed the previously detected period of 424 ms. Assuming a uniform spin-down, they estimated the period derivative, $\dot{P}=(0.7–3)\times10^{-14}$ s s^{-1}. The corresponding characteristic age of the pulsar, 200–900 kyr, is much larger than the estimated age of the SNR, $\sim$7 kyr. The values of the spin-down luminosity, $\dot{E}=(0.4–1.6)\times10^{34}$ ergs s^{-1}, and conventional magnetic field, $B=(2–4)\times10^{12}$ G, are typical for a middle-aged radio pulsar, although no manifestations of pulsar activity have been observed. If 1E 1207.4−5209 is indeed the neutron star formed in the same supernova explosion that created PKS 1209−51/52, such a discrepancy in ages could be explained either by a long initial period, close to its current value, or, less likely, by a very large braking index of the pulsar. Alternatively, the pulsar could be a foreground object unrelated to the SNR, but the probability of such a coincidence is very low.

Sanwal, Pavlov, Zavlin (MPE, Germany) and Teter analyzed the Chandra ACIS spectrum of 1E 1207.4−5209, a neutron star in the center of the supernova remnant PKS 1209-51/52, and detected two absorption features in the source spectrum. The features are centered near 0.7 and 1.4 keV; their equivalent widths are about 0.1 keV. A likely interpretation is that the features are associated with atomic transitions of once-ionized helium in the neutron star atmosphere with a strong magnetic field. The first clear detection of absorption features in the spectrum of an isolated neutron star provides an opportunity to measure the mass-to-radius ratio and to constrain the equation of state of the superdense matter.

Zavlin (MPE, Germany), Pavlov, Sanwal, Manchester (ATNF CSIRO, Australia), Trümper (MPE, Germany), Halpern (Columbia Univ.), & Becker (MPE, Germany) observed the nearest millisecond pulsar, J0437−4715, with the Chandra X-Ray Observatory. The pulsar spectrum, detected up to 7 keV, cannot be described by a simple one-component model. It consists of two components: a nonthermal power-law spectrum generated in the pulsar magnetosphere, with a photon index $\Gamma\approx2$, and a thermal spectrum emitted by heated polar caps, with a temperature decreasing outward from 2 to 0.5 MK. The lack of spectral features in the thermal component suggests that the neutron star surface is covered by a hydrogen (or helium) atmosphere. The timing analysis shows one X-ray pulse per period, with a pulsed fraction of about 40% and the peak at the same pulse phase as the radio peak. No synchrotron pulsar-wind nebula is seen in X-rays.

Safi-Harb (Univ. Manitoba, Canada), Harrus, Petre (NASA GSFC), Pavlov, Koptsevich (Ioffe Inst., Russia), & Sanwal presented the analysis of archival Chandra observations of the supernova remnant G21.5−0.9. Based on its morphology and spectral properties, G21.5−0.9 has been classified as a Crab-like SNR. The spectral analysis confirms the nonthermal nature of the extended emission. The ACIS images indicate that this component is not limb-brightened and that it shows knotty structures and a bright filament 2′ north of the center. No evidence of line emission from any part of the remnant is found. A collisional equilibrium ionization thermal model at solar abundances and nonequilibrium ionization models can be rejected. The entire remnant is best fitted with a power-law model with a photon index steepening away from the center. The total unabsorbed flux in 0.5–10 keV is 1.1×10^{-10} ergs cm^{-2} s^{-1}, with an 85% contribution from the 40″ radius core. Timing analysis of the HRC data failed to detect any pulsations. A 16% upper limit on the pulsed fraction is obtained. The physical parameters of the putative pulsar are obtained and compared with those of other plerions (such as the Crab nebula and 3C 58).

3.2.1.10 Brown Dwarfs Donald Schneider, postdoctoral scholar Gordon Richards, graduate student Michael Weinstein, and undergraduate Timothy Reichard have been using data from the Sloan Digital Sky Survey (SDSS) to investigate brown dwarfs.

The wide areal coverage, sensitivity, and long wavelength bandpass of the SDSS make it an effective survey for very cool stars. The SDSS has found a number of L and T dwarfs, objects with effective temperatures lower than M stars. The first HET survey for brown dwarfs has been published; this work reports the discovery of nearly two dozen such objects Schneider *et al.* (2002a).

3.2.2 Extragalactic Astronomy

3.2.2.1 Extragalactic Distance Indicators R. Ciardullo, J. Feldmeier (CWRU), G. Jacoby (WIYN), M.B. Laychak, R. Kuzio de Naray, and P. Durrell completed their comparison three key extragalactic distance indicators: Cepheid variables, surface brightness fluctuations (SBF), and the planetary nebula luminosity function (PNLF). Their results demonstrate that the metallicity dependence of the PNLF cutoff is in excellent agreement with theoretical predictions, and the scatter between individual Cepheid, PNLF, and SBF distance measurements is perfectly consistent with that expected from the methods' internal errors. However, their study also reveals that the Cepheid-calibrated PNLF distance scale is systematically shorter than the Cepheid-calibrated SBF scale by $\sim$0.3 mag. Ciardullo *et al.* speculate that the cause of the discrepancy is internal extinction in the calibration galaxies: if even a small amount extinction exists, it will cause the absolute magnitude of the PNLF cutoff to be underestimated, and the absolute magnitude of the SBF fluctuation to be overestimated. This error will then propagate over the entire extragalactic distance scale. Ciardullo *et al.* also use their PNLF measurement to the nuclear maser galaxy NGC 4258 to argue that the short distance scale to the Large Magellanic Cloud is correct, and that the global Hubble Constant inferred from the *HST* Key Project is too small by $\sim$7%.

3.2.2.2 Planetary Nebulae P. Durrell, C. Mihos

(CWRU), J. Feldmeier (CWRU), G. Jacoby (WIYN) and R. Ciardullo have measured the radial velocities of 35 planetary nebulae in the tidal debris of the Whirlpool Galaxy, M51. They find that the NGC 5194/95 system contains two superimposed, but kinematically distinct tidal tails which stretch out from the northern parts of the galaxy off to the northwest. Durrell *et al.* have successfully modeled these tails using a self-consistent N-body simulation, under the assumption that the companion galaxy NGC 5195 has only had a single encounter with the larger galaxy NGC 5194. These simulations improve our understanding of the system and provide further constraints on the orientation and structure of the companion.

R. Ciardullo, J. Feldmeier (CWRU), G. Jacoby (WIYN) and P. Durrell have continued their large scale surveys for planetary nebulae and red giant stars in the intergalactic space of nearby groups and clusters. To date, their [O III] λ5007 surveys for planetary nebulae cover 0.97 deg^2 in Virgo, 0.56 deg^2 in Fornax, 1.08 deg^2 in the M81 Group, and 0.13 deg^2 in a blank control field; in Virgo and the M81 Group, their complementary red giant star surveys cover 10.7 arcmin^2 and 0.3 deg^2, respectively. The data from these surveys suggest that intracluster stars are moderately old ($2\mathrm{Gyr} < \tau < 12\mathrm{Gyr}$), moderately metal-rich ($-0.8 < [Fe/H] < -0.2$), not centrally condensed, and not dynamically relaxed. The data also show that intracluster stars in the M81 Group are rare (only a couple percent of the stars are intracluster), but in systems such as Fornax and Virgo, these objects comprise $\sim$20% of the cluster. These results are still preliminary, however. Spectroscopic follow-up observations have shown that not all the sources detected via deep [O III] λ5007 imaging are planetary nebulae: in Virgo, $\sim$20% of the sources are unresolved Lyα galaxies at $z = 3.13$. In Fornax, the fraction of contaminants is almost 50%.

R. Ciardullo, M.B. Laychak, P. Durrell, G. Jacoby (WIYN) and J. Feldmeier (CWRU) have begun an [O III] λ5007 PN survey of the Local Group galaxy M33, with the purpose of determining the galaxy's disk mass from the *z*-motions of old planetary nebulae. Ciardullo *et al.* have identified over 170 PN candidates in the galaxy, and have measured the radial velocities for over 90% of them. Reductions are now in progress to measure the mass-to-light ratio of the M33's disk; when completed the results will be combined with the galaxy's total mass (obtained from its rotation curve) to determine the radial profile of the galaxy's dark matter halo.

3.2.2.3 RGB Stars in the Outer Halo of M31 P. Durrell, W. Harris (McMaster) and C. Pritchet (U. Victoria) are continuing their *VI* survey of the RGB stars in the outer halo of M31 using the 8K mosaic camera at the Canada-France-Hawaii Telescope. The I, $(V-I)$ color-magnitude diagram of a field located 20 kpc from the M31 nucleus shows that the halo population continues to be as metal-rich ([m/H]$\sim$ -0.6) as that found in more interior fields; a significant ($\sim$40%) metal-poor population is also found. Durrell *et al.* are currently analysing data for halo fields at 30 and 45 kpc from M31, along the minor axis.

3.2.2.4 Dwarf Galaxies Palma, undergraduate student Zonak (now a graduate student at Maryland), Hunsberger, Charlton, Gallagher, Durrell, and English (Manitoba) have recently completed their study of Hickson Compact Group 79, Seyfert's Sextet. *HST* images of the group show that this group contains little ongoing star formation in the form of super star clusters or tidal dwarf galaxy candidates. This is a sharp contrast to other HCGs, including HCG 92 (Stephan's Quintet) and HCG 31, which both show significant star formation presumably triggered by interactions among the giant galaxies in the group. The lack of young, star forming regions in Seyfert's Sextet is likely to be due to the different morphologies of the giant galaxies in this group (mostly early types) compared to HCGs 92 and 31 (mostly late type spirals and irregulars) and the correspondingly lower gas mass in the Sextet compared to these other two groups. Approximately 90 candidate old star clusters and several candidate dwarf galaxies were identified as potential members of Seyfert's Sextet. A Hobby–Eberly Telescope spectrum of one candidate dwarf galaxy identified it as a satellite of NGC6027e, the spiral galaxy in Seyfert's Sextet with the discordant redshift.

Palma, Majewski (Virginia), and Kuhn (Hawaii) have obtained Keck HIRES spectra for approximately 50 candidate giant star members of the Ursa Minor dwarf spheroidal. Preliminary results indicate that a number of these stars have radial velocities consistent with membership in this dSph galaxy, even though they are found outside the nominal tidal radius.

3.2.2.5 Sloan Digital Sky Survey Donald Schneider, postdoctoral scholar Gordon Richards, graduate student Michael Weinstein, and undergraduate Timothy Reichard have been using data from the Sloan Digital Sky Survey(SDSS) to investigate quasars (see section 3.2.2.6) and brown dwarfs (see section 3.2.1.10).

3.2.2.6 Active Galaxies and Quasars Hasenkopf, Eracleous (Penn State), and Sambruna (GMU) have completed a study of the hard X-ray spectra of intermediate luminosity, radio-loud quasars using ASCA observations. These spectra show the signature of a neutral absorbing medium, associated with the quasar central engine as well as Fe Kα lines. One of the quasars also shows the signature of Compton reflection at high energy. These results reinforce the trend of systematic differences between radio-loud and radio quiet AGNs already noted by Eracleous and Sambruna in earlier work.

