

**Pennsylvania State University**  
**Astronomy and Astrophysics**  
*University Park, Pennsylvania 16802-6305*

This report covers the period from September 1, 2002 to August 31, 2003.

## 1. PERSONNEL

### 1.1 Faculty

The regular members of the faculty during the academic year 2002-2003 were Professors Peter Mészáros (Department Head and Distinguished Professor), William Nielsen Brandt, Jane Charlton, Robin Ciardullo, Eric Feigelson, Gordon Garmire (Evan Pugh Professor), Pablo Laguna, Lawrence Ramsey (Department Head effective July 1), Mercedes Richards, John Nousek, Donald Schneider, Peter Usher (Emeritus), and Alexander Wolszczan (Evan Pugh Professor); Associate Professor Richard Wade; Assistant Professors Tom Abel, Michael Eracleous, Jian Ge, and Steinn Sigurdsson; Senior Scientist/Professor David Burrows; and Senior Scientist George Pavlov.

James Beatty and Lee Samuel Finn, Professors of Physics, and Stephane Coutu and Douglas Cowen, Assistant Professors 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, Caryl Gronwall, Joanne Hill, Sally Hunsberger, Nina Jansen, Shiho Kobayashi, Koji Mori, Christopher Palma, Sangwook Park, Soebur Razzaque, Deqing Ren, Peter Roming, Emanuele Ripamonti, Divas Sanwal, Ulrich Spherhake, Marcus Teter, Cristian Vignali and Bing Zhang. Joining the department as Research Associates were Jan Budaj (formerly of the Slovak Academy of Science, Slovakia), Stefan Immler (formerly of Max-Planck-Institut für extraterrestrische Physik, Germany), Wentao Wu (formerly of the University of Alabama), Toru Misawa (formerly of the National Astronomical Observatory, Japan), Masahiro Tsumimoto (formerly of Kyoto University, Japan) and Alexey Koptsevitch (formerly of Ioffe Institute for Physics and Technology, Russia).

Instructor was Scott Miller.

Adjunct Associate Professor was Hans Kraus at the Oxford University Nuclear and Astrophysics Laboratory.

### 1.2 Sabbatical Leaves

Eric Feigelson was on sabbatical leave at the Centre des Études de Saclay (Paris, France), Arcetri Observatory (Florence, Italy), and the University of New South Wales (Australian Defence Force Academy campus, Canberra, Australia).

Alex Wolszczan was on sabbatical leave at the California Institute of Technology and Jet Propulsion Laboratory (Pasadena CA), and at the Max-Planck-Institut for Radioastronomy (Bonn, Germany).

### 1.3 Visitors to the Department

Visitors to the department included Dr. Shai Kaspi (from Tel Aviv University), Dr. Ann Hornschemeier (Johns Hopkins University) and Dr. Sarah Gallagher (Massachusetts Institute of Technology) working with Dr. Niel Brandt; Dr. Ed Murphy (from the University of Virginia) working with Dr. Chris Palma and Dr. Jane Charlton; Dr. John Feldmeier (from Case Western Reserve University) working with Dr. Robin Ciardullo; Prof. Chris Mihos (from Case Western Reserve University) and Dr. Kelly Holley-Bockelmann (from the University of Massachusetts) working with Dr. Steinn Sigurdsson; Mr. Ralf Kaehler (Zuse Rechenzentrum, Berlin), Dr. Naoki Yoshida (Harvard, Center for Astrophysics), Dr. Aaron Sokasian (Harvard College Observatory), Dr. Ken Nomoto (University of Tokyo) and Dr. Ari Mahler (University of Massachusetts, Amherst) all working with Dr. Tom Abel.

## 2. ACADEMIC PROGRAM

### 2.1 Graduate & Undergraduate Majors

Twenty-five graduate and forty-two undergraduate astronomy majors were enrolled during the academic year 2002-2003. During that time 13 B.S. degrees and one Ph.D. degree were awarded in Astronomy & Astrophysics. Doctoral recipient was Michael Sipior.

### 2.2 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 2003 program entitled, Penn State Inservice Workshops in Astronomy (PSIWA), consisted of three 1-week courses: Stars and Planets, Galaxies and Cosmology, and Space Astronomy. All of the 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. Palma, Feigelson, and Brandt were the workshop instructors. Numerous department faculty, research associates and graduate students also participated in the programs.

### 2.3 Outreach

The department outreach effort continued to provide stimulating and educational programs for the general public in 2003. Once again the department hosted the Friedman

Lecture Series, public lectures sponsored by the Ronald and Susan Friedman Fund. Dr. Mario Livio of the Space Telescope Science Institute presented the first lecture on the accelerating universe. Mike Weinstein covered highlights from the Hubble Space Telescope in the second lecture. Once again this summer, members from the department teamed up with volunteer undergraduate students, Astronomy Club members, and community members to produce AstroFest: a program featuring numerous astronomical activities held during the Central Pennsylvania Festival of the Arts. More than 1,100 people visited the department over the four-day event. Additional public service programs, e.g., 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>.

## 2.4 Astronomy Club

The Astronomy Club continued to conduct monthly public observing sessions, uninterrupted since 1973. These Open Houses attract hundreds of visitors to the roof of Davey Laboratory to view selected celestial objects through various telescopes. Members also participated in outreach programs, some of which made use of the department's planetarium. Club officers are: Co-Presidents: Christeallia Amorosi and Brandon Aldinger, Treasurer: Peter Greene, Secretary: Brian Lacki. Eracleous is the Club's faculty advisor.

## 3. RESEARCH ACTIVITIES

### 3.1 Instrumentation

#### 3.1.1 Optical

*3.1.1.1 The Hobby-Eberly Telescope* The HET has completed its fourth year of early operations. Again this last year about 2/3 of HET time was scheduled for science observations in the queue mode. The remainder of the time was taken up by instrument commissioning and telescope engineering and facility improvements. 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 remains about 45%, but the program completion rate increased to 80% of the two highest rated priority bands. Data 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 27% of the time.

The HET continues to benefit from engineering and operational upgrades. At the very end of this reporting period the HET achieved its image quality goal during engineering delivering 0.88 arc second images in about 0.6 arc second seeing (FWHM). All critical problems that relate to delivered image quality have been identified and engineering solutions are in progress. We fully expect to be seeing limited in normal operation in a matter of months.

During the last reporting period it was noted that the Medium Resolution Spectrograph (MRS), the third HET facility instrument for the HET, was installed and had first light. To date the so-called direct feed mode has been commissioned and will be available for queue observing in Dec. 2003. This instrument is described in Ramsey *et al.* (2003).

During the past year, the following papers were submitted using HET data: Fan *et al.* 2003, Mukherjee *et al.* 2003, Vignali *et al.* 2003, and Lopez-Santiago *et al.* 2003.

#### 3.1.2 X-ray

*3.1.2.1 Overview of the CCD Imaging Spectrometer on Chandra* The ACIS instrument on board the Chandra X-ray Observatory continues to return excellent data after four years in orbit. During the past year a number of interesting observations were made by the ACIS team at Penn State ranging from young stars, supernova remnants, neutron stars, black holes, clusters of galaxies and very distant AGN. During the year members of the ACIS team participated with the Chandra X-ray Center in discussions of how to remove the material that has been slowly accumulating on the ACIS filter. A possible bake out of the ACIS camera is being considered as a means to drive off the contaminant. A. and G. Garmire continue to work on the young stellar content of the cometary dark cloud in Corona Australis and the central compact object in the supernova remnant RCW103. Other members of the ACIS team provide descriptions of their work under their sections.

*3.1.2.2. Software Development for ACIS* Broos has developed a new software package for the automated extraction and fitting of point source spectra from ACIS imaging data, called *acis\_extract*. It generates lightcurves, photometry, diagnostic plots, and other products. Multiple observations of a target are handled (weighted ARFs, RMFs). ARFs are lowered by the computed PSF fraction (as a function of energy) to improve flux estimates. PSF-correlation and data centroid positions are calculated for each source and can be used to improve source positions. Maximum Likelihood reconstruction of each source neighborhood allows the user to search for close pairs or groups of sources. Wide-band photometry is performed and hardness ratios are computed. Automated spectral fitting is performed using the composite source spectra, background spectra, RMFs, and ARFs. Getman has developed utilities for choosing the best spectral fit and for generating LaTeX tables of photometry and fit parameters. He has also provided sample XSPEC model scripts. Broos and Townsley have written an extensive users' manual. The package was released to community in February 2003 ([http://www.astro.psu.edu/xray/docs/TARA/ae\\_users\\_guide.html](http://www.astro.psu.edu/xray/docs/TARA/ae_users_guide.html)) and a poster describing it was presented at the March 2003 HEAD meeting.

Townsley and Broos continue to support their public Monte Carlo algorithm to model and predict the response of X-ray CCDs to photons and minimally-ionizing particles (Townsley *et al.* 2002a). They also continue to support their public code to correct for charge transfer inefficiency (CTI) in ACIS CCDs (Townsley *et al.* 2001b). The CCD simulator code was used to generate response matrices necessary for

ACIS spectral fitting of CTI-corrected data. The simulator and CTI corrector code are available to the entire X-ray astronomy community (<http://www.astro.psu.edu/users/townsley/cti/>); a similar CTI corrector has been implemented (for frontside-illuminated CCDs only) by the Chandra Science Center in their CIAO software package.

### 3.1.3 Multiple Wavelength Missions

**3.1.3.1 The Swift Gamma Ray Burst Explorer** Penn State supplied instruments (the X-Ray Telescope and UV-Optical Telescope) have been successfully integrated and tested aboard the Swift Gamma-ray Burst Explorer satellite. The Swift Mission Operations Center has completed development and is ready to begin its State College-based operations control when Swift is launched (projected May 2004). Swift is expected to discover, accurately position and retrieve data from optical, X-ray and gamma-ray emission of bursts and afterglows in unprecedented numbers. Working with the Goddard Space Flight Center team, the Penn State Mission Operations Center will be the focus of world-wide attention in a new era of burst science.

## 3.2 Observational Research

### 3.2.1 Planetary & Stellar Astronomy

**3.2.1.1 Planetary Systems** Konacki (Caltech) and Wolszczan (PSU) have measured masses and orbital inclinations of the two terrestrial-mass planets around the pulsar PSR B1257+12. The planets are about 4 times the mass of the Earth and their orbits are approximately coplanar suggesting a disk origin of the system. This result is the first precise mass measurement for low-mass planets beyond the solar system.

**3.2.1.2 Star Formation** Feigelson continued his Chandra imaging studies of the rich young stellar cluster in the Orion Nebula. The principal result published this year is that the magnetic activity of pre-main sequence stars, using X-ray luminosity as the activity tracer, does not depend on stellar rotation as it does in main sequence stars. Instead, activity is broadly linked to a combination of stellar mass, bolometric luminosity, and surface area. These relationships have not been predicted and are not understood. One possibility is that magnetic fields in the pre-main sequence phase are not generated by the rotation-dependent differential rotation of the  $\alpha-\Omega$  dynamo operating in main sequence stars, but rather by a turbulent dynamo distributed throughout the deep convection zone.

Feigelson now leads an international consortium that is expanding the X-ray study of the Orion Nebula. The Chandra Orion Ultradeep Project (COUP) subjected the region for 10 days of nearly continuous exposure, giving unprecedented long and high-signal light curves of more than 1600 magnetically active stars. Data analysis is underway and science results should emerge in 2004-05.

Feigelson works with Lawson and graduate student Lyo (UNSW@ADFA) in the study of sparse clusters of X-ray discovered older T Tauri stars. *JHKL* observations of the *ROSAT*-discovered 9 Myr-old  $\eta$  Cha cluster showed that 2/3 of these stars show an *L*-band excess, indicating that

protoplanetary disks can often be long-lived. The census of  $\eta$  Cha members is now nearly complete. The higher mass members clearly congregate in the cluster core; this mass segregation must be innate to the star forming process is present. Feigelson also lead a Chandra study of the immediate vicinity of the 3–5 Myr-old stars  $\epsilon$  Cha and HD 104237. The latter, a well-known intermediate-mass Herbig AeBe star, is found to have at least 4 stellar companions within 1500 AU. This is the highest multiplicity pre-main sequence system known, and requires a quiescent dynamical environment to have survived.

Feigelson served as a collaborator in several other Chandra studies of X-ray emission and magnetic activity in young stars. These include elucidation of X-rays from the base of the Herbig-Haro outflow from a protostar (J. Bally, lead), description of a remarkably powerful and slow X-ray flare in a weak-lined T Tauri star (N. Grosso, lead), discovery of X-rays from an older pre-main sequence brown dwarf (Y. Tsuboi, lead), and a new determination of the interstellar gas-to-dust ratio from X-ray absorption of embedded young stars (M. Vuong, lead). Feigelson presented various stellar Chandra results at workshops *Magnetism and activity of the Sun and Stars* (Toulouse FR) and *Mineralogie du systeme solaire* (Lille FR), at the IAU Symposium 219 *Stars as Suns* (Sydney AU), and in talks at a number of institutions in Europe and Australia.

Townsley, Feigelson, Broos, Garmire, and colleagues completed a large paper on diffuse X-ray emission in the high-mass star-forming regions M 17 and the Rosette Nebula (Townsley *et al.* 2003; also see the Chandra Science Center image release on M 17, <http://chandra.harvard.edu/photo/2003/m17/>, and the press release on the Rosette Nebula, <http://chandra.harvard.edu/photo/cycle1/2237/>). The Chandra observation of M 17 described here complements the ROSAT observation of this field (Dunne *et al.* 2003), showing that soft diffuse X-ray emission fills this blister H II region and may be flowing through its blown-out edge into the ISM. This hot plasma is probably generated by the winds from the OB cluster powering the H II region. The discovery of this diffuse plasma, after 30 years of theoretical work showing that it should exist, was only possible because of the high spatial resolution of the Chandra X-ray Observatory; this allowed us to resolve the diffuse plasma from the >900 stellar sources in the cluster.

Townsley, Feigelson, Broos, Garmire, Getman, and colleagues obtained the first high-spatial-resolution X-ray images and spectra of RCW 49, a bright southern H II region powered by the dense stellar cluster Westerlund 2, in a 36-ksec observation with the Advanced CCD Imaging Spectrometer (ACIS) aboard the Chandra X-ray Observatory in August 2003. This rich high-mass star-forming region reveals a complex mix of point source and diffuse X-ray emission. The cluster is resolved at the arcsecond level into hundreds of sources. Diffuse X-ray emission with at least three thermal plasma components (0.1, 0.8, and >3 keV) 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; similar plasmas have been seen in other high-mass star-

forming regions, but RCW 49 is the first region to show all three components. As such, it serves as a very useful “bridge” target, linking their observations of nearby regions such as M 17 and Rosette with other studies of more distant, massive complexes such as NGC 3603, W 51, and the Arches Cluster.

**3.2.1.3 Cataclysmic Variables** An extensive grid of synthetic mid- and far-ultraviolet spectra for accretion disks in cataclysmic variables has been presented by Wade & Hubeny. In those models, the disk was assumed to be in steady state; that is,  $T_{\text{eff}}(r)$  is specified completely by the mass  $M_{\text{WD}}$  and radius  $R_{\text{WD}}$  of the accreting white dwarf star and the mass transfer rate  $\dot{M}$ , which is constant throughout the disk. In those models,  $T_{\text{eff}}(r) \propto r^{-3/4}$ , except as modified by a cutoff term near the white dwarf. Actual disks may vary from the steady state prescription for  $T_{\text{eff}}(r)$ , however, as a result of, for example, outburst cycles in dwarf novae ( $\dot{M}$  not constant with radius) or irradiation (in which case  $T_{\text{eff}}$  in the outer disk is raised above  $T_{\text{steady}}$ ). To show how the spectra of such disks might differ from the steady case, J. A. Orosz (San Diego State Univ.) and Wade carried out a study of the ultraviolet spectra of models in which power-law temperature profiles  $T_{\text{eff}}(r) \propto r^{-\gamma}$  with  $\gamma < 3/4$  are specified. Otherwise, the construction of the models is the same as in the Wade & Hubeny grid, to allow comparison. Both the UV spectral energy distributions and the appearance of the UV line spectra were considered, and a brief discussion of the eclipse light curves of the nonstandard models was given. Comparison of these models with UV observations of nova-like variables suggests that better agreement may be possible with such modified  $T_{\text{eff}}(r)$  profiles.

AM CVn is an ultra-short-period Helium cataclysmic variable. An interesting question is whether the accretion disk or the accreting white dwarf dominates the UV spectrum from this object. Wade and Eracleous obtained HST/STIS observations of the UV spectrum of AM CVn on 2002 Feb 21, using the NUV MAMA with grating G230L to obtain 1925 s of time-tagged data covering 1600–3150 Å, and using the FUV MAMA with grating G140L to obtain 2400 s of time-tagged data covering 1140–1710 Å. Thus, complete orbital coverage of the binary star was obtained, but not coverage of the 13.4 h precessional period of the eccentric disk. The mean spectrum is approximately flat in  $f_{\nu}$ . The absorption profiles of the resonance lines of N V, Si IV, C IV, and N IV are blue-shifted, evidencing a wind that is partly occulted by the accretion disk. There is weak emission at NV, which also shows the deepest absorption. The He II 1640 Å line is asymmetric. Numerous weaker spectral features of various widths are found. Sharp (interstellar) absorption lines are also seen. The light curve shows both short-term fluctuations and a long-term decline by about 15% over the span of the observations. The UV energy distribution will be combined with data from other wavelengths to study the contribution of the stellar components and the accretion disk in this system.

