Columbia University
Department of Astronomy/Department of Physics
New York, New York 10027

[S0002-7537(93)02151-1]

This report covers the period September 2001 through August 2002 and comprises an account of astronomical research carried out in the Department of Astronomy and the Department of Physics.

Faculty and Research Associates were James Applegate, Elena Aprile, Norman Baker, Arlin Crotts, Karl-Ludwig Giboni, Eric Gotthelf, Charles Hailey, Jules Halpern, David Helfand, Lam Hui, Steven Kahn, Laura Kay (Barnard), Lloyd Motz (Emeritus), Reshmi Mukherjee (Barnard), Robert Novick (Emeritus), Frederik Paerels, Joseph Patterson, Kevin Prendergast (Emeritus), Andrew Rasmussen, Malvin Ruderman, Daniel Savin, Edward Spiegel, Jacqueline van Gorkom and David Windt. Faculty members at Biosphere 2 are Karen Vanlandingham, Philip Yecko and Catharine Garmany. New faculty appointments include Andrei Beloborodov, Zoltan Haiman, and Amber Miller.

Graduate students participating in research were Douglas Bramel, Tzu-Ching Chang, Aeree Chung, James Chonko, Alessandro Curioni, Mark Dijkstra, Akimi Fujita, Suvi Gezari, Eilat Glikman, JaeSub Hong, Mark Jackson, Miranda Jackson, Benjamin Johnson, Moo Kwang (Ryan) Joung, Ali Kinkhabwala, Maurice Leutenegger, Yuexing Li, Adam Lidz, Nestor Mirabal, Kaya Mori, Anthony Mroczkowski, James Don Neill, Kaixuan Ni, John Peterson, Andreea Petric, Pietro Reviglio, Jacob Noel-Storr, David Spiegel, Ben Sugerman, Robert Uglesich, Chuanyi Yang, Haitao Yu, Anthony Zamojski.

Undergraduates participating in research were Anne Abramson, Eve Armstrong, Randy Berkowitz, Tiffany Christatos (Barnard), Maya Cohen (Barnard), Benjamin Collins, Alexander Cosmas (Columbia Engineering), Catherine Espaillat, Adam Fallon, Rebecca Grossman (Barnard), Karina Hamalainen (Barnard), David Krohn, Rachel Semple Schuchter (Barnard), Dana Stern (Barnard), Jin Suh, Gisela Telis. Research staff assistants include Alex Bergier, Allison Brooks, Elise Laird, and Mala Mateen.

Robert Uglesich and Jaesub Hong received Ph.D. degrees.

Appointments during 2000–2001 were held by Adjunct Professors Michael Allison from the Goddard Institute for Space Science, and Michael Shara and Mordecai MacLow from the American Museum of Natural History. Postdoctoral Research Scientists appointments were held by David Alves, Edward Baltz, Ehud Behar, Martin Bureau, Fernando Camilo, Soizik Donguy, Jason Koglin, Richard Easther, Masanori Kobayashi, William Kinney, Stephen Lawrence, Patrick Cseresnjes, Caleb Scharf and Jacob Vink.

James Cordes and Saul Teukolsky were Visiting Professors from Cornell University and Dani Maoz was a visiting Professor from Tel Aviv University. Diane Wong was a visiting student, also from Cornell.

Van Gorkom completed her term as Chair of the Astronomy Department and was replaced by Helfand in July. Paerels continues as Director of the Columbia Astrophysics Laboratory. Kahn completed his term as Chair of the Physics Department in July and was replaced by Erick Weinberg. Kay became Chair of the Physics and Astronomy Department at Barnard. Halpern continued as Director of the MDM Observatory.

1. STARS AND STELLAR EVOLUTION

The Center for Backyard Astrophysics accumulated $\sim$800 nights of observation during 2001$-$2002. This network of primarily amateur astronomers does stellar photometry with small telescopes in their backyards. Columbia personnel included Patterson, the CBA founder, J. Kemp (Joint Astronomy Centre), Espaillat, Suh, and Armstrong. Center observers typically observe a star steadily for a few months, trying to amass the densest possible coverage by stressing long observation and distribution of observers in longitude. This provides a time series well suited to the study of periodic signals, and immunized from the ‘‘aliasing’’ problems inherent in data from a single site. Long-time observers are in Belgium, Denmark, Maryland, Arizona, Illinois, New Zealand, South Africa, and Australia. During this period, new nodes were established in Finland, Canada, New Mexico, and Colorado. Most programs involve the study of cataclysmic variables, justly famous for the many periods present in their light curves.

The highlight of the year was provided by the spectacular 2001 outburst of WZ Sagittae, the world’s most famous dwarf nova. Within 12 hours of discovery, CBA telescopes were parked on the star, and stayed on it for 114 days (missing just 1 day of coverage). Fourier analysis of the resultant light curves showed a delicate fine-structure in the periodic signals, with $\sim$20 incommensurate frequencies. All the frequencies obeyed the formula $n\omega_{\rm orb} - m\Omega$, where Ω is the assumed precession frequency of the accretion disk, and m and n are small integers – following the selection rules familiar from the wave solution for the hydrogen atom! The moral, at least mathematically, is that accretion disks too are governed by second-order differential equations with boundary conditions.

By studying the precession rates of CVs and X-ray binaries of known mass ratio, Patterson established a universal calibration between the (observable) precession rate and the (generally unobservable) mass ratio in such stars. This essentially permits us to weigh the unseen secondary star. By applying the relation to the 66 CVs showing superhumps, he found a well-constrained mass-radius relation for the secondaries, and identified 7 as clearly below the Kumar limit of 0.075 $M_\odot$. Large data sets, comprising typically $\sim$300 hr over $\sim$60 nights, have been collected on many other short-period stars, to study accretion-disk precession in CVs. Their study and understanding will keep analysts and modelers busy for years to come.

An ongoing campaign to observe and model field δ Scuti variables pulsating in low order radial modes is underway at the Biosphere 2 Observatory. Under the supervision of

Yecko, undergraduates Cosmas and Hamalainen are involved in both modeling and observing. Theoretical calculations of the δ Scuti instability strip, which have never before appeared in the literature, have been performed using a numerical code that includes models for turbulence and convection. Difficulty in producing exact nonlinear models, or limit cycle solutions, has been tied to a peculiarity of the δ Scuti instability strip: the unstable regions of Fundamental, First Overtone and Second Overtone modes essentially overlap.

Leutenegger and Kahn, with collaborator G. Ramsay at MSSL, present *XMM-Newton* observations of the luminous star Eta Carinae, including a high resolution soft X-ray spectrum of the surrounding nebula obtained with the Reflection Grating Spectrometer. The EPIC image of the field around Eta Car shows many early-type stars and diffuse emission from hot, shocked gas. The EPIC spectrum of the star is similar to that observed in previous X-ray observations, and requires two temperature components. The RGS spectrum of the surrounding nebula shows K-shell emission lines from hydrogen-like and helium-like nitrogen and neon, and L-shell lines from iron, but little or no emission from oxygen. The observed emission lines are not consistent with a single temperature, but the range of temperatures observed is not large, spanning $\sim 0.15-0.6$ keV. They obtain upper limits for oxygen line emission and derive a lower limit of N/O >9. This is consistent with previous abundance determinations for the ejecta of Eta Car, and with theoretical models for the evolution of massive, rotating stars.

2. γ-RAY SOURCES

Establishing the nature of the majority of the high-energy γ-ray sources discovered by the *EGRET* instrument on *CGRO* is a problem that continues to require intensive multiwavelength observational effort. This year, the Columbia group obtained *Chandra*, *HST*, and radio observations of a candidate neutron star (NS) in the error box of the brightest unidentified *EGRET* source at high Galactic latitude, 3EG J1835+5918. Its ultrasoft X-ray spectrum and lack of a radio pulsar or optical counterpart to a limit $V>28.5$ verifies that it is a radio quiet NS, probably an older or more distant version of the Geminga pulsar. Jackson *et al.* published a comprehensive study of Geminga using all available *CGRO* and *ASCA* data. Halpern and Eracleous obtained new redshifts for nine candidate γ-ray blazars, and observed several others. Optical spectra of the blazar counterparts of 3EG J0433+2908 and 3EG J0508+0540 are featureless and do not yield redshifts. These two objects are of interest because they emit above 10 GeV.

Mukherjee, Gotthelf, Halpern, and Mirabal continued their work on other unidentified *EGRET* sources. They suggested an identification for the *EGRET* source 3EG J1621+8203, most likely the second radio galaxy to be detected by *EGRET*. Work on several additional unidentified high energy sources is currently in progress.

Mukherjee and Bramel worked on *STACEE* (the Solar Tower Air Cherenkov Effect Experiment), a ground-based detector that is sensitive to high energy gamma-rays in the regime 50 to 300 GeV. This part of the electromagnetic spectrum has been largely unexplored and astrophysics in this energy range promises exciting scientific returns. *STACEE* has detected the Crab Nebula, and the active galaxy Markarian 421, thus demonstrating that lower energy thresholds can be achieved by using existing large arrays of solar heliostat mirrors to collect Cherenkov light.

The MDM Observatory continues to pursue optical and infrared observations of afterglows of γ-ray bursts (GRBs) under the direction of Halpern and Mirabal. The event rate has increased with the successful operation of the HETE-2 satellite. Several GRB locations were observed in 2001–2002, including extensive monitoring of the bright afterglow of GRB 021004, which shows several significant deviations from a power-law decay. Images and light curves from successful observations of GRBs at MDM Observatory are maintained at: `http://www.astro.columbia.edu/grouprsearch.html`.

Mirabal, Paerels and Halpern got their chance at a deep, high resolution soft X-ray spectrum of a Gamma-ray Burst afterglow on April 5, 2002. Executing a pre-approved Target of Opportunity observation, they obtained a high-resolution grating spectrum of the GRB 020405 afterglow, with a total exposure of 51 ks, using the LETGS instrument onboard *Chandra*. A significant detection of Fe peak elements and particularly medium-Z α elements (C through Si), where the highest spectral sensitivity for this choice of instrument is achieved, could have helped establish the nature of GRB progenitors. However, the spectrum appears featureless, with no evidence for emission lines, absorption edges, or narrow radiative recombination continua. The absence of iron lines indicates that the density of nearby surrounding material was unlikely to be very dense ($n \lesssim 5\times10^{12}$ cm^{-3}) at the time of the *Chandra* observation. Alternative to this explanation for the lack of emission features, any X-ray line emission taking place in a denser medium well within the light-distance traveled by the afterglow in a ‘‘nearby reprocessor’’ scenario might have been overwhelmed by the bright afterglow continuum. This apparent contradiction with other reported detections of discrete structure in afterglow spectra warrants further deep spectroscopic observations, designed to provide a definitive answer to the question of how common significant discrete X-ray emission really is (current detections are of low significance).

3. PULSARS, NEUTRON STARS, & SUPERNOVAE

Camilo, Gotthelf, Halpern, and Helfand, along with their students and collaborators, continue to make significant progress in identifying and studying neutron stars (NSs) and their environments, ranging from the very youngest within supernova remnants (SNRs), to the oldest millisecond pulsars (MSPs) in the Galactic disk and in globular clusters (GCs).

At the turn of the new century, with more than 1500 pulsars and 200 SNRs known, the number of secure Galactic pulsar–SNR associations was a paltry 10. Studying such associations is of interest in order to infer the initial period, velocity, and magnetic field distribution of NSs, as well as the ‘‘beaming fraction’’ of young pulsars, their luminosity distribution, and Galactic population and birthrate. Using a variety of X-ray and radio telescopes, the number of such associations has increased in the past two years to 16, with our group involved in all the new discoveries. This past year, in a series of four papers, Camilo *et al.* describe the detection of radio (and in some cases X-ray) pulsations from young NSs in the SNRs G292.0+1.8, 3C 58, G54.1+0.3, and in the unusual axisymmetric non-thermal nebula G359.23–0.82 (''The Mouse''). The radio luminosity of these pulsars is very low (of order 1 mJy kpc^2 at a frequency of 1400 MHz), and suggests that many more as yet undetected young pulsars may emit beamed radiation towards the Earth. Searches with the Parkes, Arecibo, GBT, and Jodrell Bank telescopes are continuing. They also continue studying the newly discovered pulsars and in particular have obtained nearly contemporaneous radio and X-ray observations of several to investigate their emission mechanism(s).

The Columbia group has also used *Chandra*, *XMM*, and *RXTE* to study a number of young SNRs and NSs. These observations with high spatial, spectral, and time resolution are shedding light on the characteristics of the young NSs and also on their interaction with their host SNRs.

Helfand, undergraduate student Collins, and Gotthelf published a detailed X-ray image and spectroscopic analysis of SNR Kes 75, a classic composite remnant containing a bright non-thermal core powered by a young, energetic pulsar with a characteristic age of only 723 years. Gotthelf, along with collaborators V. M. Kaspi, M. S. E. Roberts, and C. R. Tam (McGill), have continued investigation of the SNR G11.2–0.3. This remnant, a composite like Kes 75, contains a 69 ms pulsar whose characteristic age of 24,000 yrs is in severe conflict with the SNR age since it is the remnant of the supernova SN 386. Working with Gotthelf and Helfand, M. Agüeros (U. Washington) has used *XMM* to detect X-ray emission from G16.7+0.1, one of the faintest radio synchrotron nebulae known. Gotthelf, with collaborators D. L. Kaplan, S. R. Kulkarni (Caltech), B. M. Gaensler (Harvard), Slane, and D. A. Frail (VLA), are conducting a multiwavelength search for new NSs associated with SNRs. Also, as part of an earlier collaboration with the Caltech group, Kaplan *et al.* have reported a precise *Chandra* localization of the soft γ-ray repeater SGR 1806–20.

Gotthelf has presented a spectral analysis of nine pulsars observed by *Chandra* that show bright, resolved pulsar wind nebulae. Collectively, these objects suggest a fundamental spectral relationship between pulsars and their wind nebulae not easily explained in the framework of current models for pulsar emission mechanisms. In the 2–10 keV energy band, the spectral slope derived for the pulsars and their wind nebulae are found to be tightly correlated over the full range of measured values and the spectral index of the younger, more energetic pulsars are seen to be steeper. The former strongly constrains emission models and the latter provides an important probe of pulsar spin-down evolution. These results provide new observational insight into the emission mechanisms of young rotation-powered NSs.

