NASA's Goddard Space Flight Center
Laboratory for High Energy Astrophysics
Greenbelt, Maryland 20771

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This report covers the period from July 1, 1998 to June 30, 1999.

This Laboratory's scientific research is directed toward experimental and theoretical research in the areas of X-ray, gamma-ray, and cosmic-ray astrophysics. The range of interests of the scientists includes the Sun and the solar system, stellar objects, binary systems, neutron stars, black holes, the interstellar medium, normal and active galaxies, galaxy clusters, cosmic ray particles, gravitational wave astrophysics, and the extragalactic background radiation. Scientists and engineers in the Laboratory also serve the scientific community, including project support such as acting as project scientists and providing technical assistance to various space missions. Also at any one time, there are typically between twelve and eighteen graduate students involved in Ph.D. research work in this Laboratory. Currently these are graduate students from Catholic U., Stanford U., and the U. of Maryland.

1. PERSONNEL

Dr. Jonathan F. Ormes is the Chief of the Laboratory for High Energy Astrophysics. Dr. Neil Gehrels is Head of the Gamma Ray & Cosmic Ray Astrophysics Branch and Dr. Nicholas White is Head of the X-Ray Astrophysics Branch.

The civil service scientific staff includes: Drs. Louis Barbier, David Bertsch, Elihu Boldt, Kevin Boyce, Thomas Cline, Alice Harding, Robert Hartman, Stanley Hunter, Keith Jahoda, Frank Jones, Timothy Kallman, Demosthenes Kazanas, Richard Kelley, Frank Marshall, John Mitchell, Richard Mushotzky, Jay Norris, Ann Parsons, William Pence, Robert Petre, F. Scott Porter, Reuven Ramaty, Donald Reames, Steven Ritz, Peter Serlemitsos, Caroline Stahle, Floyd Stecker, Robert Streitmatter, Tod Strohmayer, Jean Swank, Andrew Szymkowiak, Bonnard Teegarden, David Thompson, Jack Tueller, Tycho von Rosenvinge, Kim Weaver, and William Zhang.

The following scientists are National Research Council Associates: Drs. Bram Boroson, Andrew Chen, Philip Deines-Jones, Pranab Ghosh, Taro Kotani, Gabriela Marani, Craig Markwardt, Sandor Molnar, Sergei Nayakshin, Daniel Proga, Brigitte Ragot, Samar Safi-Harb, Sean Scully, Yuichi Terashima, and Bing Zhang.

The following researchers are University Space Research Association Scientists: Drs. Glenn Allen, Lorella Angelini, Matthew Baring, Scott Barthelmy, Kevin Black (SAC), Jerry Bonnell, Patricia Boyd, William Bridgman, John Cannizzo, Kai-Wing Chan, Eric Christian, Robin Corbet, Michael Corcoran, Seth Digel, Joseph Dodoo, Stephen Drake, Ken Ebisawa, Ian George, Michael Harris, John Krizmanic, James Lochner, Daryl Macomb, Natalie Mandzhavidze, Thomas McGlynn, Alex Moiseev, Koji Mukai, Kirpal Nandra, David Palmer, Sangwook Park, Chris Shrader, Alan Smale, Steven Snowden, Yang Soong, Martin Still, Steve Sturner, Toshiaki Takeshima, Ken Watanabe, Laura Whitlock, and Tahir Yaqoob.

The following investigators are University of Maryland Scientists: Drs. Keith Arnaud, Damian Audley, Manuel Bautista, Wan Chen, Edward Colbert, Fred Finkbeiner, Keith Gendreau, Una Hwang, Michael Loewenstein, Greg Madejski, Chee Ng, Andrew Peele, Ian Richardson, David Smith, Michael Stark, Jane Turner (UMBC), and Azita Valinia.

Visiting scientists from other institutions: Drs. Vadim Arefiev (IKI), Hilary Cane (U. Tasmania), Peter Gonthier (Hope College), Thomas Hams (U. Seigen), Donald Kniffen (Hampden-Sydney College), Benzion Kozlovsky (U. Tel Aviv), Hideyo Kunieda (Nagoya U.), Eugene Loh (U. Utah), Masaki Mori (Miyagi U.), Robert Nemiroff (Mich. Tech. U.), Hagai Netzer (U. Tel Aviv), Yasushi Ogasaka (JSPS), Lev Titarchuk (George Mason U.), Alan Tylka (NRL), Robert Warwick (U. Leicester) and Andrzej Zdziarski (Copernicus Astr. Cen.).

Graduate Students doing their thesis research in this Laboratory are: from the U. of Maryland, Wayne Baumgartner, Frederick Berendse, Jennifer Catelli, Warren Focke, Sven Geier, Donald Horner, Alaa Ibrahim, Safraz Ishmael, Kip Kuntz, Peter Kurczynski, Barbara Mattson, Jason Taylor, and Dusan Turcan; from Catholic U., Charles Hall; and from Stanford U., Enectali Figueroa-Feliciano.

2. RESEARCH PROGRAMS

2.1 Sun and Solar System

Drs. Mandzhavidze and Ramaty, in collaboration with Prof. B. Kozlovsky (Tel Aviv U.), investigated solar abundances using gamma ray spectroscopy. They showed that there is evidence for the existence of chromospheric regions with enhanced He abundance, by as much as a factor of 2 over the photospheric value. The origin of this phenomenon, which has also been seen in solar wind data, is not well understood. They also showed that there is evidence in the gamma ray data for accelerated He-3 enhancements, a phenomenon that is characteristic of stochastic acceleration in impulsive flares. The gamma ray data thus complements the solar energetic particle data, which routinely shows the He-3 enhancements associated with impulsive flares.

Drs. Cane and Richardson have used observations from the Goddard particle detectors on IMP 8 to investigate near-Earth interplanetary disturbances and the associated solar events in January-May, 1997. All five energetic particle enhancements during this period followed halo CMEs observed by the SOHO LASCO coronagraph. The other $\sim$ 120 CMEs observed were not associated with particle events at Earth. The particle events exceeding 10 MeV were accompanied by X-ray and $H\alpha$ flares, and metric type II/IV radio emission. Around 80% of the Earthward-directed halo CMEs during this period produced cosmic ray density depressions at Earth

3-4 days later as CME-associated material passed Earth. Drs. Cane, Richardson and von Rosenvinge noted a ~ 153 day periodicity in the interplanetary magnetic field intensity during 1978-1982 which is related to the similar periodicity found in solar flare, sunspots and solar energetic particle events. This periodicity is not present at other times between 1963 and 1997, suggesting that it is not indicative of a solar ''clock'' mechanism.

Drs. Cane, Richardson, and von Rosenvinge have re-examined the cause of medium (~ 1 year) and long-term (22-year) galactic cosmic ray density modulations in the heliosphere and find that variations in the cosmic ray density measured by neutron monitors over a 22-year period are tracked by the inverted profile of the interplanetary magnetic field. These variations in the field strength originate in the solar magnetic field, as indicated by the open magnetic flux calculated from photospheric observations, and propagate away from the Sun throughout the heliosphere at the solar wind speed. They are not related to variations in the rate of coronal mass ejections (CMEs). Medium/long-term cosmic ray modulation is apparently caused by diffusive barriers formed by enhancements in the solar global magnetic field which surround the Sun and move outward from the Sun. This is contrary to the currently accepted paradigm in which the diffusive barriers causing modulation are formed instead by the merging of multiple CME structures in the outer heliosphere (so-called ''global merged interaction regions,'' GMIRS).

Drs. Cane, Richardson, and von Rosenvinge have also pointed out a ~ 153 day periodicity in the solar wind magnetic field in 1978-82 associated with the previously reported similar periodicity in energetic solar events such as H-alpha, gamma ray, and microwave flares, sunspots, and energetic particle events. This periodicity was not caused by field compressions associated with CMEs, but was present in the background field. Again, this is indicative of a close relationship between the evolving solar magnetic field, changes in solar activity levels, and interplanetary phenomena.

2.2 Stars

Drs. Corcoran, Swank, Petre, and Drake with Mr. K. Ishibashi (U. Minnesota) and Drs . K. Davidson (U. Minnesota), A. Damineli (U. Sao Paulo), and S. White (U. Maryland) are continuing their monitoring of the X-ray variations from the extremely massive star Eta Carinae using RXTE, ASCA and ROSAT. The most recent RXTE data show that the X- ray emission has almost completely recovered from the ''low state,'' and that the flare period has apparently increased. In addition, comparison of the ASCA spectrum with one taken at nearly the same phase in the previous cycle suggests that the 2-10 keV X-ray flux has undergone a long-term brightening of about 10% that is independent of the 5.5-year cycle identified by Damineli.