Eracleous (Penn State), Halpern (Columbia), and Storchi-Bergmann (UFRGS, Brazil) are continuing to monitor broad-line radio galaxies and LINERs in search of long-term variability of the profiles of their broad, optical, double-peaked emission lines. These emission lines are thought to originate in the outer parts of the accretion disk that fuels the central, supermassive black hole. The variability time scales are comparable to or longer than the dynamical time in the disk. The goal is to compare the variability patterns with models for dynamical phenomena in the disk, such us spiral waves or orbiting bright spots.

Eracleous (Penn State) in collaboration with Storchi-Bergmann and Nemmen da Silva (UFRGS, Brazil) have been exploring models for the variable Balmer line profiles of the weak AGN in NGC 1097. These models include eccentric accretion disks and accretion disks with spiral arms, and are constrained by observational data spanning a decade.

Eracleous (Penn State), Halpern (Columbia) and Charlton (Penn State) have constructed models for the absorption lines observed in the UV spectrum of the broad-line radio galaxy Arp 102B. The rich absorption line spectrum provides stringent constraints on simple photoionization models of the absorbing gas. The conclusion is that the absorbing gas must have a high density ($>10^{11}\mathrm{cm}^{-3}$) and it must lie fairly close to the central engine of this AGN. Considering all of the available clues, it is plausible to identify the absorber with a mild accretion disk wind.

Eracleous, Charlton, and Wise (Penn State) in collaboration with Ganguly (STScI) have completed a UV spectroscopic survey of nearby quasars with the HST. The goal was to identify variable absorption lines; such lines must be intrinsic to the quasar. Intrinsic absorption lines identified in this way provide a lower limit to the fraction of absorption lines near the quasar redshift that are intrinsic and can be targeted for further detailed study. The main conclusion of this survey is that at least 50% of absorption lines near the quasar redshift are indeed variable and thus intrinsic, which is consistent with the result of other studies employing different methods.

Eracleous (Penn State), in collaboration with Moran (Wesleyan), Leighly (Oklahoma), Chartas (Penn State), Filippenko (U. C. Berkeley), Ho (Carnegie Obs.), and Blanco (U. C. San Diego) have completed a study of the X-ray properties of the low-luminosity AGN in NGC 4395. The nuclear X-ray emission is unresolved in the Chandra image and the rapid, large-amplitude X-ray variability reported in previous studies is confirmed. The spectrum of the nuclear source shows evidence for absorption by an ionized medium. There is also evidence for spectral variability over the course of the Chandra observation, although contrary to prior reports, it appears to be uncorrelated with fluctuations in the hard X-ray count rate.

Eracleous (Penn State) in collaboration with Gliozzi and Sambruna (George Mason U.) have completed a study of the short-term X-ray variability properties of the broad-line radio galaxies 3C 390.3 and 3C 120. Both 3C 390.3 and 3C 120 are highly variable, but in a different way, This difference is quantified by means of a structure function analysis. 3C 390.3 is significantly more variable than 3C 120, despite its larger inclination angle, implying either that the X-ray variability is not dominated by the jet or that two different variability processes are simultaneously at work in 3C 390.3. The overall 4–100 keV spectra are best fitted with the constant density ionization model about with a modest ionization parameter. Time-resolved spectral analysis of 3C 390.3 shows marginal evidence of changes in the Fe Kα line parameters with the X-ray continuum flux, consistent with illumination of an accretion disk by a variable primary X-ray source.

Brandt, Vignali, Schneider, Garmire, and collaborators have been using the new generation of X-ray observatories to define the basic X-ray properties of the highest redshift quasars. In this context, exploratory *Chandra* observations of nine high-redshift ($z=4.09-4.51$) optically selected quasars have been performed. These quasars, taken from the Palomar Digital Sky Survey (DPOSS), are among the optically brightest and most luminous $z>4$ quasars known. All have been detected by *Chandra* in exposure times of $\approx$ 5–6 ks, substantially increasing the number of X-ray bright quasars with X-ray detections at $z>4$. These quasars' average broad-band spectral energy distributions are characterized by steeper optical-to-X-ray spectral slopes than those of lower-redshift samples of quasars. They confirm the presence of a significant correlation between the ultraviolet magnitude and soft X-ray flux previously found for $z>4$ quasars. The joint $\approx$ 2–30 keV rest-frame X-ray spectrum of the nine quasars is well parameterized by a simple power-law model whose photon index, $\Gamma\approx 2.0\pm0.2$, is consistent with those of lower-redshift quasars. No evidence for significant amounts of intrinsic absorption has been found ($N_{\mathrm{H}}<8.8\times10^{21}\mathrm{cm}^{-2}$ at 90% confidence). For this optically bright sample of $z>4$ quasars, they also carried out near-simultaneous optical observations with the Hobby-Eberly Telescope; this is the first time optical spectra have been published for seven of these objects.

Brandt, Schneider, and collaborators have also performed exploratory Chandra observations of the three highest redshift quasars known (z = 5.82, 5.99, and 6.28), all found in the Sloan Digital Sky Survey. These data, combined with a previous XMM-Newton observation of a $z=5.74$ quasar, form a complete set of color-selected, $z>5.7$ quasars. X-ray emission is detected from all of the quasars at levels that indicate that the X-ray to optical flux ratios of $z\approx6$ optically selected quasars are similar to those of lower redshift quasars. The observations demonstrate that it should be feasible to obtain quality X-ray spectra of $z\approx6$ quasars with current and future X-ray missions.

Donald Schneider, postdoctoral scholar Gordon Richards, graduate student Michael Weinstein, and undergraduate Timothy Reichard have been using data from the Sloan Digital Sky Survey(SDSS) to investigate quasars. The major result of the past year was the production of the first edition of the SDSS Quasar Catalog (Schneider *et al.* 2002b). This compilation contains 3814 objects, of which 3000 were previously unknown. The catalog contains five filter CCD photometry, very accurate positions, and high quality spectra that cover the wavelength range between 3800 and 9200 A for each of the quasars.

Schneider and Richards are currently leading the effort to prepare the next edition of the catalog, to be released in early 2003; this publication should contain approximately 20,000 quasars. The final SDSS Quasar Selection Algorithm was also completed in the past year (Richards *et al.* 2002a).

Other SDSS programs where Penn State personnel played a significant role were the investigations of the rare, spectacular examples of Broad Absorption Line quasars (Hall *et al.* 2002a), and the determination of the redshift of the lens in the system PMN J0134−0931 (Hall *et al.* 2002b).

Vignali, Brandt, and Schneider have investigated the X-ray properties of the color-selected radio-quiet quasars (RQQs) in the Sloan Digital Sky Survey (SDSS) Early Data

Release using *ROSAT*, *Chandra*, and XMM-*Newton* data. In the 0.16–6.28 redshift range, 136 RQQs have X-ray detections (69 from the *ROSAT* All-Sky Survey, RASS), while for 70 RQQs X-ray upper limits are obtained. The well-defined selection method utilized by the SDSS, coupled with the tight radio constraints from the FIRST/NVSS surveys, allow us to define a representative sample of optically selected RQQs whose broad-band spectral energy distributions (characterized by means of the optical-to-X-ray spectral index, α_{ox}) can be studied as a function of rest-frame ultraviolet (UV) luminosity and redshift. A partial correlation analysis applied to the SDSS sample (including the upper limits, but excluding the biased subsample of RASS detections) shows that α_{ox} is a function of rest-frame UV luminosity (i.e., α_{ox} steepens at high UV luminosities); this correlation is significant at the 3.7σ level. They do not detect a highly significant redshift dependence of α_{ox}. They also find a significant (7.8σ level) correlation between UV and X-ray luminosity, parameterized by $L_X \propto L_{UV}^{0.75\pm0.06}$, which extends previous results to the highest redshifts.

Laor (Technion) and Brandt have performed a survey of the ultraviolet absorption properties of the Boroson & Green sample of active galaxies, which extends from the Seyfert ($M_V \simeq -21$) to the luminous quasar ($M_V \simeq -27$) level. The survey is based mostly on Hubble Space Telescope archival data available for $>1/2$ of the 87 sample objects. The main finding is that soft X-ray weak quasars (SXWQs) show the strongest ultraviolet absorption at a given luminosity, and their maximum outflow velocity, v_{max}, is strongly correlated with M_V. This suggests that v_{max} is largely set by the luminosity, as expected for radiation-pressure driven outflows. Luminous SXWQs have preferentially low [O III] luminosity, which suggests they are physically distinct from unabsorbed AGN, while non-SXWQs with ultraviolet absorption are consistent with being drawn from the unabsorbed AGN population.

3.2.2.7 X-ray Studies of Broad Absorption Line Quasars For the population of quasars with broad ultraviolet absorption lines, a significant number of X-ray observations with enough counts for spectral analysis at CCD resolution are only now beginning to accumulate in the high energy archives. Gallagher, Brandt, Chartas, and Garmire (Penn State) gathered a sample of eight quasars (including four broad absorption line [BAL] quasars and three mini-BAL quasars) with *ASCA* or *Chandra* spectra with more than 200 counts; from this sample, general patterns have emerged. The power-law X-ray continua of these objects are typical of normal quasars with $\Gamma \sim 2.0$, and the signatures of a significant column density [$N_H \sim (0.1–4) \times 10^{23}$ cm^{-2}] of intrinsic, absorbing gas are clear. Correcting the X-ray spectra for this absorption recovers a normal ultraviolet-to-X-ray flux ratio, indicating that the spectral energy distributions of this population are not inherently anomalous. In addition, a large fraction of the sample shows significant evidence for complexity in the absorption. The subset of BAL quasars with broad Mg II absorption apparently suffers from Compton-thick absorption completely obscuring the direct continuum in the 2–10 keV X-ray band, complicating any measurement of their intrinsic X-ray spectral shapes.

One notable BAL quasar exhibiting Mg II absorption is Markarian 231, an ultraluminous infrared galaxy hosting both a luminous quasar and an active starburst. During a 40 ks X-ray observation, Gallagher, Brandt, Chartas, Garmire, and Sambruna (George Mason University) observed significant nuclear variability in Mrk 231, indicating that *Chandra* had probed within light hours of the central black hole. During the coming year, the study of Mrk 231 will be advanced with three additional 40 ks *Chandra* observations strategically spaced to test the hypothesis that multiple scattered and absorbed lines of sight combine to account for the nuclear X-ray spectrum. Furthermore, concurrent optical spectropolarimetry (led by collaborators Paul Smith and Dean Hines of Steward Observatory) will allow for additional constraints to be placed on the nature of the scattering mechanisms operating in both wavelength regimes.