Using the *RXTE* satellite, Gotthelf is studying the long-term rotational behavior of several young X-ray pulsars. These include the 16 ms pulsar in N157B and the 50 ms pulsar B0540–69, both of which reside in SNRs in the Large Magellanic Cloud (collaboration with F. Marshall and W. Zhang of GSFC/NASA, J. Middleditch of LANL, and Wang); the 7 s anomalous X-ray pulsar in SNR Kes 73 (with Kaspi and D. Chakrabarty of MIT); and the 324 ms pulsar in Kes 75 (with Kaspi and F. P. Gavriil of McGill). Together, these objects present a diverse sample of young pulsars with which to explore the evolution of young NSs.

Using *Chandra*, *HST*, and Parkes radio data, Camilo, in collaboration with J. E. Grindlay and P. D. Edmonds (Harvard), report on a study of the MSP population in the GC 47 Tucanae, including the detection of an unusual (possibly main sequence) optical counterpart to one of its MSPs. All 17 MSPs in the cluster with known positions are detected with *Chandra*: they are very weak and predominantly soft sources, suggestive of thermal emission from small polar caps on the NS. Surprisingly, the observed relationship between X-ray and spindown luminosity ($L_x \propto \dot{E}^{0.5}$) is apparently different from that previously reported for Galactic pulsars in the field. Also, based on the radial distribution of the soft sources detected so far, the implied total MSP population in 47 Tuc with $L_X > 10^{30}$ erg s^{-1} is about 35−90. These results will be extended by the much deeper 300 ks *Chandra* observation just completed.

Camilo and collaborators also continue to report on results of the now completed Parkes multibeam pulsar survey, as well as on further discoveries and studies of MSPs in GCs.

Sugerman and Crotts, along with researchers from Hofstra, Harvard, Notre Dame and several other institutions have been monitoring the formation of SNR 1987A, the first supernova remnant ever observed in detail from the moment of the supernova explosion onward. Using the Hubble Space Telescope and telescopes at Cerro Tololo Interamerican Observatory and Las Campanas Observatory in Chile, they have found that the ejecta from Supernova 1987A has started to collide at a large fraction of the speed of light with the surrounding nebula, seen as three rings of material which were released by the progenitor star 20,000 years before the exploson. This collision takes the form of a series of individual ''hot spots,'' some of which appear ready to soon merge and engulf the innermost portion of the nebula. Sugerman and Crotts are also using the bright flash of the supernova explosion as a radar pulse or ''light echo,'' mapping outer parts of the nebula in a way that has not been heretofore possible for any incipient supernova remnant. In another supernova (1993J) some sixty times farther away, they have used the same echo technique to find several new structures and study them in three-dimensional detail rarely seen in such distant objects.

Hailey and graduate student Mori have been studying the spectroscopy of neutron star atmospheres. They have developed a new perturbative, multi-configurational technique for solving Schrodinger's equation in an intense magnetic field. The approach permits rapid solution of the Schrodinger equation on a small computer and the generation of spectral feature positions for arbitrary ion and magnetic field strengths. They have applied this technique to the spectrum of neutron star 1E1207.4-5209 and established that the star must have a mid-atomic number atmosphere. They are also analyzing *XMM-Newton* data on the Vela pulsar. M. Jimenez-

Garate (MIT) and Hailey have been studying Her X-1 using spectroscopic data obtained with the *XMM-Newton* Observatory.

Behar, Vink, Rasmussen, and Kahn, and collaborators, have measured the X-ray emission from the young supernova remnant (SNR) N 103B, using the high-resolution cameras and spectrometers on board *XMM-Newton* and *Chandra*. The spectrum from the entire remnant is reproduced very well with three plasma components of $KT_e = 0.55$, 0.65, and 3.5 keV, corresponding roughly to line emission by the O K, Fe L, and Fe K species, respectively. Narrow band images reveal different morphologies for each component. The $kT_e = 0.65$ keV component, which dominates the emission measure, is in ionization equilibrium. This provides a lower limit of 1200 years to the age of the remnant, which is in agreement with the previously assumed age of 1500 years. Based on the measured energy of the Fe K feature at 6.5 keV, the hot (3.5 keV) component is found to be recently shocked ($\sim$200 years), and still ionizing. The high elemental abundances of O and Ne, and the low abundance of Fe, could imply that N103B originated from a Type II supernova, rather than a Type Ia, as previously thought.

Kahn and Paerels and collaborators observed the massive X-ray binary Cen X-3 over approximately one quarter of the system's 2.08 day orbit, beginning before eclipse and ending slightly after eclipse center, with the *Chandra* X-Ray Observatory High-Energy Transmission Grating Spectrometer. The spectra show K shell emission lines from hydrogen- and helium-like ions of magnesium, silicon, sulfur, and iron, as well as a Kα fluorescence emission feature from near-neutral iron. The helium-like $n = 2 \rightarrow 1$ triplet of silicon is fully resolved, and the analogous triplet of iron is partially resolved. The helium-like triplet component flux ratios outside of eclipse are consistent with emission from recombination and subsequent cascades from a photoionized plasma. In eclipse, however, the resonance lines of silicon and iron are stronger than that expected for recombination radiation, and are consistent with emission from a collisionally ionized plasma. The triplet line flux ratios at both phases can be explained more naturally, however, as emission from a photoionized plasma if the effects of resonant line scattering are included in addition to recombination radiation. They show that the emissivity due to resonant scattering depends sensitively on the line optical depth and, in the case of winds in X-ray binaries, this allows constraints on the wind velocity even when Doppler shifts cannot be resolved.

Paerels, with collaborators Cottam (GSFC) and Mendez (SRON, the Netherlands) has examined the cumulative spectrum of 28 Type I X-ray bursts from the Low Mass X-ray Binary EXO0748-676. The data were collected over more than 300 ksec of exposure with *XMM-Newton*, and provide the most detailed look at the soft X-ray Burst spectrum ever. After quantitatively accounting for the absorption spectrum arising in highly ionized circumstellar material, a number of absorption features remains unidentified; these have no known systematic instrumental origin or obvious spectroscopic interpretation. The most prominent features appear at $\sim$13.0 and 13.8 Å; as it turns out, these wavelengths coincide with the strongest transitions in the analog of the Balmer series in H-like and He-like Fe, respectively, both at a redshift of $z = 0.35$. the spectrum also shows peculiar, significant structure at the redshifted position of the H-like O Ly α wavelength. If this interpretation is correct, we have the first measurement of the gravitational redshift at the surface of a neutron star: $z = 0.35$. The constraint on the ratio of mass-to-radius from this redshift is such that it does not exclude mainstream Equations of State for either conventional neutron stars, or exotic objects (quark stars).

Chandra Fellow Vink published an article in which he describes the first detection of radioactive scandium-44 lines at 68 and 78 keV in the young supernova remnant Cas A. The detection was based on a 500 ks observation with the PDS instrument onboard the Italian/Dutch *BeppoSAX* satellite. The line flux found is in agreement with earlier detection of radioactive calcium-44 line emission, the decay product of scandium-44, with *CGRO-Comptel*. Scandium-44 is the decay product of titanium-44 a short lived radioactive element that is made in core-collapse supernovae. Its production is very sensitive to the explosion energy, explosion assymetries, and the mass-cut between the supernova ejecta and the neutron star. The observed flux translates into an intial mass of $1-2 \times 10^{-4} M_{\odot}$, which is on the high side of what is theoretically predicted.

For the same supernova remnant, Vink has collaborated with R. Willingale (Leicester) and a group led by J. Bleeker (SRON, Netherlands) on mapping doppler shifts in the Si, S and Fe X-ray line emission, as well as various other plasma parameters. The work is based on *XMM-Newton* observations and confirms the assymetric expansion of Cas A in great detail. This work also shows that, in the radial direction, shocked iron is moving at higher velocities than Si and S, in contradiction to predictions from core-collapse supernova models.

Vink collaborated with Laming on the hard X-ray emission of Cas A (based on the aforementioned *BeppoSAX* data and archival *CGRO-OSSE* data) in combination with archival Chandra observations. Using various assumptions it was possible to obtain from the hard X-ray spectra a lower limit to the average magnetic field inside Cas A in excess of 0.5 mG, whereas from the width of narrow filaments seen in the *Chandra ACIS-S* continuum images it was shown, assuming the widths are determined by synchrotron losses, that the magnetic field near the shock front is $\sim$0.1 mG.

Vink, together with J.M. Laming (NRL), worked on electron-ion temperature equilibration in the supernova remnant SN 1006. The analysis of the data is rather complex as it uses the *XMM-Newton* grating spectrometer to obtain a high resolution spectrum of a small knot in the north-west of the $30'$-diameter remnant. The knot dominates the spectrum although it is contaminated with emission from the rest of the remnant. Nevertheless, there is clear evidence for thermal broadening of the OVII lines, implying an ion temperature in the small knot more than two orders of magnitude higher than the electron temperature $\sim$1 keV.

4. ACTIVE GALACTIC NUCLEI

Behar, Kahn, and collaborators present the analysis of multi-wavelength *XMM-Newton* data from the Seyfert galaxy NGC 3783, including UV imaging, X-ray and UV lightcurves, the $0.2-10$ keV X-ray continuum, the iron Kα emission line, and high-resolution spectroscopy and modelling of the soft X-ray warm absorber. The $0.2-10$ keV spectral continuum can be well reproduced by a power-law at higher energies; they detect a prominent Fe Kα emission line, with both broad and narrow components, and a weaker emission line at 6.9 keV, which is probably a combination of Fe Kβ and Fe XXVI. They interpret the significant deficit of counts in the soft X-ray region as being due to absorption by ionized gas in the line of sight. This is demonstrated by the large number of narrow absorption lines in the RGS spectrum from iron, oxygen, nitrogen, carbon, neon, argon, magnesium, silicon, and sulphur. The wide range of iron states present in the spectrum enables them to deduce the ionization structure of the absorbing medium. They find that the spectrum contains evidence of absorption by at least two phases of gas: a hotter phase containing plasma with log ionization parameter ξ (where ξ is in units of ergs cm s^{-1}) of 2.4 or greater, and a cooler phase with log ξ centered around 0.3. The gas in both phases is outflowing at speeds of around 800 km s^{-1}. The main spectral signature of the cold phase is the Unresolved Transition Array (UTA) of M-shell iron, which is the deepest yet observed; its depth requires either that the abundance of iron, in the cold phase, is several times that of oxygen with respect to solar abundances, or that the absorption lines associated with this phase are highly saturated. The cold phase is associated with ionization states that would also absorb in the UV.

Kinkhabwala, Sako, Kahn, Paerels, and collaborators completed the analysis of the soft X-ray emission line spectrum of the Seyfert 2 galaxy NGC 1068 observed with the Reflection Grating Spectrometer on *XMM-Newton*. The entire discrete spectrum can be quantitatively modeled by emission from an extended, low density emission line region in photoionization equilibrium. A detailed study of the intensities of the strong resonance lines reveals that photoexcitation, as well as recombination, is important for line formation, providing an additional constraint on flow velocities in the emission line region. The global parameters of the emission line region are consistent with those of the medium that is responsible for the rich soft X-ray absorption line spectra observed in Seyfert 1 galaxies.

Paerels and Helfand, with graduate student Petric and undergraduate Telis, completed the analysis of a dedicated very deep X-ray observation with *Chandra* of the bright, distant ($z=4.3$) quasar QSO1508+5714. The objective was to either detect, or set a significant upper limit on, the density of intergalactic dust. Since the X-ray scattering cross section of dust particles scales with the fourth power of the particle diameter, searches for X-ray scattering halos with current instrumentation turn out to be a sensitive and unique probe of intergalactic dust (unique, because the X-ray scattering is sensitive precisely to kinds of grey dust that would be undetectable by any other means). The preliminary upper limit on the dust density is an order of magnitude below a density that could have significantly affected the evidence for an accelerated expansion of the Universe, due to extinction. The limit is low enough that it may put constraints on the global dust production and dispersal rates, and hence on the global star formation history.

The Deep Survey instrument on the *Extreme Ultraviolet Explorer* satellite obtained long, nearly continuous soft X-ray light curves of 5–33 days duration for 14 Seyfert galaxies and QSOs. Halpern, K. M. Leighly (U. Oklahoma), and H. L. Marshall (MIT) analyzed all of these archival data, which account for a total of 231 days of observation. Several of these highly variable light curves are well-suited to a search for periodicity or QPOs in the range of hours to days that might be expected from dynamical processes in the inner accretion disk around $\sim 10^8\,M_\odot$ black holes. Light curves and periodograms of the three longest observations show features that could be transient periods: 0.89 days in RX J0437.4−4711, 2.08 days in Ton S180, and 5.8 days in 1H 0419−577. The statistical significance of these signals was estimated using a method that carefully takes into account the red-noise properties of Seyfert light curves. The result is that the signals in RX J0437.4−4711 and Ton S180 exceed 95% confidence with respect to power-law noise, while 1H 0419−577 is only 64% significant. These period values appear unrelated to the length of the observation, which is similar in the three cases, but they do scale roughly as the luminosity of the object, which would be expected in a dynamical scenario if luminosity scales with black hole mass.

Halpern, Gezari, and M. Eracleous (Penn State U.) are continuing their long-term spectroscopic monitoring of very broad, double-peaked Balmer lines, which are found preferentially in radio-loud AGNs. The profiles of these double-peaked lines are highly variable on time scales of months to years, a behavior which can be exploited to evaluate models for their origin, and to study the dynamics of the accretion process in AGNs. Their recent work demonstrates that variability of the *shapes* of the emission lines must be due to dynamical motions, and cannot be explained by reverberation (light echo) effects. They also rejected the binary broad-line region hypothesis, and scenarios involving bloated stars or "clouds" in randomly inclined Keplerian orbits. Possibly cyclic behavior in several objects appears to favor dynamical or wave motions in the accretion disk as the cause. A comparison study of the ultraviolet emission lines of some of these objects is underway with *HST*. New examples of double-peaked Balmer lines continue to be discovered. An explanation of this association in terms of the ion torus (or advection-dominated accretion flow) was offered a decade ago, and continues to be attractive.