**3.2.1.4 Hot Subdwarf Stars** Stark and Wade, along with G. B. Berriman (IPAC), used the Two Micron All Sky Survey (2MASS) All-Sky Data Release Catalog to retrieve useful

near-IR  $J$ ,  $H$ , and  $K_s$  magnitudes for more than 800 hot subdwarfs (sdO and sdB stars) drawn from the “Catalogue of Spectroscopically Identified Hot Subdwarfs” of Kilkenny *et al.* This sample size greatly exceeds that of previous studies of hot subdwarfs. From 2MASS photometry alone or in combination with visual photometry (Johnson  $BV$  or Strömgren  $uvby$ ) available in the literature, it is possible to identify hot subdwarf stars that exhibit atypically red IR colors, which can be attributed to the presence of an unresolved late-type companion. Using this large sample, it was possible to define for the first time an approximately volume-limited sample of hot subdwarfs. The considerations, biases, and difficulties in defining such a sample were discussed. They find that, of the hot subdwarfs in Kilkenny *et al.*, about 40% in a magnitude-limited sample have colors that are consistent with the presence of an unresolved late-type companion. Binary stars are over-represented in a magnitude-limited sample. In an approximately volume-limited sample the fraction of composite-color binaries is about 25%.

Wade and Stark considered whether the hypothesis that “all (or most) hot subdwarf stars are in close binaries” is supported by the frequently reported observations of photometrically or spectroscopically composite character of many hot subdwarfs. As a possible counter-argument, they drew attention to resolved companions (optical pairs) of hot subdwarf stars. On a statistical basis, many of these are physically associated with the hot subdwarfs, i.e., are common proper motion pairs. These resolved pairs make a several percent contribution to the catalog of hot subdwarf stars per decade in projected separation. If they are just the relatively wide members of a binary population similar to the local G-dwarf binary population, which has a very wide distribution of orbital separations, then many of the unresolved but composite hot subdwarf binaries may not be “close” in the astrophysical sense. In that case, binary channels for hot subdwarf formation may be less important than thought, or must involve companions (white dwarfs) that do not result in a composite spectrum system.

**3.2.1.5 Chemically Peculiar Stars** Budaj wrote a review paper on Chemically Peculiar Stars for *Kozmos*, a popular Slovak astronomical journal (in Slovak).

Budaj and Jozef Drga (graduate student; Faculty of Mathematics, Physics and Informatics of the Comenius University, Bratislava, Slovakia) are studying the evolutionary status of Ap binaries by constructing the HR diagram of a sample Ap and comparison normal binaries. Ap binaries seem to be slightly older than the normal binaries but do not differ from the single Ap star in this respect.

Budaj and Marian Fenovcik (graduate student; University of Pavol Jozef Safarik, Kosice, Slovakia) are working on the calculation of synthetic spectra and the subsequent abundance analysis of six Am binaries.

Budaj and Ilian Iliev (National Astronomical Observatory, Bulgaria) suggested that the tidally induced meridional circulation of Tassoul & Tassoul might successfully compete with the diffusion processes and rotationally induced meridional circulation in chemically peculiar stars. They have begun a systematic abundance analysis of a sample of Am binaries to search for possible observable abundance anomalies

driven by tidal interaction in these systems. The first three stars, HD 33254, HD 178449, HD 198391 have already been analyzed.

Budaj with collaborators from Bulgaria and Slovakia (Iliev, Barzova, Ziznovsky, Zverko, Stateva) determined the mass ratio of two double-lined spectroscopic binary (SB2) Systems: HD 108642 and HD 434.

**3.2.1.6 Multiwavelength and Multi-epoch Observations** Richards has collected new time domain observations of Algol binaries with the Hobby-Eberly Telescope high resolution spectrograph during the Fall 2002 and Spring 2003 semesters. She obtained 16 spectra of S Equ within two months and 25 spectra of AU Mon within 6 weeks. These spectra will be used to produce new multiwavelength Doppler images of these systems at wavelengths from 4800 Å to 6700 Å.

Richards, Budaj, and Ilian Iliev (National Astronomical Observatory, Bulgaria) have begun a campaign to collect spectra of several active Algons like U CrB, and U Sge over repeated epochs. This campaign that will provide spectra that can be used to make multi-epoch Doppler tomograms of the H $\alpha$  and He I gas flows over a 3- or 4-month period. The campaign began in September 2003 and is in progress.

**3.2.1.7 Doppler Tomography** Richards was Chair of the Scientific Organizing Committee for IAU Joint Discussion No. 9 on ‘‘Astrotomography,’’ that was held at the IAU General Assembly XXV, in Sydney, Australia, July 17 - 21, 2003.

Richards and Milind Cholkar (graduate student) have been studying various techniques to invert Doppler tomograms of Algol binaries to produce Cartesian images of the multiple accretions structures identified in these systems.

**3.2.1.8 Radio Flares from RS CVn and Algol Binaries** Richards and Michael Rogers (undergraduate student) are studying the right and left circular polarized radio flare data from several binary systems. They are using the 2.3 GHz (S band) and 8.3 GHz (X band) radio flare data collected with the NRAO–Green Bank Interferometer nearly continuously over 2096 days (5.7 years). Flares on two RS CVn binaries (V711 Tau and UX Ari) and two Algol-type binaries ( $\beta$  Per and  $\delta$  Lib) are being analyzed. This study will focus on the statistical properties of the circular polarized data.

**3.2.1.9 Supernova Remnants** Park, Burrows, and Garmire have been monitoring SNR 1987A with the Chandra/ACIS, twice a year separated roughly by 6 months. As of July 2003 they have performed a total of eight Chandra/ACIS observations of SNR 1987A. The latest results include the detection of emergence of new X-ray bright spots in both eastern and the western side of the SNR, non-linearly brightening of the soft X-ray flux, radial expansion of the SNR with a blast wave shock velocity of  $\sim 5000 \text{ km s}^{-1}$ , and spectral softening due to the interaction between the blast wave and the dense circumstellar medium (CSM) (Park *et al.* 2003a,b). The X-ray ring of SNR 1987A is now nearly complete, and they expect a dramatic brightening of the SNR as the blast wave is sweeping through the main body of the dense inner ring. Their monitoring observations in coming years should be able to detect this exciting event of the ‘‘birth’’ of a supernova remnant. sloppypar Park, Burrows, Garmire and

Nousek have acquired spatially-resolved spectral analysis of a Galactic oxygen-rich SNR G292.0+1.8 which has revealed the detailed explosive nucleosynthesis products and sites from the massive progenitor star (Park *et al.* 2003c). Their Chandra/ACIS observation of G292.0+1.8 has resolved the SN ejecta material and the asymmetric CSM down to  $\sim$ arcsec angular scale. Their spectral analysis of these ejecta knots over the SNR suggested that the ejecta material in this SNR is dominated by low-Z elemental species of oxygen, neon, and magnesium which have originated from the outer layers of the ‘‘unprocessed’’ (i.e., the hydrostatic He-burning) carbon-core. They found no evidence for the nucleosynthesis products of the explosive Ne-, O- or Si-burning process from the deep interior of the progenitor. This is contrast to the case for another Galactic O-rich SNR Cassiopeia A, where ejecta material dominated by high-Z elements (Si, S, and Fe) was found. The absence of high-Z elements indicates that, unlike Cas A, the turn-over of the ejecta material was not effective in G292.0+1.8 and that the reverse shock has not reached the heavy elements near the center of the SNR. They also found a significant pressure difference between the CSM and the pulsar wind nebula (PWN) from the associated pulsar. This non-equilibrium pressure strongly supports their interpretation for the non-detection of heavy elements in terms of the unshocked heavy element ejecta in the center of the SNR.

Chandra/ACIS observations of SNRs in the Magellanic Clouds by Park, Burrows, Garmire, and Nousek have revealed the presence of magnesium- and oxygen-rich ejecta in SNRs N49B and 0103–72.6, respectively (Park *et al.* 2003d,e). These SNRs are relatively old ( $\tau \sim 10^4$  yr) and thus the detection of metal-rich ejecta from these objects is remarkable. SNR 0103–72.6 marks only the second member of the class of O-rich SNRs in the Small Magellanic Cloud (SMC) and the oldest example ( $\tau \sim 18000$  yr) of all known O-rich SNRs. The Mg-rich ejecta material discovered in N49B apparently is not accompanied by O- and Ne-rich material. This is mysterious because standard SN nucleosynthesis models predict a significant production of O and Ne material together with Mg. With the Chandra/ACIS observation of a Large Magellanic Cloud (LMC) SNR N49, they have also discovered a ‘‘bullet’’ of the ejecta material expelled from the progenitor star (Park *et al.* 2003f). The blast wave shock from N49 is interacting with dense, clumpy molecular clouds, and they found good evidence for multiple-phase shock structure, with three characteristic electron temperatures, due to the shock-cloud interaction. They also unambiguously detect the associated point-like source which is most likely the X-ray counterpart of the soft  $\gamma$ -ray repeater (SGR) 0526–66 in a quiescent phase. They confirm a very soft power law spectrum from this SGR. Mori, Burrows, Hester (Arizona State) and collaborators have performed monitoring observations of the Crab Nebula with the Chandra X-ray observatory and Hubble space telescope for five months. The Crab nebula is the prototypical pulsar wind nebula (PWN), which is powered by the spin-down energy of the pulsar. It has long been known that the inner region of the Crab Nebula is dynamically variable, but the origin of the variation was unresolved mainly due to the lack of spatial

and temporal resolution. The monitoring observations using two great observatories for the first time identified the origin of the variations with the variable inner ring and wisps emerging from it. This work observationally confirmed that these dynamical features were associated with the termination shock of the pulsar wind and its downstream flow, which were only theoretically discussed so far.

Mori, Burrows, Pavlov, and collaborators have newly discovered long-term (years) morphological variations of the Crab Nebula in addition to previously known short-term (days to months) variations. The long-term variations are clearly recognized at the torus and the southern jet. The displacements of these variations are as large as a few arcseconds so that only *Chandra*, with its superb spatial resolution, can resolve them. Through *Chandra* observations over 3 years, the torus appears to have been expanding until the midpoint of this period, but to have shrunk in the latest observation. Considering the fact that the angular extent of the torus (radius  $\sim 50''$ ) is almost constant over 25 years, the torus may repeat expansions and contractions with an amplitude of a few arcseconds and a time scale of about a decade. The southern jet shows the growth of its overall kinked structure. The similarity of the jet variability to that of Vela, another famous variable PWN, suggests that a common mechanism like MHD instability is responsible for the variability of the Crab and Vela jet.

Mori, Tsunemi (Osaka), Burrows, Garmire, and collaborators have observed Titan's transit of the Crab Nebula on 5 January 2003 with *Chandra*. Titan is Saturn's largest satellite and the only satellite in the solar system with a thick atmosphere, whose pressure near the surface is about 1.5 times greater than that of the Earth at sea level. Although the Saturnian system has a conjunction with the Crab Nebula every 30 years, it transits the Crab Nebula only about once in several hundred years because of an average offset of a few degrees, making its occurrence in 2003 a "once-in-a-lifetime" event. An "occultation shadow", which was made by Titan blocking the X-rays from the Crab Nebula, has clearly been detected and is found to be larger than the diameter of Titan's solid surface. The difference gives a thickness for Titan's atmosphere of  $882 \pm 64$  km. This value is slightly larger than those estimated from earlier Voyager observations, suggesting the possibility of temporal variation in the atmospheric thickness.

**3.2.10 Neutron Stars and Pulsars** Mignani (ESO), Manchester (ATNF), and Pavlov presented the results of deep optical observations of the old (100 Myr), nearby, isolated pulsar J0108-1431 with the ESO Very Large Telescope. Observations with the Australia Telescope Compact Array were made to determine an accurate position for the radio pulsar at the current epoch. The imaging data reveal no counterpart at the revised radio position down to  $V=28$ ,  $B=28.6$ , and  $U=26.4$ . For a distance of 130 pc, estimated from the pulsar's dispersion measure, the constraints on the optical flux put an upper limit of  $T=4.5 \times 10^4$  K for the surface temperature of the neutron star, assuming a stellar radius  $R=13$  km. An upper limit on the pulsar proper motion of  $82$  mas  $\text{yr}^{-1}$  implies a transverse velocity of  $<50$  km  $\text{s}^{-1}$ .

From a series of deep observations of the Vela pulsar

wind nebula (PWN), Pavlov, Teter, Kargaltsev, and Sanwal discovered a dim, curved outer jet that extends up to  $\sim 100''$  along the direction of the pulsar's proper motion. The jet shows strong variability, changing its shape and brightness. Bright blobs move along the jet with apparent speeds  $(0.3 - 0.6)c$  and fade on timescales of days to weeks. The spectrum of the outer jet fits a power-law model with a photon index  $\Gamma=1.3 \pm 0.1$ . The apparent average luminosity of the outer jet in the 1-8 keV band is  $3 \times 10^{30}$  ergs  $\text{s}^{-1}$ , compared to  $6 \times 10^{32}$  from the whole PWN. The X-ray emission of the outer jet can be interpreted as synchrotron radiation of ultrarelativistic electrons/positrons. This interpretation allows one to estimate the magnetic field,  $\sim 100$   $\mu\text{G}$ , maximum energy of X-ray-emitting electrons,  $\sim 2 \times 10^{14}$  eV, and energy injection rate,  $\sim 8 \times 10^{33}$  ergs  $\text{s}^{-1}$ . In the summed PWN image, a faint, strongly bent, extension of the outer jet is seen. This bending could be caused by combined action of a wind within the supernova remnant, with a velocity of a few  $\times 10$  km  $\text{s}^{-1}$ , along with the ram pressure due to the pulsar's proper motion. The more extreme bends closer to the pulsar, as well as the apparent side motions of the outer jet, can be associated with kink instabilities of a magnetically confined, pinched jet flow. Another feature found in the summed image is a dim,  $\sim 2'$  long outer counterjet, which also shows a power-law spectrum with  $\Gamma \approx 1.2 - 1.5$ . Southwest of the jet/counterjet (i.e., approximately perpendicular to the direction of pulsar's proper motion), an extended region of diffuse emission is seen. Relativistic particles responsible for this radiation are apparently supplied by the outer jet.

Mignani (ESO), De Luca (Milan), Kargaltsev, Pavlov, Zaggia (Trieste) Caraveo (Milan), and Becker (MPE) analyzed deep optical images of the Vela pulsar wind nebula (PWN) observed with HST, NTT and VLT, in various bands, and compared the optical images with those obtained with the *Chandra* ACIS. Although some features are seen in the optical images, no correlation with the X-ray structure was found. Therefore, the diffuse optical emission is more likely associated with filaments in the host Vela supernova remnant. The derived upper limits on the optical flux from the PWN are compatible with the values expected on the basis of the extrapolations of the X-ray data.

Becker (MPE), Swartz (MSFC), and Pavlov, with their co-authors from MSFC, MIT, and ESO, observed the globular cluster M28 with the *Chandra* X-ray Observatory. They showed that the apparently extended X-ray core emission seen with the *ROSAT* HRI is due to the superposition of multiple discrete sources, for which the X-ray luminosity function is determined down to a limit of about  $6 \times 10^{30}$  ergs  $\text{s}^{-1}$ . The phase-averaged X-ray spectrum of the 3.05 ms pulsar B1821-24 is best described by a power law with photon index  $\Gamma \approx 1.2$ . Marginal evidence of an emission line centered at 3.3 keV in the pulsar spectrum is found, which could be interpreted as cyclotron emission from a corona above the pulsar's polar cap if the magnetic field is strongly different from a centered dipole. Spectral analyses of the five brightest unidentified sources is presented. The brightest of these sources is interpreted as a transiently accreting neutron star in a low-mass X-ray binary, in quiescence. Fitting its spectrum with a hydrogen neutron star atmosphere model yields

the effective temperature  $T_{\text{eff}}=90_{-10}^{+30}$  eV and the radius  $R_{\text{NS}}=14.5_{-3.8}^{+6.9}$  km.

Rutledge (CalTech), Bildsten (UCSB), Brown (Univ. Chicago), Pavlov, and Zavlin (MPE) observed the type I X-ray-bursting low-mass X-ray binary KS 1731–260 in quiescence, following a 13 yr long outburst which ended in 2001 February. They show that the emission area radius for a H atmosphere spectrum is consistent with that observed from other quiescent neutron star transients,  $R=23_{-15}^{+30}$  ( $d/8$  kpc) km. Unlike all other known transient neutron stars, the duration of this recent (and the only observed) outburst is as long as the thermal diffusion time of the crust. The large amount of heat deposited by reactions in the crust will have heated the crust to temperatures much higher than the equilibrium core temperature. As a result, the thermal luminosity currently observed from the neutron star is dominated not by the core but by the crust. Simulations of the evolution of the quiescent light curve for different scenarios of the crust microphysics demonstrate that monitoring observations (with currently flying instruments) spanning from 1 to 30 yr can measure the crust cooling timescale and the total amount of heat stored in the crust. This makes KS 1731–260 a unique laboratory for studying the thermal properties of the crust by monitoring the luminosity over the next few years to decades.