Drs. Drake and White with Drs. E. Gotthelf (Columbia U.) and K.P. Singh (TIFR) continued their research on the coronal X-ray emission emitted by late-type stars with a study of the ASCA X-ray spectra of 3 rapidly-rotating, K/M dwarf stars, YY Gem, Gliese 890 and HD 197890. This study demonstrated that coronal metal abundances in these stars are either required (YY Gem) or preferred (Gliese 890 and HD 197890) to be lower than their canonical solar photospheric values. A comparison of these inferred coronal iron abundances with those of other late-type dwarfs shows that all such stars having X-ray luminosities in excess of 0.02% of their bolometric luminosities have subsolar abundances. Drake and White with Drs. R. Mewe and J. Kaastra (SRON), C. Schrijver (SLISR), J. Drake (SAO), M. Guedel (PSI), J. Schmitt (MPE), and Singh analyzed the ASCA spectrum of the corona of the nearby G2V+K1V visual binary system Alpha Centauri. The coronal plasma as seen by ASCA is basically isothermal (kT=0.3 keV), while the coronal abundances appear to be roughly solar, except for oxygen (1/3 solar) and magnesium (4x solar). Comparison with previous X-ray observations indicates that the X-ray emission from Alpha Cen is variable on a time scale of years.

Dr. Drake with Drs. S. Randich (Arcetri Astrophysical Obs.), T. Simon (U. Hawaii), Singh, and Schmitt studied the X-ray emitting properties of the intermediate-age open cluster IC 4756 with a deep observation made with the ROSAT HRI. They found that, like the similar aged cluster Praesepe, the stars in IC 4756 seem to be significantly less X-ray luminous than the Hyades, the prototypical intermediate-age open cluster. Furthermore, IC 4756 appears to be deficient in very active binary systems compared to both of these other clusters. Both of these findings suggest that age is not the only factor determining X-ray emission levels in open clusters.

2.3 Pulsars

Dr. Arnaud with the late Dr. J. Wang (U. Maryland) and Drs. B. Link (Montana State U.), K. Van Riper (White Rock Science), and J. Miralles (U. de Valencia) analyzed ROSAT observations of the isolated neutron star RXJ0720.4-3125. The data are best explained by a model for the source as a cooling-driven, highly magnetized, neutron star with a stiff equation of state. Direct quark URCA cooling can be ruled out.

Dr. Park with Dr. J. Finley (Purdue) has worked on RXTE observations as part of the multiwavelengh study of PSR 0540-69. This was the first-ever simultaneous observations of PSR 0540-69 in the X-ray and optical bandpasses.

Drs. Strohmayer and Nath are pursuing theoretical studies to interpret oscillations in bursts from 4U 1636-53 and derive mass-radius constraints. Rotational modulation and the amplitude of an oscillation is rather strongly dependent on the ratio of the neutron star mass to its radius, the compactness. This results from the strong dependence of general relativistic light deflection on the stellar compactness.

Dr. Strohmayer with Drs. A.B. Giles and K. Hill (U. Tasmania) and S. Wachter (CTIO) is coordinating an X-ray and optical observing campaign of the low mass X-ray binary (LMXB) 4U 1636-53 in order to determine whether or not the oscillation frequencies observed in many different bursts can be used to constrain the orbital parameters, and thus the mass function of the binary. X-ray observations with RXTE combined with optical photometry and spectroscopy allow for the determination of oscillation frequencies as well as the orbital phase during bursts.

Drs. Lochner, Corbet, Marshall, and Whitlock continued monitoring observations of 4 transient X-ray pulsars discovered by RXTE in the Small Magellanic Cloud from 1997 November to 1998 February. Pulse periods range from 46 to 169 seconds, and recurrences of the outbursts suggest possible periods ranging from 60 to 140 days. These systems are confirmed or likely associated with Be systems, adding a substantial knowledge to such systems in the SMC. Monitoring of this region with RXTE is ongoing.

Drs. Ghosh and Angelini with Dr. S. Pravdo (JPL) have presented results of X-ray observations of the accretion-powered pulsar GX 301-2 with instruments aboard ASCA and RXTE, supplemented by analysis of archival data from BATSE/CGRO. They discussed whether GX 301-2 has changed its spin state, entering a stochastic phase similar to that in the 1974-1984 epoch, coincident with a 25% increase in overall luminosity. They constructed a model for the 41.5 day orbital light curve of this source with its pre- periastron and near-apastron flares, wherein the flares are caused by acquisition of accretion disks by the neutron star during its passages through a tilted disk around its massive companion WRA 977. Further, they have reported detection of cyclotron features which imply magnetic fields $\sim 9 \times 10^{11}$ G on the neutron-star surface.

Dr. Thompson, in collaboration with a group of radio, X-ray, and gamma-ray astronomers, completed a multiwavelength summary of the properties of PSR B1055-52 indicating pulses whose shape and phase vary dramatically across the electromagnetic spectrum.

2.4 Galactic Binaries

Dr. Mukai has embarked on a systematic study of the ASCA spectra of non-magnetic cataclysmic variables. He finds a wide range of strengths of the Fe L emission line complex around 1 keV: in some systems, the complex dominates the ASCA spectra, and in others it is undetectable. This cannot be explained by abundance anomalies in general, since the Fe L complex is not correlated with the Fe K emission lines.

Drs. Markwardt and Swank with Dr. R. Taam (Northwestern U.) studied correlations between the energy spectrum and the Fourier power spectrum of the galactic microquasar GRS 1915+105. Using data from RXTE, they found it cycles through at least three distinct spectral/variability states, sometimes on time scales as short as a few minutes. In the spectrally hard state, a variable-frequency quasiperiodic oscillation is present in the 1-15 Hz range. The frequency of the QPO appears to be regulated by the X-ray luminosity of the accretion disk.

Drs. Strohmayer, Zhang, Swank, and Markwardt continue to investigate with RXTE data the properties of high frequency oscillations in the X-ray brightness during thermonuclear (type I) X-ray bursts from low mass X-ray binaries (LMXB). Using RXTE data from two bursters, 4U 1728-34 and 4U 1702-429, they have shown that the oscillations present in the cooling tails of bursts from these sources are highly phase coherent. They also showed that a simple exponential chirp model describes well the time evolution of the oscillation frequency in the cooling tail.

Drs. Markwardt and Swank with H. Lee (Northwestern U.) have studied the energy- dependent lags in the kilohertz quasiperiodic oscillations of four galactic low mass X-ray binaries. Using data from RXTE observations of 4U 1608-52, 4U 1636-536, 4U 1702-429 and 4U 1728-34, they have shown that soft X-ray photons lag the hard in the lower kilohertz QPO peaks. However, conventional wisdom holds that, due to Comptonization, hard X-ray photons should lag the soft. Thus, this observational result challenges the theory that the neutron star in LMXB systems is surrounded by a hot Comptonizing corona.

Drs. White and Ghosh showed that the recent discovery that star formation is an order of magnitude more active at redshift 1-3 has implications for the evolution of X-ray binaries. In particular, long lived objects such as low mass X-ray binaries (LMXRB) will stay active long after the star formation rate has declined. This will cause an excess of LMXRB at low redshift, and their descendants the milli-second radio pulsars; providing an explanation for the long standing discrepancy in the relative population of LMXRB and millisecond pulsars.

Dr. Ghosh is exploring the role of quasiperiodic oscillations (QPO) in low-mass X-ray binaries (LMXB) as probes of relativistic effects near neutron stars. Both the ‘‘kilo-Hertz’’ and the low-frequency QPOs appear to originate in regions where general relativity has significant effects on the accretion flow: the observed correlation between these two QPOs is thus a valuable probe of relativistic effects, as well as a discriminator between possible QPO models. He has shown that the similarity between the atoll- and Z-type LMXBs in QPO-QPO correlations, despite their other major differences, is a possible signature of an essential general-relativistic feature of the dynamics of accretion disks near neutron stars.

Drs. Ghosh, Markwardt and Swank with Dr. G. Sobczak (Harvard U.) have shown that power-spectral densities (PSD) of Comptonizing accretion disk coronae (ADC) are expected to have flat ‘‘shelves’’ at low frequencies, followed by roll offs to higher frequencies: they have suggested that such features are generic signatures of ADC in galactic black-hole candidates. They have further shown that quasiperiodic oscillations (QPO) can occur near the PSD break frequency, as observed, due to feedback coupling between the accretion disk and the corona.

Dr. Still with Mr. K. O’Brien and Dr. K. Horne (St Andrews) and Mr. R. Hynes (Sussex) have developed a technique for indirectly mapping accretion disks around neutron stars and black holes using light-travel delays of reprocessed X-ray flares and pulses.

Drs. Boroson, Kallman, Still and Bautista with Drs. S. Vrtilek and J. Raymond (CfA) and H. Quaintrell (OU, UK) have detected Doppler-broadened UV accretion disk emission in HST STIS spectra of the X-ray binary Hercules X-1.