Mukherjee, M. Böttcher (Ohio University) and A. Reimer (University of Bochum) worked on understanding the high energy emission from the BL Lac object W Comae, a blazar detected by *EGRET* and observed by ground-based TeV experiments. The spectral energy distribution of the source was analyzed using various leptonic and hadronic jet models. This source is a promising target for VHE gamma-ray and co-ordinated broadband observations to distinguish between leptonic and hadronic jet models for blazars.

5. SURVEYS

Gotthelf, along with collaborators D. Q. Wang and C. C. Lang (U. Massachusetts), have mapped the central $2^\circ \times 1^\circ$ of the Galaxy with the *Chandra* X-ray Observatory. This is the first large-scale, high spatial resolution X-ray spectroscopic mapping of the Galactic center region and comprises 30 $\times 12$ ks overlapping rastered pointings. These data enable the clear separation of the point source and diffuse components of the Galactic emission. Wang *et al.* have published initial results of the ''UMass/Columbia Galactic Center Chandra Survey,'' and this rich data set will continue to be exploited in coming years.

Helfand and his principal collaborators R. Becker (UC Davis) and R.L. White (STScI) completed observing for the VLA *FIRST* survey on September 1, 2002. The survey covers over 9000 deg^2 of the North Galactic cap (and a small strip in the Southern cap) mapped to a sensitivity threshold of 1 mJy at 20cm. Over 850,000 sources have been located with positional accuracies of better than $1''$. The final catalog is in preparation; the $10^{10.5}$-pixel image, and optical identification catalog, coverage maps, and a preliminary source catalog are available at http://sundog.stsci.edu.

Helfand and F. Harrison (Caltech) have completed observations for their SEXSI survey which produces Serendipitous Extragalactic X-ray Source Identifications by targeting *Chandra* moderate to deep X-ray imaging observations. The survey includes data from thirty fields representing 1.8 Msec of observing time. Over 1200 X-ray sources have been detected. The majority have optical counterparts, and spectroscopic identifications (and classifications) have been obtained for over 380 sources. This work increases by an order of magnitude the number of hard X-rays sources identified in the range $5\times10^{-15}<S_x[2-10\text{keV}]<5\times10^{-13}$ erg cm^{-2} s^{-1}. Analysis of the luminosity functions and mean spectral properties of various source classes comprising the X-ray background is in progress.

Helfand and Glikman with their *FIRST* collaborators have constructed a complete sample of IR/radio-selected red quasar candidates with $R-K>4.0$ and $J-K>1.7$, where the color selection criteria are based on their pilot survey of *FIRST*-2MASS matches lacking optical counterparts on the POSS-I survey. They have spectroscopic identifications for more than fifty candidates, approximately half of which are extremely red quasars not represented in current quasar catalogs. The goal is to determine the total fraction of the quasar population missed in optical quasar surveys. In addition, they have begun a major effort to explore the quasar radio luminosity function in order to settle definitively the issue of whether or not a strict radio-loud/radio-quiet dichotomy exists.

Helfand and Chang in collaboration with Refregier (Saclay) passed a major milestone in their quest to extract a weak lensing signal on degree-scales from the *FIRST* survey. They have completed a shapelet analysis of $\sim$800,000 *FIRST* sources by fitting to the uv data directly. Modeling of the systematic biases has also been successful. The final step, to extract the sheer measurement from these data, will be completed in the coming months.

Helfand, along with Becker and White, have completed the first installment of their sensitive, high-resolution radio image of the Milky Way. Observations of a 1.5-degree-wide strip of the plane in the range $32°>\ell>19°$, taken in the VLA B-, C-, and D-configurations, have been combined with single-dish data and used to construct high dynamic range images. Detailed comparison with the MSX mid-IR images of the plane at comparable resolution is proving invaluable in separating thermal and non-thermal emission. In collaboration with a group from the University of Leicester, they have begun mapping the same region with the *XMM-Newton* Observatory, providing a dramatic new view of stellar birth and death in the Galaxy.

Uglesich, Crotts and Baltz, plus a team of scientists at the Kapteyn Institute, Vatican Observatory, Adler Planetarium, Queens University and The Ohio State University have completed a microlensing survey of stars in the Andromeda Galaxy, M31 (using the Vatican Advanced Technology Telescope and our 1.3-meter telescope at MDM Observatory). This survey indicates that gravitational microlensing is not caused by the stars alone, but implies the presence of massive, dark objects in the halo of M31, as found by a survey of our Galaxy's halo by another, larger research group, in a conclusion that has heretofore been seen as somewhat controversial and mysterious. The fact that M31 shows the same effect argues against some hypotheses which avoid halo microlensing masses in large numbers. In 2002−3 a larger survey by many of the same investigators as well as Columbia postdocs Alves and Cseresnjes will be completed. It will be almost ten times more sensitive and should be able to locate where in M31 these microlensing masses reside, what their typical masses are, and provide clues to their likely origin. These observations are being completed at MDM Observatory, the Isaac Newton Telescope, and Kitt Peak National Observatory, with additional data from the Subaru and Canada-France-Hawaii telescopes.

Hubble Fellow Bureau and the SAURON team, a collaboration with a core of 12 members, continued the developement and operation of the SAURON spectrograph, mounted on the William Herschel Telescope (WHT) in La Palma. SAURON is an integral-field spectrograph (IFS) using a lenslet array; it has the largest field-of-view of any IFS with a similar spectral resolution, has high throughput, and allows simultaneous sky subtraction. Its design is optimized for studies of the stellar kinematics, gas kinematics, and line-strength distributions of nearby early-type galaxies. Among many improvements, a new volume-phase holographic grating was installed. Extensive data reduction and analysis software called XSAURON was also developed to obtain fully calibrated spectra and the associated kinematic and line-strength measurements. Dedicated algorithms were developed to separate accurately emission and absorption lines, allowing the extraction of accurate emission-line intensities, velocities, and absorption-line widths in the presence of strong emission. A pipeline called PALANTIR is currently being developed to reduce the data in an automated fashion.

After three and a half years of observations, Bureau and the SAURON team have completed a large survey of the kinematics and stellar populations of early-type galaxies using SAURON. A representative sample of 24 ellipticals, 24 lenticulars, and 24 spiral bulges were observed, all nearby and equally divided between field and cluster objects. Two-dimensional maps of the stellar kinematics, ionized gas distribution and kinematics, and stellar line strength indices were produced, making the SAURON survey unique in both scale, coverage, and homogeneity. The survey aims to determine the intrinsic shape of the galaxies, their orbital structure, the mass-to-light ratio as a function of radius, the age and metallicity of the stellar populations, and the frequency of kinematically decoupled cores and nuclear black holes, thus ultimately shedding light on the connection between gas, stars, and the history of star formation in these systems. Preliminary results illustrate the rich structure of early-type galaxies and include the discovery of a thin edge-on disk in the galaxy NGC3623, confirmation of the axisymmetric shape of the central regions of M32, demonstration of a LINER nucleus and a surrounding counter-rotating star-forming ring in NGC7742, and suggestion of a uniform stellar population in the decoupled core galaxy NGC5813.

Bureau and the SAURON team are currently working on the definition and calibration of the SAURON line strength indices and on a complete analysis of the stellar kinematics. In particular, the structure and frequency of central stellar disks and kinematically decoupled cores are being investigated, to constrain the importance of mergers and dissipation in the formation of early-type galaxies. Many individual galaxies have also been modeled by team members, using Schwarzschild's orbit-superposition method.

Scharf continued working with the WARPS (Wide Angle ROSAT Pointed Survey) collaboration to detect high redshift, X-ray clusters of galaxies with Ebeling (Hawaii), Jones (Birmingham) and Perlman (UMBC). Using a combination of Keck spectroscopy and Subaru infrared imaging, the WARPS has this year identified several new clusters at redshifts greater than 0.7, including the most massive, highest redshift cluster of galaxies currently known, at redshift 1.01, which also exhibits strong gravitational lens features. The WARPS also obtained new X-ray data from the *Chandra* and *XMM* observatories on 15 high redshift clusters. Scharf has worked on these data to determine X-ray gas temperatures and to constrain the high-redshift evolution of clusters. Preliminary results provide independent verification of CMB and SNe measurements of a low density cosmology dominated by a cosmological constant.

6. GALAXIES & CLUSTERS OF GALAXIES

A supermassive black hole will rip apart a star that strays within its tidal radius, causing an Eddington-limited UV/X-ray flare for several months as the orbiting debris accretes. While such events are predicted to occur once in $\sim 10^4$ yr per galaxy, an experiment was performed in 1990–91 that sampled hundreds of thousands of galaxies in the ideal wavelength band, i.e., the *ROSAT* All-Sky Survey. Several galaxies had unusual X-ray flares, but no evidence for nuclear activity in ground-based spectra. To establish beyond a reasonable doubt that these were tidal disruption events, Halpern, Gezari, and collaborators obtained narrow-slit *HST* spectra of three of these objects to search for weak, permanent Seyfert activity, the only possible alternative to the disruption hypothesis. Two of the galaxies, RX J1624.9+7554 and RX J1242.6–1119, show no evidence for emission lines or non-stellar continuum in their *HST* nuclear spectra, consistent with their interpretation as tidal disruption events. NGC 5905, previously known as a starburst HII galaxy due to its strong emission lines, has in its inner 0.1 arcseconds a nucleus with narrow emission-line ratios consistent with a Seyfert 2 galaxy. The weak Seyfert nucleus in NGC 5905, which was masked by the many surrounding H II regions in ground-based spectra, raises questions about the nature of its X-ray flare, which could have been an outburst of a previously existing AGN.

Rasmussen, Paerels, Kahn, and their colleagues at the Space Research Organization of the Netherlands discovered strong absorption lines due to highly ionized Oxygen in the X-ray spectra of bright, distant extragalactic sources. The spectra of 3C273, PKS2155−304, and Mkn 421, obtained over several days of exposure each with the RGS on *XMM-Newton*, clearly show very significant resonance line absorption due to H- and He-like O at redshift zero. The features observed in PKS2155−304 may be marginally velocity-resolved. The absorption features almost certainly arise in a hot medium pervading the Local Group, and a rough measurement of the gas temperature from the Oxygen ionization balance (assuming collisional ionization) yields $kT_e \sim 300$ eV, fully consistent with the expected virial temperature of the Local Group. Combining the measured absorbing column density with estimated line emission measures in emission lines due to the same ions (as measured for instance with the Wisconsin-GSFC microcalorimeter experiment) provides a lower limit on the scale size (of order hundreds of kpc) and an upper limit on the density (of order 10^{-4} cm^{-3}) of the absorbing medium. While providing strong evidence that most of the gas is in the form of a hot intragroup medium, these estimates do not yet constrain the total gas mass very well. The gas is relatively cool, but still easily visible in He-like O absorption lines. This raises the possibility that it may be possible to find significant amounts of similarly cool gas in other poor groups using absorption spectroscopy.

Scharf and Mukherjee discovered the first robust evidence for γ-rays emanating from halos around clusters of galaxies in the nearby Universe. Using a sophisticated statistical analysis of nine years of γ-ray data from the *Compton Gamma-Ray Observatory*, they detected a signature predicted by recent theories of the origin of extragalactic γ-rays. The γ-rays arise from the enormous flow of matter into the gravity wells of galaxy clusters, where huge shock waves form, accelerating electrons to near light-speed where they can then convert microwave photons from the Big Bang into higher energy γ-ray photons. This detection provides an entirely new method to probe the physics of galaxy clusters as well as the properties of intergalactic magnetic fields.

Scharf led an investigation, with collaborators in the UK, of X-ray emission from one of the most distant, high-redshift, and brightest sub-mm astrophysical sources known. By obtaining very deep *Chandra* X-ray data, Scharf has discovered that the source, also a powerful radio galaxy, has an extended X-ray profile – unique in sources at this redshift. This object is likely a massive galaxy caught in its early stages of formation, and probably the first building block of what will eventually become a massive cluster of galaxies. Scharf and his collaborators have begun a program of detailed study to confirm this scenario, and to determine the origin of the extraordinary cloud of X-ray emission, which may be the result of relativistic particles in the galaxy scattering the cosmic microwave background photons up to X-ray energies.

Scharf began development of a novel analysis method for measuring the temperature of X-ray emitting gas in galaxy clusters which is optimized for very faint, low photon count sources. The method, XFILT, uses a likelihood-based matched filter and can produce spatial maps of galaxy cluster temperatures as well as optimally detect emission from proposed warm filamentary structure in the intergalactic medium. This work also produced a template of optimal X-ray energy bands in which to detect galaxy clusters and groups at high redshift.

J. Hibbard (NRAO), van Gorkom, M. Rupen (NRAO) and D. Schiminovich (Caltech) assembled an HI Rogues Gallery, a collection of images of HI in weird galaxies and weird HI in otherwise normal galaxies. The atlas has appeared in the proceedings of the conference on Gas and Galaxy Evolution (ASP 240) and is also accessible on the web. It contains more than 180 systems.

A *VLA* HI survey of galaxy clusters in the local universe is being carried out by van Gorkom with H. Bravo-Alfaro (Guanajuato), K. Dwarakanath (NRAO & RRI, Bangalore), P. Guhathakurta (UCSC), B. Poggianti (Padova), D. Schiminovich (Caltech), M. Valluri (Chicago), M. Verheijen (Potsdam), E. Wilcots (Wisconsin) and A. Zabludoff (Arizona). Each cluster is imaged out to two Abell radii and the entire velocity range covered by the galaxies is searched for HI. So far 3 clusters at $z=0.06$ and 0.08 have been completed, a fourth at $z=0.03$ is in progress. Combined VLA and GMRT data have been taken on A2192 at $z=0.188$ and already one galaxy has been detected in HI at this redshift. Abramson, Krohn and Sargent analyzed the HI content, star formation rate, and merger rate in Abell 2670 as function of global and local density. The analysis shows that all the action takes place in distinct galaxy groups that are falling into the cluster for the first time. The merger rate seen near Abell 2670 is higher than the rate derived for clusters at intermediate z.