### 3.2.2 Extragalactic Astronomy

**3.2.2.1 Extragalactic Planetary Nebulae** Ciardullo, Durrell, Laychak (PSU undergraduate), Herrmann, Moody (PSU graduate students), Jacoby (WIYN), and Feldmeier (CWRU) have completed an [O III]  $\lambda 5007$  photometric survey of the planetary nebulae (PNe) of M33. By using a sample of 152 PNe, they demonstrated that the bright end of the galaxy’s [O III]  $\lambda 5007$  planetary nebula luminosity function (PNLF) has the same sharp cutoff seen in other galaxies. From the apparent magnitude of this cutoff, they derive a galactic distance modulus of  $(m-M)_0=24.86_{-0.11}^{+0.07}$ , for a distance of  $0.94_{-0.05}^{+0.03}$  Mpc. Although this value is  $\sim 0.3$  mag larger than the Cepheid distance, the discrepancy likely arises from differing assumptions about the system’s internal extinction. Their photometry also reveals that the faint-end of M33’s PN luminosity function is non-monotonic, with an inflection point  $\sim 2$  mag below the PNLF’s bright limit. This feature is probably due to the galaxy’s large population of high core-mass planetaries.

**3.2.2.2 Galaxy Kinematics** Ciardullo, Durrell, Laychak, Herrmann, Moody, Jacoby (WIYN), and Feldmeier (CWRU) have completed a radial velocity survey of 140 PNe in the disk of M33. They have, for the first time, measured the velocity ellipsoid of a galactic disk throughout the body of a galaxy. They show that M33’s line-of-sight velocity dispersion varies little over  $\sim 4$  optical disk scale lengths, and demonstrate that this apparent constancy is due to a combination of factors, including a decline in the disk’s radial velocity dispersion at galactocentric radii less than  $\sim 4$  kpc, and a gradient in the ratio of the vertical to radial velocity dispersion. They then use their data to derive the dynamical scale length of M33’s disk, and the disk’s mass-to-light ratio.

Their best-fit solution suggests that the M33’s vertical velocity dispersion decreases exponentially with a scale length that is more than two times larger than the scale length of the galaxy’s infrared  $K$ -band luminosity. Coupled with the isothermal disk approximation, these observations imply that the  $V$ -band mass-to-light ratio of M33’s disk ranges from  $M/L_V \sim 0.5$  in the galaxy’s inner regions to  $M/L_V \sim 2.4$  at  $\sim 10$  kpc. The data also show that the “maximal disk” assumption for spiral galaxy rotation curves is reasonable, at least in the inner regions of galaxies. sloppypar

**3.2.2.3 Intracluster Stellar Populations** Ciardullo, Feldmeier (CWRU), Jacoby (WIYN), and 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]  $\lambda 5007$  surveys for planetary nebulae cover  $0.97$  deg<sup>2</sup> in Virgo,  $0.56$  deg<sup>2</sup> in Fornax,  $1.08$  deg<sup>2</sup> in the M81 Group, and  $0.13$  deg<sup>2</sup> in a blank control field. in Virgo and the M81 Group, their complementary red giant star surveys cover  $10.7$  arcmin<sup>2</sup> and  $0.3$  deg<sup>2</sup>, respectively. The data from these surveys suggest that intracluster stars are moderately old ( $2$  Gyr  $< \tau < 12$  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 between 10% and 20% of the cluster.

Durrell, DeCesar (PSU undergraduate), Ciardullo, Hurley-Keller (CWRU), and Feldmeier (CWRU) have undertaken a deep wide-field  $VI$  survey of the M81 group of galaxies (using the CFH12K camera on the Canada-France-Hawaii Telescope) in order to search for stars that may lie between the primary galaxies. Preliminary results from the 2 science fields show that there are few RGB stars in a field located 50–80 kpc from M81; the intragroup fraction is small, comprising  $< 2\%$  of the total galactic luminosity. In addition to the red stars, clumps of blue stars have also been discovered within the HI tidal arm between M81 and NGC 3077. Color-magnitude diagrams of two of these clumps show that these blue stars have formed as recently as 30–70 Myr, or long after the most recent interactions that formed the HI streamers. Both objects are  $\sim 1$  kpc across and considered tidal dwarf candidates.

**3.2.2.4 Stellar Populations** Durrell, Harris (McMaster) and Pritchett (U. Victoria) have nearly completed 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 halo field located 30 kpc from the M31 nucleus shows that the halo population in this distant field has a metallicity distribution function (MDF) similar in form (a dominant metal-rich population) to that found in a field located at 20 kpc. Durrell and Côté (Rutgers) are currently working on a Keck photometric  $VI$  study of 3 fields in the outer halo of M31 to investigate the MDF of the red-giant stars in these regions.

**3.2.2.5 Dwarf Galaxies** Palma, Hunsberger, Charlton, Durrell, and Gallagher (now at UCLA) have cataloged the candidate dwarf galaxies in Hickson Compact Group 92,

Stephan's Quintet, using their Hubble Space Telescope images of the group. Among this sample, they find that several of the bluest star forming regions are aligned with an Hsc I tidal tail that has no optical counterpart. Depending on the fate and nature of these objects, a tidal origin of dwarf galaxies may be more common than if only optical tails were responsible.

Knierman (a PSU undergraduate student now at Arizona), Charlton, Hunsberger, Gallagher, and collaborators published results on the formation of star clusters in tidal debris. They searched HST/WFPC2 images of four colliding galaxy pairs and found many blue clusters in the western tail of NGC 3256, and varying numbers in other regions. They indicated that it is not obvious what factors (e.g. H I mass, dynamical age) influence the formation of clusters, but suggested that large tidal dwarf formation may require different conditions.

**3.2.2.6 Sloan Digital Sky Survey** Schneider, Brandt, postdoctoral scholar Richards (now at Princeton University), and undergraduates Reichard and Trump have been using data from the Sloan Digital Sky Survey (SDSS) to investigate quasars. Schneider is the Chair of the SDSS Quasar Science Working Group; the main effort of the past year has been the production of the second edition of the SDSS Quasar Catalog (Schneider *et al.* 2003). This catalog contains accurate positions, five band CCD photometry, and digital spectra for 16,713 quasars in the SDSS First Data Release. The first edition of the SDSS Broad Absorption Line Quasar Catalog (Reichard *et al.* 2003) was the Honors thesis of Reichard.

The SDSS quasar team announced the discovery of the most distant quasar (redshift of 6.4) in January 2003 (Fan *et al.* 2003). Three quasars at redshifts larger than three were identified in this paper; the spectra of two of the three quasars reported in this work were obtained with the Hobby-Eberly Telescope. The near infrared properties of a set of high-redshift ( $z > 4$ ) quasars was presented by Pentericci *et al.* (2003).

Since the discovery of "red quasars" in the 1990s, there has been much speculation that current quasar surveys, which are primarily based in optical wavelengths, may be missing a significant fraction (a majority?) of the quasar population. The broad wavelength coverage and near-infrared sensitivity of the SDSS greatly enhances this survey's ability, compared to most previous optical studies, to detect red quasars (Richards *et al.* 2003).

**3.2.2.7 Active Galaxies and Quasars** Chartas in collaboration with Brandt and Gallagher reported the discovery of a relativistic X-ray absorbing outflow in the mini-BAL quasar PG 1115+080. The *XMM-Newton* spectrum of PG 1115+080 indicates the presence of complex low-energy absorption in the 0.2–0.6 keV observed energy band and high-energy absorption in the 2–5 keV observed energy band. The high-energy absorption is best modeled by two Gaussian absorption lines with rest-frame energies of 7.4 keV and 9.5 keV. Assuming that these two lines are produced by resonant absorption due to Fe xxv  $K\alpha$ , they infer that the X-ray absorbers are outflowing with relativistic velocities of 0.10c and 0.34c, respectively. They have also detected significant vari-

ability of the energies and widths of the X-ray BALs in PG 1115+080 and APM 08279+5255 over timescales of 19 and 1.8 weeks (proper-time), respectively. The BAL variability in APM 08279+5255 supports their earlier conclusion that these absorbers are most likely launched at relatively small radii of  $\lesssim < 10^{16} (M_{BH}/M_{\odot})^{1/2}$  cm.

Chartas in collaboration with Dai, Eracleous, and Garmire reported results from a mini-survey of relatively high redshift ( $1.7 < z < 4$ ) gravitationally lensed radio-quiet quasars observed with the *Chandra X-ray Observatory*. The magnification effect allows a search for changes in quasar properties such as the accretion process over three orders of magnitude in intrinsic X-ray luminosity, a search for evolution of X-ray variability, and extends the study of quasar properties to unlensed X-ray flux levels as low as a few  $\times 10^{-15}$  erg  $s^{-1}$   $cm^{-2}$ . They presented a comparison between the X-ray properties of quasars at redshifts near the peak of their comoving number density, thought to have occurred at  $z \sim 2$ , and those before and after this era. This comparison may provide clues to what caused the dramatic decay of the quasar number density as the Universe expanded. They find a significant correlation between X-ray spectral slope and  $L_X$  with a Spearman rank correlation coefficient of 0.82 significant at  $> 99.8$  % confidence. Such a correlation does not exist in nearby  $z < 0.1$  quasars suggesting that quasars at redshifts near the peak of their number density may have different accretion properties.

**3.2.2.8 Galaxy Evolution** Gronwall, as a member of the Advanced Camera for Surveys (ACS) Instrument Definition Team utilized this new instrument on the Hubble Space Telescope to study the evolution of galaxies both in the cluster and in the field. Recent results include the study of the color-magnitude relation in a distant ( $z \sim 1.2$ ) cluster which shows little or no evolution with respect to local clusters. This implies that elliptical galaxies were formed and in place at redshifts greater than one (Blakeslee *et al.* 2003). Other work focuses on the study of ACS grism spectra of the Hubble Deep Field North. The grism spectra are providing redshifts of emission-line galaxies several magnitudes fainter than those obtained by ground-based spectroscopy. By identifying galaxies via their  $H\alpha$  and [O II]-emission they will obtain a sample ideal for studying the evolution of star-forming galaxies out to  $z \sim 1.5$ .

In collaboration with John Salzer (Wesleyan), Gronwall has continued working on the KPNO International Spectroscopic Survey (KISS) for nearby emission-line galaxies (ELGs). This is a modern objective-prism survey which combines the wide field survey capability of a Schmidt telescope combined with the deep sensitivity of a CCD detector. The first survey lists for galaxies selected both in the red ( $H\alpha$ ) and the blue ([O III] $\lambda$ 5007) have been completed. The first blue survey strip covers 117  $deg^2$  and includes 223 ELG candidates or 1.9 per square degree. The first red ( $H\alpha$ -selected) survey strip covers 62  $deg^2$  and includes 1128 ELG candidates for a surface density of 18.1 per square degree. These surface densities are significantly higher than previous surveys of this type. Significant progress on obtaining follow-up spectroscopy of this sample was made this past year utilizing the Hobby-Eberly Telescope to observe several

hundred of the faintest objects in the survey. The galaxies targeted are low-metallicity candidates, and abundance quality spectra of the best candidates from the HET targets will be obtained this coming spring in an attempt to increase the numbers of known low-metallicity galaxies. Other ongoing work with KISS includes: studying the multiwavelength properties of KISS ELGs by cross-correlating their survey lists with existing surveys in the x-ray, radio, and far-infrared, and measuring the chemical properties and star-formation rates of these galaxies. Future work plans for studying the multiwavelength properties of star-forming galaxies using upcoming data from the GALEX and SIRTf satellites. Gronwall presented results from KISS at the IAU General Assembly in Sydney, Australia.

**3.2.2.9 Intrinsic Quasar Absorption Lines** Ganguly (PSU graduate student, now a postdoc at the Space Telescope Science Institute), Masiero (PSU undergraduate), and Charlton published a paper on an 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.

Wise (PSU graduate student), Eracleous, Charlton, and Ganguly completed a study variability of associate narrow absorption lines, comparing data obtained with FOS to data obtained about 10 years later with STIS. They found that at least 20% of the associated narrow absorption lines in low redshift ( $z < 1$ ) quasars are intrinsic. They plan followup studies of some of these objects, to determine the variability timescale and to examine the nature of the change at higher resolution.

Palma, Ganguly, Charlton, Eracleous, Masiero (PSU undergraduate), Ryan Lynch (PSU undergraduate), and Lackey (PSU undergraduate) have nearly completed a search for intrinsic absorption in the HST archive of STIS/Echelle quasar spectra. The strategy for the search, which focused on quasars at redshifts less than 1.5, was to identify all doublets in the spectra and apply partial coverage analysis to find a lower limit on the number of quasars with intrinsic absorption (not all intrinsic absorbers will necessarily exhibit partial covering). A number of intrinsic absorbers, with clear evidence for partial covering) have been identified in this study.

Lackey, Charlton, Eracleous, and Ganguly have been pursuing photoionization models to better understand the physical conditions of intrinsic absorbers. The NV absorption in these objects is often quite strong compared to the Lyman-alpha absorption, and they found that this is primarily an effect of partial covering. In fact, many transitions are saturated, but the partial coverage causes them all to have approximately the same equivalent width.

**3.2.2.10 Gamma-Ray Bursts** Schaefer, Gerardy, Hoflich, Panaitescu, Quimby, Mader, Hill, Kumar, Wheeler, Eracleous, Sigurdsson, Mészáros, Zhang, Wang, Hessman, and Petrosian (Texas, Penn State, Stanford, Goettingen) published an analysis of GRB 021004: a Massive Progenitor Star Surrounded by Shells. They present spectra of the optical

transient obtained with the Hobby-Eberly telescope starting 15.48, 20.31 hours, and 4.84 days after the burst and a spectrum obtained with the H. J. Smith 2.7 m Telescope starting 14.31 hours after the burst. GRB021004 is the first afterglow whose spectrum is dominated by absorption lines from high ionization species with multiple velocity components separated by up to 3000 km/s. They argue that these lines are likely to come from shells around a massive progenitor star.

**3.2.2.11 Quasar Absorption Lines and Galaxy Evolution** The intervening quasar absorption line group at Penn State, during the reporting period, included faculty members Charlton and Churchill, graduate students Ding and Narayanan, and undergraduate students Lynch, Masiero, and Milutinovic. Several former undergraduate students also published works completed during their time at Penn State. They are listed here along with their graduate institutions: Mellon (Virginia), Rigby (Arizona), Zonak (Maryland). In August 2003, Churchill began work as an assistant professor at New Mexico State University.

The focus of the quasar absorption line group's effort has been to attempt to break the "code" of the spectra by modeling the multiple chemical transitions observed in various absorption line systems. The power of this is that it facilitates detailed studies of the evolution of the interstellar medium, gaseous halos, and high velocity clouds of galaxies. Another emphasis of the effort is study of the class of weak Mg II absorbers, which have near solar metallicity, but are known *not* to be within  $\sim 50$  kpc of giant galaxies. These objects are surprisingly abundant, with at least 1 million for every giant galaxy in the universe. The group's strategy to investigate them includes searches for weak Mg II absorbers at very low redshifts, considerations of their geometries based on numbers and inferred phase structures, and simulations of the evolution of these intriguing systems.

Graduate student, Ding, has led two papers that feature detailed studies of strong Mg II absorbers. One features a very rich system at  $z \sim 0.93$  toward the quasar PG 1206 +459, which has a kinematic spread of  $\sim 1000$  km/s. This system is likely to be due to absorption through three separate galaxies, two giants and one dwarf. All three subsystems have multiple phases of gas. The high ionization/low density phases have similar kinematic spreads to the low ionization/high density phases. However, in one of the giant galaxy absorbers the high ionization gas has narrow, distinct components, and in the other the high ionization profile structures are smooth and reminiscent of those of the Milky Way corona. The other paper led by Ding featured the  $z \sim 0.99$  system toward PG 1634+706, which is noteworthy because it is a C IV-deficient, strong Mg II absorber. Ding hypothesized that the system may be C IV-deficient because it has a low metallicity, component with a large Doppler parameter, which is needed to fit Lyman-alpha and higher order Lyman series lines.

Churchill, Mellon, Charlton, and Vogt exploited a unique opportunity to study a  $z = 1.39$  damped Lyman-alpha absorber at two different positions, separated by  $\sim 135$  pc. This was possible because of a double-image lensed quasar, Q0957+561A and B, which lies behind the DLA structure. Despite the relatively close lines of sight, there is no direct

connection between the substructure/clouds in the two sight-lines. Photoionization models implied individual cloud sizes of 1-25pc and densities of 2-20 cubic centimeters. The conclusion is that the DLA cloud and those that surround it are similar to groupings of cold ISM clouds in the Milky Way.

Zonak led a paper that featured a multiple-cloud, weak Mg II system at  $z \sim 1.04$  along the line of sight toward PG 1634+706. This system is interesting because it has two separate groupings of low ionization components, separated by about 150 km/s, and two separate high ionization components, each offset by  $\sim 50$  km/s from the low ionization regions. The metallicities of the low ionization components are fairly low, about 3% of the solar value, and the broad, high ionization components apparently have a somewhat higher metallicity. The various inferred properties suggested their favored model in which the two subsystems are produced by condensed clouds far out in the opposite extremes of a multi-layer dwarf galaxy superwind.