Dr. Still with Mr. T. Ash and Dr. A. Norton (OU, UK), Drs. A. Reynolds (ESTEC), P. Roche and L. Morales-Rueda (Sussex) have redetermined the mass of the X-ray binary Cygnus X-3 using radial velocity measurements of the subgiant companion star.

Dr. Still with Drs. L. Morales-Rueda and Roche (Sussex) have detected the optical counterpart of long milli-Hz QPOs in the cataclysmic variable GK Persei. They isolated the signal in Doppler-broadened emission lines to determine that the events are the result of normal-duration QPOs beating with the spin frequency of the magnetic white dwarf star.

Drs. Focke and Swank have analyzed data from XTEJ1748-288, a galactic black hole candidate and superluminal jet source. The source has shown a rich range of behavior characteristic of galactic black hole transients, including many correlations between spectral and timing behavior. Work is in progress with Dr. Titarchuk to interpret these properties in the context of hydrodynamic and Comptonization models.

Drs. Shrader and Titarchuk have begun tests of a new method for parameter estimation in black-hole binaries based on their high-energy spectra. The methodology is based on the bulk-motion Comptonization model for black-hole accretion. It has recently been applied to Nova Muscae 1991 and LMC X-1. In the case of Nova Muscae 1991 the resulting mass determination, when compared to estimates based on dynamical studies, argues for a revision of some source distance estimates. This technique is complementary to more common methods based on optical spectroscopy, which are often hampered by obscuration by dust and/or the limited brightness contrast between the accretion disk and the secondary.

Dr. Boroson has been studying X-ray binaries (where a neutron star or black hole gravitationally captures gas from a normal companion star.) His main interest has been understanding the mass transfer between the stars, and the outer structure of the accretion disk that forms. For LMC X-4, in which a neutron star accretes from a star with a strong stellar wind, he demonstrated techniques that can infer the velocity field of the wind, and found evidence for a more massive wind than previous observations showed. He is comparing more recent data on this star system with computer simulations of the flow of the stellar wind. For Hercules X-1, in which stellar winds are not expected to be as important, he found conflicting evidence on whether the disk shape is symmetric or warped from the shape of the emission lines and from the eclipse of the system. supernovae and supernovae remnants.

Drs. Titarchuk and V. Osherovich (Code 690.2) have presented a dimensional analysis of two characteristic time scales in the boundary layer where the disk adjusts to the rotating neutron star (NS). The boundary layer is treated as a transition region between the NS surface and the first Keplerian orbit. The radial transport of the angular momentum in this layer is controlled by a viscous force defined by the Reynolds number, which in turn is related to the mass accretion rate. They show that the observed low-Lorentzian frequency is associated with radial oscillations in the boundary layer, where the observed break frequency is determined by the characteristic diffusion time of the inward motion of the matter in the accretion flow. Predictions of their model regarding relations between those two frequencies and frequencies of kHz QPO's compare favorably with recent observations for the source 4U 1728-34. Their work contains a theoretical classification of kHz QPO's in NS binaries and the related low frequency features. Thus, results concerning the relationship of the low-Lorentzian frequency of viscous oscillations and the break frequency are presented in the framework of a two-oscillator model of kHz QPO's viewed as Keplerian oscillations in a rotating frame of reference.

2.5 Supernovae and Supernova Remnants

Drs. Hwang and Petre with Dr. J. Hughes (Rutgers) carried out a spectral study of the Galactic supernova remnant W49B using archival ASCA observations. Their analysis of the emission lines shows that the Si and S emission is spectrally complex, in contrast to emission from other elements, and that the ejecta are not required to be stratified by element as previously suggested. Their data also give persuasive evidence for the first detection of Cr and Mn in X-rays from a cosmic source.

Drs. Safi-Harb, Petre, and Arnaud with Drs. J. Keohane (NCSSM), S. Reynolds (NCSU), and Ms. K. Dyer analyzed the young radio-bright Galactic SNR, G41.1-0.3 (3C397), in order to improve our understanding of the X-ray emission processes in Composite-type supernova remnants (SNRs). The ASCA spectrum is best described by a two-component non-equilibrium ionization thermal model, suggesting that the remnant is young (a few 1,000 years old). A broadband imaging and spectral study of this remnant with ROSAT, ASCA, and RXTE suggests that a compact object might be buried under the thermal emission from the SNR; and that 3C397 is perhaps a transition object from the young Shells (e.g., Tycho, Cas A) into the more evolved Composites (e.g, Vela).

2.6 Cosmic Rays

Dr. Streitmatter leads the High Energy Cosmic Ray (HECR) research group (Drs. Barbier, Christian, Krizmanic, Mitchell, Moiseev, Ormes, and graduate student Mr. Geier) in pursuing a broad-based investigative program seeking to unravel the processes of galactic cosmic ray propagation and acceleration, as well as characterizing the cosmic ray sources themselves.

The HECR group is a member of the WiZard/CAPRICE collaboration, which is headed by Dr. S. Stochaj at New Mexico State University and is carrying out a program of measuring antimatter fluxes and limits in the 0.1 - 40 GeV range and measurements of atmospheric muon fluxes.

Drs. Ormes, Mitchell, Moiseev, and Streitmatter participate in the Balloon-Borne Experiment with Superconducting Solenoid (BESS) collaboration led by a group of Japanese investigators (Dr. S. Orito *et al.*). This instrument has made five flights measuring antiproton fluxes and antihelium flux limits at low energies. The recently published results from this work have improved the limits on the flux ratio of antihelium/helium to 1 x 10^{-6}, a factor of 30 better than previous limits, and established the low energy ($\approx$ 300 - 3000 MeV) antiproton fluxes with unprecedented precision. More than 450 antiprotons have been clearly identified. The flight during the summer of 1998 was very successful, with an additional 400 antiprotons detected. There are 4 presentations to be made at the 1999 Salt Lake ICRC on BESS 1998 results.

Dr. Streitmatter and Dr. A. Stephens (Tata Institute of Fundamental Research) have reviewed computational techniques used in cosmic ray transport calculations, and put forward a technique for obtaining exact solutions to the leaky box model.

The AIP Conference Proceedings for the Workshop on Observing Giant Cosmic Ray Air Showers From $> 10^{20}$ eV from Space (ed. Drs. Krizmanic, Ormes and Streitmatter) was published in 1998.

Dr. Ramaty, in collaboration with Drs. E. Vangioni-Flam and M. Casse (Institute d'Astrophysique de Paris) and K. Olive (U. of Minnesota), co-organized the LiBeB, Cosmic Rays and Related X- and Gamma-Rays conference in Paris in December 1998. Ramaty also acted as the lead editor of the conference Proceedings, which has now appeared as volume 171 of the Astronomical Society of the Pacific Conference Series. The unique aspect of this conference was the elaboration of the strong relationship between the origin and evolution of the light elements, in particular beryllium, and the origin of the cosmic rays. In collaboration with Drs. R. Lingenfelter (UCSD) and J. Higdon (Claremont Colleges), Ramaty has further studies the origin of the cosmic rays, emphasizing the role of acceleration of metal enriched supernova ejecta in the hot phase of the interstellar medium.

Drs. F. Stecker and M. Salamon (U. Utah) have recomputed the photodisintegration rate of ultrahigh energy heavy nuclei caused by interactions with both the 3K cosmic background radiation and the intergalactic radiation field produced by stellar processes in galaxies, of which the IR background is particularly important. They have performed a Monte Carlo calculation using detailed energy dependent cross sections and threshold energies for nuclides from helium-2 through iron-56. They find that nuclei with total energies below about 300 EeV have longer propagation paths against energy loss than those previously calculated. This result is primarily due to the use of the more realistic spectral energy distribution of the IR background calculated by Malkan and Stecker in 1998, which agrees with current data. The Malkan-Stecker IR background fluxes are roughly an order of magnitude lower than fluxes crudely estimated in the 70s which gave shorter mean free paths for nuclei against photodisintegration. The longer mean free paths obtained by Stecker and Salamon admit the possibility that the highest energy cosmic rays observed may have started out as heavy nuclei.

Drs. Cane, Richardson and von Rosenvinge, in collaboration with Dr. G. Wibberenz (U. of Kiel), have investigated the cause of medium ($\sim$ 1 year) and long-term (22-year) galactic cosmic ray density modulations in the heliosphere. Cosmic ray density variations measured by neutron monitors over a 22-year period track the inverted profile of the interplanetary magnetic field intensity. The field intensity variations originate in the solar magnetic field and propagate away from the Sun at the solar wind speed. This suggests that medium/long-term cosmic ray modulations are caused by expanding diffusive barriers, which surround the Sun and are formed by enhancements in the solar global magnetic field. This contrasts with the current paradigm in which the diffusive barriers form by the merging of multiple transient solar wind structures in the outer heliosphere (so-called ‘‘global merged interaction regions’’).