Chung, van Gorkom, K. O'Neil (NAIC) and G. Bothun (U. Oregon) imaged in HI a sample of low surface brightness galaxies that were found to deviate strongly from the Tully-Fisher relation based on Arecibo observations. Analysis of the VLA data and a further analysis of the Arecibo sample shows that the Arecibo results were seriously affected by confusion. After correcting for this effect, there is no evidence in the O'Neil sample for deviations from the Tully-Fisher relation.

Zamojski and van Gorkom with Hibbard (NRAO) and J. Stocke (Colorado) have searched the environment of a sample of nearby Lyα absorbers for neutral hydrogen in emission. The goal is to identify a possible parent population of HI emitters which are physically associated with the absorbers. The conclusion is that the nearby absorbers follow the structure outlined by the luminous galaxies, but are not clearly associated with individual galaxies.

Noel-Storr and van Gorkom with S. Baum, C. O'Dea, G. Verdoes-Klein (all STSci) and C.M. Carollo (ETH, Zurich) are analyzing *HST STIS* data of a representative sample of nearby radio galaxies. The goal is to derive the masses of the black holes and to determine the physical conditions of the gas surrounding the black hole.

Following similar work using periodic orbit calculations and hydrodynamical simulations, Bureau and E. Athanassoula (Observatoire de Marseille) have used N-body simulations of unstable disks to develop tools to identify bars in edge-on spiral galaxies kinematically and to constrain their viewing angles. This is necessary because bars in edge-on spirals can not be identified reliably using morphological arguments alone. Furthermore, because stars can move along quasi-periodic and chaotic orbits, the previous models were overly simplistic. The new diagnostics again rely on characteristic bar signatures in the observed position-velocity diagrams. Contrasting with an axisymmetric disk, the most important features are a double-peaked rotation curve, a rather flat velocity dispersion peak with secondary maxima, and a Gauss-Hermite h_3 profile correlating with V. The latter appears to be a telltale signature of triaxiality, whether figure rotation is present or not. These diagnostics are a necessary first step to studying the vertical and three-dimensional structure of bars and, to a lesser extent, triaxial systems.

Chung and Bureau have measured the stellar kinematics of a large sample of boxy and peanut-shaped (B/PS) bulges, which represent about 45% of all edge-on spirals. Long-slit spectra were obtained along the major axes of 30 galaxies, 24 with B/PS bulges and 6 with more spheroidal morphologies. The line-of-sight velocity distributions were derived with the Fourier Correlation Quotient (FCQ) method and parametrized with Gauss-Hermite polynomials. Applying the bar diagnostics developed by Bureau and E. Athanassoula (Observatoire de Marseille), bar signatures were identified in 25 galaxies. For virtually all galaxies with a B/PS bulge, the rotation curve shows a double-hump feature with a dip or plateau, and the dispersion is either peaked or flat at the center, with secondary peaks present where V flattens out. These features are probably related to the bar strength and the presence of an inner ring. The asymmetry parameter h_3 correlates with V in what appears to be the barred regions, as expected for non-axisymmetric disks. Unlike the expectations from simulations, however, h_3 shows a strong anti-correlation with V in the very center of most early-type galaxies. This indicates that these galaxies most likely contain inner stellar disks formed from gas accumulated at the center of the bars, and not taken into account by the N-body simulations. Chung and Bureau concluded that most spirals with a B/PS bulge are indeed an edge-on projection of a thick bar, as suggested by simulations, and that the skewness of the velocity profiles (h_3) is a useful tracer of asymmetries in disks.

Together with G. Aronica (Ruhr-Universitat Bochum) and E. Athanassoula (Observatoire de Marseille), Bureau is studying the vertical structure of bars using K-band imaging of the same sample of boxy and peanut-shaped bulges studied with Chung. Unsharp-masking reveals embedded rings and truncated outer disks seen in projection, confirming that these bulges are bars seen edge-on. Fits to the vertical light distribution also show that the disk scale height varies considerably with radius, supporting formation through bar buckling. More detailed comparisons with N-body simulations are ongoing.

Bureau and F. Masset (CE-Saclay) carried out a detailed study of NGC2915, a blue compact dwarf galaxy embedded in an extended, low surface brightness HI disk exhibiting a two-armed spiral structure and a central bar-like component. Commonly accepted mechanisms are unable to explain the existence of these patterns and disk dark matter (scaling with the HI distribution) or a rotating triaxial dark halo were proposed as alternative solutions. To explore these mechanisms, hydrodynamical simulations were run for each case and compared to observations using customized column density and kinematic constraints. The spiral structure can be accounted for both by an unseen bar or triaxial halo, the former fitting the observations slightly better. However, the large bar mass or halo pattern frequency required make it unlikely that the spiral wave is driven by an external perturber. In particular, the spin parameter λ is much higher than predicted by current cold dark matter structure formation scenarios. The massive disk models show that when the observed gas surface density is scaled up by a factor of about ten, the disk develops a spiral structure resembling closely that observed. This is consistent with more limited studies in other galaxies and suggests that the disk of NGC2915 contains much more mass than is visible, tightly linked to the neutral hydrogen. A classic (quasi-)spherical halo is nevertheless still required, as increasing the disk mass further to fit the circular velocity curve would make the disk violently unstable. Scaling the observed surface density profile by an order of magnitude brings the disk and halo masses to comparable values within the disk radius. The surface density remains under Kennicutt's star formation threshold for a gaseous disk and no stars are expected to form, consistent with the observations.

With E.K. Verolme (Leiden Observatory) and collaborators, Bureau constructed self-consistent dynamical models of the nearby compact elliptical galaxy M32 using Schwarzschild's orbit-superposition method. High-quality kinematic measurements obtained with SAURON and HST/STIS were used. The group determined a best-fitting black hole mass of $M_\bullet = (2.5 \pm 0.5) \times 10^6\ M_\odot$ and a stellar I-band mass-to-light ratio of $(1.85 \pm 0.15)\ M_\odot / L_\odot$. For the first time, the inclination along which M32 is observed was also constrained, to $i = 70° \pm 5°$. Assuming that M32 is indeed axisymmetric, the averaged observed flattening of 0.73 then corresponds to an intrinsic flattening of 0.68 ± 0.03. The phase-space distribution and intrinsic velocity structure of the best-fitting model was also probed and the effect of regularization on the orbit distribution investigated.

Peterson, Kahn, Paerels, and collaborators completed their survey of the soft X-ray emission line spectra of bright, compact cooling flow clusters. A total of fourteen cooling flows has been observed with the RGS on *XMM-Newton*, and the qualitative properties of the discrete spectra are all similar to the peculiar spectrum of the first bright cooling flow observed with the RGS (Abell 1835): emission from the lower ionization stages of the Fe L series is significantly weaker than the predictions from an isobaric cooling flow; in most cases, emission from the cooler gas is in fact undetectable. These observations have now established beyond doubt that cooling flows are not simply passively radiatively cooling volumes of gas, but that their thermodynamics must be considerably more complex. The implications of this finding are currently fueling a vigorous debate on the physics of cooling gas in clusters.

Paerels, Peterson, and collaborators completed the analysis of the X-ray emission line spectrum of M87. The emission line region is clearly spatially resolved, and the fact that the surface brightness distribution is very similar in ions with widely separated ionization potentials indicates that the radiating gas has a multiphase thermal structure. The emission is well-modeled by an isothermal component at $kT_e = 1.8$ keV in addition to a 'truncated' (in temperature) cooling flow; the properties of the latter are very similar to those of the cooling flows observed in the larger cooling flow spectroscopic survey.

Xu, Peterson, Kahn, Behar, Paerels, and collaborators analyzed the X-ray emission line spectrum of the bright elliptical galaxy NGC 4636. They detect the effect of resonance scattering of photons in the strongest $n = 2 - 3$ emission line of Fe XVII, which measurably broadens the spatial extent of the galaxy in this line. The measured extent actually provides an independent constraint on the amplitude of the random velocity field of the Fe XVII bearing gas, which turns out to be surprisingly dynamically 'cold' (rms velocity spread of order 60 kms^{-1}, comparable to the linewidth observed in OVI with *FUSE*). A fully quantitative interpretation of the observed emission line strengths, which includes the finite angular extent of the source, and allows for temperature and density gradients as well as taking into account radiative transfer in the strongest lines, has produced the first robust estimate of the elemental abundances of the hot gas in this elliptical. The observed abundance pattern is completely inconsistent with expectations based on simple models for the nucleosynthetic evolution of the ISM in ellipticals. And, as is the case with the cooling flow clusters, the observed near-isothermal nature of the hot ISM implies that the thermodynamics of this medium are not understood (it's cooling timescale is very short). The absence of any evidence for random bulk motion, which could reveal the presence of bulk kinetic energy input, is all the more puzzling in this context.

7. INSTRUMENTATION DEVELOPMENT

Aprile, Curioni, Giboni, Kobayashi and Ni worked on the Liquid Xenon Gamma-Ray Imaging Telescope (LXeGRIT) project. The main activity this year has been the analysis of the data gathered during the Fall 2000 Balloon Flight Campaign in Ft. Sumner, NM. The two main goals of this analysis are: 1) a detailed study of the γ-ray and charged particle background measured for the first time in a liquid xenon detector at balloon altitude; and 2) imaging studies of the Crab Nebula with this novel Compton telescope prototype. A first result on the measured background rate in the LXeGRIT instrument at balloon altitude was presented in August at the SPIE 2002 conference. This study shows that the rate of background events is encouragingly low and quite well-understood, being consistent with the rate expected from

Monte Carlo simulations of the known atmospheric and cosmic diffuse backgrounds. A more detailed study is in preparation. Preliminary results on the imaging of the Crab were also presented at the SPIE 2002 conference. They are still studying the impact of event selections on signal/background during the flight. Efforts are directed towards identifying the selections which are the most favorable in order to obtain the maximum statistical significance for the signal in the $1-3$ MeV energy band. This work includes careful studies of the events rejected in a first analysis, optimization of the Compton sequence reconstruction algorithm and other analysis software, all with the help of Monte Carlo simulations and improved background models for a likelihood imaging analysis. Both these sudies rely heavily on the careful calibration (energy resolution, imaging performance, detection efficiency) of the instrument, which has been continuosly refined throughout the last year. Studies of detector upgrades, most notably, a new light detection system based on compact, metal-channel PMTs operated at liquid xenon temperature, have also been part of our research effort this past year.

Aprile, Baltz, Giboni, Kobayashi, Hailey, Hui and Ni, with collaborators at Princeton, Brown, Rice and LLNL have studied and proposed a new experiment for dark matter WIMPs using liquid xenon as target. The experiment, called XENON, has been accepted by NSF for a two-year development phase.

Hailey and students Mori and Hong (now a post-doc at Harvard) have been working on novel methods to detect dark matter. One method, now a NASA-funded project, is to indirectly detect the cosmic antideuterons produced in neutralino annihilations. Antideuterons would be detected via the X-ray signature they produce when they are captured into a gas and produce excited antiatoms.

Koglin, Windt, Chonko, Yu, Jimenez-Garate (MIT) and Hailey are constructing segmented glass optics for use on the High Energy Focusing Telescope balloon experiment *(HEFT)*. *HEFT* will provide arcminute images of the sky from 20-100 keV energy band. They are also investigating segmented glass optics for use on the *Contellation-X* Hard X-ray Telescope.

Kahn, Rasmussen, and Paerels are involved in technology development investigations for the Grating/CCD experiment on the *Constellation-X* mission. Kahn is the Instrument Product Team (IPT) lead for this experiment, and Rasmussen is the Deputy IPT lead. In addition, Kahn is a member of the Facility Science Team for the mission as a whole. In collaboration with groups at MIT and the University of Colorado, they have been involved in a wide range of technology investigations for this experiment, including: the development of thin, flat silicon substrates, the production of X-ray gratings via X-ray lithographic techniques, the development of event-driven CCDs, and the possible incorporation of off-plane grating designs. In addition, they have coordinated activities on this experiment with the project offices at GSFC and SAO.

Windt is working on the development of multilayer X-ray optics. Optimized Mo/Si multilayer coatings, designed for normal-incidence operation in the EUV, have been developed for the Solar-B/EIS instrument in collaboration with the Naval Research Laboratory. The EIS spectrometer, which will obtain high-resolution spectra and images of the solar corona, comprises two multilayer-coated optics – a parabolic focusing mirror and an ion-etched concave grating. One half of each optic is coated with a short-band multilayer spanning the range $170-210$ Å, and the other half with a long-band multilayer spanning the range $250-290$ Å , in order to observe a wide range of emission lines. Solar-B is scheduled for launch in 2004.

Windt and his collaborators E.M. Gullikson (LBNL) and C. Walton (LLNL) have recently developed ultra-short period multilayers designed for use at normal-incidence in the range $15-30$ Å. These coatings could be used to construct normal-incidence X-ray telescopes tuned to, e.g., the N VII, O VII or O VIII resonance lines in the soft X-ray band, and will thus enable the eventual development of diffraction-limited soft X-ray telescopes having sub-mas resolution, and X-ray interferometers having sub-microarcsecond resolution.

Windt, Donguy, Hailey, and Koglin, and their collaborators V. Honkimaki, E. Ziegler (ESRF), F.E. Christensen (DSRI), C.M.H. Chen, F.A. Harrison (Caltech), and W. Craig (LLNL) have developed a new W/SiC multilayer coating designed for use at grazing-incidence in the hard X-ray band above 100 keV. This coating, which has significantly greater performance relative to previously investigated multilayers, will enable the development of a sensitive nuclear line telescope designed to observe key nuclear decay lines (e.g., 57Co – 122 keV, 56Ni – 158 keV) from young SNR as well as both core-collapse (Type Ib and Type II) and Type Ia SNE.

8. LABORATORY ASTROPHYSICS

Kahn and collaborators report measurements of emission spectra of iron in the extreme ultraviolet recorded at an electron density of $\sim 5\times10^{11}\mathrm{cm}^{-3}$ using the Lawrence Livermore electron beam ion trap, EBIT-II. They present a summary of observed emission lines, including wavelengths and emission intensities. They also illustrate their technique for isolating pure charge states of the desired ion, and present spectra of pure Fe VII -X. Their measurements add a large number of newly identified lines to existing line lists in the extreme ultraviolet region, $60-140$ Å. While many of these lines are quite weak, they add up to a significant flux that can seriously affect interpretations of global fitting models, especially when applied to stars with material at the appropriate temperatures, such as Procyon, Alpha Cen, and the Sun.