Though spectroscopic X-ray observations offer specific information on individual objects, larger homogeneous survey are required to elucidate the X-ray properties of the BAL quasar population as a whole. To this end, Gallagher, Brandt, Chartas, and Sambruna examined the initial results from a complete sample of exploratory X-ray observations of BAL quasars from the Large Bright Quasar Survey (LBQS). This survey is composed of short (5–7 ks) *Chandra* ACIS-S3 observations designed to significantly constrain X-ray fluxes and hardness ratios. The low background and excellent spatial resolution of *Chandra* permit sensitive observations in these relatively short times. This sample avoids the selection biases of some previous surveys while providing X-ray data of similar quality. Of 20 BAL quasars observed to date, 15 have been detected. In general, the results are consistent with absorption as the primary cause of X-ray weakness in BAL quasars. In addition, Gallagher, Brandt, Chartas, Garmire and Sambruna are extending this study to probe the connection between X-ray and ultraviolet absorption with ground-based spectroscopy obtained with the Hobby-Eberly telescope concurrently with the X-ray data.

Chartas in collaboration with Brandt, Gallagher and Garmire reported the discovery of X-ray broad absorption lines (BALs) from the BALQSO APM 08279+5255 originating from material moving at relativistic velocities with respect to the central source. The large flux magnification by a factor of $\sim$ 100 provided by the gravitational lens effect combined with the large redshift ($z = 3.91$) of the quasar have facilitated the acquisition of the first high signal-to-noise X-ray spectrum of a quasar containing X-ray BALs. Our analysis of the X-ray spectrum of APM 08279+525 places the rest-frame energies of the two observed absorption lines at 8.1 and 9.8 keV. The detection of each of these lines is significant at the $>$ 99.9% confidence level based on the *F*-test. Assuming that the absorption lines are from Fe XXV K α, the implied bulk velocities of the X-ray BALs are $\sim 0.2c$ and $\sim 0.4c$, respectively. The observed high bulk velocities of the X-ray BALs combined with the relatively short recombination time-scales of the X-ray absorbing gas imply that the absorbers responsible for the X-ray BALs are located at radii of $< 2 \times 10^{17}$ cm, within the expected location of the UV absorber. With this implied geometry the X-ray gas could provide the necessary shielding to prevent the UV absorber from being completely ionized by the central X-ray source, consistent with hydrodynamical simulations of line-driven disk winds. Estimated mass-outflow rates for the gas creating the X-ray BALs are typically less than a solar mass per year. Our spectral analysis also indicates that the continuum X-ray emission of APM 08279+5255 is consistent with that of a typical radio-quiet quasar with a spectral slope of $\Gamma = 1.72^{+0.06}_{-0.05}$.

Chartas in collaboration with Brandt, Gallagher, and Garmire reported on results from a mini-survey of gravitationally lensed broad absorption line quasars performed with the *Chandra* and *XMM-Newton* observatories. In all cases we find that the spectral slopes of the unabsorbed specta are consistent with those of normal radio-quiet quasars and their X-ray faintness is due to absorption with typical hydrogen column densities ranging from $\sim 10^{22}$ - 10^{24} cm^{-2}, consistent with previous observations. In several of the BALQSOs of our sample the S/N was sufficient to allow for a more complex spectral analysis. For these systems we placed constraints on the kinematics, ionization state and geometry of BAL winds. In particular, we report on the discovery of the first X-ray BALs in the gravitationally lensed quasars APM 08279+5255 and PG 1115+080. The blueshifted energies of these X-ray BALs imply that the X-ray absorbing material is outflowing at relativistic velocities. One of the key implications of this study is that the X-ray BALs appear to be located interior to the UV BAL region and may therefore represent the shielding gas proposed in several theoretical studies of line-driven disk winds. Our re-analysis of the *Chandra* observation of H 1413+117 finds evidence for microlensing which enables us to probe the geometry of the nuclear region of this BALQSO.

3.2.2.8 Intrinsic Quasar Absorption Lines In February 2002, Rajib Ganguly successfully defended his Ph.D. thesis titled "Origins and Properties of QSO-Intrinsic Narrow Absorption Lines and Their Host QSOs." He is presently a postdoc working with Dr. Kenneth Sembach at the Space Telescope Science Institute. Ganguly's thesis included results from several papers published in past years, as well as some new results on a remarkable intrinsic absorption complex along the line of sight toward the quasar RXJ 1230.8 +0115. This system shows clear signs of an intrinsic origin: smooth wind-like profiles, high ionization, and partial coverage of the central engine. Also, two of the sub-systems are line-locked with the third, which is formally classified as a mini-BAL. This work has recently been submitted for publication in the Astrophysical Journal.

3.2.2.9 Quasar Microlensing Dai, Chartas, Agol (Caltech), Bautz (MIT), and Garmire, presented in an article submitted to The Astrophysical Journal the observations of the gravitationally lensed system Q2237+0305 (Einstein Cross) performed with the Advanced CCD Imaging Spectrometer (ACIS) onboard the *Chandra X-ray Observatory* on 2000 September 9, and on 2001 December 8 for 30.3 ks and 9.5 ks, respectively. Imaging analysis resolved the four X-ray images of the Einstein Cross. A possible fifth image is detected; however, the poor signal-to-noise ratio of this image combined with contamination produced by a nearby brighter image make this detection less certain. We investigated possible origins of the additional image. Fits to the combined spectrum of all images of the Einstein Cross assuming a simple power law with Galactic and intervening absorption at the lensing galaxy yielded a photon index of $1.90^{+0.05}_{-0.05}$ consistent with the range of Γ measured for large samples of radio-quiet quasars. For the first *Chandra* observation of the Einstein Cross this spectral model yielded a 0.4–8.0 keV X-ray flux of $4.6\times10^{-13} erg\, s^{-1}\, cm^{-2}$ and a 0.4–8.0 keV luminosity corrected for a macrolensing magnification of about 16 of $6.3\times10^{44} erg\, s^{-1}$. The X-ray flux ratios of the images are consistent with the optical flux ratios which are affected by microlensing suggesting that the X-ray emission is also microlensed. A comparison between our measured column densities and those inferred from extinction measurements suggests a higher dust-to-gas ratio in the lensing galaxy than the average value of our Galaxy. Finally, we reported the detection at the 99.99% confidence level of a broad emission feature near the redshifted energy of the Fe K α line. The rest frame energy, width, and equivalent width of this feature are $E_{line} = 5.7^{+0.2}_{-0.3}$ keV, $\sigma_{line} = 0.87^{+0.30}_{-0.15}$ keV, and $EW = 1178.$ eV, respectively. This broad emission feature is present in only the spectrum of the brightest image A suggesting that microlensing induced by stars in the lensing galaxy may be presently magnifying emission along the line of sight to image A.

3.2.2.10 Gamma-Ray Sources Halpern (Columbia), Eracleous (Penn State), and Mattox (Francis Marion U.) continued their program of identification of the counterparts of high-energy gamma-ray sources. They have identified the optical counterparts of 16 blazars suggested as the high-energy gamma-ray sources detected by the EGRET instrument on *CGRO*.

3.2.2.11 Quasar Absorption Lines and Galaxy Evolution The quasar absorption line group at Penn State continues work to establish connections between quasar absorption line systems and the structures that produce them. Analysis of high resolution spectra, covering a wide range of chemical transitions, can provide constraints on the multiple phases of gas that are usually present. The team is working to assemble a large sample in order to draw more general conclusions about galaxy evolution. During this reporting period, the team included faculty members Jane Charlton and Chris Churchill, graduate students Rajib Ganguly and Jie Ding, and undergraduate students Nick Bond, Joe Masiero, Rick Mellon, and Stephanie Zonak.

Graduate student, Jie Ding, completed a study of a strong MgII absorber at $z \sim 0.99$ along the line of sight toward the quasar PG 1634+706. This absorber is of particular interest because it is "CIV-deficient," i.e. it has weak CIV absorption relative to MgII. Ding, and her co-authors Charlton, Zonak, and Churchill, propose that this could be due to a low metallicity in a phase of gas that produced broad absorption in the Lyman series lines. The system is unusual in that most of the observed CIV absorption comes from the same phase of gas as the MgII absorption. This phase could be related to a galactic halo or the diffuse medium in an early-type galaxy. The strong absorption in SiIV relative to CIV could be produced in an extra, collisionally ionized phase, which is perhaps shock–heated above the photoionization equilibrium temperature.

The same $z \sim 0.99$ absorber toward PG 1634+706 is an excellent example of a common problem for strong MgII absorbers. The MgI absorption is too strong to be produced in the same phase with the MgII, under conditions of photoionization equilibrium. Ding and her co-authors devised a solution in which the MgI arises in a small, cool cloud that produces a narrower absorption features. With MgI on the linear part of its curve of growth, and MgII on the flat part of its curve of growth, it is possible to obtain a relatively larger ratio of MgI to MgII.

Research Associate, Chris Churchill, along with Steven Vogt (UCO/Lick) and Charlton, established that the strong MgI absorption occurs in a large fraction of the sample of clouds that results from Voigt profile fitting of a large sample of strong MgII absorbers at redshift $0.4 < z < 1.2$. Churchill's paper, recently accepted by the Astrophysical Journal, presents the formal statistical results from a study of the Voigt profile fits to the HIRES/Keck spectra. The column densities of FeII and MgII are correlated at a 9-sigma level, which is not surprising. However, it is interesting that the ratio of the MgI to MgII column densities is anti-correlated with the MgII column density at a 5-sigma level.

The QAL team has also studied some weaker MgII absorption systems. The $z \sim 1.04$ absorber toward PG 1634+706 is an example of a multi-cloud weak MgII absorber (with a MgII rest frame equivalent width less than 0.3A). This system, which has been modeled by undergraduate student, Stephanie Zonak (now a graduate student at the University of Maryland) is distinguished by its low metallicity ($\sim$3% solar), by its low ionization kinematics that shows two subsystems separated by 150km/s, and by its two high ionization phases, each of which is offset by $\sim$50 km/s from one of the low ionization phases. Even with detailed constraints on the physical conditions and kinematics of this absorption system, it is difficult to connect it with a particular kind of galaxy or galaxy environment. The best guesses are superwinds from dwarf galaxies, or the outer regions/debris of an interacting disk.

Detailed modeling of STIS/HST and HIRES/Keck spectra has also been performed for three single-cloud, weak MgII absorbers along the same quasar PG 1634+706 line of sight. These weak MgII absorbers are constrained to have close to solar metallicity in their low ionization phases. To produce the observed CIV absorption, they must each have an additional high ionization phases. Two of the systems have additional offset high ionization clouds. This work has been completed by Charlton and other members of the team, and submitted to the Astrophysical Journal.

One critical aspect to the interpretation of these modeling efforts is learning exactly what type of galaxy and what location in the galaxy is being probed by each quasar line of sight. An important paper, shedding light on this issue, was published by Charles Steidel (Caltech) and various coauthors including Churchill. This paper compared galaxy morphology (from HST images) and kinematics (from low resolution spectroscopy of the galaxies) to high resolution absorption profiles (from HIRES/Keck). All five galaxies are relatively normal spirals. In four of them, the velocities of the MgII absorption components are consistent with primary production in extended disks or rotating layers that are extensions of the disks. The fifth case is an exception, with the absorption centered at the systemic velocity of the galaxy, despite a large disk inclination angle. Additional studies of this type will be essential to understanding the results of detailed modeling of quasar absorption line systems.