Drs. Richardson, Cane and Wibberenz have noted a 22-year variation in the amplitude of galactic cosmic ray depressions at Earth associated with corotating high-speed solar wind streams during the last five solar minima. The modulations are $\sim$ 50% larger during epochs when the global magnetic field direction $A>0$ than when $A<0$. The opposite dependence on A might be expected in current models in which cosmic rays enter over the poles when $A>0$, and enter along the current sheet, and hence would be more strongly influenced by high-speed streams near the ecliptic, when $A<0$.

Drs. Jones and Baring, along with Dr. D. Ellison (NC State U.), showed that one could understand the origin of the anomalous cosmic rays by the acceleration of interstellar pick- up ions by the solar wind termination shock. These pick-up ions, observed by the Ulysses spacecraft, are neutral interstellar atoms that enter the heliosphere unhindered by the solar wind. Subsequently ionized by solar UV or by collisions with solar wind ions, they are then carried by the solar wind to its termination shock where they are accelerated to the energies observed in the anomalous cosmic rays. Their Monte Carlo calculations of this process showed that, although pre energization of the ions before reaching the shock was not ruled out, it was not required. Jones and Baring also published a work with Dr. J. Jokipii (U. Arizona) showing that any plasma simulations that were not fully three dimensional had built in constraints that could strongly influence the results. A primary result that has appeared in the literature showing that perpendicular shocks could not accelerate particles by diffusive shock acceleration was shown to be foreordained by the use of less that three dimensions in the simulation. This work casts serious doubt on the validity of this result.

2.7 Black Hole Astrophysics

An accreting black hole is, by definition, characterized by the drain; matter goes in and nothing comes out. As this can only happen in a black hole, it provides a way to see ‘‘a black hole,’’ a unique observational signature. The accretion proceeds almost in a free-fall manner close to the black hole horizon, where the strong gravitational field dominates the pressure forces. Drs. P. Laurent (Saclay) and Titarchuk calculate (by using Monte-Carlo simulations) the specific features of X-ray spectra formed as a result of upscattering of the soft (disk) photons in the converging inflow (CI) within about 3 Schwarzschild radii of the black hole. The full relativistic treatment has been implemented to reproduce these spectra. They show that spectra in the soft state of black hole systems (BHS) can be described as the sum of a thermal (disk) component and the convolution of some fraction of this component with the CI upscattering spread (Green's) function. The latter boosted photon component is seen as an extended power-law at energies much higher than the characteristic energy of the soft photons.

Drs. K. Borozdin (Los Alamos), M. Revnivtsev, S. Trudolyubov (IKI Moscow), Shrader and Titarchuk have advanced their analysis of the high-energy radiation from black hole (BH) transients, using archival data obtained primarily with the Rossi X-ray Timing Explorer (RXTE), and a comprehensive test of the bulk motion Comptonization (BMC) model for the high-soft state continuum. The emergent spectra of over 30 separate measurements of GRO J1655-40, GRS 1915+105, GRS 1739-278, 4U 1630-47 XTE J1755-32, and EXO ~ 1846-031 X-ray sources are successfully fitted by the BMC model, which has been derived from basic physical principles in previous work. This in turn provides direct physical insight into the innermost observable regions where matter impinging upon the event horizon can effectively be directly viewed. The Bulk-Motion Comptonization (BMC) model is characterized by three parameters: the disk color temperature, a geometric factor related to the illumination of the black hole (BH) site by the disk and a spectral index related to the efficiency of the bulk motion upscattering. For the case of GRO J1655-40, where there are distance and mass determinations, a self consistency check of the BMC model has been made.

Dr. Ghosh investigated the viscous stability of thin, Keplerian accretion disks in regions where general relativistic (GR) effects are essential. For gas pressure dominated (GPD) disks, the Newtonian conclusion that such disks are viscously stable was reversed by GR modifications in the behaviors of viscous stress and surface density over an annular region not far from the innermost stable orbit. For radiation pressure dominated (RPD) disks, the Newtonian conclusion that they were viscously unstable remained valid after including GR modifications.

In collaboration with Dr. R. Blandford (Caltech), Dr. Gehrels published a paper in Physics Today on black holes. The paper discussed the new understanding of galactic and AGN black holes that are developing from recent observations across the electromagnetic spectrum and described the progress expected from upcoming instruments.

2.8 Interstellar Matter and Molecular Clouds

Dr. Digel together with Dr. R. Mukherjee (Barnard College), Prof. E. Aprile (Columbia U.), and Dr. F. Xu (Columbia U.), studied the diffuse gamma-ray emission observed by EGRET in Orion, which contains the nearest giant molecular cloud complex and massive star-forming regions. This updated a previous study with significant additional exposure that is now available. Marginally significant point sources detected in the earlier work are no longer seen, although an extended, low-significance soft-spectrum excess remains. Gamma-ray data and radio surveys were also used to determine the molecular mass and the high-energy cosmic ray density in Orion.

2.9 Our Galaxy

Dr. Snowden and Mr. Kuntz with Drs. M. Freyberg (MPE) and W. Sanders (U. Wisconsin) have created a catalog of 378 shadows in the 1/4 keV diffuse X-ray background identified in the ROSAT All-Sky Survey data.

Mr. Kuntz and Dr. Snowden have completed a study of the spectral energy distribution of the diffuse soft X-ray background, concluding that the emission attributed to the galactic halo is composed of two thermal components. Using this spectrum, Mr. Kuntz is continuing his study of X-ray absorption by molecular clouds as a method to determine their masses.

Dr. Park used an ASCA observation for a spectral analysis of the Galactic diffuse X-ray background. In the 0.5-2.0 keV band the emission appears to originate from an ''intermediate'' component of ~ 1 keV plasma which is distributed 1-3 kpc from the Sun in the Galactic plane. The 2-10 keV emission is likely associated with a 3-5 keV plasma which is distributed throughout the plane.

Dr. Park with Dr. Y.-H. Chu (U. Illinois Urbana-Champaign) carried out optical absorption line observations to support the study of an X-ray shadow detected at l,b=8,-8. These observations will help determine the distance scale to the molecular cloud that casts the X-ray shadow.

Drs. Markwardt, Swank and Marshall are performing regular monitoring scans of the galactic bulge region with RXTE. RXTE performs a raster scan of approximately 250° twice weekly, continuing at least until the end of 1999. The goals are to monitor known persistent sources, search for transient outbursts and new sources, and map the diffuse hard X-ray emission near the galactic center. They are coordinating with Dr. J. in't Zand (SRON, Netherlands), who oversees BeppoSAX Wide Field Camera images of the same region. To date approximately forty sources have been detected by RXTE, eight of which were previously unseen.

2.10 Gamma Ray Bursts

Drs. Marani, Norris, and Bonnell continued a collaboration with Dr. J. Scargle (NASA/ARC) on Bayesian analysis algorithms designed to fit gamma-ray burst (GRB) temporal profiles. Drs. Norris, Bonnell, and Watanabe studied the possible connection between GRBs and supernovae, quantifying the number of GRBs, which resemble the putative association of the single-pulsed GRB 980425 with the unusual supernove 1998bw. Drs. Marani, Norris, and Bonnell, with Dr. K. Hurley (UC Berkeley) and Dr. R. Nemiroff (Michigan Tech U.), positing GRBs as gravitational lenses, placed constraints on the fraction of dark matter in compact objects in the range of $\sim 10^{-16}$ to 10^{9} solar masses. Drs. Bonnell and Norris showed that the putative no high-energy emission subset of GRBs can be attributable to brightness bias.

Graduate student Jennifer Catelli continues to analyze spectra from the EGRET NaI (Tl) detector for 1-100 MeV emission from gamma-ray bursts. Recent detections include GRB 990123, for which simultaneous optical emission was seen.

Drs. Norris, Bonnell and Watanabe searched for a possible association of single-pulse gamma-ray bursts and Type Ib/c supernovae and concluded that the two phenomena are not related.

2.11 Active Galaxies

Drs. Weaver and Yaqoob examined the robustness of the evidence for extreme gravitational redshifts for the Fe K alpha line profile in MCG-6-30-15. They found that the ASCA data do not uniquely support this interpretation, and can be equally well explained by occultation of the continuum source and the putative line-emitting accretion disk. This model can also explain the unusually large equivalent width of the line during a deep minimum in source intensity. These results caution against the overinterpretation of observational results that have low statistical significance.

Dr. Weaver with Dr. C. Reynolds (U. Colorado) show from modeling the Fe K alpha line in the ASCA spectra of four X-ray-bright narrow emission line galaxies that two equally viable physical models can describe the observed line profile. The first consists of emission from a nearly pole-on accretion disk, while the second is a superposition of emission from an accretion disk viewed at an intermediate inclination of $\sim 48°$ and a distinct, unresolved feature that presumably originates some distance from the galaxy nucleus.