Kahn and collaborators at LLNL and GSFC have measured the intensity ratios of the $3s\rightarrow2p$ and $3d\rightarrow ep$ lines in Fe XVII on the Livermore electron beam ion trap, employing a complementary set of spectrometers, including a high-resolution crystal spectrometer and the GSFC 32-pixel calorimeter. The resulting laboratory data are in agreement with satellite measurements of the Sun and astrophysical sources in collisional equilibrium, such as Capella, Procyon, and NGC 4636. The results disagree with early laboratory measurements and assertions that processes not accounted for in laboratory measurement must play a role in the formation of the Fe XVII spectra in solar and astrophysical plasmas.

Kahn and collaborators at LLNL, GSFC, and Auburn University present a comprehensive $\Delta n=1$ iron L-shell X-ray line emission survey, measured using the electron beam ion trap, EBIT-II, at LLNL, which was equipped with flat crystal spectrometers to measure the wavelengths of over 150 features between 10.6 and 18 Å. They present wavelengths, line identifications, and relative intensities of all of the significant $\Delta n=1$ emission lines from Fe XVIII-XXIV at electron densities of $\sim 10^{12} \mathrm{cm}^{-3}$ resulting from direct electron impact excitation from the ground state and the subsequent radiative cascades. This data set includes $2-3$ times as many lines as are found in current standard line lists.

Kahn and collaborators at LLNL and GSFC report measurements of emission cross sections of iron L-shell $3\rightarrow 2$ lines in Fe^{23+} performed on the electron beam ion trap EBIT-II using a combination of a crystal spectrometer and the spare 6×6 element X-Ray Spectrometer microcalorimeter from the *Astro-E* X-ray satellite mission. Use of the microcalorimeter enables for the first time the normalization of line emission cross sections, i.e. the ratio of effective electron impact excitation cross sections that include radiative cascades, to the well-established cross section of radiative electron capture. This provides the normalization of relative line intensity measurements using crystal spectrometers.

Savin has calculated the rate coefficients for $\mathrm{D}(1s)+\mathrm{H}^+ \rightleftharpoons \mathrm{D}^+ + \mathrm{H}(1s)$ using recently published theoretical cross sections. He presented results for temperatures T from 1 K to 2×10^5 K and provided fits to his data for use in plasma modeling. His calculations are in good agreement with previously published rate coefficients for $25 \leqslant T \leqslant 300$ K, which covers most of the limited range for which those results were given. His new rate coefficients for $T \gtrsim 100$ K are significantly larger than the values most commonly used for modeling the chemistry of the early universe and of molecular clouds. This may have important implications for the predicted HD abundance in these environments. Using his results, Savin has modeled the ionization balance in high redshift QSO absorbers. He finds that the new rate coefficients decrease the inferred D/H ratio by $\lesssim 0.4\%$. This is a factor of $\gtrsim 25$ smaller than the current $\gtrsim 10\%$ uncertainties in QSO absorber D/H measurements.

Savin, Behar, and Kahn and their collaborators G. Gwinner, A.A. Saghiri, M. Schmitt, M. Grieser, R. Repnow, D. Schwalm, and A. Wolf (MPI for Nuclear Physics), T. Bartsch, A. Müller, and S. Schippers (Univ. of Giessen), N.R. Badnell (Univ. of Strathclyde), M.H. Chen (LLNL), and T.W. Gorczyca (Western Michigan) have measured the resonance strengths and energies for dielectronic recombination (DR) of Fe XX forming Fe XIX via $N=2\rightarrow N'=2$ ($\Delta N=0$) core excitations. They have also calculated the DR resonance strengths and energies using AUTOSTRUCTURE, HULLAC, MCDF, and R-matrix methods, four different state-of-the-art theoretical techniques. On average the theoretical resonance strengths agree to within $\lesssim 10\%$ with experiment. However, the 1σ standard deviation for the ratios of the theoretical-to-experimental resonance strengths is $\gtrsim 30\%$ which is significantly larger than the estimated relative experimental uncertainty of $\lesssim 10\%$. This suggests that similar errors exist in the calculated level populations and line emission spectrum of the recombined ion. Savin *et al.* confirm that theoretical methods based on inverse-photoionization calculations (e.g., undamped R-matrix methods) will severely overestimate the strength of the DR process unless the calculations include the effects of radiation damping. The team also finds that the coupling between the DR and radiative recombination (RR) channels is small. They have used their experimental and theoretical results to produce Maxwellian-averaged rate coefficients for $\Delta N=0$ DR of Fe XX. For $kT \gtrsim 1$ eV, which includes the predicted formation temperatures for Fe XX in an optically thin, low-density photoionized plasma with cosmic abundances, the experimental and theoretical results are in good agreement. Savin *et al.* have also used their R-matrix results, topped off using AUTOSTRUCTURE for RR into $J \geqslant 25$ levels, to calculate the rate coefficient for RR of Fe XX. Their RR results are in good agreement with previously published calculations.

Savin and his collaborator J.M. Laming (NRL) have investigated how the relative elemental abundances inferred from the solar upper atmosphere are affected by uncertainties in the dielectronic recombination (DR) rate coefficients used to analyze the spectra. They find that the inferred relative abundances can be up to a factor of ≈ 5 smaller or ≈ 1.6 times larger than those inferred using the currently recommended DR rate coefficients. They have also found a plausible set of variations to the DR rate coefficients which improve the inferred (and expected) isothermal nature of solar coronal observations at heights of $\gtrsim 50$ arcsec off the solar limb. Their results can be used to help prioritize the enormous amount of DR data needed for modeling solar and stellar upper atmospheres. Based on this work, their list of needed rate coefficients for DR onto specific isoelectronic sequences reads, in decreasing order of importance, as follows: O-like, C-like, Be-like, N-like, B-like, F-like, Li-like, He-like, and Ne-like. Their work will help to motivate and prioritize future experimental and theoretical studies of DR.

Savin and his collaborators T.W. Gorczyca (Western Michigan) and N.R. Badnell (University of Strathclyde) have performed radiation-damped *R*-matrix scattering calculations for the photorecombination of Fe^{17+} forming Fe^{16+}, significantly improving upon earlier results for this ion. However, they have shown theoretically that all *R*-matrix methods are unable to account accurately for the phenomena of radiative decay following autoionization. For Fe^{17+}, they have demonstrated numerically that this results in an overestimate of the DR cross section at the series limit. They have further commented on the need for fine resonance resolution and the inclusion of radiation damping effects. Overall, slightly better agreement with experiment is still found with the results of perturbative calculations, which are computationally more efficient than *R*-matrix calculations by more than two orders of magnitude.

Savin and Kahn and their collaborators J. Linkemann, A.A. Saghiri, M. Schmitt, M. Grieser, R. Repnow, D. Schwalm, and A. Wolf (MPI for Nuclear Physics), T. Bartsch, A. Müller, and S. Schippers (Justus-Liebig-University), M.H. Chen (LLNL), N.R. Badnell (University of Strathclyde), and T.W. Gorczyca and O. Zatsarinny (Western

Michigan) have measured resonance strengths and energies for dielectronic recombination (DR) of Fe XIX forming Fe XVIII via $N=2\rightarrow N'=2$ and $N=2\rightarrow N'=3$ core excitations. All measurements were carried out using the heavy-ion Test Storage Ring at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany. They have also calculated these resonance strengths and energies using two independent, state-of-the-art techniques: the perturbative Multiconfiguration Breit-Pauli (MCBP) and Multiconfiguration Dirac-Fock (MCDF) methods. Overall, reasonable agreement is found between our experimental results and theoretical calculations. The most notable discrepancies are for the $3l3l'$ resonances. The calculated MCBP and MCDF resonance strengths for the $n=3$ complex lie, respectively, $\approx 47\%$ and $\approx 31\%$ above the measured values. These discrepancies are larger than the estimated $\lesssim 20\%$ total experimental uncertainty in their measurements. They have used their measured $2\rightarrow 2$ and $2\rightarrow 3$ results to produce a Maxwellian-averaged rate coefficient for DR of Fe XIX. Their experimentally-derived rate coefficient is estimated to be good to better than $\approx 20\%$ for $k_BT_e \geqslant 1$ eV. Fe XIX is predicted to form in photoionized and collisionally ionized cosmic plasmas at $k_BT_e \geqslant 1$ eV. Hence, their rate coefficient is suitable for use in ionization balance calculations of these plasmas. Previously published theoretical DR rate coefficients are in poor agreement with their experimental results. None of these published calculations reliably reproduces the magnitude or temperature dependence of the experimentally-derived rate coefficient. Their MCBP and MCDF results agree with the experimental rate coefficient to within $\approx 20\%$.

9. THEORETICAL ASTROPHYSICS

Spiegel's main concern in the past year has been with the dynamics of rarefied gases. The degree of rarefaction is indicated by the Knudsen number ϵ, defined as the ratio of particle mean free path over a characteristic macroscopic scale in the dynamics of the gas. For a sound wave, ϵ is equivalent to the ratio of the period of the wave to the mean flight time of the constituent particles. As reported last year, both the structure of shock waves and the propagation speed of sound waves at high ϵ could be well predicted (as judged by experiments) if a suitable modification of the standard Chapman-Enskog procedure is made. The result is a modification of the Navier-Stokes equations, which fare less well than the new theory. On the other hand, no continuum theory has as yet been successful at predicting the dissipation rates of sound waves at *large* Knudsen numbers such as one encounters in astrophysical gases and stellar systems.

In an attempt to improve on the present theories, Spiegel and J.-L. Thiffeault (Applied Physics and Applied Mathematics, Columbia) have taken the new approach to second order in ϵ. The outcome is a modification of the Burnett equations familiar in kinetic theory, and the new theory does well at predicting the dissipation for $\epsilon \leqslant 1$, but does not give a good description of the dissipation at large ϵ. The calculations for the second order theory (given in a paper now in preparation) are heavy and it is not intended to go to beyond second order. Rather, it now seems preferable to take a hybrid approach mixing features of the microscopic and macroscopic descriptions. For this purpose, a new model of the kinetic equation has been formulated and its consequences are being explored.

Yecko and S. Zaleski (Paris VI) have continued work on instability in two-phase fluids with interfacial forces. Temporal instability theory is complete and attention has now shifted to spatial theory and to transient amplification, where large amplitude growth has been found for high spanwise wavenumber modes of the type associated with streamwise streaks and vortices in boundary layer flows. Transient growth calculations have not previously been attempted for this problem though there is observational evidence for unstable modes of this character. A campaign of direct numerical simulations of two-phase shear layers has also been performed and has shown that viscosity controls the length scale of primary breakup of the interface in flows of high Reynolds and Weber numbers. All previous theories have neglected the role of viscosity though it is known to be important from experimental data.

Yecko has completed a study of the behavior of three-dimensional disturbances in rotating boundary layer flows of the Blasius and suction form. Maximum transient amplification factors and growth rates have been calculated for weak rotation in both cases, showing: (a) a tendency for modes of large transient amplification without rotation to be converted by the rotation to strongly eigenvalue unstable modes; and (b) the essential role of the cross-stream, or non-parallel, base flow component – without this, in the exact parallel approximation, artificial instability regions are found. Also of note is that the influence of rotation is opposite in this fully viscous calculation to that found in inviscid theory. Future application of this study will be made to star-accretion disk boundary layers.

Windt has investigated theoretically the feasibility of detecting needle-like dust grains, possibly present at large redshifts, by their X-ray halos. The presence of such dust has been proposed as an alternative hypothesis to the interpretation of the apparent systematic dimming of high-redshift Type Ia SNE as evidence of accelation in the cosmological expansion of the universe. He finds that the X-ray halos produced by cosmological dust would be too faint to be observed with current X-ray telescopes.

Ruderman worked on the following topics: (1) ''Propeller effect'' spin-down of ''magnetospheres'' (with Mori). One result is that canonicaly defined spin-down ages $(P/2\dot{P})$ jump to the times remaining before such spin-down is completed $(\sim 10^6 \mathrm{yr})$ a soon as propeller driven spin-down begns. Application will be made to RXJ 1856.6 as one among several such observed neutron star candidates. (2) Expected $e^{\pm}$ production in the closed mgnetospheres of pulsars with spin-down powers $\gtrsim 10^{34} \mathrm{ergs}^{-1}$, and how synchortron radiation from these pairs relates to observed low energy power law component X-rays from such pulsar. (3) Cyclotron resonance X-ray backscattering by such pairs of the thermal X-rays from the pulsar surfaces and its consequences for interpreting *ROSAT*, *Chandra*, and *XMM-Newton* observations. (4) Interpretaiton of the observed very large changes in the Crab pulsar's sub-pulse positions, number, and polarization at frequencies above 4 GHz as echoes from cyclotron resonance scattering by outer-magnetosphere protons and *alpha*-particles (with J. Cordes). (5) Effect on thermal X-ray and optical emission of the liquid metal (with very anisotropic properties) expected to form the surface of a spun-down magnetars with surface $B \sim 10^{15}$G.

Easther has focussed on inflation and the cosmological implications of string theory. In collaboration with B. Greene (Columbia Math Dept.), Kinney and G. Shiu (Wisconsin), he has worked on the possibility that string theory and/or quantum gravity may make subtle modifications to the standard inflationary predictions for the CMB spectrum. With Greene and Mark Jackson, he has examined the role of winding strings (fundamental strings that completely wrap a compact direction of the primordial universe) in determining the effective dimensionality of spacetime. Kinney, as a single author and in collaboration with Richard Easther, has begun an investigation of the "flow equation" formalism for inflation. Kinney and Easther have used this idea to develop Monte Carlo Reconstruction, a novel method for inverting observational constraints to learn about the physics responsible for inflation.

PUBLICATIONS

Agüeros, M.A., Helfand, D.J., & Gotthelf, E.V. 2002, "Detection of X-ray Emission from SNRG16.7+0.1," ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 241.

Alcock, C., Allsman, R., Alves, D. *et al.* 2002, "The MACHO Project Large Magellanic Cloud Variable Star Inventory. XII. Three Cepheid Variables in Eclipsing Binaries," ApJ, 573, 338.