3.2.3 The Chandra Deep Field-North Survey

3.2.3.1 Extended X-ray Sources Bauer, Alexander, Brandt, Hornschemeier, Garmire, Schneider, and collaborators used the Chandra Deep Field-North survey to study faint X-ray emission from groups and clusters of galaxies in the region surrounding the Hubble Deep Field-North (HDF-N), yielding the most sensitive probe of extended X-ray emission at cosmological distances to date. Six sources were found, the majority of which align with apparent groups of optically bright galaxies. Their angular sizes, spectral properties, and X-ray luminosities—assuming they lie at the same distances as the galaxies coincident with the X-ray emission—are generally consistent with the properties found for nearby groups of galaxies. One source is notably different and is likely to be a poor-to-moderate X-ray cluster at high redshift (i.e., $z > 0.7$), given its large angular extent, a double-peaked X-ray morphology, and an overdensity of unusual objects [Very Red Objects, optically faint ($I \geqslant 24$) radio and X-ray sources]. They found the surface density of extended X-ray sources in this observation to be 167^{+97}_{-67} deg^{-2} at a limiting soft-band flux of 3×10^{-16} erg cm^{-2} s^{-1} and that no evolution in X-ray luminosity function of clusters is needed to explain this value.

3.2.3.2 X-ray Emission from Very Red Objects The multi-wavelength properties of Very Red Objects (VROs; $I - K \geqslant 4$) are poorly understood as many are optically faint ($I \geqslant 24$) and undetected at most wavelengths. The CDF-N team provided the tightest constraints to date on their X-ray (0.5–8.0 keV) properties using a 70.3 arcmin^2 region of the Chandra Deep Field-North containing the HDF-N. The CDF-N team found that VROs detected in the hard band (2.0–8.0 keV) had flat X-ray spectral slopes ($\Gamma \approx 0.9$) and X-ray properties consistent with those expected from luminous obscured AGN; the fraction of such sources in the $K \leqslant 20.1$ VRO population is 14^{+11}_{-7}%. Conversely, the average X-ray spectral slope of VROs detected in the soft band (0.5–2.0 keV) but not the hard band was comparatively steep ($\Gamma > 1.4$), and the X-ray emission from these sources was consistent with that expected from less energetic processes (i.e., star formation, low-luminosity AGN activity, and normal elliptical galaxy emission). Stacking analyses of the X-ray emission from VROs not individually detected at X-ray energies yielded significant detections ($\geqslant$99% confidence level) in the soft band and the full band (0.5–8.0 keV). The CDF-N team found this X-ray emission to be produced predominantly by the optically brightest VROs. The simplest explanation of this result is that the CDF-N team has detected the average X-ray emission from non-active VROs with low X-ray-to-optical flux ratios [$\log(f_X/f_I) \approx -2$]; this is consistent with that expected if the majority of these VROs are $\approx M_I^*$ elliptical galaxies. A number of VROs were also detected with mid-infrared (15 μm) and radio emission, and we provided constraints on the nature of this emission.

3.2.3.3 X-Ray Emission from Luminous Infrared Starburst Galaxies Using the Chandra Deep Field-North and 15 μm ISOCAM HDF-N surveys the CDF-N team found a tight correlation between the population of strongly evolving starbursts discovered in faint 15 μm ISOCAM surveys and the apparently normal galaxy population detected in deep X-ray surveys. Up to 100% of the X-ray detected emission-line galaxies (ELGs) had 15 μm counterparts, in contrast to 10–20% of the X-ray detected absorption-line galaxies and AGN-dominated sources. None of the X-ray detected ELGs were detected in the hard band (2–8 keV), and their stacked-average X-ray spectral slope of $\Gamma \approx 2.0$ suggested a low fraction of obscured AGN activity within the X-ray detected ELG population. The characteristics of the $z = 0.4$–1.3 X-ray detected ELGs were consistent with those expected for M82 and NGC 3256-type starbursts; these X-ray detected ELGs were found to contribute $\approx$ 2% of the 0.5–8.0 keV X-ray background.

3.2.3.4 X-ray and Radio Source Populations The CDF-N team investigated the relationship between faint X-ray and 1.4 GHz radio source populations detected within $3'$ of the HDF-N using the Chandra Deep Field-North and 40μJy VLA surveys. Within this region, the CDF-N team found that $\approx$42% of the 62 X-ray sources have radio counterparts and $\approx$71% of the 28 radio sources have X-ray counterparts. Among the different source populations sampled, the CDF-N team found that the majority of the 18 X-ray detected emission-line galaxies (ELGs) have radio and mid-infrared *ISOCAM* counterparts and appear to be luminous star-forming galaxies at $z = 0.3$–1.3. Importantly, the radio-detected ELGs make up $\approx$35% of the X-ray source population at 0.5–8.0 keV X-ray fluxes between $\approx (1-5) \times 10^{-16}$ erg cm^{-2} s^{-1} and signal the emergence of the luminous, intermediate-redshift starburst galaxy population in the X-ray band. They found that the locally determined correlation between the X-ray luminosities and 1.4 GHz radio luminosity densities of late-type galaxies can be extended to include the luminous intermediate-redshift ELGs, suggesting that the X-ray and radio emission processes are generally associated in star-forming galaxies. This result implies that the X-ray emission can be used as an indicator of star formation rate for star-forming galaxies.

3.2.3.5 On the Nature of Bright SCUBA Sources The CDF-N team provided X-ray constraints and performed X-ray spectral analyses of radio-detected bright SCUBA ($f_{850\mu\mathrm{m}} \geqslant 5$ mJy) sources within a 70.3 arcmin^2 region of the Chandra Deep Field-North survey. X-ray emission was detected from six (75^{+25}_{-30}%) of the eight radio-submm sources in this region; our analyses suggested that this corresponds to an X-ray detected fraction of the bright submm source population of >31%. Four of the X-ray detected sources had flat effective X-ray spectral slopes ($\Gamma < 1.0$), suggesting obscured AGN activity. X-ray spectral analyses showed that one of these sources may be a Compton-thick AGN while the other three are likely to be Compton-thin AGNs. Although these AGNs are dominant at X-ray energies, a comparison to the well-studied heavily obscured AGN NGC 6240 suggested that their contribution to the submm emission was small ($\approx$ 1%). The X-ray constraints for the other four radio-submm sources were consistent with those expected from luminous star-formation activity.

3.3 Theoretical Studies

3.3.1 Planets

3.3.1.1 Planetary Systems Sigurdsson worked on the dynamical stability of planetary systems and planet detection in collaboration with Debes; and on planetary formation and detection in collaboration with Mandell and Murray. A formal collaboration with PSARC was negotiated in collaboration with Wolszczan.

3.3.2 Theoretical Astrophysics

3.3.2.1 Intracluster Stars Sigurdsson continued work on modeling of intracluster stars in collaboration with Ciardullo and Durrell.

3.3.2.2 Pulsar & Magnetar Studies Zhang found that in the hot environments of the anomalous X-ray pulsars and the soft gamma-ray repeaters, as indicated by their luminous, pulsed, quiescent X-ray emission, γ-rays generated from the inner gaps have shorter attenuation lengths via two photon pair production than via magnetic photon splitting. He then claimed that the AXP/SGR environments may not be pairless, even if photon splitting could completely suppress one photon pair production in super-strong magnetic fields. The apparent radio quiescence of magnetars is discussed.

Collaborating with Harding and Muslimov (NASA /GSFC), Zhang investigated the conditions required for the production of electron-positron pairs above a pulsar polar cap (PC) and the influence of pair production on the energetics of the primary particle acceleration. They allow both one-photon and two-photon pair production by either curvature radiation (CR) photons or photons resulting from inverse-Compton scattering of thermal photons from the PC by primary electrons, and found that, while only the younger pulsars can produce pairs through CR, nearly all known radio pulsars are capable of producing pairs through non-resonant inverse-Compton scatterings. The effect of the neutron star equations of state on the pair death lines is explored. They show that pair production is facilitated in more compact stars and more massive stars. They also find that two-photon pair production may be important in millisecond pulsars if their surface temperatures are above about three million degrees K. They also identified two regimes in the pulsar spin parameter space, such that the high-energy luminosity follows different dependences on the spindown energy. The prediction will be tested by GLAST in the near future.

Zhang gave a brief review about some recent progress in understanding radio pulsar death. Pulsar radio emission is believed to be originated from the electron-positron pairs streaming out from the polar cap region. Pair formation, an essential condition for pulsar radio emission, is believed to be sustained in active pulsars via one photon process from either the curvature radiation (CR) or the inverse Compton scattering (ICS) seed photons, or sometimes via two photon process. In pulsars with super-critical magnetic fields, some more exotic processes, such as magnetic photon splitting and bound pair formation, will also play noticeable roles. He described how these effects are synthesized to discuss radio pulsar death both in the conventional long-period regime due to the turnoff of the active gap, and in the high magnetic field regime due to the possible suppression of the free pair formation.

Zhang, Meszaros, Dai (Nanjing) and Waxman (Weizmann) studied the TeV neutrino emission from magnetars. They show that young, fast-rotating magnetars emit TeV neutrinos through photomeson interactions. They identify a neutrino cut-off band in the magnetar period-magnetic field strength phase diagram, corresponding to the photomeson interaction threshold, and point out that four currently known magnetars are close to this threshold. When they are above threshold, and if the accelerators are beamed towards Earth with a solid angle $\Delta\Omega_{\nu}$, some close magnetars can have neutrino fluxes $\sim 10^{-11}(\Delta\Omega_{\nu}/0.01)^{-1}\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ for a high neutrino efficiency , leading to upward muon event rates $\sim 30(\Delta\Omega_{\nu}/0.01)^{-1}\mathrm{km}^{-2}\mathrm{yr}^{-1}$ in large Cherenkov detectors. Young magnetars in the metagalaxy produce a diffuse TeV neutrino background of estimated event rate $>0.1\mathrm{km}^{-2}\mathrm{yr}^{-1}$ These predicted rates make magnetars interesting targets for the planned km^3 neutrino detectors.

3.3.2.3 Gamma-Ray Bursts Zhang and Meszaros continued to study Gamma-ray burst (GRB) fireballs as well as their afterglow properties. They discussed a GRB fireball with an additional energy injection, either in the form of a Poynting-flux-dominated outflow or a kinetic-energy-dominated matter shell. They found that a total injection energy comparable to that of the impulsive energy in the initial fireball is required to make a detectable signature in the afterglow lightcurves. They have modeled the injection processes in detail and presented the broadband lightcurve predictions with the injection signatures. These are expected to be tested in the near future when catching early GRB afterglows become possible. The detections of these signatures will provide diagnostics about the nature of the fireball and of the central engine.