Dr. Weaver with Drs. T. Heckman (JHU) and M. Dahlem (ESA/ESTEC) presented an in- depth analysis of ROSAT and ASCA X-ray data for a far-infrared flux-limited sample of seven nearby edge-on starburst galaxies. All of the normal-sized spiral galaxies in the sample had hot gas in their halos, as does the small peculiar galaxy M82. Fits to joint PSPC + ASCA spectra, indicate the presence of two gas phases, one at 0.2-0.4 keV and another at 0.65-0.9 keV.

Drs. Weaver and Colbert with Dr. A. Wilson (UMD) presented ASCA results of the LINER galaxy NGC 2639. This galaxy contains a water vapor megamaser, suggesting the presence of a nuclear accretion disk or torus viewed close to edge-on. The X-ray spectrum shows emission in excess of a power-law model at energies greater than 4 keV; which is interpreted as compact, nuclear, hard X-ray emission with the lower energies photoelectrically absorbed by an equivalent hydrogen column of $\sim 5 \times 10^{23}$ cm^{-2}. If the masing molecular gas is responsible for the X-ray and radio absorption, the required ionization fraction of the torus is $> 1.3 \times 10^{-5}$, which is comparable to the theoretical upper limit for X-ray heated molecular gas.

Drs. Yaqoob, Nandra, George, Turner, and Serlemitsos with Dr. A. Ptak (Carnegie Mellon) reported the detection of an unusual X-ray emission-line feature in the high-redshift quasar PKS 0637-752, using the ASCA satellite. The energy of the line does not correspond to any known atomic transition; if it is Doppler blueshifted OVII, the implied bulk velocity is $\sim 0.75c$.

Dr. Yaqoob published a reanalysis of an ASCA observation of the cluster of galaxies 1E0657-56 in which it was claimed that the gas temperature was so high that a ''flat'' cosmology was ruled out. He showed that the high temperature was due to errors in the previous analysis and that a flat Universe was not ruled out by the data.

Dr. Turner analyzed ROSAT and ASCA data from Mkn 231, an active galaxy of particular interest due to its large infrared luminosity and the presence of several blueshifted broad absorption line (BAL) systems. These ASCA data provided only the second hard X-ray spectrum of a BAL AGN published to date. Extended emission was found in the 0.1-2 keV band, of size-scale ~ 30 kpc in diameter, cospatial with the host galaxy. The extended emission has a luminosity L(0.1-2 keV) $\sim 10^{42}$ erg s^{-1} and is probably associated with starburst activity in the galaxy.

Drs. Turner, Nandra, and George found evidence for frequency-dependent variability in the narrow-line-Seyfert 1 galaxy Ton S180. This may indicate that the hard X-rays are produced by Compton upscattering of softer photons in a region akin to an accretion disk corona.

Drs. Shrader and Titarchuk are exploring the application of the bulk-motion Comptonization model to a subclass of AGN, the narrow-line Seyfert-1 galaxies (NLS1s). The NLS1s are known to exhibit unusually steep X-ray spectra, and it has been speculated that they may represent the extragalactic analog of the high-soft spectral state seen in Galactic black-hole X-ray binaries. They suggest that the soft X-rays are the high-energy extension of the thermal emission of an accretion disk, while the harder, power-law component results from Compton scattering of soft disk photons by a relativistic bulk inflow onto the central black hole.

Stimulated by a high optical state of the blazar 3C 279, the Compton Observatory viewed that object as a Target of Opportunity in January 1999. It was seen to be bright, similar to the levels seen in June 1991 and January 1996. Unlike the 1996 observation, however, it showed no flare similar to the extraordinary one in February 1996. Data from the 1999 observation will be included in several upcoming papers. Stecker has collaborated on a paper with Drs. A. Konopelko and J. Kirk (Max-Planck Inst., Heidelberg) and Dr. A. Mastichiadis (U. Athens) in which they analyze the high energy gamma-ray spectra obtained by the HEGRA (High Energy Gamma-Ray Array) and Whipple telescope groups for the nearby BL Lac object Mkn 501 in the energy range between 0.3 and 24 TeV. They make the case that the observed rollover in the high energy end of the spectrum (above 5 TeV), which is particularly evident in the HEGRA data, is an absorption effect caused by pair production interactions with the extragalactic infrared radiation whose flux is that given by Malkan and Stecker in 1998.

Drs. Bautista and Titarchuk have studied the formation of the H-like iron (Fe $\sim$ XXVI) Ly-alpha line at 6.97 keV in Narrow-line Seyfert 1 galaxies in the framework of current models for accretion into a black hole. They find that Fe XXVI Ly-alpha emission is most likely formed by resonant fluorescence due to the strong radiation field in the region near the black hole or, possibly, in the interphase between a hot corona and the optically thick alpha-disk. Alternatively, the line could be formed by collisional excitation at a temperature of approximately 12 keV in accretion flows dominated by advection or gravitational accretion flows with strong shocks. For either resonant fluorescence or collisional excitation the equivalent width of the Fe XXVI Ly-alpha line is a powerful temperature diagnostic of the emitting region. They propose some observational tests to distinguish between collisional and resonant fluorescent excitation of the line.

Dr. Kazanas along with Dr. A. Mastichiadis (U. of Athens) have proposed a novel way to understanding the flares of blazars and the origin of relativistic electrons responsible for the gamma ray emission in these objects. Their models assumes that much of the energy associated with the blazars' relativistic jets is contained in a population of relativistic protons, which in fact help accelerate the jet to relativistic speeds. This energy is released catastrophically to produce a population of relativistic electrons, by an instability triggered by the presence of a ‘‘mirror’’ (i.e. a line emitting cloud), ahead of the relativistically outflowing plasma. The more interesting aspect of this mechanism is that the conditions necessary for this instability are in close agreement with those thought to prevail at these environments and that the same process should be applicable to the relativistic blast waves of gamma ray bursts.

2.12 Clusters of Galaxies

Dr. Arnaud with Dr. R. Dupke (U. Alabama) showed that in the center of the Perseus cluster the Ni to Fe abundance ratio is approximately four times Solar. This ratio is consistent with convective deflagration models for the SN Ia that provide the Ni in the intracluster medium but is inconsistent with delayed detonation models. In disagreement with some other authors, they show that it is not necessary for the iron K alpha line to be optically thick.

2.13 Extragalactic Background

Mr. Kuntz continues his dissertation work searching for small amplitude spatial fluctuations on $5'$ to $50'$ scales in the soft X-ray background, using a number of large mosaics of broadband ROSAT data. Such fluctuations are thought to have the potential to contain the ‘‘missing’’ baryons in the local universe.

Based on data obtained with the HEXTE instrument on RXTE, Drs. Boldt and Mushotzky, in collaboration with Mr. D. MacDonald (UC Riverside) along with Drs. A. Fabian (IoA, Cambridge) and D. Gruber (UCSD), have studied the granularity of the cosmic X-ray background (CXB) at energies much higher than previously examined. The fluctuations in surface brightness are found to imply a substantial unresolved foreground source population whose spectrum over the band 15.5 - 24.9 keV is significantly flatter than that of the CXB. It suggests that this radiation arises from severely absorbed sources, possibly low luminosity AGNs obscured by an enhanced density of material at the central region of the host galaxies.

Dr. Watanabe with Drs. D. Hartmann, M. Leising and L.-S. The (Clemson U.) demonstrated that Type Ia supernovae can be a major contributor to the cosmic gamma-ray background (CGB) in the MeV region using information of the star formation history, which has been well studied recently.

Dr. Watanabe continued a collaboration with Drs. Leising (Clemson U.), G. Share and R. Kinzer (NRL) to analyze the CGB data from the Solar Maximum Mission (SMM) gamma-ray spectrometer in energy region between 0.3 and 8 MeV. Their result agrees well with other recent satellite data such as COMPTEL data.

2.14 Catalogs

Drs. Park, Angelini, and White are pursuing the XCAT– the unified X-ray source catalog project. The first phase of the project has been completion of WGACAT, which includes updating and inspection of various aspects of the catalog. Several kinds of problems have been found in more than 250 observation sequences. Some problems have also been found in several sequences of the Revision 2 ROSPUBLIC archive data.

Drs. Hwang, Petre, and Snowden continue their efforts to assemble an archive of the ROSAT observations of supernova remnants.