Alcock, C., Allsman, R., Alves, D. *et al.* 2001, "Direct detection of a Microlens in the Milky Way," Nature, 414, 617.

Alcock, C., Allsman, R., Alves, D. *et al.* 2001, "Astrometry with the MACHO Data Archive. I. High Proper Motion Stars toward the Galactic Bulge and Magellanic Clouds," ApJ, 562, 337.

Alcock, C., Allsman, R., Alves, D. *et al.* 2001, "The MACHO Project: Microlensing Detection Efficiency," ApJS, 136, 439.

Alcock, C., Allsman, R., Alves, D. *et al.* 2001 "Erratum: The MACHO Project: Microlensing Optical Depth toward the Galactic Bulge from Difference Image Analysis," ApJ, 557, 1035.

Alves, D., Rejkuba, M., Minniti, D,. Cook, K. 2002, "K-Band Red Clump Distance to the Large Magellanic Cloud," ApJ, 573, L51.

Alves D., Bergier, A., Crotts, A., & Cseresnjes, P. 2002, "MEGA: Variable Stars in M31's Globular Clusters," in *New Horizons in Globular Cluster Astronomy*, eds. G. Piotto, G. Meylan, G. Djorgowski and M. Riello (San Francisco: ASP).

Alves D., Bergier, A., Crotts, A., & Cseresnjes, P. 2002, "Building the MEGA Image Subtraction Pipeline in the Era of Virtual Observatories," in *Toward an International Virtual Observatory*, eds. Gorski K.M., *et al.*, (Berlin: Springer-Verlag).

Aprile E., *et al.* 2002, "The LXeGRIT Compton Telescope Prototype: Current Status and Future Prospects," Proceedings SPIE, Conf. Vol. 4851 - 140.

Curioni A., *et al.* 2002, "On the Background Rate in the LXeGRIT Instrument during the 2000 Balloon Flight," Proceedings SPIE, Conf. Vol. 4851 - 151.

Aprile E., *et al.* 2002, "XENON: A 1 Tonne Liquid Xenon Experiment For a Sensitive Dark Matter Search," in Proc. of the International Workshop on Techniques and Applications of Xenon Detectors (Xenon02), Tokyo, astro-ph/0012276.

Asztalos, S.J., Gondolo, P., Kinney, W.H., & Schnee, R.W. 2001, "Dark Matter and Relic Particles," in Proceedings of Snowmass 2001, Snowmass, CO, in press.

Bacon, R., Copin, Y., Monnet, G., Miller, B.W., Allington-Smith, J.R., Bureau, M., Carollo, C.M., Davies, R.L., Emsellem, E., Kuntschner, H., Peletier, R.F., Verolme, E.K., & de Zeeuw, P.T. 2001, "The SAURON Project. I. The Panoramic Integral-Field Spectrograph," MNRAS, 326, 23.

Balcells, M., van Gorkom, J.H., Sancisi, R. & del Burgos, C. 2001, "HI in the Shell Elliptical Galaxy NGC 3656," AJ, 122, 1758.

Baltz, E.A., Gyuk, G., Crotts, A.P.S. 2002, "Event Rates and Timescale Distributions from Realistic Microlensing Models of M31," ApJ, in press.

Baltz, E.A., Edsjo, J., Freese, K. & Gondolo, P. 2001, "The Cosmic Ray Positron Excess and Neutralino Dark Matter," Phys. Rev. D, 65, 063511.

Baltz, E.A. & Gondolo, P. 2002, "Improved Constraints on Supersymmetric Dark Matter from Muon g-2," Phys. Rev. D, submitted.

Behar, E., Sako, M., & Kahn, S.M. 2001, "Soft X-Ray Absorption by Fe^{0+} to Fe^{15+} in Active Galactic Nuclei," ApJ, 563, 497.

Behar, E.& Netzer, H. 2002, "Inner-Shell 1s-2p Soft X-Ray Absorption Lines," ApJ, 570, 165.

Behar, E., Kinkhabwala, A., Sako, M., Paerels, F., Kahn, S.M., Brinkman, A.C., Kaastra, J., & van der Meer, R. 2002, "A Physically-Consistent Model for X-ray Emission by Seyfert 2 Galaxies Demonstrated using NGC 1068," ASP Conf. Ser. 255: Mass Outflow in Active Galactic Nuclei: New Perspectives, 43

Birch, A.C., Kosovichev, A.G., Spiegel, E.A., & Tao, L. 2001, "Resonant Vibrational Instabilities in Magnetized Stellar Atmospheres," Solar Phys., 199, 291-306.

Bloom, J.S., *et al.* 2002, "Detection of a Supernova Signature Associated with GRB011121," ApJL, 572, L45.

Blustin, A.J., Branduardi-Raymont, G., Behar, E., Kaastra, J.S., Kahn, S.M., Sako, M., & Steenbrugge, K.C. 2002, "Understanding the Soft X-ray Spectra of AGN," in *Proc. X-ray Spectroscopy of AGN with Chandra and XMM-Newton*, p. 31.

Boettcher, M., Mukherjee, R., & Reimer, A. 2002, "Predictions of the High-Energy Emission from BL Lac Objects: The Case of W Comae," 2002, ApJ, 581, 0000, in press.

Bond, H.E. & Alves, D.R. 2001, "Post-AGB Stars in Globular Clusters and Galactic Halos," in *Post-AGB Objects as a Phase of Stellar Evolution*, eds. R. Szczerba and S. K. Górny (Boston: Kluwer).

Branduardi-Raymont, G., Page, M.J., Sako, M., Kahn, S.M., Kaastra, J.S., & Brinkman, A.C. 2002, ''XMM-Newton RGS Observations of Soft X-ray Emission Lines from Relativistic Accretion Disks,'' ASP Conf. Ser. 255: Mass Outflow in Active Galactic Nuclei: New Perspectives, 31.

Bravo-Alfaro, H., Cayatte, V., van Gorkom, J.H., & Balkowski, C. 2001, ''VLA HI Imaging of the Brightest Spiral Galaxies in Coma. II. The HI Atlas and Deep Continuum Imaging of Selected Early Type Galaxies,'' A&A, 379, 347.

Bravo-Alfaro, H. van Gorkom, J. H., Cayatte, V., & Balkowski, C. 2001, ''Dynamics and Environmental Effects in Coma from a VLA HI Survey,'' in *Gas & Galaxy Evolution*, eds. J.E. Hibbard, M.P. Rupen, & J.H. van Gorkom, ASP Conf. Ser., 240, 626.

Brinkman, A.C., Kaastra, J.S., van der Meer, R.L.J., Kinkhabwala, D.A., Paerels, F., Kahn, S.M., & Sako, M. 2002, ''High Resolution X-ray Spectroscopy of NGC 1068 observed with RGS on XMM-Newton and LETGS on Chandra,'' in *Proc. X-ray Spectroscopy of AGN with Chandra and XMM-Newton*, p. 199.

Brisudova M., Kinney, W.H., & Woodard R., 2001, ''Homogeneous and Isotropic Charge Densities to Accelerate the Universe,'' Class. Quant. Grav., 18, 3929, gr-qc/0105072.

Brisudova M., Kinney, W.H., & Woodard R., 2002, ''Cosmology with a Long Range Repulsive Force'' Phys. Rev. D, 65 (2002) 103513, hep-ph/0110174.

Brown, G.V., Beiersdorfer, P., Liedahl, D.A., Widmann, K., Kahn, S.M., & Clothiaux, E.J. 2002, ''Laboratory Measurements and Identification of the Fe XVIII-XXIV L-Shell X-Ray Line Emission,'' ApJS, 140, 589.

Bureau, M. & Carignan, C. 2002, ''Environment, Ram Pressure, and Shell Formation in HoII,'' AJ, 123, 1316.

Bureau, M. 2002, ''Structure and Dynamics of Bulges,'' DDA, 33.0301.

Camilo, F., Manchester, R.N., Gaensler, B.M., & Lorimer, D.R. 2002, ''Heartbeat of the Mouse: a Young Radio Pulsar Associated with the Axisymmetric Nebula G359.23−0.82,'' ApJL, 579, L25.

Camilo, F., Lorimer, D.R., Bhat, N.D.R., Gotthelf, E.V., Halpern, J.P., Wang, Q.D., Lu, F.J., & Mirabal, N. 2002, ''Discovery of a 136 Millisecond Radio and X-Ray Pulsar in Supernova Remnant G54.1+0.3,'' ApJL, 574, L71.

Camilo, F., *et al.* 2002, ''Discovery of Radio Pulsations from the X-Ray Pulsar J0205+6449 in Supernova Remnant 3C58 with the Green Bank Telescope,'' ApJL, 571, L41.

Camilo, F., Manchester, R.N., Gaensler, B.M., Lorimer, D.R., & Sarkissian, J. 2002, ''PSRJ1124−5916: Discovery of a Young Energetic Pulsar in the Supernova Remnant G292.0+1.8,'' ApJL, 567, L71.

Chen, H. *et al.* 2002, ''Measurement of Emission Cross Sections for $n=3\rightarrow2$ Lines in Li-like Fe^{23+},'' ApJL, 567, L169.

Chen, X., Rao, H., & Spiegel, E.A. 2001, ''A Continuum Description of Rarefied Gas Dynamics. I. Derivation From Kinetic Theory,'' PRE, 64, 046308.

Chen, X., Rao, H., & Spiegel, E.A. 2001, ''A Continuum Description of Rarefied Gas Dynamics. II The Propagation of Ultrasound,'' PRE, 64, 046309.

Chen, X., Rao, H., & Spiegel, E.A. 2002, ''A Continuum Description of Rarefied Gas Dynamics. III The Structure of Shock Waves,'' PRE, 65, 0263.

Chen, X., & Spiegel, E.A. 2002, ''Continuum Equations for Rarefied Gases,'' in Proceedings ''Wascom 2002,'' 11th Conference on Waves and Stability in Continuous Media, eds. R. Monaco, M.P. Bianchi, & S. Rionero, (World Scientific: Singapore), p. 150-160.

Chen, X. & Spiegel, E.A. 2001, ''The Radiative Bulk Viscosity,'' MNRAS, 323, 865-871.

Chung, A., van Gorkom, J.H., O'Neil, K., & Bothun, G., 2002, ''Low Surface Brightness Galaxies and the Tully Fisher Relation,'' AJ, 123, 2387.

Collins, B.F., Gotthelf, E.V., & Helfand, D.J. 2002, ''Chandra X-ray Spectroscopy of Kes75, its Young Pulsar, and its Synchrotron Nebula,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 237.

Cottam, J., Paerels, F., & Mendez, M. 2002, ''Gravitationally Redshifted Absorption Lines in the X-ray Burst Spectra of a Neutron Star,'' Nature, in press.

Crawford, F., Gaensler, B.M., Kaspi, V.M., Manchester, R.N., Camilo, F., Lyne, A.G., & Pivovaroff, M.J. 2002, ''SNRG292.2−0.5: A Radio Supernova Remnant Associated with the Young Pulsar J1119−6127,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 41.

Crotts, A.P.S. 2002, ''Halo Microlensing in M31,'' in *The New Cosmology Confronts Observation: KITP CMB '02*, eds. K. Freese, M. Kamionkowski, J. Ruhl, & M. White, in press.

Cseresnjes, P., 2001, ''RR Lyrae Stars in the Sagittarius Dwarf Galaxy: Period Analysis,'' A&A, 375, 909.

D'Amico, N., Possenti, A., Fici, L., Manchester, R.N., Lyne, A.G., Camilo, F., & Sarkissian, J. 2002, ''Timing of Millisecond Pulsars in NGC6752: Evidence for a High Mass-to-Light Ratio in the Cluster Core,'' ApJL, 570, L89.

De Zeeuw, P.T., Bureau, M., Emsellem, E., Bacon, R., Carollo, C.M., Copin, Y., Davies, R.L., Kuntschner, H., Miller, B.W., Monnet, G., Peletier, R.F., & Verolme, E.K. 2002, ''The SAURON Project. II. Sample and Early Results,'' MNRAS, 329, 513.

Donahue, M., Scharf, C., Mack, J., Lee, P., Postman, M., Rosati, P., Dickinson, M, Voit, G.M., & Stocke, J., 2002, ''Distant Cluster Hunting. II. A Comparison of X-Ray and Optical Cluster Detection Techniques and Catalogs from the ROSAT Optical X-Ray Survey,'' ApJ, 569, 689.

Doron, R. & Behar, E. 2002, ''The X-Ray Spectrum of Fe^{16+} Revisited with a Multi-Ion Model,'' ApJ, 574, 518.

Easther, R. & Kinney, W.H. 2002, ''Monte Carlo Reconstruction of the Inflationary Potential,'' Phys. Rev. D., submitted, arXiv:astro-ph/0210345.

Easther, R., Greene, B.R., Kinney, W.H., & Shiu, G. 2002, ''A Generic Estimate of Trans-Planckian Modifications to the Primordial Power Spectrum in Inflation,'' Phys. Rev. D, 66, 023518, arXiv:hep-th/0204129.

Easther, R., Greene, B.R., & Jackson, M.G. 2002, ''Cosmological String Gas on Orbifolds,'' Phys. Rev. D 66, 023502, arXiv:hep-th/0204099.

Easther, R., Greene, B.R., Kinney, W.H., & Shiu, G. 2002, ''Imprints of Short Distance Physics on Inflationary Cosmology,'' Phys. Rev. D., submitted, arXiv:hep-th/0110226.

Easther, R., Greene, B.R., Kinney, W.H., & Shiu, G. 2001, ''Inflation as a Probe of Short Distance Physics,'' Phys. Rev. D, 64, 103502, arXiv:hep-th/0104102.

Edmonds, P.D., Gilliland, R.L., Camilo, F., Heinke, C.O., & Grindlay, J.E. 2002, ''A Millisecond Pulsar Optical Counterpart with Large-Amplitude Variability in the Globular Cluster 47 Tucanae,'' ApJ, in press (astro-ph/0207426).

Eracleous, M., Halpern, J.P., & Charlton, J.C. 2002, ''The *ASCA* X-ray Spectrum of Arp 102B and Evaluation of Simple Models for its Associated Metastable Fe II Absorber,'' ApJ, in press (astro-ph/0209341).