Efforts to understand the mysterious, single-cloud weak Mg II absorbers included a detailed study of the phase structure of three systems at  $z \sim 1$  along the line of sight toward PG 1634+706. Each absorber had a broader C IV component centered on its Mg II component, suggested a lower density, but kinematically related gaseous phase. Two of the three absorbers had one or more offset C IV components as well, at velocities at which Mg II was not detected. The inferred sizes show that the region producing high ionization absorption is larger/thicker than the 1-100 pc regions that produce the Mg II absorption. In two of the three systems, the metallicity of the Mg II phase was greater than solar.

Recently, Milutinovic, Charlton, Rigby, Ding, Masiero, and Palma have conducted a simple survey of the high resolution HST/STIS Echelle archive, which nonetheless has led to some fundamental conclusions. The simplest geometry for the Mg II and C IV components of single-cloud, weak Mg II absorbers has the Mg II in a small spherical cloud embedded in a larger C IV region. This, however, is ruled out by Milutinovic's recent study, because there are fewer C IV-only systems found in the archive than there are systems with both low ionization absorption and C IV absorption. This suggests a sheetlike geometry, which may have a natural connection with the cosmic web, seen in cosmological structure formation simulations. A manuscript is in preparation.

Narayanan (graduate student) has conducted a survey, looking for the analogs of weak Mg II absorbers at low redshift by searching for Si II and C II absorption, which would be covered in HST/STIS E140M spectra. He has found several such absorbers, which are excellent candidates for followup imaging studies. He plans a formal analysis to determine the number of weak Mg II absorbers per unit redshift. He has also explored photoionization models of these systems. He conducted simulations to explore the evolution of the systems due to the diminishing extragalactic background radiation. They are expected to have increasing importance of their C IV phases relative to the Mg II phases, and to even in some cases transition from single-cloud to multiple-cloud weak Mg II absorbers.

*3.2.2.12 X-ray Studies of Luminous High-Redshift Quasars* X-ray studies of luminous high-redshift ( $z > 4$ ) quasars have

advanced substantially over the past few years, largely due to results from the new generation of X-ray observatories. X-ray emission has now been detected from more than 80 such quasars; most detections have been made by Penn State researchers. Recently, Vignali *et al.* (2003) have reported on Chandra and XMM-Newton observations of a sample of 13 quasars at  $z \approx 4.7-5.4$  mostly taken from the Sloan Digital Sky Survey (SDSS). The present sample complements previous X-ray studies of  $z \geq 4$  quasars, in which the majority of the objects are optically more luminous and at lower redshifts. All but two of these quasars have been detected in the X-ray band, thus doubling the number of  $z \geq 4.8$  X-ray detected quasars; the two non-detections are likely to be due to a short exposure time in one case and to the presence of intrinsic absorption in the other. Vignali *et al.* (2003) confirm and extend to the highest redshifts the presence of a correlation between  $AB_{1450}$  magnitude and soft X-ray flux for  $z \geq 4$  quasars, and the presence of a steeper optical-to-X-ray spectral energy distribution for high-luminosity, high-redshift quasars than for lower-luminosity, lower-redshift quasars. The second effect is likely due to a known luminosity correlation, whose significance has been confirmed via partial correlation analysis. The joint  $\approx 2.5-36$  keV rest-frame spectrum of the  $z > 4.8$  SDSS quasars observed thus far by Chandra is well parameterized by a power law with photon index  $\Gamma = 1.84^{+0.31}_{-0.30}$ ; this photon index is consistent with those of  $z \approx 0-3$  quasars and that obtained from joint spectral fitting of  $z \approx 4.1-4.5$  optically luminous Palomar Digital Sky Survey quasars. No evidence for widespread intrinsic X-ray absorption has been found.

*3.2.2.13 X-ray Spectroscopic and Variability Studies of Nearby Active Galaxies* Immler *et al.* (2003) have reported on an X-ray observation of the Seyfert 1.5 galaxy Markarian 6 obtained with the EPIC instruments onboard XMM-Newton. Archival BeppoSAX PDS data from 18-120 keV were also used to constrain the underlying hard power-law continuum. The results from spectral analyses generally favor a double partial-covering model, although other spectral models such as absorption by a mixture of partially ionized and neutral gas cannot be firmly ruled out. The best-fitting model consists of a power law with a photon index of  $\Gamma = 1.81^{+0.22}_{-0.20}$  and partial covering with large column densities up to  $N_{\text{H}} \sim 10^{23} \text{ cm}^{-2}$ . A narrow emission line consistent with Fe K $\alpha$  fluorescence at  $6.45^{+0.03}_{-0.04}$  keV is also detected with an equivalent width of  $93^{+26}_{-20}$  eV. Joint analyses of XMM-Newton, ASCA, and BeppoSAX data further provide evidence for both spectral variability (a factor of  $\sim 2$  change in absorbing column) and absorption-corrected flux variations (by  $\sim 60\%$ ) during the  $\sim 4$  year period probed by the observations.

*3.2.2.14 X-ray Studies of Starburst Galaxies* Bauer & Brandt (2003) have presented a Chandra and HST study of IC 10 X-1, the most luminous X-ray binary in the closest starburst galaxy to the Milky Way. The new hard X-ray observation of X-1 confirms that it has an average 0.5-10 keV luminosity of  $1.5 \times 10^{38} \text{ erg s}^{-1}$ , is strongly variable (a factor of  $\approx 2$  in  $< 3$  ks), and is spatially coincident with the Wolf-Rayet (WR) star [MAC92] 17A in IC 10. The spectrum of X-1 is

best fit by a power law with  $\Gamma \approx 1.8$  and a thermal plasma with  $kT \approx 1.5$  keV, although systematic residuals hint at further complexity. Taken together, these facts suggest that X-1 may be a black hole belonging to the rare class of WR binaries; it is comparable in many ways to Cyg X-3. The Chandra observation also finds evidence for extended X-ray emission co-spatial with the large non-thermal radio superbubble surrounding X-1.

Bauer, Brandt, & Lehmer (2003) have investigated the X-ray properties of the starburst galaxy IC 342 using a 10 ks XMM-Newton observation. Thirty-five sources are detected coincident with the disk of IC 342 (more than tripling the number known), of which  $\approx 31$  are likely to be intrinsic to IC 342. This point-source population exhibits a diverse range of spectral properties and has an X-ray luminosity function slope comparable to that of starburst galaxies such as M82 and the Antennae, while its relative lack of extended X-ray emission is similar to the properties of quiescent spirals. Although they find no evidence for short-term variability from any of the X-ray sources, they do detect long-term variability between this observation and the 1991 ROSAT and 1993/2000 ASCA observations for five sources. Notably, the second most luminous source in IC 342 (X-2) is found to be in its lowest luminosity state to date, although the shape of the spectrum is intermediate between the previously observed low/hard and high/soft states. IC 342 X-1, on the other hand, is found to be in an identical state to that observed in 2000 with ASCA. Assuming X-1 is in an anomalous very high (VH) state, then either (1) X-1 has remained in this state between 2000 and 2002, and is therefore the longest duration VH-state binary ever observed, or (2) it was simply caught in a VH state by chance in both the 2000 ASCA and 2002 XMM-Newton observations. The spectrum of the nucleus is best fit by an absorbed two-component model consisting of a thermal plasma with a temperature of  $kT \approx 0.3$  and a power law with a photon index of  $\Gamma \approx 2.53$ . The relative fluxes of the two spectral components suggest that the nucleus is complex, with a soft extended component contributing approximately half of the total luminosity.

### 3.2.3 The Chandra Deep Field-North Survey and Other Deep X-ray Surveys

**3.2.3.1 X-ray and Optical Catalogs** Alexander *et al.* (2003) have created point-source catalogs for the  $\approx 2$  Ms exposure of the Chandra Deep Field-North, currently the deepest X-ray observation of the Universe. Nearly 600 X-ray sources are detected over an  $\approx 448$  arcmin<sup>2</sup> area in up to seven X-ray bands. Source positions have been determined using matched-filter and centroiding techniques; the median positional uncertainty is  $\approx 0.3''$ . The X-ray colors of the detected sources indicate a broad variety of source types, although absorbed active galaxies are clearly the dominant type. This  $\approx 2$  Ms exposure is approximately photon limited for regions close to the aim point, and they predict that exposures up to  $\approx 25$  Ms (0.5–2.0 keV) and  $\approx 4$  Ms (2–8 keV) should remain nearly photon limited; Chandra can achieve significantly higher sensitivities in an efficient nearly photon-limited manner and be largely free of source confusion. The same techniques have also been used to produce the best

available point-source catalogs for the  $\approx 1$  Ms Chandra Deep Field-South (CDF-S).

Optical and near-infrared catalogs for the X-ray sources in the Chandra Deep Field-North have been delivered by Barger *et al.* (2003). High-quality multicolor imaging data are available for all point sources in the X-ray-selected catalog, and reliable spectroscopic redshifts are available for 284. The spectroscopic redshift distribution shows two broad redshift spikes that have clearly grown over those originally seen in the  $\approx 1$  Ms exposure. The spectroscopically identified extragalactic sources already comprise 75% of the measured 2–8 keV light. Redshift slices versus 2–8 keV flux show that an impressive 54% of the measured 2–8 keV light arises from sources at  $z < 1$  and 68% from sources at  $z < 2$ . Thus, major accretion onto supermassive black holes has occurred since the Universe was half its present age. Photometric redshifts have also been utilized to place further constraints upon the nature of the X-ray sources.

**3.2.3.2 X-ray Emission Associated with Normal and Starburst Galaxies** Hornschemeier *et al.* (2003) have studied optically bright, X-ray faint (OBXF) sources identified in an 178.9 arcmin<sup>2</sup> area having high effective exposure within the Chandra Deep Field-North. Forty-three OBXF sources are found in this area, comprising  $\approx 15\%$  of the X-ray sources above a 0.5–2 keV flux of  $\approx 2.3 \times 10^{-17}$  erg cm<sup>-2</sup> s<sup>-1</sup>. The OBXF population consists mainly of normal and starburst galaxies detected out to cosmologically significant distances ( $z = 0.06$ – $0.845$ ), providing a window on the X-ray emission from galaxies at redshifts much closer to the cosmic star formation peak than was possible prior to Chandra. The X-ray luminosity distribution of OBXF sources extends to higher luminosity than does that of ‘‘normal’’ galaxies, indicating that a significant fraction are likely low-luminosity active galaxies or have vigorous star formation. The 0.5–2 keV number counts for the OBXF galaxies are much steeper than for the general X-ray source population. Indeed, the number of OBXF sources has doubled between the 1 Ms and 2 Ms surveys.

**3.2.3.3 The X-ray Emission Properties of Moderate-Luminosity Active Galaxies at High Redshift** Vignali *et al.* (2002) have presented X-ray spectral analyses of the two  $z > 4$  active galaxies thus far spectroscopically identified in the Chandra Deep Field-North, at redshifts of 5.186 and 4.137. The rest-frame  $\approx 2.5$ –40 keV spectra are the first for optically faint  $z > 4$  active galaxies. The  $z = 5.186$  quasar is well fitted by a power-law model with photon index  $\Gamma = 1.8 \pm 0.3$ , consistent with those of lower-redshift, unobscured active galaxies. The other active galaxy has a flatter effective X-ray photon index, suggesting the presence of intrinsic absorption.

**3.2.3.4 Connection with the Great Observatories Origins Deep Survey** Substantial work has been performed combining the Chandra Deep Field-North and Chandra Deep Field-South surveys with the HST Advanced Camera for Surveys component of the Great Observatories Origins Deep Survey (GOODS); results from this powerful combination are now starting to be delivered. For example, Cristiani *et al.* (2003) present a sample of 17 high-redshift ( $3.5 < z < 5.2$ ) quasar

candidates in the  $320 \text{ arcmin}^2$  area of the GOODS, selected in the magnitude range  $22.45 < z_{850} < 25.25$ . On the basis of seven spectroscopic and ten photometric redshifts, the best estimate is that the final sample will contain between two and four quasars with  $4 < z < 5.2$ . A dearth of high-redshift, moderate-luminosity ( $M_{145} \approx -23$ ) quasars is observed with respect to predictions based on (1) the extrapolation of the  $z \sim 2.7$  luminosity function, according to a pure luminosity evolution calibrated by the results of the Sloan Digital Sky Survey; and (2) a constant universal efficiency in the formation of super-massive black holes in dark-matter halos. Evidence is gathered in favor of suppression of the formation or feeding of supermassive black holes in low-mass halos.

Hornschemeier *et al.* (2003) have used the combined X-ray and GOODS data to identify a sample of 10 highly reliable off-nuclear ( $\geq 2 \text{ kpc}$ ) X-ray sources at  $z = 0.03\text{--}0.25$  in late-type host galaxies. They extend the study of this enigmatic population up to higher redshifts and larger look-back times than has been possible before, finding that the fraction of optically luminous galaxies exhibiting luminous off-nuclear sources at  $z \approx 0.1$  is larger than at the current time ( $\approx 36\%$  versus  $\approx 8\%$ ). The X-ray luminosities of the GOODS off-nuclear X-ray sources are comparable to or slightly greater than the integrated point-source X-ray luminosities of nearby galaxies, providing a possible constraint on the X-ray luminosity function at higher star-formation rates. X-ray variability demonstrates that several of these sources are likely single accreting black holes.

### 3.3 Theoretical Studies

#### 3.3.1 Theoretical Astrophysics

**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. A formal collaboration with PSARC was negotiated in collaboration with Wolszczan.

**3.3.1.2 Radiative Transfer in Chemically Peculiar Stars** Budaj and Mike Dworetzky (University College London, UK) calculated fully consistent NLTE radiative accelerations on Ne in the atmospheres of late B stars. The calculations take into account neon fine structure as well as shadowing of neon lines using the entire Kurucz line list, bound-bound, bound-free, and free-free opacity of H, He, and C, as well as some non-LTE effects. They showed that radiative accelerations were well below the gravitational acceleration over the entire range of  $T_{\text{eff}}$ , and they predicted that in the stable atmospheres, devoid of disturbing motions, Ne should sink and be observed as underabundant. This agrees with the recent observations of low Ne abundances in HgMn stars.

Budaj with V. G. Elkin (Special Astrophysical Observatory (SAO), Russia) and Hubeny (NOAO, Tuscon) carried out a preliminary NLTE analysis of CCD spectra obtained by the 6m SAO telescope of an extreme helium sdO star BD +254655 and derived the basic parameters of the star.

**3.3.1.3 Line Profile Synthesis** Budaj and Richards have written a Fortran code called SHELLSPEC to solve simple radiative transfer along the line of sight in moving media and

sum the output intensities through the 2D projection surface of a 3D object. Assumptions include LTE in an optically thin plasma. This code will be used to generate synthetic line profiles using output from a PPM hydrodynamics code. These synthetic profiles will be used to produce simulated trailed spectra and Doppler tomograms of accretion structures in binaries which undergo direct impact accretion when the gas stream strikes the photosphere of the mass gaining star.

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

**3.3.1.5 Pulsar Studies** Zhang (PSU), Z. G. Dai (NJU, PSU), Mészáros (PSU), Waxman (Weizmann Inst), and Harding (NASA/GSFC) investigated the production of high energy neutrinos from magnetars. Magnetars can accelerate cosmic rays to high energies through the unipolar effect, and are also copious soft photon emitters. They show that young, fast-rotating magnetars whose spin and magnetic moment point in opposite directions emit high energy neutrinos from their polar caps 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. Within uncertainties, they point out four possible neutrino emission candidates among the currently known magnetars, the brightest of which may be detectable for a chance on-beam alignment. Young magnetars in the universe would also contribute to a weak diffuse neutrino background, whose detectability is marginal, depending on the typical neutrino energy.

**3.3.1.6 Gamma-Ray Bursts** Graduate student Gou, Mészáros, Abel and Zhang investigated the detectability of long GRB afterglows from very high redshifts, where bright reverse shock emission last longer in the observer frame, and its importance for detection and analysis purposes relative to the forward shock increases. They consider two different models for the GRB environment, based on current ideas about the redshift dependence of gas properties in galaxies and primordial star formation. They calculate the observed flux as a function of the redshift and observer time for typical GRB afterglows, taking into account intergalactic photoionization and Lyman- $\alpha$  absorption opacity as well as extinction by the Milky Way Galaxy. The fluxes in the X-ray and near IR bands are compared with the sensitivity of different detectors such as Chandra, Swift and JWST. They find that Chandra and Swift can potentially detect GRBs out to very high redshifts  $z \geq 13$  and 30, respectively. In the K and M bands, the JWST and ground-based telescopes are potentially able to detect GRBs even one day after the trigger out to  $z \sim 16$  and 33, if present. While the X-ray band is insensitive to the external density and to reverse shocks, the near IR bands provides a sensitive tool for diagnosing both the environment and the reverse shock components.

Mészáros and Rees (Cambridge) investigated Gamma-ray bursts as X-ray depth-gauges of the Universe. They discuss the X-ray flux of gamma-ray burst afterglows at redshifts in the range 3-30, including the effects of the intergalactic He II absorption. They point out that strong X-ray lines may form

locally in burst afterglows starting minutes after the trigger. This can provide distinctive X-ray distance indicators out to the redshifts where the first generation of massive stars form.

Kobayashi and Zhang investigated the early optical afterglows from wind-type gamma-ray bursts. The emission is evaluated in both the thick and thin shell regimes. They discuss the angular time delay effect and the post-shock evolution of the fireball ejecta, which determine the decay index of the prompt optical emission and the duration of the radio flare. They discuss distinct emission signatures of the wind environment compared with the constant interstellar medium environment. They also present two recipes for directly constraining the initial Lorentz factor of the fireball using the reverse and forward shock optical afterglow data for the wind case.