3. OPERATING ORBITAL FLIGHT MISSIONS

3.1 Compton Gamma Ray Observatory (CGRO)

The Compton Gamma Ray Observatory (CGRO) has been in orbit since April 1991. The spacecraft and instruments are performing well, and the science return is large. The four instruments onboard cover an unprecedented six orders of magnitude in energy, 30 keV to 30 GeV, with an order of magnitude improvement in sensitivity over previous missions. The scientific theme of CGRO is the study of physical processes taking place in the most dynamic sites in the Universe, including supernovae, novae, pulsars, black holes, active galaxies, gamma-ray bursts, and solar flare. The first 15 months of the mission (Phase 1) were dedicated to a full-sky survey. A Guest Investigator program has been implemented and a Science Support Center established at the Goddard Space Flight Center to support the Guest Investigators. Dr. Gehrels is Project Scientist and Drs. Bertsch and Norris are Deputy Project Scientists. In its seventh year of operation, CGRO has made many exciting discoveries. The Energetic Gamma-Ray Experiment Telescope (EGRET) instrument has continued to find that many blazars, at extremely large distances, emit more energy in gamma rays than all other types of emission put together, and seem to brighten and fade even during a 2-week observation. EGRET has also detected high-energy gamma-ray emission from gamma-ray bursts up to 90 minutes after the burst. The Burst and Transient Source Experiment (BATSE) has observed a total now of over 2200 gamma-ray bursts. They are isotropically distributed on the sky and have a deficit of weak bursts compared to a homogenous distribution in space. A new accurate-location capability has been implemented by the BATSE team for rapid release of $\sim$ 1 degree positions for bright bursts. The Compton Imaging Telescope (COMPTEL) in combination with the ROSAT x- ray mission has found a new supernova remnant ($\sim$ 900 years old) shining in the light of gamma-rays emitted from 44Ti decay.

3.2 Energetic Gamma Ray Experiment Telescope (EGRET)

The EGRET instrument, which covers the energy range from 30 MeV to over 30 GeV, has a limited lifetime due to the limited spark chamber gas supply. In order to conserve its capability for the most important sources, the instrument is now only operating in a narrow field of view mode and essentially only for targets of opportunity. The efficiency is seriously degraded and significant corrections are required, especially at lower energies. However, a recent observation of Geminga demonstrated that a reasonable spectrum and intensity measurement is still possible for strong sources. An in-flight calibration paper by Dr. J. Esposito (MCST/SSAI) and the EGRET team will be published in July. Highlights from EGRET's observations during the mission include: (1) the finding of a new class of objects – high energy gamma-ray emitting blazars, (2) the emission of high energy gamma-rays from a burst for over an hour, with some gamma-rays having energies over a GeV and two having energies of over 10 GeV, (3) the observation of seven high-energy gamma-ray pulsars, (4) the determination with high certainty that cosmic rays are galactic, (5) the detailed mapping of the Galactic diffuse radiation and the measurement of the pion bump in the high-energy spectrum, (6) the absence of micro-second bursts and its implication for certain physics unification theories, (7) the long time of over eight hours for observing energetic solar particles following a flare, and (8) a measurement of the extragalactic diffuse radiation and its consistency with that expected from AGN emission.

3.3 Solar Anomalous and Magnetospheric Explorer (SAMPEX)

Dr. von Rosenvinge is Project Scientist for and a Co-Investigator on the SAMPEX small explorer mission launched in 1992. SAMPEX is in an extended mission phase to study both trapped and interplanetary anomalous cosmic rays, the charge states of solar energetic particles, and the acceleration of magnetospheric particles and their effects on the upper atmosphere. SAMPEX has also documented the build-up of energetic particles in the magnetosphere which frequently accompany satellite failures.

3.4 Advanced Satellite for Cosmology and Astrophysics (ASCA)

The joint Japanese-U.S. ASCA mission continues to work well and produce excellent data. However, its orbit continues to decay, with the reentry predicted to be sometime during calendar year 2000. Therefore, the AO-7 proposal review, which the Guest Observer Facility (GOF) successfully supported during the latter half of 1998, will be its last formal proposal cycle. The ASCA archive at HEASARC now contains over 2,200 public (and 2,800 total) sequences. Drs. Yaqoob, Mukai, Gendreau, and others continue to support the instrument teams' efforts to improve the calibration. Dr. T. Dotani (ISAS) has made several key improvements in the SIS calibration (although unresolved issues remain), and the GIS re-calibration effort is approaching closure. The GOF is in the process of assembling a document detailing the deficiencies in the current low-energy calibration of the SIS.

3.5 Transient Gamma-Ray Spectrometer (TGRS) on the GGS/Wind Spacecraft

The Transient Gamma Ray Spectrometer (TGRS) is a high-resolution gamma-ray astronomy experiment aboard the WIND spacecraft. The team, consisting of Drs. Teegarden, Cline, Gehrels, Ramaty, Harris, Palmer, Naya, Seifert, and grad student Mr. Kurczynski, along with K. Hurley (Space Sciences Laboratory, UC Berkeley), has continued to analyze the data returned from TGRS. A high resolution spectrum of positron annihilation radiation from the Galactic center has been obtained using an on-board occulter. When the occulter is not used, the entire southern sky is observed by the detector, enabling useful survey work to be done. An extensive search for positron annihilation radiation from novae has therefore been undertaken, the first results from which have been reported by Dr. Harris and associates.

Mr. Kurczynski is completing a PhD thesis on a thorough search for narrow gamma ray lines in the spectra of a large number of gamma ray bursts which TGRS detected. Long-term monitoring of the degradation of the detector due to cosmic-ray irradiation has also been examined.

3.6 The Energetic Particle Acceleration, Composition, and Transport Experiment (EPACT) on the ISTP/Wind Spacecraft

Dr. von Rosenvinge is the Principal Investigator for the Energetic Particles: Acceleration, Composition, and Transport (EPACT) experiment, developed in conjunction with Drs. Reames and Barbier for the Wind spacecraft and launched in November, 1994. Dr. G. Mason (U. Maryland) is also a coinvestigator. Sensitivity for low energy particles has been increased by two orders of magnitude, so that high sensitivity studies of the anomalous component, Corotating Interaction Regions and ^{3}He-rich events have been possible. Recent studies have utilized this high sensitivity to observe composition changes as a function of time during individual solar energetic particle events. This behavior is not simple but is in reasonable agreement with a theory developed by Drs. Reames, Ng, and Tylka. This theory attributes acceleration to a coronal/interplanetary shock and includes the effects of wave-particle interactions, with the waves being produced primarily by protons interacting with the shock.

3.7 Konus, a Gamma-Ray Burst Experiment from Russia on the ISTP/Wind Spacecraft

Konus, a Russian GRB Experiment on the GGS-Wind Spacecraft, the first Russian experiment in astrophysics or space science flown on a NASA mission, was launched on the GGS-Wind spacecraft in November, 1994 (Dr. E.P. Mazets, St. Petersburg, PI). Dr. Cline is the Konus co-PI at Goddard. This gamma ray burst (GRB) monitor detects events at half the rate of the most sensitive GRB experiment in orbit, CGRO-BATSE, but has the advantage of continuous, all-sky coverage, not being shadowed by the Earth at its great distance. In addition to its utility in GRB studies, the Konus experiment has been involved in a variety of recent soft gamma repeater (SGR) studies, contributing to the detection of the flare-ups of formerly quiescent SGRs, to the discovery of a new SGR this last year, and to the detection of the 1998 August 27 giant SGR flare, the first repeat of the 1979 March 5 phenomenon since that time. Another transient studied in detail with Konus was the bursting pulsar GRO J1744-28. Also, Drs. Barthelmy and P. Butterworth (GSFC/Raytheon) have included Konus data into the GCN automatic reporting system (see the IPN and GCN paragraphs), enabling electronic distribution of Konus GRB data to observers world-wide, upon the up-to-two-day delayed receipt at Goddard.

3.8 Rossi X-ray Timing Explorer (RXTE)

The Rossi X-ray Timing Explorer (RXTE) will have been in orbit 4 years at the end of 1999. The spacecraft continues to meet all of its operational requirements. Continued operation through 2002 has been recommended and is being planned. The spacecraft carries the collimated Proportional Counter Array (PCA) and High Energy X-ray Timing Experiment (HEXTE), that point at X-ray sources for 2-200 keV measurements on time- scales from microseconds to years, and the All Sky Monitor (ASM) that obtains long term lightcurves of sources brighter than a few microJanskys, and detects new sources as well as changes in known sources. As much as 25% of the pointed detectors observing time is for targets of opportunity (TOOs), that is, made in response to discoveries of either the ASM, the CGRO's BATSE, or other space or ground based observatories. There is a large data base of public data obtained from TOO observations that were not part of accepted proposals. Information on the detectors, data access, data analysis tools, and results of the mission are available on the Web at http://heasarc.gsfc.nasa.gov/docs/xte/XTESOC.html.

RXTE opened up, with its combination of large area, flexible data modes, and high-rate telemetry, the phase space of temporal measurements above 100 Hz, and especially above 500 Hz. All of some sub-classes of accreting neutron stars in low-mass X-ray binaries have been found to exhibit quasi-periodic oscillations between 400 Hz and 1200 Hz. While alternative models of these oscillations are still being developed, they all agree that the oscillations originate within a few kilometers of the neutron star surface, a location in which the effects of gravity are important. The saturation of frequency at a maximum for a given source appears to confirm the General Relativity prediction of the existence of an innermost stable orbit. The spectra and the frequencies have been shown to be well correlated in several sources of both the Z and the Atoll type; this is providing a crucial basis for identifying the accretion flow geometry. The low frequency oscillations that appear at the same time as the high frequency ones have been shown to be correlated with them so that they are either associated with them or respond to the same physical parameter, such as the mass flow rate. Interestingly, the low frequency oscillations of the neutron star sources bear the same relation to each other as do those of the black hole candidates.