Zhang and Meszaros considered a gamma-ray burst (GRB) model based on an anisotropic fireball with an axisymmetric power-law distribution of the energy per solid angle with index -k, and allow for the observer's viewing direction being at an arbitrary angle with respect to the jet axis. This model can reproduce the key features expected from the conventional on-axis uniform jet models, with the novelty that the achromatic break time in the broadband afterglow lightcurves corresponds to the epoch when the relativistic beaming angle is equal to the viewing angle rather than to the jet half opening angle. Under certain conditions, GRBs may be modeled by a quasi-universal beaming configuration, and an approximately standard energy reservoir. The conclusion also holds for some more general forms of angular energy distributions.

Meszaros, Ramirez-Ruiz (Cambridge), Rees (Cambridge) and Zhang investigated the relationship between the quasi-thermal baryon-related photosphere in relativistic outflows, and the internal shocks arising outside them, which out to a limiting radius may be able to create enough pairs to extend the optically thick region. They found that variable gamma-ray light curves are likely to arise outside this limiting pair-forming shock radius, while X-ray excess bursts may arise from shocks occurring below it. A possible relation to the recent identified so-called X-ray flashes is discussed. This model leads to a simple physical interpretation of the observational gamma-ray variability-luminosity relation.

Zhang and Meszaros also revisited various variants of the GRB prompt emission fireball models within a a unified framework, and critically reexamine the GRB spectral break predictions in these models. This was motivated by the recent identification of X-ray flashes as well as the finding of positive correlations between Ep and some burst luminosity. The spectral break model properties may be tested against the current and upcoming GRB data, through which the nature of the fireball as well as the mechanism and site of the GRB emission will be identified. In view of the current data, various models are appraised through a simple Monte-Carlo simulation, and a tentative discussion about the possible nature of X-ray flashes is presented.

Kobayashi, Ryde (Stanford) and MacFadyen (Caltech) investigated the luminosity and variability of collimated gamma-ray bursts. Within the framework of the internal shock model, they study the luminosity and the variability from collimated fireballs, with particular attention to the role of the photosphere due to $e^{\pm}$ pairs produced by internal shock synchrotron photons. It is shown that the observed Cepheid-like relationship between the luminosity and the variability can be interpreted as a correlation between the opening angle of the fireball jet and the mass included at the explosion with a standard energy output. They show that such a correlation can be a natural consequence of the collapsar model. Using a multiple-shell model, they numerically calculate the temporal profiles of gamma-ray bursts. Collimated jets, in which the typical Lorentz factors are higher than in wide jets, can produce more variable temporal profiles due to smaller angular spreading time scales at the photosphere radius. Their simulations quantitatively reproduce the observed correlation.

Kobayashi and Meszaros investigated the production of gravitational waves by various gamma-ray burst progenitor models, in particular compact mergers and massive stellar collapses. These models have in common a high angular rotation rate, and the final stage involves a rotating black hole and accretion disk system. We consider the in-spiral, merger and ringing phases, and for massive collapses we consider the possible effects of asymmetric collapse and break-up, as well bar-mode instabilities in the disks. We calculate the strain and frequency of the gravitational waves expected from various progenitors, at distances based on occurrence rate estimates. Based on simplifying assumptions, we give estimates of the probability of detection of gravitational waves by the advanced LIGO system from the different GRB scenarios.

Waxman (Weizmann Institute) and Meszaros showed that the collapsar model of gamma-ray bursts results in a series of successive shocks and rarefaction waves propagating in the ‘‘cork’’ of stellar material being pushed ahead of the jet, as it emerges from the massive stellar progenitor. These shocks result in a series of characteristic, increasingly shorter and harder thermal X-ray pulses, as well as a non-thermal γ-ray pulse, which precede the usual non-thermal MeV γ-rays. We consider jets escaping from both compact (CO or He dwarf) and blue supergiant stellar progenitors. The period, fluence and hardness of the pulses serves as a diagnostic for the size and density of the outer envelope of the progenitor star.

Meszaros reviewed the subject of gamma-ray burst theories in an Annual Reviews of Astronomy and Astrophysics article, including an overview of observations at all electromagnetic wavelengths, latest developments in models of afterglows and progenitors, and prospects for emission and detection of gravitational waves, cosmic rays and ultra-high energy neutrinos from GRB.

3.3.2.4 AGN and Blazars Meszaros’s group recently investigated GeV Emission from TeV Blazars. Collaborating with Dai (NJU, China) and Waxman (Weizmann Ins., Israel), Zhang, Gou and Mészáros studied the consequence of the inverse Compton scattering off the cosmic microwave background photons by the electron-positron pairs generated through interaction of the blazar TeV photons with the infrared background photons. They modeled the recent 1997 flares of Mrk 501 in detail and predict the existence of a hitherto undiscovered GeV emission component. They found that typical duration of the GeV emission is determined by the flaring activity time and the energy-dependent magnetic deflection time. They numerically calculate the scattered photon spectrum for different intergalactic magnetic field (IGMF) strengths, and find a spectral turnover and flare duration at GeV energies which are dependent on the field strength. The GeV flux levels predicted are consistent with existing EGRET upper limits, and should be detectable above the synchrotron – self Compton (SSC) component with the GLAST for IGMFs $\lesssim 10^{-16}$ G, as expected in voids. Such detections would provide constraints on the strength of weak IGMFs.

3.3.2.5 Cosmic Ray Studies Razzaque, Ralston (Kansas) and Jain (Kansas) studied the interactions of ultra-high energy cosmic rays with the microwave background in the LPM regime. Above 10^{19} eV observed cosmic rays show disagreements with the expected Greisen-Zatsepin-Kuzmin bound, suggesting that the laws governing interactions at those energies need to be reevaluated. They find that direct loss effects previously neglected affect the Landau-Pomeranchuk-Migdal suppression of energy losses of electrons and positrons in showers initiated by arbitrary primaries above 10^{19} eV. They present exact formulae for direct energy losses, and performed numerical integrations to show that the actual cosmic ray energy losses are substantially greater than LPM estimates, but the energy at which crossover occurs depends on the model.

3.3.2.6 Black Holes Sigurdsson worked on modeling of the effects of supermassive black holes in elliptical galaxies, in collaboration with Mihos, Holley-Bockelmann, Hernquist and Norman, and a separate but related project on binary black hole dynamics in collaboration with Hemsendorf and Spurzem.

3.3.2.7 Gravitational Radiation Sigurdsson continued work on exploring astrophysical sources of gravitational radiation under the auspices of the NSF funded Physics Frontier Centre (PI Finn).

3.3.3 Computational Astrophysics

3.3.3.1 Star and Galaxy Formation Tom Abel, postdoctoral scholar Emanuele Ripamonti, graduate students John Wise and Britton Smith, have started to investigate theoretical aspects of star and galaxy formation via numerical simulations. They have installed a 26 processor Beowulf system with 28GB of main memory and 1.5 Tb of storage and began several investigations using this new resource.

3.3.3.2 First Stars Abel, Bryan and Norman published the first self consistent ab initio numerical simulation of the formation of a primordial star within the cosmological context in Science Magazine. They showed that within current models of structure formation the first luminous object are expected to be massive stars that form in isolation. These massive stars may likely leave black holes as remnants and perhaps even produced detectable gamma ray bursts.

3.3.3.3 Reionization and the Intergalactic Medium Abel and Wandelt (UIUC) developed a new method to follow three dimensional radiative transfer around a point source. In this novel technique adaptive rays are cast solving the transfer equation via long characteristics. Their approach dramatically improves the numerical efficiency over previous approaches based on static rays casting. An approach similar to theirs has been employed by Abel with Razoumov, Norman and Scott to study the reionization of hydrogen in the intergalactic medium. They find that the current vacuum dominated flat cosmological model of structure formation can reasonably produce reionization redshifts in agreement with observations.

Also using three dimensional radiative transfer techniques, Sokasian (Harvard), Abel and Hernquist (Harvard) have shown that the observations of helium optical depths in the IGM are consistent with expected UV output from optically selected quasars. In particular, their work shows that although most of the helium in the universe may be ionized by redshift ~ 3.3 the optical depths may stay above unity much below these redshifts.

3.3.3.4 Galaxy Formation Together with van den Bosch (MPA), Croft (CMU), and Hernquist (Harvard), Abel has carried out smooth particle hydrodynamics simulations of forming proto–galaxies in a ΛCDM cosmology. They characterized the angular momentum distribution in the for the first time not only for the dark matter component but also for the gas within them. They find that between 5 and 50 percent of the gaseous material can be initially counter-rotating in comparison to the total angular momentum vector. They outlined a scenario in which these characteristics of the angular momentum profile may allow for the formation of bulges in disk galaxies.

3.3.4 History of Astronomy

Throughout most of written history the Earth was believed to lie at the center of creation, while the seven Ancient Planets (Sun, Moon, Mercury, Venus, Mars, Jupiter, and Saturn) revolved about it. The entire arrangement was encased in a shell of stars beyond which was the abode of the Prime Mover. This geocentric arrangement reached an advanced state of refinement in the ''Almages'' of Claudius Ptolemy. In 1543 the book ''De revolutionibus'' by the Polish mathematician Nicholas Copernicus completely revised the cosmic world view, for it removed the Earth from the center of the planetary system and placed the Sun there instead. Tycho Brahe devised a hybrid geo- heliocentric model built on the fact that he could detect no stellar parallax and on the principle that nature abhorred wasted space. Thus Tycho's model was extremely small. By contrast, in 1576 Tycho's contemporary, the English mathematician Thomas Digges, shattered the last and outermost sphere of the stars in a work entitled ''A perfect description of the celestial orbes.'' The model embraced Copernicanism and advanced beyond it to a new and revolutionary vision – an infinite universe of stars like the Sun. In the sixteenth century these rival models went unnoticed by poets, but recent research has shown that Shakespeare may well have celebrated the competition between them in the play Hamlet.

In April 2001 Peter Usher presented a paper ''Advances in the Hamlet Cosmic Allegory'' at the Fifth Annual Edward de Vere Studies Conference, held at Concordia University in Portland Oregon, in which further identifications were announced (Usher 2001a). These included the character Marcellus, named for the sixteenth century poet Pietro Angelo Manzoli, better known as Marcellus Palingenius Stellatus, the Stellified Poet, who wrote the poem ''Zodiacus Vitae'' (The Zodiac of Life) in twelve Books. The eleventh book demonstrated that Palingenius had a clear qualitative understanding of the Law of Flux. This point was recently reemphasized (Usher 2001b) in the context of Shakespeare's support for the so-called ''New Astronomy.'' The reason for the popularity of Palingenius in the writings of the scientist Digges was that Palingenius anticipated the concept of the physically infinite universe. This fact was duly recognized by Shakespeare in the naming of Marcellus, who accompanies Horatio from the seat of heliocentricism in Wittenberg, Germany.