Zhang, Kobayashi, and Mészáros studied the early optical afterglows of GRB and their implications for the initial Lorentz factor and the central engine. Early optical afterglows have been observed from GRB 990123, GRB 021004, and GRB 021211, which reveal rich emission features attributed to reverse shocks. It is expected that Swift will discover many more early afterglows. They investigated in a unified manner both the forward and the reverse external shock emission components, and introduce a straightforward recipe for constraining the initial Lorentz factor of the fireball using early optical afterglow data. The scheme is largely independent of the shock microphysics. They identify two types of combinations of the reverse and forward shock emission, and explore their parameter regimes. They also discuss a possible diagnostic for magnetized ejecta. There is evidence that the central engine of GRB 990123 is strongly magnetized.

Balázs (Konkoly Observatory, Budapest), Bagoly (Eotvos University, Budapest), Horvath (Bolyai Military University, Budapest), A. Mészáros (Charles University, Prague), and P. Mészáros published a paper on the difference between the short and long gamma-ray bursts. They argue that the distributions of both the intrinsic fluence and the intrinsic duration of the gamma-ray emission in gamma-ray bursts from the BATSE sample are well represented by log-normal distributions, in which the intrinsic dispersion is much larger than the cosmological time dilatation and redshift effects. They perform separate bivariate log-normal distribution fits to the BATSE short and long burst samples. The bivariate log-normal behavior results in an ellipsoidal distribution, whose major axis determines an overall statistical relation between the fluence and the duration. They show that this fit provides evidence for a power-law dependence between the fluence and the duration, with a statistically significant different index for the long and short groups. They discuss possible biases, which might affect this result, and argue that the effect is probably real. This may provide a potentially useful constraint for models of long and short bursts.

Asano (Osaka U) and Kobayashi studied the dispersion of break energy in the gamma-ray burst internal shock model. In order to investigate the dispersion of the spectral break energy in gamma-ray bursts, they simulate internal shocks, including effects of shell-splitting after shell collisions and the Thomson optical depth due to electron-positron pairs produced by synchrotron photons. They produce pseudo ob-

servational data and estimate the break energy. If the distribution of initial Lorentz factors of shells has only one peak, many pulses with a break energy much lower than the typical observed value should be detected, while the effect of the Thomson optical depth reduces pulses with a break energy of  $>1$  MeV. If the Lorentz factor distribution has multiple peaks, the distribution of the break energy can be consistent with observations.

Kobayashi and Zhang studied the re-brightening in the GRB 021004 optical afterglow, which can be explained within the framework of the standard fireball model. The optical light curve of the forward shock emission is expected to rise initially and to decay after the typical synchrotron frequency crosses the optical band. They show that such a rising phase emission was caught for GRB 021004, together with a reverse shock emission. With the standard values of parameters obtained in other afterglow observations, they constructed example cases in which theoretical estimates reasonably fit the broadband observations. Thus, the early re-brightening might be a common feature in optical afterglows.

Kobayashi, Ryde (Stanford) and MacFadyen (CalTech) considered the luminosity and variability of collimated gamma-ray bursts. Within the framework of the internal shock model, they study the luminosity and variability in gamma-ray bursts from collimated fireballs. In particular they pay attention to the role of the photosphere due to  $e^\pm$  pairs produced by the 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 also show that such a correlation can be a natural consequence of the collapsar model. Narrow 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. Using a multiple-shell model, they numerically calculate the temporal profiles of gamma-ray bursts and show that their simulations reproduce the observed correlation.

Bagoly, Csabai (Eotvos U), A. Mészáros (Prague), P. Mészáros, Horváth (Bolyai U), Balázs (Konkoly Obs.), and Vavrek (Prague) studied a method of gamma photometric redshifts for long gamma-ray bursts. They use the fact that the soft tail of the gamma-ray bursts' spectra show excesses from the exact power-law dependence. They show that this departure can be detected in the peak flux ratios of different BATSE DISCSC energy channels. This effect allows to estimate the redshift of the bright long gamma-ray bursts in the BATSE Catalog. A verification of these redshifts is obtained for the 8 GRB which have both BATSE DISCSC data and measured optical spectroscopic redshifts. There is good correlation between the measured and estimated redshifts, and the average error is  $\Delta z \approx 0.33$ . The method is similar to the photometric redshift estimation of galaxies in the optical range, hence it can be called as "gamma photometric redshift estimation." The estimated redshifts for the long bright gamma-ray bursts are up to  $z \approx 4$ . For the the faint long bursts - which should be up to  $z \approx 20$  - the redshifts cannot be determined unambiguously with this method.

Waxman (Weizman Inst) and Mészáros studied the process of Collapsar Uncorking and Jet Eruption in GRB. They show 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 gamma-ray pulse, which precede the usual non-thermal MeV gamma-rays. They 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.

Lloyd-Ronning (LANL), X. Dai, and Zhang discussed the structure of quasi-universal jets for Gamma-Ray Bursts. The idea that GRBs originate from uniform jets has been used to explain numerous observations of breaks in the GRB afterglow lightcurves. They explore the possibility that GRBs instead originate from a structured jet that may be quasi-universal, where the variation in the observed properties of GRBs is due to the variation in the observer viewing angle. They test how various models reproduce the jet data of Bloom, Frail, & Kulkarni (2003), which show a negative correlation between the isotropic energy output and the inferred jet opening angle (in a uniform jet configuration). They find, consistent with previous studies, that a power-law structure for the jet energy as a function of angle gives a good description. However, a Gaussian jet structure can also reproduce the data well, particularly if the parameters of the Gaussian are allowed some scatter. They place limits on the scatter of the parameters in both the Gaussian and power-law models needed to reproduce the data, and discuss how future observations will better distinguish between these models for the GRB jet structure. In particular, the Gaussian model predicts a turnover at small opening angles and in some cases a sharp cutoff at large angles, the former of which may already have been observed. They also discuss the predictions each model makes for the observed luminosity function of GRBs and compare these predictions with the existing data.

Zhang and Mészáros published an analysis of gamma-ray burst spectral break models. Typical gamma-ray burst spectra are characterized by a spectral break,  $E_p$ , which for bright BATSE bursts is found to be narrowly clustered around 300 keV. Recently identified X-ray flashes, which may account for a significant portion of the whole GRB population, seem to extend the  $E_p$  distribution to a broader range below 40 keV. Positive correlations among  $E_p$  and some other observed parameters have been noticed. On the other hand, within the cosmological fireball model, the issues concerning the dominant energy ingredient of the fireball as well as the location of the GRB emission site are still unsettled, leading to several variants of the fireball model. Here they analyze these models within a unified framework, and critically re-examine the  $E_p$  predictions in the various model variants. Attention is focused on the predictions of the narrowness of the  $E_p$  distribution in different models, and the correlations among  $E_p$  and some other measurable observables. These model properties may be tested against the current and up-

coming 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.

Mészáros, Zhang, Ramirez-Ruiz, and Rees (Cambridge) considered the connection between X-ray Rich GRB, Photospheres and Variability. They investigate 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. 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 X-ray flashes is discussed. This model leads to a simple physical interpretation of the observational gamma-ray variability-luminosity relation.

Zhang and Mészáros discussed the gamma-ray burst beaming as a possible universal configuration with a standard energy reservoir. They discuss 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. If all the GRB fireballs have such a similar energy distribution form with  $1.5 < k < (or \sim) 2$ , GRBs may be modeled by a quasi-universal beaming configuration, and an approximately standard energy reservoir. The conclusion also holds for some other forms of angular energy distributions, such as the Gaussian function.

*3.3.1.7 AGN and Blazars* Z. G. Dai (Nanjing), Zhang, Gou, Mészáros and Waxman (Weizman) considered the GeV emission from TeV blazars and their dependence on the strength of the intergalactic magnetic fields. Several high-frequency peaked BL Lac objects such as Mrk 501 are strong TeV emitters. However, a significant fraction of the TeV gamma rays emitted are likely to be absorbed in interactions with the diffuse IR background, yielding electron-positron pairs. Hence, the observed TeV spectrum must be steeper than the intrinsic one. Using the recently derived intrinsic  $\gamma$ -ray spectrum of Mrk 501 during its 1997 high state, they study the inverse-Compton scattering of cosmic microwave photons by the resulting electron-positron pairs, which implies the existence of a hitherto undiscovered GeV emission. The 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. They also estimate the scattered photon flux in the quiescent state of Mrk 501. 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 *Gamma-Ray Large Area Space Telescope (GLAST)* for IGMFs  $\lesssim 10^{-16}$  G, as expected in voids. Such detections would provide constraints on the strength of weak IGMFs.

**3.3.1.8 Cosmic Ray Studies** Razzaque and Ralston (U. Kansas) studied the global anisotropy of cosmic ray data above  $4 \times 10^{19}$  eV. The distribution of arrival directions of ultra-high energy cosmic rays may yield clues to their mysterious origin. They introduce a method of *invariant statistics* to analyze cosmic ray data which eliminates coordinate-dependent artifacts. When combined with maximum likelihood analysis, the method is capable of quantifying deviations of the distribution from isotropy with high reliability. They test our method against published AGASA events with energies above  $4 \times 10^{19}$  eV. Angular cuts from observational limitations are taken into account. A model based on the Fisher distribution reveals the rotation of the Earth with the axis  $\hat{n}$  along the direction ( $5^h 53.36^m, 85.78^\circ$ ) in ( $RA, DEC$ ) coordinates, which is within  $5^\circ$  of the equatorial north pole. Global anisotropy of the data, if any, hinges on finer understanding of detector acceptance than what is available from the published literature.

Kravchenko, Razzaque, *et al.* obtained limits on the ultra-high energy electron neutrino flux from the RICE experiment. This is based on analysis of data taken by the RICE experiment during August, 2000. The RICE receiver array at South Pole monitors cold ice for radio-wavelength Cherenkov radiation resulting from neutrino-induced in-ice showers. For energies above 1 EeV, RICE is an effective detector of over  $15 \text{ km}^3 \text{ sr}$ . Potential signal events are separated from backgrounds using vertex location, event reconstruction, and signal shape. These are the first terrestrial limits exploiting the physics of radio Cherenkov emissions from charged-current  $\nu_e + N \rightarrow e + N'$  interactions.

Kravchenko, Razzaque, *et al.* discussed recent results from the RICE experiment at the South Pole. They present a compilation of recent results, submitted to the 2003 International Cosmic Ray Conference (Tsukuba, Japan). These include: a) Revised Monte Carlo estimates of the radiofrequency signals produced by electromagnetic showers in ice, b) an updated search for ultra-high energy (UHE) neutrinos based on detection of radio-wavelength Cherenkov radiation; such radiation results from neutrino-induced electromagnetic showers in cold Polar ice, and c) an in situ measurement of the index of refraction through the South Polar firn.

Razzaque, Seunarine, Besson, McKay, Ralston, and Seckel (U. Kansas) discussed the coherent radio pulses from GEANT generated electromagnetic showers in ice. They re-evaluate their published calculations of electromagnetic showers generated by GEANT 3.21 and the radio frequency pulses they produce in ice. They are prompted by a recent report showing that GEANT 3.21-modeled showers are sensitive to internal settings in the electron tracking subroutine. They report the shower and pulse characteristics obtained with different settings of GEANT 3.21 and with GEANT 4. The default setting of electron tracking in GEANT 3.21 they used in previous work speeds up the shower simulation at the

cost of information near the end of the tracks. They find that settings tracking electron and positron to lower energy yield a more accurate calculation, a more intense shower, and proportionately stronger radio pulses at low frequencies. At high frequencies the relation between shower tracking algorithm and pulse spectrum is more complex. They obtain radial distributions of shower particles and phase distributions of pulses from 100 GeV showers that are consistent with their published results.

**3.3.1.9 Neutrino Astrophysics** Razzaque, Mészáros, and Waxman (Weizman Inst) discussed neutrino signatures of the supernova - gamma ray burst relationship. They calculate the TeV-PeV neutrino fluxes of gamma-ray bursts associated with supernovae, based on the observed association between GRB 030329 and supernova SN 2003dh. The neutrino spectral flux distributions can test for possible delays between the supernova and the gamma-ray burst events down to much shorter timescales than what can be resolved with photons. As an illustrative example, they calculate the probability of neutrino induced muon and electron cascade events in a km scale under-ice detector at the South Pole, from the GRB 030329. Their calculations demonstrate that km scale neutrino telescopes are expected to detect signals that will allow to constrain supernova-GRB models.

The same authors also discussed neutrino tomography of gamma ray bursts and massive stellar collapses. Neutrinos at energies above TeV can serve as probes of the stellar progenitor and jet dynamics of gamma ray bursts arising from stellar core collapses. They can also probe collapses which do not lead to gamma-rays, which may be much more numerous. They calculate detailed neutrino spectra from shock accelerated protons in jets just below the outer stellar envelope, before their emergence. They present neutrino flux estimates from such pre-burst jets for two different massive stellar progenitor models. These should be distinguishable by IceCube, and they discuss the implications.

Fryer (LANL) and Mészáros considered neutrino-driven explosions in GRBs and hypernovae. They derive the critical density at which these outbursts occur in the collapsar model. The agreement between this derivation and results from past collapsar simulations (MacFadyen & Woosley 2000) is excellent, implying that they have captured the essential physics. They then use this derivation to study a range of progenitors for collapsar gamma-ray bursts. They derive how much of the star will accrete onto the black hole core before the infall density drops below this critical density, leading to an estimate of the remnant black hole mass for GRBs and hypernovae. They also estimate the time delays between gravity wave or neutrino signals and the onset of the explosion or burst event. This derivation, combined with future observational constraints, provides a physical insight into the structure of the GRB progenitor.

Razzaque, Mészáros, and Waxman (Weizman Inst.) Studied high energy neutrinos from gamma-ray bursts with precursor supernovae. The high energy neutrino signature from proton-proton and photo-meson interactions in a supernova remnant shell ejected prior to a gamma-ray burst provides a test for the precursor supernova, or supranova, model of gamma-ray bursts. Protons in the supernova remnant shell,

and photons entrapped from a supernova explosion or a pulsar wind from a fast-rotating neutron star remnant provide ample targets for protons escaping the internal shocks of the gamma-ray burst to interact and produce high energy neutrinos. They calculate the expected neutrino fluxes, which can be detected by current and future experiments.

The IceCube Collaboration (Ahrens, Cowen, Mészáros, Razzaque, *et al.*) discussed the sensitivity of the IceCube detector to astrophysical sources of high energy muon neutrinos. They present the results of a Monte-Carlo study of the sensitivity of the planned IceCube detector to predicted fluxes of muon neutrinos at TeV to PeV energies. A complete simulation of the detector and data analysis is used to study the detector's capability to search for muon neutrinos from sources such as active galaxies and gamma-ray bursts. They study the effective area and the angular resolution of the detector as a function of muon energy and angle of incidence. They present detailed calculations of the sensitivity of the detector to both diffuse and pointlike neutrino emissions, including an assessment of the sensitivity to neutrinos detected in coincidence with gamma-ray burst observations. After three years of data taking, IceCube will have been able to detect a point source flux of  $E^2 \cdot dN/dE = 7 \cdot 10^{-9} \text{ cm}^{-2} \text{ s}^{-1} \text{ GeV}$  at a 5-sigma significance, or, in the absence of a signal, place a 90 % c.l. limit at a level  $E^2 \cdot dN/dE = 2 \cdot 10^{-9} \text{ cm}^{-2} \text{ s}^{-1} \text{ GeV}$ . A diffuse  $E^{-2}$  flux would be detectable at a minimum strength of  $E^2 \cdot dN/dE = 1 \cdot 10^{-8} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \text{ GeV}$ . A gamma-ray burst model following the formulation of Waxman and Bahcall would result in a 5-sigma effect after the observation of 200 bursts in coincidence with satellite observations of the gamma-rays.

**3.3.1.10 Numerical Relativity** The Penn State numerical relativity group was established to explore the computational aspects of General Relativity and its applications to Gravitational-Wave Astrophysics. The group members are affiliated with the Departments of Astronomy & Astrophysics, Mathematics, and Physics under the Center for Gravitational Physics and Geometry (CGPG) and Center for Gravitational Wave Physics (CGWP). For the last several years the main focus of the group's effort has been the numerical simulation of the coalescence of binary black holes. Binary black holes are expected to be one of the primary sources of gravitational radiation to be detected by interferometers such as LIGO, VIRGO, GEO600, TAMA and LISA. In the last year, the most significant milestone was the long-term stable and convergent evolutions of a wobbling black hole in which the black hole singularity was excised from the computational domain (for details <http://www.astro.psu.edu/nr/>). Recent publications include Laguna (2003), Sperhake *et al.* (2003), Tichy *et al.* (2003), and Laguna & Shoemaker (2002).

**3.3.1.11 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 Spurzem *et al.*

**3.3.1.12 Gravitational Radiation** Kobayashi and Mészáros investigated the gravitational wave emission expected from

gamma-ray bursts arising from compact stellar mergers, and possibly also from bursts associated with fast-rotating massive stellar core collapses. These models have in common a high angular rotation rate, and observations provide evidence for jet collimation of the photon emission, with properties depending on the polar angle, which may also be of relevance for X-ray flashes. Here they consider the gravitational wave emission and its polarization as a function of angle which is expected from such sources. They discuss possible correlations between the burst photon luminosity, or the delay between gravitational wave bursts and X-ray flashes, and the polarization degree of the gravitational waves.