The RXTE learning Center continues to make RXTE's new discoveries accessible to the public, students and teachers. A booklet ''Shedding a New Light on the Universe'' was released. The ''Tour the ASM Sky'' leads to displays of data of the sources and suggested teacher-written lesson plans for using it.

3.9 Interplanetary Gamma-Ray Burst Timing Network (IPN)

The Interplanetary Network now incorporates gamma-ray burst (GRB) information from the Ulysses mission (Dr. K. Hurley of UC Berkeley, PI), Compton-GRO (Dr. G . Fishman of MSFC, BATSE PI), GGS-Wind (Dr. Teegarden, TGRS PI, and Drs. E. Mazets of St. Petersburg and Cline, Konus co-PIs), and Near Earth Asteroid Rendezvous (Drs. R. Gold, APL, and J. Trombka, GSFC). The comparison of data from these missions can result in the determination of a GRB source location only several arc minutes in size. Also, if circumstances permit the detection of GRBs or SGRs in the x-ray domain with the Rossi-XTE mission, collaborative studies are carried out with experimenters on that mission. The most recent and critical addition to the IPN was the NEAR mission, completing the first three-way, long-baseline interplanetary GRB array since the deaths of PVO and Mars Observer in the early 1990s, and the first such IPN in the modern era of automatic, rapid data distribution (see the GCN paragraph). The precision of this network, including NEAR, has been accurately calibrated using the well-determined source locations of both certain SGRs and of a recent GRB-associated optical transient. Systematic errors are essentially absent, at levels well below those from gamma-ray count-rate fluctuations.

3.10 Advanced Composition Explorer (ACE)

The Advanced Composition Explorer (ACE) was successfully launched on August 25, 1997. LHEA scientists involved include Drs. Christian and von Rosenvinge (Project Scientist). ACE includes two instruments which were developed jointly by Caltech, GSFC, and Washington U. in St. Louis. The Cosmic Ray Isotope Spectrometer has made unprecedented new measurements of heavy cosmic ray isotopes. These measurements include observations of the isotopes ^{59}N and ^{59}Co which suggest that there is a delay of $\sim$ 105 years or more between the synthesis of ^{59}Ni by supernovae and its acceleration to cosmic ray energies. The Solar Isotope Spectrometer (SIS) has measured isotopes in the Anomalous Cosmic Rays (ACRs) and in solar energetic particle events. The large collection power and resolution of SIS has allowed it to observe many previously unmeasured rare elements as well as to make measurements of different isotopes. The isotopic abundances are observed to vary significantly from event to event.

4. FUTURE FLIGHT MISSIONS

4.1 The Monitoring X-ray Experiment (MOXE)

The Monitoring X-ray Experiment (MOXE) is an all-sky monitor being developed as one of the core instruments for the Spectrum-X-Gamma mission. MOXE is a collaboration between LHEA (Drs. Black and Kelley), the Los Alamos National Laboratory (Drs. W. Priedhorsky and E. Fenimore), and the Russian Space Research Institute (Drs. K. Borozdin, A. Kaniovsky, and V. Arefiev). It will monitor several hundred X-ray sources on a daily basis, and will be the first instrument to continuously monitor most of the X-ray sky, thus providing long-term light curves of many galactic as well as some extra galactic sources. MOXE will also alert users of more sensitive instruments on Spectrum-X-Gamma to transient activity.

MOXE distinguishes itself with respect to other all-sky monitors in its high duty cycle, thus having unprecedented sensitivity to transient phenomena with time scales between minutes and hours. This duty cycle is a result of both the instrument design and Spectrum-X- Gamma's four day orbit. The instrument consists of a set of 6 X-ray pinhole cameras based on imaging proportional counters. Together, they view 4π steradians (except for a 20 degree by 80 degree patch around the Sun). With a 24 hour exposure, MOXE will have a sensitivity of about 2 μCrab and be able to locate a 10 μCrab source to better than 0.5 degrees.

The MOXE flight instrument is complete and has passed a flight acceptance test at Goddard and is ready for delivery. The MOXE engineering model has been delivered to the Russian Space Research Institute and undergone complex tests there with other engineering model instruments on Spectrum-X-Gamma.

The MOXE team is also studying the implementation of a similar instrument on the International Space Station. This instrument would take advantage of the large instantaneous sky coverage of a MOXE-style instrument and the real-time telemetry of the ISS for unique studies of short-lived (seconds to hours) transient X-ray phenomena.

4.2 X-ray Multi-Mirror (XMM)

A Guest Observer Facility has been organized to support US participation in the European XMM project. XMM, which is now scheduled for launch on 15 December 1999, will cover the 0.1 - 15 keV energy range with large effective area, moderate angular resolution (15″), and moderate (CCD) and high (grating) spectral resolution. XMM will include an Optical Monitor for simultaneous coverage of the UV/optical band. The GOF is currently supporting software development at Leicester U. (the Standard Analysis Software, SAS) and GSFC (QuickSim and ProcSim simulation software). The main activity of the past year for GOF scientists Drs. Snowden and Still was the support of the AO-1 proposal process, which opened 19 January and closed 17 April 1999.

4.3 X-Ray Spectrometer (XRS/Astro-E)

The Cycle 1 NRA of the ASTRO-E Guest Observer program will be released on 1999 July 15. Consequently, a major focus of the ASTRO-E Guest Observer Facility (GOF) has been to prepare documentation and software for proposal preparation and submission. Among our products are the Technical Description which is intended to contain all information necessary to write an ASTRO-E observing proposal; Maki, a web-based tool to investigate the observing windows and fields-of-view; and an XRS simulator. In addition, the GOF, in collaboration with the hardware teams, as well as the Astrophysics Data Facility at NASA GSFC, have tested the first stage software to produce FITS files on ground test data; established a framework for importing software from the instrument teams for guest observer use, and started the development of several other programs for data processing.

The X-Ray Spectrometer (XRS) is one of several instruments that will be flown on the Japanese X-ray observatory Astro-E in early 2000. The instrument consists of an array of cryogenically cooled X-ray microcalorimeters capable of an energy resolution of $\sim$ 12 eV over the range 0.3 - 12 keV. Such detectors are thermal sensors that determine the energies of individual X-ray photons by sensing the temperature increase they produce when absorbed in a small detector element. In order to measure the small change in temperature with high signal-to-noise, the detector must be operated below 0.1 K. The project is a collaborative effort between NASA and ISAS in Japan. A detector assembly, adiabatic demagnetization refrigerator (ADR), superfluid helium cryostat, and associated analog and digital electronics have been developed at GSFC and installed in a solid neon dewar developed in Japan. A set of five aluminized polyimide filters manufactured by Luxel Corporation for rejecting non-X-ray emission are also being delivered by GSFC. The X-ray optics for the XRS (and four CCD cameras) will be conical foil mirrors developed by Drs. Serlemitsos, Soong, and Chan at GSFC. The overall development of the instrument, including testing and preparation of the microcalorimeter array, anticoincidence detector, fabrication of the detector assembly and calibration are being carried out in the X-Ray Astrophysics Branch through the efforts of Drs. Kelley (PI), Audley, Boyce, Gendreau, Porter, Stahle, Szymkowiak, H. Moseley (Goddard's Laboratory for Astronomy and Solar Physics), and D. McCammon (U. Wisconsin). Dr. Stephen Holt (Director of Space Sciences) is the Project Scientist for the NASA involvement in Astro-E.

During the past year the instrument was completed, tested and delivered to Japan. However, there were several problems along the way that had to be overcome. One of these was with the detector array. The array that was originally installed for flight (a 6x6 array, minus the four corner pixels for 32 channels) suffered damage on subsequent cool downs. Although the precise cause was not determined, it was almost certainly due to a combination of thermo-mechanical stress in the detector mount and the very fragile nature of the specific implementation of the 2-dimensional detector geometry. Modifications to both the detector design and mounting scheme were developed that would have probably allowed us to use this type of array, but there was insufficient time to fabricate new arrays or fully qualify a new detector mount. It was decided instead to use the previously developed bilinear array, which consists of two rows of 16 pixels and is inherently more robust. A bilinear array was installed and calibrated over a five week period in December 1998 - January 1999.

The other problems involved the ADR system. The ADR contains a helium gas-gap heat switch that must remain very hermetic, but was found to be susceptible to leakage. New heat switches were fabricated with design improvements. Similarly, the ADR salt pill must remain hermetic to a very high degree and concern developed with the original design. A new salt pill was developed and fabricated at the University of Wisconsin. This salt pill has a number of improvements over the original design, one of which is that it has about 50% more cooling capacity. This means that the ADR cycle time has gone from about once every 24 hours to once every 36-40 hours in orbit.