3.3.5 Atomic Physics

Sampson and coworkers have continued their work on fully relativistic calculations of atomic processes in highly charged ions. Formulae have been derived for the resonance contribution to the collision strengths for the transitions between magnetic sublevels in highly charged ions due to impact with an electron beam. This contribution is treated as the two step process of electron capture followed by autoionization to the final sublevel of the transition with the effects of the possibilities of instead autoionization to a different final level or radiative decay included. Numerical results were obtained for He-like oxygen and iron and for Be-like oxygen. A review of all of our fully relativistic work of the past 13 or 14 years is being prepared for Physics Reports.

3.3.6 Statistical Astronomy

Astrostatistical investigations at Penn State are now addressing statistical methodology for the Virtual Observatory, where very large databases are distributed in distant locations. The project underway seeks to develop streaming methods for very large samples, clustering and classification of very large multivariate samples, and application of standard statistics in a Web services environment.

PUBLICATIONS

Abel, T, Bryan, G.L., Norman, M.L. 2002 ''The Formation of the First Star in the Universe'' Science, 295, 93

Abel, T. & Wandelt, B. D. 2002, ''Adaptive ray tracing for radiative transfer around point sources,'' MNRAS, 330, L53

Alexander, D.M., Aussel, H., **Bauer, F.E.**, **Brandt, W.N.**, **Hornschemeier, A.E.**, **Vignali, C.**, **Garmire, G.P.**, & **Schneider, D.P.** 2002, ''The Chandra Deep Field-North Survey. XI. X-Ray Emission from Luminous Infrared Starburst Galaxies,'' ApJ, 568, L85

Alexander, D.M., **Bauer, F.E.**, **Brandt, W.N.**, **Hornschemeier, A.E.**, **Vignali, C.**, **Garmire, G.P.**, **Schneider, D.P.**, **Chartas, G.**, & **Gallagher, S.C.**, 2002, ''The Chandra Deep Field-North Survey. XIII. on the nature of bright SCUBA sources,'' AJ, submitted

Alexander, D.M., **Vignali, C.**, **Bauer, F.E.**, **Brandt, W.N.**, **Hornschemeier, A.E.**, **Garmire, G.P.**, & **Schneider, D.P.** 2002, ''The Chandra Deep Field-North Survey. X. X-ray emission from Very Red Objects,'' AJ, 123, 1149

Babu, G.J., **Feigelson, E.D.,** 2002, ''Statistical methodology for the National Virtual Observatory,'' in The National Virtual Observatory (S. G. Djorgovski, ed.), San Francisco:ASP, 272, in press

Bauer, F.E., **Alexander, D.M.**, **Brandt, W.N.**, **Hornschemeier, A.E.**, Miyaji, T., **Garmire, G.P.**, **Schneider, D.P.**, Bautz, M.W., **Chartas, G.**, Griffiths, R.E., & Sargent, W.L.W. 2001, ''The Chandra Deep Field-North Survey. IX. Extended X-ray Sources,'' AJ, 123, 1163

Bauer, F.E., **Alexander, D.M.**, **Brandt, W.N.**, **Hornschemeier, A.E.**, **Vignali, C.**, **Garmire, G.P.**, & **Schneider, D.P.** 2002, ''The Chandra Deep Field-North Survey. XII. X-ray and Radio Source Populations,'' AJ, in press; astro-ph/0207433

Boller Th., Fabian A.C., Sunyaev R., Trümper J., Vaughan S., Ballantyne D.R., **Brandt W.N.**, Keil R., Iwasawa K., 2002, ''XMM-Newton discovery of a sharp spectral feature at $\sim$7 keV in the Narrow-Line Seyfert 1 galaxy 1H 0707−495,'' MNRAS, 329, L1

Bond, N., **Churchill, C. W.**, **Charlton, J. C.**, & Vogt, S. S. 2001, ''High-Redshift Superwinds as the Source of the Strongest Mg II Absorbers: A Feasibility Analysis,'' ApJ, 562, 641

Brandt W.N., **Alexander D.M.**, **Hornschemeier A.E.**, **Garmire G.P.**, **Schneider D.P.**, Barger A.J., **Bauer F.E.**, **Broos P.S.**, Cowie L.L., **Townsley L.K.**, **Burrows D.N.**, **Chartas G.**, **Feigelson E.D.**, Griffiths R.E., **Nousek J.A.**, Sargent W.L.W., 2001, ''The Chandra Deep Field-North survey. V. 1 Ms source catalogs,'' AJ, 122, 2810

Brandt W.N., **Schneider D.P.**, Fan X., Strauss M.A., Gunn J.E., Richards G.T., Anderson S.F., Vanden Berk D.E., Bahcall N.A., Brinkmann J., Brunner R., Chen B., Hennessy G.S., Lamb D.Q., Voges W., York D.G., 2002, ''Exploratory Chandra observations of the three highest redshift quasars known,'' ApJ, 569, L5

Burrows, D.N., Schnopper, H.W., Turner, M., Singh, K-P 2002, ''The soft X-ray telescope (SXT) on the Indian satellite, ASTROSAT,'' APS/HEAD , N17.015.

Charlton, J. C., **Churchill, C. W.**, **Ding, J.**, **Zonak, S.**, **Bond, N. A.**, & **Rigby, J. R.** 2002, ''Phase Structure of Weak MgII Absorbers: Star Forming Pockets Outside of Galaxies,'' in ASP proceedings ''Extragalactic Gas at Low Redshift,'' ed. J. Mulchaey, p. 122.

Charlton, J. C., **Ding, J.**, **Zonak, S.**, **Churchill, C. W.**, & **Bond, N. A.** 2002, ''High Resolution STIS/HST and HIRES/Keck Spectra of Three Weak Absorbers Toward PG1634+706,'' ApJ, submitted

Chartas, G., Brandt, W. N., Gallagher, S. C., & Garmire, G. P. 2002, ''Chandra Detects Relativistic Broad Absorption Lines from APM 08279+5255,'' ApJ, in press (astro-ph/0207196)

Chartas, G., Agol, E., **Eracleous, M., Garmire, G.,** Bautz, M. W., & Morgan, N. D. 2002, ''Caught in the Act: Chandra Observations of Microlensing of the Radio-loud Quasar MG J0414+0534,'' ApJ, 568, 509

Chartas, G., Brandt, W. N., Gallagher, S. C., & Garmire, G. P. 2002, ''An X-ray Survey of Gravitationally Lensed BALQSOs,'' submitted to Astron. Nachr.

Chester, M., **Nousek, J.**, Gehrels, N., Marshall, F. 2002, ''Rapid Response Astronomy Using the Swift GRB Explorer,'' APS/HEAD, N17.048.

Churchill, C. W. 2001, ''MgII Absorber Number Density at z 0.05: Implications for Ω_{DLA} Evolution,'' ApJ, 560, 92

Churchill, C. W., **Charlton, J. C.**, & **Masiero J.**, 2002, ''Mapping Metal-Enriched High Velocity Clouds to Very Low HI Column Densities,'' in ASP proceedings ''Extragalactic Gas at Low Redshift,'' ed. J. Mulchaey, p. 236.

Ciardullo, R., Feldmeier, J.J., Jacoby, G.H., **Kuzio de Naray, R.**, **Laychak, M.B.**, & **Durrell, P.R.** 2002, ''Planetary Nebulae as Standard Candles. XII. Connecting the Population I and Population II Distance Scales,'' ApJ, 577, 31

Ciardullo, R., Feldmeier, J.J., **Krelove, K.**, Barlett, R., Jacoby, G.H., & Gronwall, C. 2001, ''A Measurement of the Contamination in [O III] λ5007 Surveys of Intracluster Stars and the Surface Density of $z=3.13$ Lyα Galaxies,'' ApJ, 566, 784

Collier S., Crenshaw D.M., Peterson B.M., **Brandt W.N.**, Clavel J., Edelson R., George I.M., Horne K., Kriss G.A., Mathur S., Netzer H., O'Brien P.T., Pogge R.W., Pounds K.A., Romano P., Shemmer O., Turner T.J., Wamsteker W., 2001, ''Multiwavelength monitoring of the Narrow-Line Seyfert 1 galaxy Akn 564: II. Ultraviolet continuum and emission-line variability,'' ApJ, 561, 146

Cowie L.L., **Garmire G.P.**, Bautz M.W., Barger A.J., **Brandt W.N.**, **Hornschemeier A.E.**, 2002, ''2–8 keV X-ray number counts determined from Chandra blank field observations,'' ApJ, 566, L5

Dai, X., Chartas, G., Agol. E., Bautz, M. W., & **Garmire, G. P.** 2002, ''*Chandra* Observations of QSO 2237 +0305,'' submitted to ApJ

Dai, Z.G., **Zhang, B.**, **Gou, L.J.**, **Mészáros, P.** & Waxman, E. 2002, ''GeV emission from TeV blazars and intergalactic magnetic fields,'' ApJ Letters, in press (astro-ph/0209091)

Debes, J., and **Sigurdsson, S.**, 2002 ''Are there unstable planetary systems around White Dwarfs?'' ApJ, 572, 556

Di Matteo, T., Perna, R., **Abel, T.**, & Rees, M. J. 2002, ''Radio Foregrounds for the 21 Centimeter Tomography of the Neutral Intergalactic Medium at High Redshifts'' ApJ, 564, 576

Ding, J., **Charlton, J. C.**, **Zonak, S. G.**, & **Churchill, C. W.** 2002, ''A Quadruple Phase Strong MgII Absorber at z 0.9902 Toward PG 1634+706,'' ApJ, submitted

Donley J.L., **Brandt W.N.**, **Eracleous M.**, Boller Th., 2002, ''Large-amplitude X-ray outbursts from galactic nuclei: A systematic survey using ROSAT archival data,'' AJ, 124, 1308

Donley, J., Fried, R., Jones, C. & **Wade, R. A.** 2002, ''Light Maxima of the RRab Variable TU UMa in Early 2002,'' Inf. Bull. Variable Stars, 5273

Durrell, P. R., Ciardullo, R., Feldmeier, J. J., Jacoby, G. H., and **Sigurdsson, S.**, 2002 ''Intracluster Red Giant Stars in the Virgo Cluster'' ApJ, 570, 119

Durrell, P.R., Mihos, J.C., Feldmeier, J.J., Jacoby, G.H., & **Ciardullo, R.** 2003, ''Kinematics of Planetary Nebulae in M51's Tidal Debris,'' ApJ, in press (Jan. 2003)

Elsner, R.F. and 15 others, 2002, ''Discovery of soft X-ray emission from Io, Europa and the Io plasma torus,'' Astrophys. J., 572, 1077

Eracleous, M., Shields, J. C., Chartas, G., & Moran, E. C. 2002, ''Three LINERs under the Chandra X-Ray Microscope,'' ApJ, 565, 108.

Eracleous, M., Wade, R. A., Mateen, M., & Lanning, H. H. 2002, ''A Spectroscopic Reconnaissance of Ultraviolet-bright Stars,'' PASP, 114, 207.