Kobayashi and Mészáros studied the gravitational radiation expected from various gamma-ray burst progenitors, in particular compact mergers and massive stellar collapses. The final stage involves a rotating black hole and accretion disk system. They consider the in-spiral, merger and ringing phases. For massive collapses they consider the possible effects of asymmetric collapse and break-up, as well bar-mode instabilities in the disks. They calculate the strain and frequency of the gravitational waves expected from various progenitors, at distances based on occurrence rate estimates. Based on simplifying assumptions, they give estimates of the probability of detection of gravitational waves by the advanced LIGO system from the different GRB scenarios.

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

### 3.3.2 Computational Astrophysics

**3.3.2.1 First Stars** The department hosted a three day international conference with the title "First Stars II" organized by Abel. Some seventy experts in the field of primordial star formation, stellar evolution, metal poor stars, and structure formation gathered from around the world discussing the progress made in the past four years after the first "First Stars" conference took place in Garching, Germany. The talk contributions and some video footage is made available online through the WWW (<http://TomAbel.com/II/>).

**3.3.2.2 Fragmentation of Primordial Gas Clouds** Ripamonti and Abel studied primordial star formation by investigating the cooling processes ( $\text{H}_2$  rovibrational lines and Collision Induced Emission) at the relevant high densities ( $10^{11} - 10^{18} \text{ cm}^{-3}$ ), and whether they could affect fragmentation properties of primordial protostellar clouds. The new continuum cooling instability they find does in a linear instability analysis not lead to further fragmentation. Consequently, primordial stars should be isolated massive stars with no binaries or planets around them. Full three dimensional calculations are desirable and are made possible by the purely local approximations to radiative transfer formulated by them.

**3.3.2.3 Cosmological Hydrogen Reionization** Using three dimensional cosmological radiative transfer modeling and very high resolution cosmological smooth particle hydrodynamical simulations Abel and collaborators have studied the reionization of hydrogen at high redshifts. The study by Sokasian *et al.* (2003) shows that to simultaneously fit the

optical depths measured in high redshift quasars and the recent WMAP results require a boosted UV production rate per collapsed baryon at redshifts greater than six. A finding that seems in accordance with the top heavy initial mass functions of primordial stars derived from ab initio numerical simulations. Using a similar methodology Sokasian, Abel and Hernquist argued that even at a redshift of three one expects galaxies to contribute about the same amount as all quasars to the intergalactic ionizing background responsible for keeping hydrogen ionized. sloppypar

**3.3.2.4 Simulations of Early Structure Formation** Together with Yoshida, Hernquist and Sugiyama, Abel carried out very high resolution cosmological SPH simulations. Their study confirms numerous previous findings obtained with the Eulerian adaptive mesh refinement (AMR) hydrodynamical calculations relating the formation of the very first objects in the universe. They also show that the accretion history of an cosmological object has a large influence on the mass it needs to reach before molecular hydrogen cooling becomes efficient. They reproduce these results with an analytical model. Machacek, Bryan & Abel (2003) show by means of complex three dimensional AMR simulations that an early X-ray background influences first structure formation much less as had been estimated in earlier analytic work. These studies lay the ground work for allowing the expected number of primordial supernovae and gamma ray bursts to be estimated with a minimum of free parameters. These predictions are underway and have been presented by Wise and Abel (2003) at three conferences this year. In these models primordial, metal-free stars were one possible source of ionizing photons. Their deaths is the most likely time observations can be made. Therefore, they estimate the rate of these supernovae on the sky. The main result is that we can expect to observe these supernovae at a rate of  $0.65 \text{ /yr /arcmin}^2$  with a peak at  $z=25$ . UV radiation effectively diminishes primordial star formation at late times.

Implementing a phenomenological model of star formation and feedback the first grid based calculations of cosmological simulations of the formation of dwarf galaxies at high redshift have been presented by Tassis *et al.* (2003). The authors find galactic winds to be ubiquitous and that a mass metallicity relation as observed locally is naturally obtained in these calculations.

### 3.4 Statistical Astronomy

Feigelson and Prof. G. Jogesh Babu (Statistics, Penn State) edited and published proceedings from their third *Statistical Challenges in Modern Astronomy* conferences. These provide a cross-disciplinary forum for astronomers and statisticians to discuss advanced methodologies for astronomical research. They also continued a research enterprise, in collaboration with Carnegie-Mellon University and CalTech, to provide statistical methodologies for the Virtual Observatory.

### 3.5 History of Astronomy

Usher continued his work on the history of astronomy. Thomas Digges (1546 - 1595) is regarded as the author of

the physically infinite universe and an early advocate of heliocentrism. He advanced these models unobtrusively in 1576 in an appendix to an almanac that was founded by his father and that was superficially based on politically correct bounded geocentrism. Somehow Digges escaped serious persecution from the time of the publication of his revolutionary idea to the end of his life in 1595. This was a remarkable achievement given the prevailing climate of intolerance.

Recent studies indicate that the full extent of Thomas Digges work has gone unrecognized to this day. Not only was he the first to propose an infinite universe, but evidence exists (Usher 2001, 2002) that he was also the first to provide empirical evidence in support of the New Astronomy. It has long been speculated that the Digges model of an infinite universe was backed by telescopic evidence, but heretofore no supporting evidence has been found either in the form of a telescopic relic or of data acquired telescopically. A paper delivered in January 1997 at the meeting of the AAS held in Toronto, Canada, suggested that Shakespeare's *Hamlet* was (among other things) a cosmic allegory that specifically alludes to an infinite universe. Shakespeare is known for accuracy in matters of natural philosophy, and it seems unlikely that both he and Thomas Digges would have risked reference to the concept of physically infinite space, without good reason. In *Pantometria* of 1571 Thomas Digges promised a full account of Copernicanism, but owing to harassment that work never appeared. However a consequence of the allegorical hypothesis is that Shakespeare's Canon might contain some of the promised information.

The two papers cited above support that prediction. It is clear from the text of *Hamlet* that by 1576 Thomas Digges knew of (i) the roughness of the Moon's surface, (ii) the phases of Venus, (iii) the Great Red Spot, (iv) the resolution of the Milky Way into stars, as well as (v) sunspots and (vi) the approximate number of naked eye stars. This information could only have been acquired telescopically. Thus the beginning of astronomical telescopic observation is pushed back by about 35 years or more, to the third quarter of the sixteenth century, or earlier.

An unexpected benefit of this work is that it gives a plausible explanation for the origin of the coined name "Ophelia." It is probably a feminine rendition of *op-* as in "opposite" plus *helios*, the Greek word for "sun." Hamlet's beloved seems destined for a position complementary to the royal Sun, but the tragedy is that misfortunes intervene.

## PUBLICATIONS

- Alexander, D. M., Bauer, F. E., Brandt, W. N., Schneider, D. P., Hornschemeier A. E., Vignali, C., Barger, A. J., Broos, P. S., Cowie, L. L., Garmire, G. P., Townsley, L. K., Bautz, M. W., Chartas, G., Sargent W. L. W.** 2003, "The Chandra Deep Field-North survey. XIII. 2 Ms point-source catalogs," *AJ*, 126, 539
- Ahrens, J. *et al.* (The IceCube Collaboration, including **Mészáros, P., & Razzaque, S.**) 2003, "Sensitivity of the IceCube Detector to Astrophysical Sources of High Energy Muon Neutrinos," *Astroparticle Phys.*, in press (astro-ph/0305196)
- Asano, K., & **Kobayashi, S.** 2003, "Dispersion of Break

- Energy in the Gamma-Ray Burst Internal Shock Model,” PASJ, 55, 579
- Baganoff, F. K., Maeda, Y., Morris, M., Bautz, M. W., **Brandt, W. N.**, W. Cui, J. P. Doty, **Feigelson, E. D.**, **Garmire, G. P.** Pravdo, S. H., Ricker, G. R., & **Townsend, L. K.** 2003, “Chandra X-ray Spectroscopic Imaging of Sgr A\* and the Central Parsec of the Galaxy,” ApJ, 591, 891
- Bagoly Z., Csabai I., Mészáros, A., **Mészáros, P.**, Horváth I., Balázs L. G. & Vavrek R. 2003, “Gamma Photometric Redshifts for Long Gamma-Ray Bursts,” A&A, 398, 919
- Balázs L. G., Bagoly Z., Horváth, I., Mészáros, A., & **Mészáros, P.** 2003, “On the difference between the short and long gamma-ray bursts,” A&A, 401, 129
- Bally, J., **Feigelson, E. D.**, Reipurth, B. 2003, “X-rays from the vicinity of a protostar, L1551 IRS 5: Reflection or Fast Shocks?,” ApJ, 584, 843
- Barger, A. J., Cowie, L. L., **Brandt, W. N.**, Capak, P., **Garmire, G. P.**, **Hornschemeier, A. E.**, Steffen, A. T., & Wehner, E. H. 2002, “X-ray, optical, and infrared imaging and spectral properties of the 1 Ms Chandra Deep Field-North sources,” AJ, 124, 1839
- Barger, A. J., Cowie, L. L., Capak, P., **Alexander, D. M.**, **Bauer, F. E.**, Fernandez, E., **Brandt, W. N.**, **Garmire, G. P.**, & **Hornschemeier, A. E.** 2003, “Optical and infrared properties of the 2 Ms Chandra Deep Field-North X-ray sources,” AJ, 126, 632
- Barger, A. J., Cowie, L. L., Capak, P., **Alexander, D. M.**, **Bauer, F. E.**, **Brandt, W. N.**, **Garmire, G. P.**, & **Hornschemeier, A. E.** 2003, “Very high redshift X-ray selected active galactic nuclei in the Chandra Deep Field-North,” ApJ, 584, L61
- 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. The link between faint X-ray and radio source populations,” AJ, 124, 2351
- Bauer, F. E.**, **Brandt, W. N.**, & **Lehmer B.**, 2003, “The X-ray properties of the nearby star-forming galaxy IC 342: The XMM-Newton view,” AJ, in press, astro-ph/0308278
- Bauer F. E.**, & **Brandt W. N.** 2003, “Chandra and Hubble Space Telescope confirmation of the luminous and variable X-ray source IC 10 X-1 as a possible Wolf-Rayet, black-hole binary,” ApJ, in press; astro-ph/0310039
- Becker, W., Swartz, D. A., **Pavlov, G. G.**, Elsner, R. F., Grindlay, J., Mignani, R., Tennant, A. F., Backer, D., Pulong, L., Testa, V., & Weisskopf, M. C. 2003, “Chandra X-Ray Observatory Observations of the Globular Cluster M28 and Its Millisecond Pulsar PSR B1821-24,” ApJ, 594, 798
- Benítez, N., Ford, H., Bouwens, R., Menanteau, F., Blakeslee, J., **Gronwall, C.**, Illingworth, G., Meurer, G., Broadhurst, T. J., Clampin, M., Franx, M., Hartig, G., Magee, D., Sirianni, M., Ardila, D. R., Bartko, F., Brown, R. A., Burrows, C. J., Cheng, E. S., Cross, N. J. G., Feldman, P. D., Golimowski, D. A., Infante, L., Kimble, R. A., Krist, J. E., Lesser, M. P., Levay, Z., Martel, A. R., Miley, G. K., Postman, M., Rosati, P., Sparks, W. B., Tran, H. D., Tsvetanov, Z. I., White, R. L., & Zheng, W. 2003, “Faint Galaxies in Deep ACS observations,” ApJ, in press
- Blakeslee, J. P., Tsvetanov, Z. I., Riess, A. G., Ford, H. C., Illingworth, G. D., Magee, D., Tonry, J. L., Benítez, N., Clampin, M., Hartig, G. F., Meurer, G. R., Sirianni, M., Ardila, D. R., Bartko, F., Bouwens, R., Broadhurst, T., Cross, Nicholas, Feldman, P. D., Franx, Marijn, Golimowski, David A., **Gronwall, C.**, Kimble, R., Krist, J., Martel, A. R., Menanteau, F., Miley, G., Postman, M., Rosati, P., Sparks, W., Strolger, L.-G., Tran, H. D., White, R. L., & Zheng, W. 2003, “Discovery of Two Distant Type Ia Supernovae in the Hubble Deep Field-North with the Advanced Camera for Surveys,” ApJ, 589, 693
- Blakeslee, John P., Franx, Marijn, Postman, Marc, Rosati, Piero, Holden, Brad P., Illingworth, G. D., Ford, H. C., Cross, N. J. G., **Gronwall, C.**, Benítez, N., Bouwens, R. J., Broadhurst, T. J., Clampin, M., Demarco, R., Golimowski, D. A., Hartig, G. F., Infante, L., Martel, A. R., Miley, G. K., Menanteau, F., Meurer, G. R., Sirianni, M., White, R. L. 2003, “Advanced Camera for Surveys Photometry of the Cluster RDCS 1252.9-2927: The Color-Magnitude Relation at  $z = 1.24$ ,” ApJ, 596, L143
- Boller Th., Tanaka Y., Fabian A. C., **Brandt W. N.**, Gallo L. C., Anabuki N., Haba Y., Vaughan S. 2003, “XMM-Newton spectral properties of the Narrow-Line Seyfert 1 galaxy IRAS 13224-3809,” MNRAS, 343, L89
- Bouwens, R. J., Illingworth, G. D., Rosati, P., Lidman, C., Broadhurst, T., Franx, M., Ford, H. C., Magee, D., Benítez, N., Blakeslee, J. P., Meurer, G. R., Clampin, M., Hartig, G. F., Ardila, D. R., Bartko, F., Brown, R. A., Burrows, C. J., Cheng, E. S., Cross, N. J. G., Feldman, P. D., Golimowski, D. A., **Gronwall, C.**, Infante, L., Kimble, R. A., Krist, J. E., Lesser, M. P., Martel, A. R., Menanteau, F., Miley, G. K., Postman, M., Sirianni, M., Sparks, W. B., Tran, H. D., Tsvetanov, Z. I., White, R. L., Zheng, W. 2003, “Star Formation at  $z = 6$ : i-Dropouts in the Advanced Camera for Surveys Guaranteed Time Observation Fields,” ApJ, 595, 589
- Budaj, J.** 2003, “Chemically Peculiar Stars,” Kozmas, in press (in Slovak)
- Budaj, J.**, & Dworetzky, M. M. 2002, “Radiative Accelerations on Ne in the Atmospheres of Late B stars,” MNRAS, 337, 1340
- Budaj, J.**, Elkin, V., & Hubeny, I., 2003, “Preliminary Analysis of an Extreme Helium sdO Star: BD+254655,” in Modeling of Stellar Atmospheres, eds. N.E. Piskunov, W. W. Weiss, and D. F. Gray, in press
- Budaj, J.**, Iliev, I.Kh. 2003, “Abundance Analysis of Am binaries and Search for Tidally Driven Abundance Anomalies I. HD 33254, HD 178449, HD 198391,” MNRAS, in press
- Budaj, J.**, Iliev, I. Kh., Barzova, I. S., Ziznovsky, J., Zverko, J., Stateva, I. 2003, “Direct Mass Ratio Determination in the SB2 Systems HD 108642 and HD 434,” IBVS, 5423
- Charlton, J. C.** 2003, “Studying the Gaseous Phases of Galaxies with Background QSOs,” in *Hubble’s Science Legacy: Future Optical/Ultraviolet Astronomy from*