Frail, D.A., *et al.* 2002, ''GRB010222: A Burst within a Starburst,'' ApJ, 565, 829.

Gezari, S., Ghez, A.M., Becklin, E.E., Larkin, J., McLean, I.S., & Morris, M. 2002, ''Adaptive Optics Near-Infrared Spectroscopy of the Sagittarius A* Cluster,'' ApJ, 576, 790.

Gorczyca, T.W., Badnell, N.R., & Savin, D.W. 2002, ''Shortcomings of the *R*-Matrix Method for Treating Dielectronic Recombination,'' Phys. Rev. A, 65, 062707.

Gotthelf, E.V., Halpern, J.P., & Dodson, R. 2002, ''Detection of Pulsed X-Ray Emission from PSR B1706−44,'' ApJL, 567, L125.

Gotthelf, E.V., Gavriil, F.P., Kaspi, V.M., Vasisht, G., & Chakrabarty, D. 2002, ''A Phase-connected Timing Solution for the Magnetar Candidate 1E1841−045,'' ApJL, 564, L31.

Gotthelf, E.V., Zhang, W., Marshall, F.E., Middleditch, J., & Wang, Q.D. 2002, ''Hiccups in the Night: X-ray Monitoring of the Two Crab-like LMC Pulsars,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 365.

Gotthelf, E.V., Gavriil, F.P., Kaspi, V.M., Vasisht, G., & Chakrabarty, D. 2002, ''15 Years Going Steady – Timing the Magnetar 1E1841−045,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 309.

Gotthelf, E.V. & Olbert, C.M. 2002, ''Chandra Spectroscopy of Pulsars and their Wind Nebulae,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 171.

Gotthelf, E.V.& Olbert, C.M. 2002, ''From Pulsar Spin to Pulsar Wind: The Spectral Connection?'' Neutron Stars, Pulsars, and Supernova Remnants, 159.

Gregg, M.D., Lacy, M., White, R.L., Glikman, E., Helfand, D., Becker, R.H., & Brotherton, M.S. 2002, ''The Reddest Quasars,'' ApJ, 564, 133.

Grindlay, J.E., Camilo, F., Heinke, C.O., Edmonds, P.D., Cohn, H., & Lugger, P. 2002, ''Chandra Study of a Complete Sample of Millisecond Pulsars in 47 Tuc and NGC6397,'' ApJ, in press (astro-ph/0208280).

Grindlay, J.E., Heinke, C.O., Edmonds, P.D., & Camilo, F. 2002, ''Chandra on Millisecond Pulsars in Globular Clusters,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 343.

Gu, M.F., Kahn, S.M., Savin, D.W., Behar, E., Beiersdorfer, P., Brown, G.V., Liedahl, D.A., & Reed, K.J. 2001, ''Laboratory Measurements of Iron L-Shell Emission: 3 →2 Transitions of Fe XXI-XXIV between 10.5 and 12.5 Å ,'' ApJ, 563, 462.

Hailey, C.J., Christensen, F.E., Craig, W.W., Harrison, F.A., J. Koglin, J., Peter, R., Zhang, W.W., & D.L. Windt 2002, ''Overview of Segmented Glass Optics Development for the Constellation-X Hard X-ray Telescope,'' in *X-ray and Gamma-ray Telescopes and Instruments for Astronomy*, SPIE 4851-59, in press.

Halpern, J.P., Gotthelf, E.V., Mirabal, N., & Camilo, F. 2002, ''The Next Geminga: Deep Multiwavelength Observations of a Neutron Star Identified with 3EGJ1835+5918,'' ApJL, 573, L41.

Halpern, J.P., Eracleous, M., Mukherjee, R., & Gotthelf, E.V. 2002, ''Erratum: ''3EGJ2016+3657: Confirming an EGRET Blazar behind the Galactic Plane'' (ApJ, 551, 1016 [2001]),'' ApJ, 572, 693.

Halpern, J.P., Gotthelf, E.V., Camilo, F., Collins, B., & Helfand, D.J. 2002, ''The New Gamma-ray Pulsar PSR J2229 +6114, its Pulsar Wind Nebula, and Comparison with the Vela Pulsar,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 199.

Hands, A., Warwick, R., Watson, M., & Helfand, D.J. 2002, ''The Galactic Plane Observed by XMM-Newton,'' in *New Visions of the X-ray Universe in the XMM-Newton and Chandra Era*, in press (astro-ph/0202180).

Helfand, D.J., Collins, B.F., & Gotthelf, E.V. 2002, ''Chandra X-ray Imaging Spectroscopy of the Young Supernova Remnant Kesteven 75,'' ApJ, in press (astro-ph/0209348).

Helfand, D.J. 2001, ''High-Energy Astronomy: 60 New Octaves of Discovery Space,'' PASP, 113, 1159.

Hibbard, J.E., van Gorkom, J.H., Rupen, M.P., & Schiminovich, D., 2001, ''An HI Rogues Gallery,'' in *Gas & Galaxy Evolution*, eds. J.E. Hibbard, M.P. Rupen, & J.H. van Gorkom, ASP Conf. Ser., 240, 657.

Hjorth, J., *et al.* 2002, ''The Afterglow and Complex Environment of the Optically Dim Burst GRB980613,'' ApJ, 576, 113.

Hobbs, G., *et al.* 2002, ''A Very Large Glitch in PSRJ1806 −2125,'' MNRAS, 333, L7.

Hoffman, G.L. & van Gorkom, J.H. 2001, ''The Fine Structure of DDO 154,'' in *Gas & Galaxy Evolution*, eds. J.E. Hibbard, M.P. Rupen, & J.H. van Gorkom, ASP Conf. Ser., 240, 290.

Hong, J., Craig, W.W., Graham, P., Hailey, C.J., Spooner, N.J.C., & Tovey, D.R. 2002, ''The Scintillation Efficiency of Carbon and Hydrogen Recoils in an Organic Liquid Scintillator for Dark Matter Searches,'' AstroParticle Physics, 16, 333.

Horellou, C., Black, J.H., van Gorkom, J.H., Combes, F., van der Hulst, J.M., & Charmandaris, V. 2001, ''Atomic and Molecular Gas in the Merger Galaxy NGC 1316 (Fornax A) and its Environment,'' A&A, 198, 3608.

Hui, L. & Kinney, W.H., 2002, ''Short Distance Physics and the Consistency Relation for Scalar and Tensor Fluctuations in the Inflationary Universe'' Phys. Rev. D, 65, 103507, astro-ph/0109107.

Jackson, M.S., Halpern, J.P., Gotthelf, E.V., & Mattox, J.R. 2002, ''A High-Energy Study of the Geminga Pulsar,'' ApJ, 578, 935.

Jernigan, J.G., Peterson, J.R., Kahn, S.M., & Paerels, F.B.S. 2001, ''Emission Measure Imaging of Hot Gas in X-ray

Clusters,'' in Two Years of Science with Chandra, Abstracts from the Symposium held in Washington, DC, 5-7 September, 2001, p. 32.

Jimenez-Garate, M.A., Hailey, C.J., den Herder, J.W., Zane, S. & Ramsay, G. 2002, ''High Resolution X-ray Spectroscopy of Her X-1 with XMM-Newton RGS: CNO Element Abundance Measurements and Density Diagnostics of a Photoionized Plasma,'' ApJ, 578, 391.

Jimenez-Garate, M.A., Hailey, C.J., Craig, W.W., & Christensen, F.E. 2002, ''Thermal Forming of Glass Microsheets for X-ray Telescope Mirror Segments,'' Applied Optics, in press.

Kaastra, J.S., Steenbrugge, K.C., Raassen, A.J.J., van der Meer, R.L.J., Brinkman, A.C., Liedahl, D.A., Behar, E., & de Rosa, A. 2002, ''X-ray Spectroscopy of NGC 5548,'' A&A, 386, 427.

Kahn, S.M. *et al.* 2002, ''The Complex Soft X-ray Spectral Structure of MCG-6-30-15 and Mrk 766,'' in *Proc. X-ray Spectroscopy of AGN with Chandra and XMM-Newton*, p. 1.

Kaplan, D.L., Fox, D.W., Kulkarni, S.R., Gotthelf, E.V., Vasisht, G., & Frail, D.A. 2002, ''Precise Chandra Localization of the Soft Gamma-Ray Repeater SGR1806−20,'' ApJ, 564, 935.

Kaspi, V.M., Gotthelf, E.V., Gaensler, B.M., & Lyutikov, M. 2001, ''X-Ray Detection of Pulsar PSRB1757−24 and Its Nebular Tail,'' ApJL, 562, L163.

Kaspi, V.M., Roberts, M.E., Vasisht, G., Gotthelf, E.V., Pivovaroff, M., & Kawai, N. 2001, ''Chandra X-Ray Observations of G11.2−0.3: Implications for Pulsar Ages,'' ApJ, 560, 371.

Kaspi, V.M., Gotthelf, E.V., Gaensler, B.M., & Lyutikov, M. 2002, ''X-ray Detection of PSRB1757−24 and its Nebular Tail,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 233.

Kaspi, V.M.& Helfand, D.J. 2002, ''Constraining the Birth Events of Neutron Stars,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 3.

Keck, J.W. *et al.* 2001, ''Long-Term Multiwavelength Observations of GRS 1758-258 and the Advection-dominated Accretion Flow Model,'' ApJ, 563, 301.

Kemp, J., *et al.* 2002, ''Rapid Oscillations in Cataclysmic Variables. XV. HT Camelopardalis,'' PASP, 114, 623.

Kinkhabwala, A. et al. 2002, ''XMM-Newton Reflection Grating Spectrometer Observations of Discrete Soft X-Ray Emission Features from NGC 1068,'' ApJ, 575, 732.

Kinkhabwala, A., Sako, M., Behar, E., Paerels, F., & Kahn, S.M. 2001, ''X-ray Spectroscopy of Seyfert 2 Galaxies,'' in Two Years of Science with Chandra, Abstracts from the Symposium held in Washington, DC, 5-7 September, 2001, p. 57.

Kinney, W.H., 2002, ''Inflation: Flow, Fixed points and Observables to Arbitrary Order in Slow Roll,'' Phys. Rev. D, 66, 083508, astro-ph/0206032.

Kishimoto, M., Kay, L., Antonucci, R., Hurt, T., Cohen, R., & Krolik, J. 2002, ''UV Imaging Polarimetry of the Peculiar Seyfert 2 Galaxy Mrk 477,'' ApJ, 567, 790.

Kishimoto, M., Kay, L.,Antonucci, R., Hurt, T., Cohen, R., & Krolik, J. 2002, ''UV Imaging Polarimetry of the Seyfert 2 Galaxy Mrk 3,'' ApJ, 565, 155.

Koglin, J., Christensen, F.E., Craig, W.W., Hailey, C.J., Jensen, C.P., Sileo, M., & Windt, D.L. 2002, ''Development and Production of Hard X-ray Multilayer Optics for HEFT,'' in *X-ray and Gamma-ray Telescopes and Instruments for Astronomy*, SPIE, 4851-67, in press.

Krajnovic, D., Bacon, R., Bureau, M., Carollo, C.M., Copin, Y., Davies, R.L., Emsellem, E., Kuntschner, H., McDermid, R., Miller, B.W., Monnet, G., Peletier, R.F., Verolme, E.K., & de Zeeuw, P.T. 2001, ''Ionized Gas in Spheroids: The SAURON Survey,'' in *The Central Kpc of Starbursts and AGN: The La Palma Connection*, eds. J.H. Knapen, J.E. Beckman, I. Shlosman, & T.J. Mahoney (San Francisco: ASP), 699.

Kuntschner, H., Davies, R.L., McDermid, R.M., Peletier, R.F., Bureau, M., Copin, Y., Verolme, E.K., de Zeeuw, P.T., Bacon, R., Emsellem, E., Carollo, C.M., Miller, B.W., Monnet, G. 2001, ''SAURON: A Panoramic View of the Stellar Populations and Dynamics in Nearby Galaxies,'' AGM, 18, MS 05 03.

Lacy, M., Gregg, M., Becker, R.H., White, R.L., Glikman, E., Helfand, D., & Winn, J.N. 2002, ''The Reddest Quasars. II. A Gravitationally Lensed FeLoBAL Quasar,'' AJ, 123, 2925.

Li, Y. & van Gorkom, J.H. 2001, ''Multiphase ISM of NGC 4406,'' in Gas and Galaxy Evolution, eds J. Hibbard, M.P. Rupen, & J.H. van Gorkom, ASP Conf. Ser., 240, 625.

Li, Y., Gu, M.F., & Kahn, S.M. 2001, ''Spectroscopic Signatures of Conduction-mediated Transition Layers above an X-ray-illuminated Disk,'' ApJ, 560, 644.

Liedahl, D.A., Sako, M., Kahn, S.M., & Paerels, F. 2001, ''Silicon Ion Fluorescence Spectra in Vela X-1 and Cygnus X-3,'' in Two Years of Science with Chandra, Abstracts from the Symposium held in Washington, DC, 5-7 September, 2001, p. 124.

Lorimer, D.R., Camilo, F., & Xilouris, K.M. 2002, ''Arecibo Timing Observations of 17 Pulsars along the Galactic Plane,'' AJ, 123, 1750.

Manchester, R.N., *et al.* 2002, ''Young Pulsars from the Parkes Multibeam Pulsar Survey and their Associations,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 31.

Mazzotta, P., Kaastra, J.S., Paerels, F.B., Ferrigno, C., Colafrancesco, S., Mewe, R., & Forman, W.R. 2002, ''Evidence for a Heated Gas Bubble inside the 'Cooling Flow' Region of MKW 3s,'' ApJL, 567, L37.

McLin, K.M., Stocke, J., Penton, S.V., Weyman, R.J., & van Gorkom, J.H. 2001, ''Search for a Relationship Between Galaxies and the Local Lya Forest: First Results,'' in *Gas & Galaxy Evolution*, eds. J.E. Hibbard, M.P. Rupen and J.H. van Gorkom, ASP Conf. Ser., 240, 74.

Mirabal, N., *et al.* 2002, ''Time-Dependent Optical Spectroscopy of GRB 010222: Clues to the GRB Environment,'' ApJ, 578, 818.