Feigelson, E.D., 2001, ''Chandra studies of star forming regions,'' in X-ray Astronomy 2000 (R. Giacconi, L. Stella & S. Serio, eds.), San Francisco:ASP, ASP Conf. Ser. 234, 131

Feigelson, E.D., Broos, P., Gaffney, J.A., Garmire, G., Hillenbrand, L.A., Pravdo, S.H., **Townsley, L., Tsuboi, Y.** 2002 ''X-ray stars in the Orion Nebula,'' Astrophys. J., 574, 258

Feigelson, E.D., Garmire, G.P., Pravdo, S.H. 2002, ''Magnetic flaring in the pre-main sequence Sun and implications for the early solar system,'' Astrophys. J., 572, 335

Feldmeier, J.J., **Ciardullo, R.**, Jacoby, G.H., & **Durrell, P.R.** 2003, ''Intracluster Planetary Nebulae in the Virgo Cluster II. Imaging Catalog,'' ApJ, submitted

Gallagher, S. C., **Brandt, W. N.**, **Chartas, G.**, **Garmire, G. P.**, & Sambruna, R. M. 2002, ''X-raying the Ultraluminous Infrared Starburst Galaxy and Broad Absorption Line QSO, Markarian 231, with it Chandra,'' ApJ, 569, 655

Gallagher, S. C., **Brandt, W. N.**, **Chartas, G.**, & **Garmire, G. P.** 2002, ''X-ray Spectroscopy of QSOs with Broad

Ultraviolet Absorption Lines,'' ApJ, 567, 37

Gallagher, S. C., **Brandt, W. N.**, **Chartas, G.**, & Sambruna, R. M. 2002, ''An Exploratory it Chandra Survey of Large Bright Quasar Survey Broad Absorption Line QSOs,'' Workshop on X-ray Spectroscopy of AGN with Chandra and XMM-Newton, held at MPE Garching, December 3-6, 2001, MPE Report 279, 117

Ganguly, R., 2002, ''Properties of QSO-Intrinsic Narrow Ultraviolet Absorption,'' in ASP proceedings ''Mass Outflow in Active Galactic Nuclei: New Perspectives,'' ed. D. M. Crenshaw, S. R. Kraemer, and I. M. George, p. 111

Ganguly, R., **Masiero, J**, **Charlton, J. C.**, & Sembach, K. R., 2002, ''An Intrinsic Absorption Complex Toward RXJ 1230+0115,'' ApJ,submitted

Getman, K. V., **Feigelson, E. D.**, **Townsley, L.**, Bally, J., Lada, C. J., & Reipurth, B. 2002, ''*Chandra* Study of Young Stellar Objects in the NGC 1333 Star-forming Cloud,''ApJ, 575, 354

Goodrich R.W., Campbell R., Chaffee F.H., Hill G.M., Sprayberry D., **Brandt W.N.**, **Schneider D.P.**, **Kaspi S.**, Fan X., Gunn J.E., Strauss M.A., 2001, ''*J*-band spectroscopy of the $z=5.74$ BAL QSO SDSSp J104433.04–012502.2,'' ApJ, 561, L23

Hall, P.B., Anderson, S.F., Strauss, M.A., York, D.G.., **Richards, G.T.**, Fan, X., Knapp, G.R., **Schneider, D.P.**, Vanden Berk, D.E., *et al.*, 2002a, ''Unusual Broad Absorption Line Quasars from the Sloan Digital Sky Survey,'' ApJS, in press

Hall, P.B., **Richards, G.T.**, York, D.G., Keeton, C.R., Bowen, D.V., **Schneider, D.P.**, Schlegel, D., and Brinkmann, J. 2002b, ''The Redshift of the Lensing Galaxy in PMN J0134−0931,'' ApJL, 575, 51

Harding, A. K., Muslimov, A. G. & **Zhang, B.**, 2002, ''Regimes of pulsar pair formation and particle energetics,'' ApJ, 576, 366

Hasenkopf, C. A., Sambruna, R. M., & **Eracleous, M.** 2002, ''X-Ray Spectra of Intermediate-Luminosity, Radio-loud Quasars,'' ApJ, 575, 127.

Hemsendorf, M., **Sigurdsson, S.,** and Spurzem, R., 2002 ''Collisional dynamics around binary black holes in galactic centers'' ApJ, in press

Hillenbrand, L.A., Carpenter, J.M., **Feigelson, E.D.**, 2001, ''The Orion star-forming region,'' in From Darkness to Light (T. Montmerle & P. André, eds.), San Francisco:ASP, 439

Holley–Bockelmann, K., Mihos, C. J., **Sigurdsson, S.**, Hernquist, L., and Norman, C., 2002 ''Models of Cuspy Triaxial Galaxies with Central Black Holes'' ApJ567, 187

Hornschemeier A.E., **Brandt W.N.**, **Alexander D.M.**, **Bauer F.E.**, **Garmire G.P.**, **Schneider D.P.**, Bautz M.W., Chartas G., 2002, ''The Chandra Deep Field-North survey. VIII. X-ray constraints on spiral galaxies from $0.4<z<1.5$,'' ApJ, 568, 82

Inal, M.K., Zhang, H.L.,**Sampson, D.H.,** & Fontes, C.J.,2002, ''Effect of Inner-Shell Ionization on the Circular Polarization of the FeXXV (1s2s)1 - (1s2)0 Line Produced by Collisions with a Longitudinally Polarized Electron Beam,'' Phys. Rev.A, 65, 032727

Kalirai, J.S., Ventura, P. Richer, H.B., Fahlman, G.G., **Durrell, P.R.**, D'Antona, F., & Marconi, G. 2002, ''The CFHT Open Star Cluster Survey. III. The White Dwarf Cooling Age of the Rich Open Star Cluster NGC 2099 (M37),'' AJ, 122, 3239

Kaspi S., **Brandt W.N.**, George I.M., Netzer H., Crenshaw D.M., Gabel J.R., Hamann F.W., Kaiser M.E., Koratkar A., Kraemer S.B., Kriss G.A., Mathur S., Mushotzky R.F., Nandra K., Peterson B.M., Shields J.C., Turner T.J., Zheng W., 2002, ''The ionized gas and nuclear environment in NGC 3783. I. Time-averaged 900 ks Chandra grating spectroscopy,'' ApJ, 574, 643

Kobayashi, S, and **Mészáros, P.**, 2002, ''Gravitational Radiation from Gamma-Ray Burst Progenitors,'' ApJ, submitted (astro-ph/0210211)

Kobayashi, S, Ryde, F and MacFadyen, A, 2002, ''Luminosity and Variability of Collimated Gamma-ray Bursts'' ApJ in press (astro-ph/0110080)

Kundu, A. *et al.*, including **Palma, C.** 2002 ''Exploring Halo Substructure with Giant Stars III: First Results from the Grid Giant Star Survey and Discovery of a Possible Nearby Sagittarius Tidal Structure in Virgo,'' ApJL, 576, 125

Laor A., **Brandt W.N.**, 2002, ''The luminosity dependence of ultraviolet absorption in active galactic nuclei,'' ApJ, 569, 641

Lawson, W.A., Crause, L.A., Mamajek, E.E. & **Feigelson, E.D.** ''ECHA J0843.3-7905: Discovery of an 'old' classical T Tauri star in the η Chamaeleontis cluster,'' 2002, MNRAS, 329, L29

Maeda, Y., Baganoff, F.K., **Feigelson, E.D.**, Bautz, M.W., **Brandt, W.N., Burrows, D.N.**, J. P. Doty, **Garmire, G.P.**, Morris, M., Pravdo, S.H., Ricker, G.R., **Townsley, L.K.** 2002 ''A Chandra study of Sgr A East: A supernova remnant regulating the activity of our Galactic Center?'' Astrophys. J., 570, 671

Mamajek, E.D., **Feigelson, E.D.**, 2001, ''The dispersal of young stars and the greater Sco-Cen Association,'' in Young Stars near Earth: Progress and Prospects, (R. Jayawardhana & T. P. Greene, eds.), San Francisco:ASP, ASP Cof Ser. 244, 104

Mészáros, P., Ramirez-Ruiz, E., Rees, M. J., & **Zhang, B.**, 2002, ''X-ray Rich GRB, Photospheres and Variability,'' ApJ, 578, 812

Mészáros, P., 2002, ''Theories of Gamma Ray Burst Sources,'' Annu. Rev. Astron. Astrophys., 40, 137-69

Nousek, J. A., **Chester, M. M.**, Gehrels, N., Marshall, F. E., Swift Team 2001, ''Rapid Response Astronomy Using the Swift GRB Explorer,'' BAAS 45, 11.

Nousek, J. A., Gehrels, N. 2002, ''The Swift GRB Explorer Mission,'' APS/HEAD, X6.010.

Palma, C., Zonak, S. G., Hunsberger, S. D., Charlton, J. C., Gallagher, S. C., Durrel, P. R., & English, J. 2002,''The Beginning of the End: it Hubble Space Telescope Images of Seyfert's Sextet,'' AJ, in press (astro-ph/0208284)

Palma, C., Majewski, S. R., Siegel, M. H., Patterson, R. J., Ostheimer, J. C., & Link, R. 2002, ''Exploring Halo Substructure with Giant Stars IV: The Extended Distribution of the Ursa Minor indent Dwarf Spheroidal,'' AJ, submitted (astro-ph/0205194)

Palma, C., Majewski, S. R., & Johnston, K. V. 2002, ''On the Distribution of Orbital Poles of Milky Way Satellites,'' ApJ, 564, 736

Pavlov, G. G., Zavlin, V. E., **Sanwal, D.**, & Trümper, J. ''1E 1207.4−5209: The Puzzling Pulsar at the Center of the Supernova Remnant PKS 1209−51/52,'' 2002, ApJ, 569, L95

Plucinsky, P. P., Schulz, N. S., Marshall, H. L., Grant, C. E., **Chartas, G., Sanwal, D., Teter, M. A.,** Vikhlinin, A. A., Edgar, R. J., Wise, M. W., Allen, G. E., Virani, S. S., DePasquale, J. M., Michael T. & Raley, M. T., ''The Flight Spectral Response of the ACIS Instrument'' To appear in Astronomical Telescopes and Instrumentation 2002 (SPIE), (astro-ph/0209161)

Pravdo, S.H., **Feigelson, E.F., Garmire, G., Maeda, Y., Tsuboi, Y.** & J. Bally, 2001, ''Discovery of X-rays from the protostellar outflow HH2,'' Nature, 413, 708

Ralston, J.P., **Razzaque, S.** and Jain, P., 2002, ''Ultra-high energy quenching of the LPM effect: Implications for GZK-violating Events,'' PRL, submitted (astro-ph/0209455)

Razoumov, A.O., Norman, M.L., **Abel, T.**, & Scott, D. 2002, ''Cosmological Hydrogen Reionization with Three-dimensional Radiative Transfer,'' ApJ, 572, 695