- Space*, eds. K. R. Sembach, J. C. Blades, G. D. Illingworth, and R. C. Kennicutt, ASP Conference Proceedings, 291, 172
- Charlton, J. C.** 2003, "Absorption Signatures of the Gaseous Phases of Galaxies," in *The IGM/Galaxy Connection: The Distribution of Baryons at  $z=0$* , eds. J. L. Rosenberg and M. E. Putman, ASSL Conference Proceedings, 281, 143
- Chartas, G., Brandt, W. N., Gallagher, S. C., & Garmire, G. P.** 2002, "Chandra detects relativistic broad absorption lines from APM 08279+5255," *ApJ*, 579, 169
- Chartas, G., Brandt, W. N., & Gallagher, S. C.** 2003, "XMM-NEWTON Reveals the Quasar Outflow in PG 1115+080," *ApJ*, 595, 85
- Chartas, G., Dai, X., Eracleous, M., & Garmire, G. P.** 2003, "A Study of Quasar Evolution with the Aid of Lensing," in *Multi-Wavelength Cosmology Conference*, in press
- Chartas, G., Dai, X., & Garmire, G. P.** 2003, "Chandra and XMM-Newton Results on the Hubble Constant from Gravitational Lensing," in *Carnegie Observatories Astrophysics Series, Vol. 2: Measuring and Modeling the Universe*, ed. W. L. Freedman (Pasadena: Carnegie Observatories), in press
- Ciardullo, R., Mihos, J. C., Feldmeier, J. J., Durrell, P. R., & Sigurdsson, S.** 2003, "The Systematics of Intracluster Starlight," IAU Symp. 217, Recycling Intergalactic and Interstellar Matter, in press
- Clampin, M., Krist, J. E., Ardila, D. R., Golimowski, D. A., Hartig, G. F., Ford, H. C., Illingworth, G. D., Bartko, F., Benítez, N., Blakeslee, J. P., Bouwens, R. J., Broadhurst, T. J., Brown, R. A., Burrows, C. J., Cheng, E. S., Cross, N. J. G., Feldman, P. D., Franx, M., Gronwall, C., Infante, L., Kimble, R. A., Lesser, M. P., Martel, A. R., Menanteau, F., Meurer, G. R., Miley, G. K., Postman, M., Rosati, P., Sirianni, M., Sparks, W. B., Tran, H. D., Tsvetanov, Z. I., White, R. L., Zheng, W. 2003, "Hubble Space Telescope ACS Coronagraphic Imaging of the Circumstellar Disk around HD 141569A," *AJ*, 236, 385
- Cowie, L. L., Barger, A. J., Bautz, M. W., **Brandt, W. N., Garmire, G. P.**, 2003, "The redshift evolution of the 2–8 keV X-ray luminosity function," *ApJ*, 584, L57
- Cristiani, S., **Alexander, D. M., Bauer, F. E., Brandt, W. N., Chatzichristou, E. T., Fontanot, F., Grazian, A., Koekemoer, A. M., Lucas, R. A., Monaco, P., Nonino, M., Padovani, P., Stern, D., Tozzi, P., Treister, E., Urry C. M., Vanzella, E.** 2003, "The space density of high-redshift QSOs in the GOODS survey," *ApJ*, in press, astro-ph/0309049
- Dai Z. G., Zhang, B., Gou, L. J., Mészáros, P. & Waxman, E.** 2002, "GeV Emission from TeV Blazars and Intergalactic Magnetic Fields," *ApJ*, 580, L7
- DeCesar, M. E., Durrell, P. R., Ciardullo, R., Hurley-Keller, D., & Feldmeier, J. J.** 2003, "A Search for Stars in the M81 Group's HI Tidal Tails," BAAS, in press
- Ding, J., Charlton, J. C., Zonak, S. G., & Churchill, C. W.** 2003, "A Quadruple Phase Strong MgII Absorber at  $z = 0.9902$  Toward PG 1634+706," *ApJ*, 587, 551
- Ding, J., Charlton, J. C., Churchill, C. W., & Palma, C.** 2003, "The Multiphase Absorption Systems Toward PG 1206+459," *ApJ*, 590, 746
- Dunne, B. C., Chu, Y.-H., Chen, C.-H. R., Lowry, J. D., **Townsley, L.**, Gruendl, R. A., Guerrero, M. A., & Rosado, M. 2003, "Diffuse X-Ray Emission from the Quiescent Superbubble M 17, the Omega Nebula," *ApJ*, 590, 306
- 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*, 582, 170
- Durrell, P. R., Ciardullo, R., Laychak, M. B., Jacoby, G. H., Feldmeier, J.J., & Moody, K.** 2002, "The Kinematics of M33's Disk Planetary Nebulae," BAAS, 34, 1116
- Durrell, P. R., DeCesar, M., Ciardullo, R., & Feldmeier, J.J.** 2003, "A CFH12K Survey of RGB Stars in the M81 Group," IAU Symp. 217, Recycling Intergalactic and Interstellar Matter, in press
- Eracleous, M., Halpern, J. P., & Charlton, J. C.** 2003, "The ASCA X-Ray Spectrum of Arp 102B and Evaluation of Simple Models for Its Associated Metastable FeII Absorber," *ApJ*, 582, 633
- Fan, X., Strauss, M. A., **Schneider, D. P.**, Becker, R. H., White, R. L., Haiman, Z., Gregg, M. D., Pentericci, L., Grebel, E. K., Narayanan, V. K., Loh, Y.-S., Richards, G. T., Gunn, J. E., Lupton, R. H., Knapp, G. R., Ivezić, Z., **Brandt, W.N., et al.** 2003, "A Survey of  $z > 5.7$  Quasars in the Sloan Digital Sky Survey II. Discovery of Three Additional Quasars at  $z > 6$ ," *AJ*, 125, 1649
- Feigelson, E. D. & Babu, G. J.** (eds.) 2003, *Statistical Challenges in Modern Astronomy*, New York: Springer-Verlag, in press
- Feigelson, E. D., Gaffney, J. A., Garmire, G., & Hillenbrand, L., Townsley, L.** 2003, "X-rays in the Orion Nebula Cluster: Constraints on the origins of magnetic activity in pre-main sequence stars," *ApJ*, 584, 911
- Feigelson, E. D., Lawson, W. A., & Garmire, G. P.** 2003 "The epsilon Chamaeleontis young stellar group and the characterization of sparse stellar clusters," *ApJ*, in press
- Feldmeier, J.J., **Ciardullo, R., Jacoby, G.H., & Durrell, P.R.** 2003, "Intracluster Planetary Nebulae in the Virgo Cluster II. Imaging Catalog," *ApJS*, 145, 65
- Feldmeier, J., **Ciardullo, R., Jacoby, G., & Durrell, P.R.** 2003, "Intracluster Planetary Nebulae in Galaxy Clusters and Groups," IAU Symp. 217, Recycling Intergalactic and Interstellar Matter, in press
- Fryer, C. L. & **Mészáros, P.** 2003, "Neutrino-driven Explosions in GRBs and Hypernovae," *ApJ*, 588, L25
- Gabel, J. R., Crenshaw, D. M., Kraemer, S. B., **Brandt, W. N., George, I. M., Hamann, F. W., Kaiser, M. E., Kaspi S., Kriss, G. A., Mathur, S., Mushotzky, R. F., Nandra, K., Netzer, H., Peterson, B. M., Shields, J. C., Turner, T. J., & Zheng, W.** 2003, "The ionized gas and nuclear environment in NGC 3783. II. Averaged HST/STIS and FUSE spectra," *ApJ*, 583, 178
- Gabel, J. R., Crenshaw, D. M., Kraemer, S. B., **Brandt, W. N., George, I. M., Hamann, F. W., Kaiser, M. E., Kaspi, S., Kriss, G. A., Mathur, S., Mushotzky, R. F., Nandra, K., Netzer, H., Peterson, B. M., Shields, J. C., Turner, T. J., & Zheng W.** 2003, "The ionized gas and nuclear en-

- vironment in NGC 3783. III. Detection of a decreasing radial velocity in an intrinsic ultraviolet absorber,” *ApJ*, 595, 120
- Ganguly, R., Masiero, J., Charlton, J. C., & Sembach, K. R.**, 2003, “An Intrinsic Absorption Complex Toward RXJ 1230+0115,” *ApJ*, in press
- Ganguly, R., Masiero, J., Charlton, J. C., & Sembach, K. R.**, 2003, “The Exquisite Spectrum of RX J1230.8+0115,” in *Hubble’s Science Legacy: Future Optical/Ultraviolet Astronomy from Space*, eds. K. R. Sembach, J. C. Blades, G. D. Illingworth, and R. C. Kennicutt, ASP Conf. Proc., 291, 367
- Ganguly, R., Sembach, K. R., & Charlton, J. C.** 2003, “Absorption Signatures of the Gaseous Phases of Galaxies,” in *The IGM/Galaxy Connection: The Distribution of Baryons at  $z=0$* , eds. J. L. Rosenberg and M. E. Putman, ASSL Conf. Proc., 281, 283
- Giozzi, M., Sambruna, R. M., & **Brandt, W. N.** 2003, “On the origin of the X-rays and the nature of accretion in NGC 4261,” *A&A*, 408, 949
- Gou L. J., Mészáros, P., Abel, T., & Zhang, B.** 2003, “Detectability of Long GRB Afterglows from Very High Redshifts,” *ApJ*, submitted (astro-ph/0307489)
- Grosso, N., Montmerle, T., **Feigelson, E. D.**, & Forbes, T. G. 2003, “Chandra observation of an unusually long and intense X-ray flare from a young solar-like star,” *A&A*, submitted
- Hemsendorf, M., **Sigurdsson, S.** & Spurzem, R. 2002, “Collisional dynamics around binary black holes in galactic centers,” *ApJ*, 581, 1256
- Hester J. J., **Mori K., Burrows D. N.**, Gallagher J. S., Graham J. R., Halverson M., Kader A., Michel F. C., Scowen P., 2002, “Hubble Space Telescope and Chandra Monitoring of the Crab Synchrotron Nebula,” *ApJ*, 577, 49
- Hornschemeier, A. E., Bauer, F. E., Alexander, D. M., Brandt, W. N., Sargent, W. L. W., Bautz M. W., Conselice, C., Garmire, G. P., Schneider, D. P., & Wilson G.** 2003, “The Chandra Deep Field-North survey. XV. Optically bright, X-ray faint sources,” *AJ*, 126, 575
- Hornschemeier, A. E., Alexander, D. M., Bauer, F. E., Brandt, W. N., Chary, R., Conselice, C., Grogin, N. A., Koekemoer, A. M., Mobasher, B., Paolillo, M., Ravindranath, S., & Schreier, E. J.** 2003, “Lower mass black holes in the GOODS? Off-nuclear X-ray sources,” *ApJ*, in press, astro-ph/0308408
- Immler, S., Brandt, W. N., Vignali, C., Bauer, F. E., Crenshaw, D. M., Feldmeier, J. J., & Kraemer, S. B.** 2003, “Probing the complex and variable X-ray absorption of Markarian 6 with XMM-Newton,” *AJ*, 126, 153
- Kallman, T., **Mészáros P.**, & Rees, M. J. 2002, “Iron K Lines from Gamma Ray Bursts,” *ApJ*, 593, 946
- Kargaltsev, O., Pavlov, G. G., Teter, M. A., & Sanwal, D.** 2003, “The jets of the Vela pulsar,” *New Astron. Rev.*, 47, 487
- Knierman, K. A., Gallagher, S. C., Charlton, J. C., Hunsberger, S. D., Whitmore, B., Kundu, A., Hibbard, J. E., & Zaritsky, D.** 2003, “From Globular Clusters to Tidal Dwarfs: Structure Formation in the Tidal Tails of Merging Galaxies,” *AJ*, 126, 1227
- Koekemoer, A. M., **Alexander, D. M., Bauer, F. E., Bergeron, J., Brandt, W. N., Chatzichristou, E., Cristiani, S., Fall, S. M., Grogin, N. A., Livio, M., Mainieri, V., Moustakas, L., Padovani, P., Rosati, P., Schreier, E. J., & Urry C. M.** 2003, “A possible new population of sources with extreme X-ray/optical ratios,” *ApJ*, in press, astro-ph/0306407
- Kobayashi, S. & Zhang, B.** 2003, “Early Optical Afterglows from Wind-Type Gamma-Ray Bursts,” *ApJ*, in press, astro-ph/0304086
- Kobayashi, S. & Mészáros, P.** 2003, “Polarized Gravitational Waves from Gamma-Ray Bursts,” *ApJ*, 585, L89
- Kobayashi, S. & Mészáros, P.** 2003, “Gravitational Radiation from Gamma-Ray Burst Progenitors,” *ApJ*, 589, 861
- Kobayashi, S., Ryde, F., & MacFadyen, A.** 2002, “Luminosity and Variability of Collimated Gamma-ray Bursts,” *ApJ*, 577, 302
- Kobayashi, S. & Zhang, B.** 2003, “GRB 021004: Reverse Shock Emission,” *ApJ*, 582, L75
- Konacki, M., **Wolszczan, A.**, & Stairs, I. H. 2003, “Geodetic Precession and Timing of the Relativistic Binary Pulsars PSR B1534+12 and PSR B1913+16,” *ApJ*, 589, 495
- Konacki, M., & **Wolszczan, A.** 2003 “Masses and Orbital Inclinations of Planets in the PSR B1257+12 System,” *ApJ*, 591, L147
- Konacki, M., & **Wolszczan, A.** 2003, “Earth-size Planets in the PSR B1257+12 Planetary System,” *BAAS*, 202, 5503
- Kramer, M., Lyne, A. G., Hobbs, G., Löhmer, O., Carr, P., Jordan, C., & **Wolszczan, A.** 2003, “Proper Motion, Age and Initial Spin Period of PSR J0538+2817 in S147,” 2003, *ApJ*, 593, L31
- Kravchenko, I., Frichter, G. M., Miller, T., Piccirillo, L., Seckel, D., Spiczak, G. M., Seunarine, S., Allen, C., Bean, A., Besson, D., Box, D. J., Buniy, R., Drees, J., McKay, D., Meyers, J., Perry, L., Ralston, J., **Razzaque, S.**, & Schmitz, D. W. 2003 “Limits on Ultra-High Energy Electron Neutrino Flux from the RICE Experiment,” *Astropart. Phys.*, 19, 15
- Kuhn, J. R., Fleck, J., Kocevski, D., Majewski, S., & **Palma, C.** 2003, “Models and Evidence for Light-Weight Local Galaxies,” in *IAU Symp. 220, Dark Matter in Galaxies*, in press
- Laguna, P.** 2003, “Conformal-thin-sandwich initial data for a single boosted or spinning black hole puncture,” *Phys.Rev.D*, submitted
- Lee, J. C., Salzer, J. J., Impey, C., Thuan, T. X., & **Gronwall, C.** 2002, “HI Properties of Low-Luminosity Star-Forming Galaxies in the KPNO International Spectroscopic Survey,” *AJ* 124, 3088
- Levan, A., Fruchter, A., Welch, D., **Palma, C.**, Henderson, B., Siegel, M., & Burud, I. 2002, “GRB 021211: CTIO observations,” *GRB Circ. Network*, 1758, 1
- Lewandowski, W., & **Wolszczan, A.** 2003, “Timing Characteristics of Radio pulsars in the Supernova Remnants S147 and W44,” in *Pulsars, AXPs and SGRs observed with BeppoSAX and other Observatories*, Aracne Editrice, Roma, G. Cusumano, E. Massaro, T. Mineo (eds.), p. 67