Mirabal, N., Paerels, F., & Halpern, J. 2002, ''High Resolution Spectroscopy of GRB020405 with the Chandra LETGS,'' ApJ, submitted.

Mori, K. & Hailey, C. 2002, ''Atomic Calculation for the

Atmosphere of Strongly Magnetized Neutron Stars,'' ApJ, 564, 914.

Mori, K., Hailey, C.J., Baltz, E.A., Craig, W.W., Kamionkowski, M., Serber, W.T., & Ullio, P. 2002, ''A Novel Antimatter Detector Based on the Deexcitation of Exotic Atoms,'' ApJ 566, 604.

Mori, K. & Hailey, C. 2002, ''Evidence for a Mid-Atomic Number Atmosphere in the Neutron Star 1E1207.4-5209,'' ApJL 578, L133.

Morris, D.J., *et al.* 2002, ''The Parkes Multibeam Pulsar Survey – II. Discovery and Timing of 120 Pulsars,'' MNRAS, 335, 275.

Mukherjee, R. 2002, ''Results on High Energy Emission from Blazars,'' Proceedings of the XXII Moriond Astrophysics Meeting *The Gamma-Ray Universe*, eds. A. Goldwurm, D. Neumann, and J. Tran Thanh Van, The Gioi Publishers.

Mukherjee, R., Halpern, J., Mirabal, N., & Gotthelf, E.V. 2002, ''Is the EGRET Source 3EGJ1621+8203 the Radio Galaxy NGC6251?'' ApJ, 574, 693.

Olbert, C.M., Keohane, J.W., Arnaud, K.A., Dyer, K.K., Reynolds, S.P., & Safi-Harb, S. 2002, ''A New Compact Object / Supernova Remnant Association in SNR 3C396,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 225.

Paparella, F., Spiegel, E.A., & Talon, S. 2002, ''Shear and Mixing in Doubly Diffusive Convection,'' Geoph. & Astrophys. Fluid Dyn., 96, 271.

Patterson, J., *et al.* 2002, ''Superhumps in Cataclysmic Binaries. XXIII. RX1643+34 and V442 Ophiuchi,'' PASP, in press.

Patterson, J., *et al.* 2002, ''The 2001 Superoutburst of WZ Sagittae,'' PASP, 114, 721.

Patterson, J., *et al.* 2002, ''Superhumps in Cataclysmic Binaries. XXI. HP Librae,'' PASP, 114, 65.

Patterson, J. 2001, ''Accretion-Disk Precession and Substellar Secondaries in Cataclysmic Variables,'' PASP, 113, 736.

Peletier, R.F., Bacon, R., Bureau, M., Cappellari, M., Copin, Y., Davies, R.L., Emsellem, E., Falcon-Barroso, J., Krajnovic, D., Kuntschner, H., McDermid, R., Miller, B.W., Verolme, E.K., Wernli, F., & de Zeeuw, P.T. 2001, ''The SAURON Survey of Early-Type Galaxies in the Nearby Universe,'' ING Newsletter, 5, 5.

Perlman, E., Horner, D., Jones, L., Scharf, C., Ebeling, E., Wegner, G., & Malkan, M. 2002, ''The WARPS Survey. VI. Galaxy Cluster and Source Identifications from Phase I,'' ApJS, 140, 265.

Poggianti, B.M. & van Gorkom, J.H. 2001, ''Environmental Effects on Gas and Galaxy Evolution in Clusters,'' in *Gas & Galaxy Evolution*, eds J.E. Hibbard, M.P. Rupen, & J.H. van Gorkom, ASP Conf. Ser., 240, 589.

Popowski, P. *et al.* 2002, ''MACHO Project Analysis of the Galactic Bulge Microlensing Events with Clump Giants as Sources,'' in *Astrophysical Ages and Times Scales*, eds. T. von Hippel, C. Simpson, and N. Manset (San Francisco: ASP) (astro-ph/0202502).

Provenzale, A., Spiegel, E.A., & Toniolo, C. 2002, ''Diagnosing the On-Off Syndrome,'' Phys. Rev. E, in press.

Raassen, A.J.J. et al. 2002, ''High-Resolution X-ray Spectroscopy of Procyon by Chandra and XMM-Newton,'' A&A, 389, 228.

Ramsay, G., Zane, S., Jimenez-Garate, M., den Herder, J.W. & Hailey, C.J. 2002, ''XMM-Newton EPIC Observations of Her X-1,'' MNRAS, in press, astro-ph 0209020.

Rasmussen, A.P., Paerels, F., Kahn, S.M., den Herder, J.W., & de Vries, C. 2002, ''Detection of Intergalactic OVII and OVIII Resonance Absorption Lines with the Reflection Grating Spectrometer on XMM-Newton,'' ApJ, submitted.

Roberts, M.S.E., Tam, C., Kaspi, V.M., Lyutikov, M., Gotthelf, E.V., Vasisht, G., & Kawai, N. 2002, ''The Pulsar Wind Nebula of G11.2−0.3,'' ASP Conf. Ser. 271: Neutron Stars in Supernova Remnants, 229.

Rolfe, D.J., Haswell, C.A., & Patterson, J. 2001,''Late Superhumps and the stream-disc impact in IY UMa,'' MNRAS, 324, 529.

Sakelliou, I. *et al.* 2002, ''High Resolution Soft X-ray Spectroscopy of M87 with the Reflection Grating Spectrometers on XMM-Newton,'' A&A, 391, 903.

Sako, M. *et al.* 2002, ''Soft X-ray Spectra of Seyfert 2 Galaxies,'' in *Proc. X-ray Spectroscopy of AGN with Chandra and XMM-Newton,* p. 191.

Savin, D.W., Kahn, S.M., Linkemann, J., Saghiri, A.A., Schmitt, M., Grieser, M., Repnow, R., Schwalm, D., Wolf, A., Bartsch, T., Müller, A., Schippers, S., Chen, M H., Badnell, N.R., Gorczyca, T.W., & Zatsarinny, O. 2002, ''Dielectronic Recombination of Fe XIX forming Fe XVIII: Laboratory Measurements and Theoretical Calculations,'' ApJ, 576, 1098.

Savin, D.W. 2002, ''Rate Coefficients for $D(1s)+H^+ \rightleftharpoons D^+ + H(1s)$ Charge Transfer and Some Astrophysical Implications,'' ApJ, 566, 599.

Savin, D.W., Behar, E., Kahn, S.M., Gwinner, G., Saghiri, A.A., Schmitt, M., Grieser, M., Repnow, R., Schwalm, D., Wolf, A., Bartsch, T., Müller, A., Schippers, S., Badnell, N.R., Chen, M.H., & Gorczyca, T.W. 2002, ''Dielectronic Recombination (via $2\rightarrow2$ core excitations) and Radiative Recombination onto Fe XX: Laboratory Measurements and Theoretical Calculations,'' ApJS, 138, 337.

Savin, D.W., & Laming, J.M. 2002, ''Uncertainties in Dielectronic Recombination Rates: Effects on Solar and Stellar Upper Atmosphere Abundance Determinations,'' ApJ, 566, 1166.

Scharf, C. & Mukherjee, R., 2002., ''A Statistical Detection of Gamma-Ray Emission from Galaxy Clusters: Implications for the Gamma-Ray Background and Structure Formation,'' ApJ, 580, 0000, in press.

Scharf, C., 2002, ''Optimal Chandra and XMM-Newton Bandpasses for Detecting Low-Temperature Groups and Clusters of Galaxies,'' 2002, ApJ, 572, 157.

Schurch, N.J., Warwick, R.S., Kinkhabwala, A., Griffiths, R.E., & Kahn, S.M. 2002, ''Probing the Ionization Structure of the Extended NLR in NGC 4151,'' in *Active Galactic Nuclei: from Central Engine to Host Galaxy Abstract Book*, eds. S. Collin, F. Combes and I. Shlosman. To be published in ASP (Astronomical Society of the Pacific), Conference Series, p. 31.

Skillman, D.R., *et al.* 2002, ''Superhumps in Cataclysmic

Binaries. XXII. 1RXS J232953.9+062814,'' PASP, 114, 630.

Slane, P.O., Helfand, D.J., & Murray, S.S. 2002, ''New Constraints on Neutron Star Cooling from Chandra Observations of 3C58,'' ApJL, 571, L45.

Spiegel, E.A. & Thiffeault, J.-L. 2002, ''Equations of Motion for Stellar Dynamics,'' Astrophysical Fluid Dynamics; *Gough Festschrift*, in press.

Splaver, E.M., Nice, D.J., Arzoumanian, Z., Camilo, F., Lyne, A.G., & Stairs, I.H. 2002, ''Probing the Masses of the PSRJ0621+1002 Binary System Through Relativistic Apsidal Motion,'' ApJ, in press (astro-ph/0208281).

Steenbrugge, K.C. *et al.* 2002, ''X-Ray Spectral Study of NGC 4593,'' in *Proc. X-ray Spectroscopy of AGN with Chandra and XMM-Newton*, p. 295.

Stern, D., *et al.* 2002, ''Chandra Detection of a Type II Quasar at $z=3.288$,'' ApJ, 568, 71.

Sugerman, B.E.K., Lawrence, Stephen S., Crotts, A.P.S., Bouchet, P., Heathcote, S.R. 2002, ''Evolution and Geometry of Hot Spots in Supernova Remnant 1987A'' ApJ, 572, 209.

Sugerman, B.E.K., Lawrence, S.S., Crotts, A.P.S., Garnavich, P.M., Kirshner, R.P., Challis, P., Supernova INtensive Studies (SINS) Collaboration 2002, ''Evolution of Hot Spots in Supernova Remnant 1987A,'' BAAS, 200, 78.05.

Sugerman, B.E.K., Crotts, A.P.S. 2002, ''Multiple Light Echoes from Supernova 1993J,'' ApJL, in press.

Telis, G., Petric, A., Paerels, F., & Helfand, D.J., 2002, A Direct Upper Limit on the Density of Cosmological Dust from the Absence of an X-ray Scattering Halo around the $z=4.3$ Quasar QSO 1508+5714,'' ApJL, submitted.

Thieberger, R. & Spiegel, E.A. 2002, ''Luminosity Effects in Projected Fractals,'' Bull. Indian Astr. Soc., 30, 461-471.

Thorstensen, J.R., Fenton, W.H., Patterson, J., Kemp, J., Halpern, J., & Baraffe, I. 2002, ''QZ Serpentis: A Dwarf Nova with a 2 Hour Orbital Period and an Anomalously Hot, Bright Secondary Star,'' PASP, 114, 1117.

Thorstensen, J.R., Patterson, J., Kemp, J., & Vennes, S. 2002, ''The Dwarf Novae of Shortest Period,'' PASP, 114, 1108.

Thorstensen, J.R. *et al.* 2002, ''1RXS J232953.9+062814: A Dwarf Nova with a 64 Minute Orbital Period and a Conspicuous Secondary Star,'' ApJL, 567, L49.

Van der Heyden, K., Behar, E., Vink, J., Rasmussen, A., Kaastra, J., Bleeker, J., Kahn, & S., Mewe, R. 2002, ''High-Resolution X-ray Imaging and Spectroscopy of SNR N103B'' A&A, 392, 955.

Ban der Marel, R., Alves, D., Hardy, E., & Suntzeff, N. ''New Understanding of Large Magellanic Cloud Structure, Dynamics and Orbit from Carbon Star Kinematics,'' AJ (accepted) astro-ph/0205161.

Verolme, E.K., Cappellari, M., Copin, Y., van der Marel, R.P., Bacon, R., Bureau, M., Davies, R.L., Miller, B.M., & de Zeeuw, P.T. 2002, ''A SAURON Study of M32: Measuring the Intrinsic Flattening and the Central Black Hole Mass,'' MNRAS (accepted) astro-ph/0201086.

Vink, J., Laming, M., Kaastra, J., Bleeker, J., Bloemen, H., & Oberlack, U. 2001, ''Detection of the 67.9 keV and 78.4 keV Lines A Associated with the Radio-active Decay of ^{44}Ti in Cassiopeia A,'' ApJL, 560, L79.

Wallace, P.M., Halpern, J.P., Magalhães, A.M., & Thompson, D.J. 2002, ''An Active Galactic Nucleus Identification for 3EGJ2006−2321,'' ApJ, 569, 36.

Wang, Q.D., Gotthelf, E.V., & Lang, C.C. 2002, ''A Faint Discrete Source Origin for the Highly Ionized Iron Emission from the Galactic Centre Region,'' Nature, 415, 148.

Welch, D. *et al.*, 2002, ''Frequency Analysis of a Subset of Fundamental Mode RR Lyrae Stars from the MACHO Project Large Magellanic Cloud Database,'' in *Radial and Nonradial Pulsations as Probes of Stellar Physics*, eds. C. Aerts, T. Beding, & J. Christensen-Dalsgaard (San Francisco: ASP).

Willingale, R., Bleeker, J., van der Heyden, K., Kaastra, J., & Vink J., 2002, ''X-Ray Spectral Imaging and Doppler Mapping of Cassiopeia A,'' A&A, 382, 1039.

Windt, D.L. 2002, ''The Feasibility of Detecting 'Cosmological' Gray Dust,'' ApJL, 564, L61-64.

Windt, D.L., Gullikson, E.M., & Walton, C.C. 2002, ''Normal-Incidence Reflectance of Optimized W/B4C Multilayers in the Tange 1.4 nm - 2.4 nm,'' Opt. Lett., in press.

Windt., D.L., Kahn, S.M., & Sommargren, G.E. 2002, ''Diffraction-Limited Astronomical X-Ray Imaging and X-Ray Interferometry Using Normal-Incidence Multilayer Optics,'' Proc. SPIE., 4851, in press.

Windt, D.L., Donguy, S., Hailey, C.J., Koglin, J., Honkimaki, V., Ziegler, E., Christensen, F.E., Chen, C.M.H., Harrison, F.A., & Craig, W.W. 2002, ''W/SiC X-Ray Multilayers Optimized for Use Above 100 keV,'' Proc. SPIE, 4851, in press.

Yecko, P., Zaleski, S. & Fullana, J.-M. 2002, ''Viscous Modes in Two-Phase Mixing Layers,'' Phys. Fluids 14(12), 4115.

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