Richards, G.T., Fan, X., Newberg, H.J., Strauss, M.A., Vanden Berk, D.E., **Schneider, D.P.**, Yanny, B., *et al.* 2002a, ''Spectroscopic Target Selection in the Sloan Digital Sky Survey: The Quasar Sample,'' AJ, 123, 2945

Richards, G.T., Vanden Berk, D.E., **Reichard, T.A.**, Hall, P.B., **Schneider, D.P.**, SubbaRao, M., Thakar, A.R., and York, D.G., 2002b, ''Broad Emission Line Shifts in Quasars: An Orientation Measure for Radio-Quiet Quasars?,'' AJ, 124, 1

Richards, M. T. 2001, ''Doppler Tomography of Eclipsing and Non-eclipsing Algols,'' *Astrotomography: Indirect Imaging Methods in Observational Astronomy*, Springer Lecture Notes in Physics Series, Vol. 573, H.M.J. Boffin, D. Steeghs, & J. Cuypers (eds.), p. 276 (Invited Review)

Richards, M. T. 2002, ''Images of Active Mass Transfer in Direct Impact Close Binary Systems,'' in *Proceedings of 3D Stellar Structure Workshop*, ASP Conference Series, Rob Cavallo, Stefan Keller, Sylvain Turcotte (eds.), in press

Richards, M. T., Waltman, E. B., & Ghigo, F. 2002, ''Statistical Analysis of Continuous Radio Flare Data from RS CVn and Algol-type Binaries,'' BAAS, 34, 653

Richards, M. T., Waltman, E. B., & Ghigo, F. 2002, ''Statistical Analysis of 5-year Continuous Radio Flare Data from β Per, V711 Tau, δ Lib, and UX Ari,'' ApJ, submitted (No. 56386)

Rigby, J. R., **Charlton, J. C.**, & **Churchill, C. W.** 2002, ''The Population of Weak Mg II Absorbers. II. The Properties of Single−Cloud Systems,'' ApJ, 565, 743

Roming, P.W., Liechty, J.C., Sohn, D.H., **Shoemaker, J.R.**, **Burrows, D.N.**, **Garmire, G.P.** 2002, ''Markov chain Monte Carlo algorithms for optimizing grazing incidence optics for wide-field x-ray survey imaging,'' in X-Ray Optics for Astronomy: Telescopes, Multilayers, Spectrometers, and Missions (SPIE 4496, 146).

Rutledge, R., Bildsten, L., Brown, E., **Pavlov, G. G.**, & Zavlin, V. E., ''Variable Thermal Emission from Aquila X-1 in Quiescence'' 2002, ApJ, 577, 346

Rutledge, R., Bildsten, L., Brown, E., **Pavlov, G. G.**, & Zavlin, V. E., ''A Possible Transient Neutron Star in Quiescence in the Globular Cluster NGC 5139'' 2002, ApJ, 578, 405

Safi-Harb, S., Harrus, I., Petre, R., **Pavlov, G. G.**, Koptsevich, A. B., & **Sanwal, D.**, ''X-Ray Observations of the Supernova Remnant G21.5-0.9,'' 2001, ApJ, 561, 308

Sambruna, R. M., **Eracleous, M.**, & Mushotzky, R. F. 2002, ''Constraining the central engine of radio-loud AGNs,'' NewAR, 46, 215.

Sanwal, D., Pavlov, G. G., Zavlin, V. E., & **Teter, M. A.**, ''Discovery of Absorption Features in the X-Ray Spectrum of an Isolated Neutron Star,'' 2002, ApJ, 574, L61

Schneider, D.P., Knapp, G.R., Hawley, S.L., Covey, K.R., Fan, X., **Ramsey, L.W.**, **Richards, G.T.**, *et al.* 2002a, ''L Dwarfs Found in Sloan Digital Sky Survey Commissioning Data II. Hobby-Eberly Telescope Observations,'' AJ, 123, 458

Schneider, D.P., Richards, G.T., Fan, X., Hall, P.B., Strauss, M.A., *et al.* 2002b, ''The Sloan Digitual Sky Survey Quasar Catalog: Early Data Release,'' AJ, 123, 567

Schulz N.S., **Brandt W.N.**, 2002, ''Variability of the X-ray P Cygni line profiles from Circinus X-1 near zero phase,'' ApJ, 572, 971

Sigurdsson, S., 2002, ''Testing gravity in large extra dimensions . . . ,'' International Journal of Modern Physics D, in press (Honorable Mention, essay competition of the Gravity Research Foundation 2002)

Sigurdsson, S., 2002, ''Loss-cone: past, present and future,'' Class. Quant. Grav, in preparation

Sigurdsson, S., 2002, ''Adiabatic growth of supermassive black holes in galaxies,'' Conf Proc., 1st Centennial Carnegie Symposium, in preparation

Sigurdsson, S., 2002, ''Pulsars and black holes in globular clusters,'' PASP Conf. Proc., Radio Pulsars: Crete 2002

Sipior, M., and **Sigurdsson, S.,** 2002, ''Nova Sco and coalescing low mass black hole binaries as LIGO sources'' ApJ, 572, 962

Soinski, T. L. & **Richards, M. T.** 2002, ''The Long-term Characteristics of Radio Flares from V711 Tau, β Per and UX Ari,'' BAAS, 34, 653

Sokasian, A., **Abel, T.**, & Hernquist, L. 2002, ''The Epoch of Helium Reionization,'' MNRAS, 332, 601

Stark, M. A., Wade, R. A., Orosz, J. A. & Berriman, G. B. 2001, ''Hot Subdwarf Membership in Visual Binaries,'' BAAS, 199, 06.15

Steidel, C. C., Kollmeier, J. A., Shapley, A. E., **Churchill, C. W.**, Dickinson, M., & Pettini, M. ''The Kinematic Connection Between Absorption Gas Toward QSOs and Galaxies at Intermediate Redshift,'' ApJ, 570, 526

Storchi-Bergmann, T., Nemmen da Silva, R., & **Eracleous, M.** 2002, ''The accretion disk in the nucleus of NGC1097: constraints from 10 yrs of observations,'' in *Active Galactic Nuclei: from Central Engine to Host Gal-*

axy, eds. S. Collin, F. Combes & I. Shlosman, ASP Conference Series (San Fransisco: ASP), in press.

Sambruna, R. M., Maraschi, L., Tavecchio, F., Urry, C. M., Cheung, C. C., **Chartas, G.,** Scarpa, R., & Gambill, J. K. 2002, ''A Survey of Extended Radio Jets in Active Galactic Nuclei with Chandra and the Hubble Space Telescope: First Results,''ApJ, 571, 206

Townsley, L.K., **Broos, P.S.**, **Chartas, G.**, **Moskalenko, E.**, **Nousek, J.A.**, & **Pavlov, G.G.** 2002a, ''Simulating CCDs for the *Chandra* Advanced CCD Imaging Spectrometer,'' Nuclear Instruments and Methods in Physics Research, Section A, 486, 716

Townsley, L.K., **Broos, P.S.**, **Nousek, J.A.**, & **Garmire, G.P.** 2002b, ''Modeling Charge Transfer Inefficiency in the *Chandra* Advanced CCD Imaging Spectrometer,'' Nuclear Instruments and Methods in Physics Research, Section A, 486, 751

Tsujimoto, M., Koyama, K., Tsuboi, Y., **Chartas, G.,** Goto, M., Kobayashi, N., Terada, H., & Tokunaga, A. T. 2002, ''Deep Near-Infrared Observations of the X-Ray-emitting Class 0 Protostar Candidates in the Orion Molecular Cloud 3,'' ApJ, 573, 270

Usher, Peter, 2001a. ''Advances in the Hamlet Cosmic Allegory'' The Oxfordian 4, 25-49.

Usher, Peter, 2001b. Letter to the Editor. The Shakespeare Newletter 51 No. 4, 82.

van den Bosch, F.C., **Abel, T.**, Croft, R.A.C., Hernquist, L., & White, S.D.M. 2002, ''The Angular Momentum of Gas in Protogalaxies. I. Implications for the Formation of Disk Galaxies,'' ApJ, 576, 21

Vignali, C., **Brandt, W.N.**, **Schneider, D.P.**, **Garmire, G.P.**, & Kaspi, S. 2002, ''X-ray lighthouses at the end of the ''Dark'' Age. Probing the most luminous $z>4$ Palomar Digital Sky Survey Quasars with Chandra,'' AJ, submitted

Vignali, C., **Brandt, W.N.**, & **Schneider, D.P.** 2002, ''X-ray emission from radio-quiet quasars in the SDSS early data release. The $\alpha_{\rm ox}$ dependence upon UV luminosity,'' AJ, submitted

Wade, R. A. & **Stark, M. A.** 2001, ''Are VIMs Bad for SIM?: Assessing the Impact of Variability-Induced Movers on the SIM Grid,'' BAAS, 199, 09.01

Waxman, E and **Mészáros P.**, 2002, ''Collapsar Uncorking and Jet Eruption in GRB,'' ApJ, submitted (astro-ph/0206392)

Zavlin, V. E., **Pavlov, G. G., Sanwal, D.**, Manchester, R. N., Trümper, J., Halpern, J. P., & Becker, W., ''X-ray Radiation from the Millisecond Pulsar J0437-4715,'' 2002, ApJ, 569, 894

Zhang, B., 2001, ''On the radio quiescence of anomalous X-ray pulsars and soft Gamma-ray repeaters,'' ApJ, 562, L59

Zhang, B., 2002, ''Radio pulsar death,'' in Proc. of Sino-Germany workshop on radio astronomy on galactic objects, galaxies, and AGNs (eds. Han & Willebinski), Aug. Xi'an, ChA&A, in press (astro-ph/0209160)

Zhang, B., & **Mészáros, P.**, 2001, ''GRB afterglows: two post-standard effect,'' in Proc. of GRB and Afterglow Astronomy (eds. Ricker *et al.*), Nov. 5-9, Woods Hole, AIP Conference Proceedings, in press

Zhang, B., & **Mészáros, P.**, 2002a, ''Gamma-ray bursts with continuous energy injection and their afterglow signature,'' ApJ, 566, 712

Zhang, B., & **Mészáros, P.**, 2002b, ''Gamma-ray bursts beaming: a universal configuration with a standard energy reservoir?,'' ApJ, 571, 876

Zhang, B., & **Mészáros, P.**, 2002c, ''An analysis of gamma-ray burst spectral break models,'' ApJ, 581, in press (astro-ph/0206158)

Zhang, B., Mészáros, P., Dai, Z-G., Waxman, E., 2002d, ''TeV Neutrinos from Magnetars,'' PRL, submitted (astro-ph/0210382)

Zhang, H.L., & **Sampson, D.H.,** 2002, ''Resonance Contributions to Collision Strengths for Transitions between Magnetic Sublevels in Highly Charged Ions by Impact with an Electron Beam,'' Phys. Rev.A, accepted

George Chartas
Peter Mészáros