- Lewandowski, W., **Wolszczan, A.**, Feiler, G., Konacki, M., & Softysiński, T. 2003, "Arecibo Timing and Single Pulse Observations of 18 Pulsars," astro-ph/0309452
- Lloyd-Ronning, N., **Dai, X.**, **Zhang, B.** 2003, "On the Structure of Quasi-Universal Jets for Gamma-Ray Bursts," ApJ, in press (astro-ph/0310431)
- Lopez-Santiago, J., Montes, D., Fernandez-Figueroa, M. J., & **Ramsey, L. W.** 2003, "Rotational modulation of the photospheric and chromospheric activity in the young, single K2-dwarf PW And," A&A, in press
- Lyo, A.-R., Lawson, W. A., **Feigelson, E. D.** & Crause, L. A. 2003, "Population and dynamical state of the  $\eta$  Chamaeleontis sparse young open cluster," MNRAS, in press
- Lyo, A.-R., Lawson, W. A., Mamajek, E. E., **Eric D. Feigelson**, Sung, E.-C., Crause, L. A., 2003, "Infrared study of the  $\eta$  Chamaeleontis cluster and the longevity of circumstellar discs," MNRAS, 338, 616
- Machacek, M. E., Bryan, G. L., & **Abel, T.** 2003, "Effects of a soft X-ray background on structure formation at high redshift," MNRAS, 338, 273
- Martel, A. R., Ford, H. C., Tran, H. D., Illingworth, G. D., Krist, J. E., White, R. L., Sparks, W. B., **Gronwall, C.**, Cross, N. J. G., Hartig, G. F., Clampin, M., Ardila, D. R., Bartko, F., Benítez, N., Blakeslee, J. P., Bouwens, R. J., Broadhurst, T. J., Brown, R. A., Burrows, C. J., Cheng, E. S., Feldman, P. D., Franx, M., Golimowski, D. A., Infante, L., Kimble, R. A., Lesser, M. P., McCann, W. J., Menanteau, F., Meurer, G. R., Miley, G. K., Postman, M., Rosati, P., Sirianni, M., Tsvetanov, Z. I., Zheng, W. 2003, "Coronagraphic Imaging of 3C 273 with the Advanced Camera for Surveys," AJ, 125, 2964
- Mészáros, P.** 2003, "Gamma-Ray Bursts: the Supernova Connection," News & Views review, Nature, 423, 809
- Mészáros, P.**, & Rees, M. J. 2003, "Gamma-ray bursts as X-ray depth-gauges of the Universe," ApJL591, L91
- Mészáros, P.** 2003, "Gamma-Ray Bursts: the Supernova Connection," Nature, News & Views, 423, 809
- Mészáros, P.**, Ramirez-Ruiz, E., Rees M. J., **Zhang, B.** 2002, "X-ray Rich GRB, Photospheres and Variability," ApJ, 578, 812
- Mignani, R. P., De Luca, A., **Kargaltsev, O.**, **Pavlov, G. G.**, Zaggia, S., Caraveo, P. A., & Becker, W. 2003, "Search for the Optical Counterpart of the Vela Pulsar X-Ray Nebula," ApJ, 594, 419
- Mignani, R. P., Manchester, R. N., & **Pavlov, G. G.** 2003, "Search for the Optical Counterpart of the Nearby Pulsar PSR J0108-1431," ApJ, 582, 978
- Mori K.**, **Burrows D. N.**, **Pavlov G. G.**, Hester J. J., Shibata S., Tsunemi H. 2003, "Year-scale morphological variation of the X-ray Crab Nebula," to appear in *Young Neutron Stars and Their Environments*, (IAU Symposium 218, ASP Conference Proceedings), eds. F. Camilo and B. M. Gaensler
- Mori K.**, Tsunemi H., Katayama, H., **Burrows D. N.**, **Garmire G. P.**, Metzger A. E., "An X-ray measurement of Titan's atmospheric extent from its transit of the Crab Nebula," in preparation
- Muno, M. P., Baganoff, F. K., Bautz, M. W., **Brandt, W. N.**, **Broos, P. S.**, **Feigelson, E. D.**, **Garmire, G. P.**, Morris, M. R., Ricker, G. R., & **Townsley, L. K.** 2003, "A Chandra catalog of X-ray sources toward the Galactic Center," ApJ, 589, 225
- Mukherjee, R., Halpern, J. P., Gotthelf, E. V., **Eracleous, M.**, & Mirabal, N. 2003, "Search for a Point-Source Counterpart of the Unidentified Gamma-Ray Source TeV J2032+4130 in Cygnus," ApJ, 589, 487
- Netzer, H., Kaspi, S., Behar, E., **Brandt, W. N.**, Chelouche, D., George, I. M., Crenshaw D. M., Gabel, J. R., Hamann, F. W., Kraemer, S. B., Kriss, G. A., Nandra, K., Peterson, B. M., Shields, J. C., Turner, & T. J. 2003, "The ionized gas and nuclear environment in NGC 3783. IV. Variability and modeling of the 900 ks Chandra spectrum," ApJ, in press, astro-ph/0309096
- Orosz, J. A., & **Wade, R. A.** 2003, "Ultraviolet Spectra of Cataclysmic Variable Accretion Disks with Nonsteady T(r) Laws," ApJ, 593, 10320
- Palma, C.**, **Hunsberger, S. D.**, **Charlton, J. C.**, **Durrell, P. R.**, & Gallagher, S. C. 2003, "A Catalogue of Candidate Dwarf Galaxies in Stephan's Quintet from it Hubble Space Telescope WFPC2 Images," AJ, submitted
- Palma, C.**, **Hunsberger, S. D.**, **Charlton, J. C.**, **Durrell, P. R.**, & **Gallagher, S. C.** 2002, "A Census of the Dwarf Galaxies in Stephan's Quintet Including New Tidal Dwarf Galaxy Candidates," BAAS, 34, 1293
- Palma, C.**, Majewski, S. R., Siegel, M. H., Patterson, R. J., Ostheimer, J. C., & Link, R. 2003, "Exploring Halo Substructure with Giant Stars IV: The Extended Distribution of the Ursa Minor Dwarf Spheroidal," AJ, 125, 1352
- Palma, C.**, **Zonak, S. G.**, **Hunsberger, S. D.**, **Charlton, J. C.**, **Gallagher, S. C.**, **Durrell, P. R.**, & English, J. 2002, "The Beginning of the End: Hubble Space Telescope Images of Seyfert's Sextet," AJ, 124, 2425
- Park, S.**, Zhekov, S. A., **Burrows, D. N.**, Michael, E., McCray, R., & **Garmire, G. P.** "Chandra Observations of SNR 1987A," 2003a, Adv. in Space Res., in press
- Park, S.**, **Burrows, D. N.**, **Garmire, G. P.**, Zhekov, S. A., & McCray, R. 2003b, "Monitoring The Evolution of SNR 1987A with *Chandra*," To appear in *Young Neutron Stars and Their Environments*, (IAU Symposium 218, ASP Conf Proc), eds. F. Camilo and B. M. Gaensler
- Park, S.**, Hughes, J. P., Slane, P. O., **Burrows, D. N.**, **Garmire, G. P.**, & **Nousek, J. A.** 2003c, "Nucleosynthesis in The Oxygen-Rich Supernova Remnant G292.0+1.8 from *Chandra* X-Ray Spectroscopy," ApJL, submitted
- Park, S.**, Hughes, J. P., Slane, P. O., **Burrows, D. N.**, Warren, J. S., **Garmire, G. P.**, & **Nousek, J. A.** 2003d, "Detection of Magnesium-Rich Ejecta in The Middle-Aged Supernova Remnant N49B," ApJ, 592, L41
- Park, S.**, Hughes, J. P., **Burrows, D. N.**, Slane, P. O., **Nousek, J. A.**, & **Garmire, G. P.** 2003e, "0103-72.6: A New Oxygen-Rich Supernova Remnant in The Small Magellanic Cloud," ApJL, in press
- Park, S.**, **Burrows, D. N.**, **Garmire, G. P.**, **Nousek, J. A.**, Hughes, J. P., & Williams, R. M. "X-Ray Emission from Multi-Phase Shock in The Large Magellanic Cloud Supernova Remnant N49," 2003f, ApJ, 586, 210
- Pavlov, G. G.**, **Teter, M. A.**, **Kargaltsev, O.**, & **Sanwal, D.**

- 2003, "The Variable Jet of the Vela Pulsar," *ApJ*, 591, 1157
- Pentericci, L., Rix, H.-W., Prada, F., Fan, X., Strauss, M. A., **Schneider, D. P.**, *et al.* 2003, "The Near-IR Properties and Continuum Shapes of High-Redshift Quasars from the Sloan Digital Sky Survey," *A&A*, 410, 75
- Pohlen, M., Martinez-Delgado, D., Majewski, S., **Palma, C.**, Prada, F., & Balcells, M. 2003, "Tidal Streams around External Galaxies," in *Satellites and Tidal Streams*, eds. Prada *et al.*, (San Francisco: ASP), in press (astro-ph/0308142)
- Ramsey, L. W.**, **Engel, L. G.**, **Sessions, N.**, **DeFilippo, C.**, **Graver, M.**, & Mader, J. 2003, "The Hobby-Eberly Telescope medium resolution spectrograph and fiber instrument feed," in *Instrument Design and Performance for Optical/Infrared Ground-based Telescopes*, eds. M. Iye, A. F. Moorwood, Proc. SPIE Vol. 4841, p. 1036-1044
- Razzaque, S.**, Seunarine, S., Besson, D. Z., McKay, D. W., Ralston, J. P., & Seckel, D. 2003, "Addendum to "Coherent radio pulses from GEANT generated electromagnetic showers in ice," *Phys. Rev. D* (submitted) [astro-ph/0306291]
- Razzaque, S.**, **Mészáros, P.**, & Waxman, E. 2003, "Neutrino Tomography of Gamma Ray Bursts and Massive Stellar Collapses," *Phys.Rev.D*, in press (astro-ph/0303505)
- Razzaque, S.**, **Mészáros, P.**, & Waxman, E. 2003, "Neutrino signatures of the supernova - gamma ray burst relationship," *Phys. Rev. D*, submitted (astro-ph/0308239)
- Razzaque, S.**, **Mészáros, P.**, & Waxman, E. 2002, 2003, "High Energy Neutrinos from Gamma-Ray Bursts with Precursor Supernovae," *Phys. Rev. Lett.*, 90, 241103
- Razzaque, S.**, & Ralston, J. P. 2003, "On The Global Anisotropy of Cosmic Ray Data above  $4 \times 10^{19}$  eV," *JCAP* 07, 007
- Reichard, T. A.**, **Richards, G. T.**, **Schneider, D. P.**, *et al.* 2003, "A Catalog of Broad Absorption Line Quasars from the Sloan Digital Sky Survey Early Data Release," *AJ*, 125, 1711
- Richards, G. T.**, Hall, P. B., Vanden Berk, D. E., Strauss, M. A., **Schneider, D. P.**, **Weinstein, M. A.**, **Reichard, T. A.**, *et al.* 2003, "Red and Reddened Quasars in the Sloan Digital Sky Survey," *AJ*, 126, 1131
- Richards, M. T.** 2003, "Images of Active Mass Transfer in Direct Impact Close Binary Systems," *3D Stellar Structure Workshop*, ASP Conference Series, eds. Sylvain Turcotte, Stefan Keller, & Rob Cavallo, 120, in press
- Richards, M. T.** 2003, "Doppler Tomography of Algols," *Astron. Nachr.*, in press
- Richards, M. T.**, Waltman, E. B., Ghigo, F., & Richards, D. St.P. 2003, "Statistical Analysis of 5-year Continuous Radio Flare Data from  $\beta$  Per, V711 Tau,  $\delta$  Lib, and UX Ari," *ApJS*, 147, 337
- Richards, M. T.**, Waltman, E. B., Ghigo, F., & Richards, D. St.P. 2003, "Periodicities of Radio Flares in RS CVn and Algol Binaries," in *IAU Symposium 219, Stars as Suns: Activity, Evolution, and Planets*, eds. A. Benz, & A. K. Dupree, ASP Conf. Ser., in press
- Ripamonti, E.**, & **Abel, T.** 2003, "Fragmentation and the Formation of Primordial Protostars: The possible Role of Collision Induced Emission," *MNRAS*, in press
- Rutledge, R., Bildsten, L., Brown, E., **Pavlov, G. G.**, & Zavlin, V. E. 2002, "Crustal Emission and the Quiescent Spectrum of the Neutron Star in KS 1731-260," *ApJ*, 580, 413
- Schaefer, B. E., Gerardy, C. L., Hoflich, P., Panaitescu, A., Quimby, R., Mader, J., Hill, G. J., Kumar, P., Wheeler, J. C., **Eracleous, M.**, **S. Sigurdsson**, **Mészáros, P.**, **Zhang, B.**, Wang, L., Hessman, F., & Petrosian, V. 2002, "GRB021004: a Massive Progenitor Star Surrounded by Shells," *ApJ*, 588, 387
- Schneider, D.P.**, Fan, X., Hall, P. B., Jester, S., Richards, G. T., Stoughton, C., Strauss, M. A., SubbaRao, M., Vanden Berk, D. E., Anderson, S. F., **Brandt, W. N.**, Gunn, J.E., Gray, J., **Trump, J. R.**, *et al.* 2003, "The Sloan Digital Sky Survey Quasar Catalog II. First Data Release," *AJ*, 126, in press
- Sigurdsson, S.** 2002, "Testing gravity in large extra dimensions..." *International Journal of Modern Physics D*, 11.10, 541
- Sigurdsson, S.** 2003, "Loss-cone: past, present and future," *Class. Quant. Grav*, 20, S45
- Sigurdsson, S.** 2002, "Adiabatic growth of supermassive black holes in galaxies," in *1st Centennial Carnegie Symposium*, ed. L Ho, Vol. 1, in press
- Sigurdsson, S.** 2002, "Pulsars and black holes in globular clusters," *PASP Conf. Proc.*, Radio Pulsars: Crete 2002, 302, 391
- Sigurdsson, S.** 2003, "Astrophysics of Captures," to appear in *The Astrophysics of Gravitational Wave Sources*, ed. J. Centrella, AIP Conf. Proc., in press
- Sigurdsson, S.**, Richer, H. B., Hansen, B. M., Stairs, I. H., & Thorsett, S. E. 2003, "A Young White Dwarf Companion to Pulsar B1620-26: Evidence for Early Planet Formation," *Science*, 301, 193
- Sokasian, A, **Abel, T.**, Hernquist, L., & Springel, V. 2003, "Cosmic reionization by stellar sources: Population II stars," *MNRAS*, 344, 607
- Sperhake, U.**, Smith, K. L., Kelly, B., **Laguna, P.**, & Shoemaker, D. 2003, "Impact of densitized lapse slicings on evolutions of a wobbling black hole," *Phys. Rev. D.*, submitted
- Stark, M. A.**, & **Wade, R. A.** 2003, "Single and Composite Hot Subdwarf Stars in the Light of 2MASS Photometry," *AJ*, 126, 1455
- Stark, M. A.**, **Wade, R. A.**, & Berriman, G. B. 2003, "Single and Composite Hot Subdwarf Stars in the Light of 2MASS All-Sky Photometry," *Ap&SS*, in press (astro-ph/0309194)
- Tassis, K., **Abel, T.**, Bryan, G. L., & Norman, M. L. 2003, "Numerical Simulations of High-Redshift Star Formation in Dwarf Galaxies," *ApJ*, 587, 13
- Townsley, L. K.**, **Feigelson, E. D.**, Montmerle, T., **Broos, P. S.**, Chu, Y.-H., & **Garmire, G. P.** 2003, "10 MK Gas in M 17 and the Rosette Nebula: X-Ray Flows in Galactic HII Regions," *ApJ*, 593, 874
- 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,” *Nuc. Instr. and Methods in Phys. Res.*, 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,” *Nuc. Instr. and Methods in Phys. Res.*, 486, 751
- Tran, H. D., Sirianni, M., Ford, H. C., Illingworth, G. D., Clamin, M., Hartig, G., Becker, R. H., White, R. L., Bartko, F., Benítez, N., Blakeslee, J. P., Bouwens, R., Broadhurst, T. J., Brown, R., Burrows, C., Cheng, E., Cross, N., Feldman, P. D., Franx, M., Golimowski, D. A., **Gronwall, C.**, Infante, L., Kimble, R. A., Krist, J., Lesser, M., Magee, D., Martel, A. R., McCann, Wm. J., Meurer, G. R., Miley, G., Postman, M., Rosati, P., Sparks, W. B., & Tsvetanov, Z. 2003, “Advanced Camera for Surveys Observations of Young Star Clusters in the Interacting Galaxy UGC 10214,” *ApJ*, 585, 750
- Tsuboi, Y., Maeda, Y., **Feigelson, E. D., Garmire, G., Chartas, G., Mori, K., Pravdo, S. H., & Townsley, L.** 2003 “Coronal X-ray emission from an intermediate-age brown dwarf,” *ApJ*, 587, L51
- Usher, P.** 2001, “Sixteenth Century Astronomical Telescope,” *BAAS*35, No. 4, 1363
- Usher, P.** 2002, “Shakespeare’s Support for the New Astronomy,” *The Oxfordian* 5, 132
- Vignali, C., Bauer, F. E., Alexander, D. M., Brandt, W. N., Hornschemeier, A. E., Schneider, D. P., & Garmire, G. P.**, 2002, “The *Chandra* Deep Field-North survey. XVI. The X-ray properties of moderate-luminosity active galaxies at  $z > 4$ ,” *ApJ*, 580, L105
- Vignali, C., Brandt, W. N., & Schneider, D. P.** 2003, “X-ray emission from radio-quiet quasars in the Sloan Digital Sky Survey early data release: The  $\alpha_{\text{ox}}$  dependence upon ultraviolet luminosity,” *AJ*, 125, 433
- Vignali, C., Brandt, W. N., Schneider, D. P., Anderson, S. F., Fan, X., Gunn, J. E., Kaspi, S., Richards, G. T., & Strauss, M. A.** 2003, “*Chandra* and XMM-Newton observations of the first quasars: X-rays from the age of cosmic enlightenment,” *AJ*, 125, 2876
- Vignali, C., Brandt, W. N., Boller, Th., Fabian, A. C., & Vaughan, S.** 2003, “Arakelian 564: An XMM-Newton view,” *MNRAS*, in press, astro-ph/0310278
- Vuong, M. H., Montmerle, T., Grosso, N., **Feigelson, E. D., Verstraete, L., & Ozawa, H.** 2003, “Determination of the gas-to-dust ratio in nearby dense clouds using X-ray absorption measurements,” *A&A*, 408, 581
- Wade, R. A., & Eracleous, M.** 2002, “New Ultraviolet Observations of AM CVn,” *BAAS*, 34, 1301
- Wade, R. A., & Stark, M. A.** 2003, “Are All Hot Subdwarf Start in Close Binaries?,” *Ap&SS*, in press (astro-ph/0309195)
- Waxman, E. & **Mészáros, P.** 2003, “Collapsar Uncorking and Jet Eruption in GRB,” *ApJ*, 584, 390
- Wegner, G., Salzer, J. J., Jangren, A., **Gronwall, C.**, & Melbourne, J. 2003, “Spectroscopy of KISS Emission-Line Galaxy Candidates: I. MDM Observations,” *AJ*125, 2373
- Wise, J. H., & Abel, T.** 2003, “The Number of Supernovae from Primordial Stars in the Universe,” *American Institute of Physics Conference Series*, 666, 97
- Wise, J. H., & Abel, T.** 2002, “The Number of Supernovae from Primordial Stars in the Universe,” 34, 1169
- Wise, J. H., Eracleous, M., Ganguly, R., & Charlton, J. C.** 2003, “A Search for Variability in Quasar Narrow, Associated Absorption Lines,” *ApJ*, submitted
- Yoshida, N., **Abel, T.**, Hernquist, L., Sugiyama, N. 2003, “Simulations of Early Structure Formation: Primordial Gas Clouds,” *ApJ*, 592, 645
- Zhang, B., Dai, Z. G., Mészáros, P. & Waxman, E.** 2003, “High Energy Neutrinos from Magnetars,” *ApJ*, 595, 346
- Zhang, B., Kobayashi, S., & Mészáros, P.** 2003, “GRB early optical afterglow: implications for the initial Lorentz factor & the central engine,” *ApJ*, 585, L89
- Zhang, B. & Mészáros, P.** 2002, “Gamma-ray burst beaming: a universal configuration with a standard energy reservoir?,” *ApJ*, 571, 876
- Zhang, B. & Mészáros, P.** 2002, “An analysis of gamma-ray burst spectral break models,” *ApJ*, 581, 1236
- Zhang, B., & Sigurdsson, S.** 2003, “Electromagnetic signals from planetary collisions,” *ApJL*, 596, L97
- Zonak, S. G., Charlton, J. C., Ding, J., Churchill, C. W., & Palma, C.** 2003, “The Absorption Signatures of Dwarf Galaxies: The  $z=1.04$  Multi-cloud Weak MgII Absorber Toward PG1634+706,” *ApJ*, submitted

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