The XRS Insert was delivered in January 1999 where it was then integrated with the neon dewar. The instrument was then closed out, pumped down for five weeks, cooled with liquid cryogens and performance tested. The performance of the instrument was excellent, giving typically 12 eV resolution at 6 keV on all channels. The XRS was shipped to ISAS where it was subjected to a vibration test. The Astro-E Observatory will be integrated for flight starting in September 1999, after which it will be vibrated and shipped to the launch site in December. The launch is set for late January 2000.

4.4 International Gamma-Ray Astrophysics Laboratory (INTEGRAL)

INTEGRAL is a joint ESA-NASA gamma-ray astronomy mission that will be the successor to the Compton Observatory and GRANAT missions. It was selected by ESA in June 1993 as its next Medium Class scientific mission (M2) with payload selection in June 1995. The launch is scheduled for 2001. It will be an observatory class mission that will perform high-resolution spectroscopy and imaging in the 20 keV to 30 MeV region. There will be two main instruments, a spectrometer and an imager. By taking advantage of new technology, the INTEGRAL will have greatly improved performance over prior comparable missions, e.g., 40 time better energy resolution and 10 times better angular resolution than the Compton Observatory. The GSFC is participating in the mission planning and in the development of the scientific data analysis software for the spectrometer. The Goddard scientists involved are Drs. Teegarden (NASA Project Scientist), Gehrels (Mission Scientist), Shrader, and Sturner.

4.5 Gamma-ray Large Area Space Telescope (GLAST)

Drs. Bertsch, Bonnell, Digel, Gehrels, Hunter, Krizmanic, Moiseev, Leonard, Norris, Ormes, Ritz, Silvis, and Thompson are GSFC members of a large consortium (Prof. P. Michelson of Stanford is the PI) developing the Gamma-ray Large Area Space Telescope (GLAST), the next-generation high-energy gamma-ray mission. With a large field of view ($>$ 2.5 sr), large effective area ($>$ 8000 cm^2), greatly improved point spread function ($<$ 0.35 degree for E$>$ 1 GeV), and unattenuated acceptance to high energies, GLAST will measure the cosmic gamma-ray flux in the energy range 20 MeV to $>$ 300 GeV with unprecedented precision and greater than a factor 30 higher sensitivity than the existing EGRET detector. The launch is planned for 2005. GLAST will open a new and important window on a wide variety of high energy phenomena, including black holes and active galactic nuclei; gamma-ray bursts; supernova remnants; and searches for new phenomena such as supersymmetric dark matter annihilations and primordial black hole evaporation. The proposed instrument consists of a large effective area Si-strip precision tracker, a 9 radiation length CsI hodoscopic calorimeter, and a segmented plastic tile anticoincidence detector (ACD).

GSFC is the lead institution responsible for the ACD, including all hardware and readout electronics. Dr. Ormes, the ACD subsystem manager, and Drs. Moiseev and Thompson are designing the flight unit and implementing a prototype for the ACD to be used in a GLAST prototype tower beam test in 1999. Drs. Norris, Bonnell, and Silvis are performing instrument simulations to optimize the design of the instrument. Dr. Digel is simulating the capabilities of GLAST for astronomical source detection. Drs. Ritz and Krizmanic collaborated with Dr. W.N. Johnson (NRL) on the development and production of a very large dynamic range, low-noise, low-power ASIC for the calorimeter readout. Drs. Gehrels, Ormes and Ritz are members of the GLAST Instrument Development Steering Committee (GIDSC), which is the central management group of the collaboration. Dr. Leonard coordinated outreach activities for GLAST at GSFC. Dr. Gehrels is chair of the GIDSC. Dr. Gehrels was the co-chair of the GLAST Facility Science Team (Norris, Ormes and Ritz were also members). Dr. Ormes served as the GLAST study scientist for NASA. The project scientist is currently Dr. Bertsch.

4.6 Constellation-X

The Constellation-X mission, planned for launches in 2008-2010, is a high throughput X- ray facility emphasizing observations at high spectral resolution (E/DE $\sim$ 300-3000) and broad energy bandpass (0.25-40 keV), providing a factor of nearly 100 increase in sensitivity over current X-ray spectroscopy missions. The Facility Science Team (FST), responsible for defining the mission, met in September of 1998 at GSFC. The mission configuration was changed to fly four identical spacecrafts instead of six, maintaining the same collecting area. The FST conducted a simulated observing program to demonstrate that the mission's capabilities are compatible with its science goals. The results of this study was released in the form of a 50-page report. Significant progress was made in technology development. These include progress in developing lightweight X-ray optics and the demonstration of a calorimeter with energy resolution of 2.4 eV FWHM at 1.5 keV and 4.7 eV FWHM at 5.9 keV, respectively, by Dr. K. Irwin and his team at NIST/Boulder.

4.7 Orbiting Wide-angle Light-collectors (OWL)—Airwatch

A collaboration led by Dr. Streitmatter is working on the design of an instrument for detecting the highest energy cosmic rays by observing from space the fluorescence light from giant air showers with energies greater than 10^{20} eV produced when these particles interact with the atmosphere. The Orbiting array of Wide-angle Light-collectors (OWL) collaboration includes the HECR group from GSFC, Marshall Space Flight Center (Drs. M. Watson and M. Christl), U. of Alabama (Drs. Y. Takahashi, J. Dimmock, T. Parnell) and U. of Utah (Drs. P. Sokolsky, G. Loh, P. Sommers). The OWL group has formed a collaboration with the Airwatch group in Italy led by Drs. R. Stallio, (U. of Trieste) and L. Scarsi (U. of Palermo).

4.8 Positron Electron Magnet Spectrometer (POEMS); PAMELA

Dr. Mitchell is leading HECR group work in the PAMELA collaboration, a multinational collaboration designing a polar orbiting permanent magnet spectrometer which will make measurements of antiprotons, positrons and electrons over a large energy range. Members include six physics departments of Istituto Nazionale Fisica Nucleare (Italy, INFN, Dr. P. Spillantini *et al.*), Moscow Engineering Physics Institute (Dr. A. Galper et al.), New Mexico State U. (Dr. S. Stochaj), U. of Siegen (Germany, Drs. M. Simon, W. Menn, M. Hof) and Royal Institute of Technology (Sweden, Dr. P. Carlson *et al.*). PAMELA is approved by INFN and ASI for flight in late 2002 or early 2003.

4.9 Laser Interferometer Space Antenna (LISA)

Gravitational radiation has the potential of providing a powerful new window on the universe for observing the behavior of astronomical systems under conditions of strongly non-linear gravity and super-high velocities. Because of seismic and gravity gradient noise on Earth, searches for gravitational radiation at frequencies lower than 10 Hz must be done in space. The frequency range $10^{-4} \rightarrow 1$ Hz contains many of the most astrophysically interesting sources. In this band, predicted emission includes that associated with the formation or coalescence of massive black holes in galactic nuclei. Laser interferometry among an array of spacecraft in heliocentric orbit with separations on the order of a thousand Earth radii could reach the sensitivity to observe low-frequency gravitational radiation from likely sources out to cosmological distances, and would be an important complement to the ground-based experiments already being constructed. A specific concept for this space observatory known as Laser Interferometer Space Antenna (LISA) is under study as an advanced mission for the next decade. The LISA observatory for gravitational radiation is a cluster of three spacecraft that uses laser interferometry to precisely measure distance changes between widely separated freely falling test masses housed in vehicles situated at the corners of an equilateral triangle 6×10^6 km on a side. It is an ESA/NASA mission that is part of the NASA SEU roadmap for the latter half of the next decade. Drs. Boldt and Teegarden are members of the mission definition team, and are in the process of establishing an effort here in support of the LISA project. Dr. E. Waluschka of the Optics Branch has been in Boulder Colorado for almost a year working with Dr. P. Bender of JILA on the design and modeling of the LISA optics. Drs. Boldt, Teegarden and Waluschka participated in the Second International LISA Symposium at Caltech in July; Dr. Boldt reported there on evidence for a substantial population of supermassive black hole quasar remnants in the local universe. Drs. Boldt and Waluschka participated in a technology review at JPL in November. Dr. Teegarden hosted a joint JPL/JILA/GSFC session here in Greenbelt during January for the purpose of exploring the possibility of a preliminary mission based on the New Millennium DS-5 program.

4.10 Advanced Cosmic-ray Composition Experiment for the Space Station (ACCESS)

Several cosmic ray instruments for the International Space Station (ISS) are currently being studied. The Advanced Cosmic-ray Composition Experiment for the Space Station (ACCESS) will study the fundamental questions of how galactic cosmic rays are accelerated and transported in the Galaxy. Elements up through iron will be measured to high energies ($\sim 10^{15} eV$) to directly explore the ‘‘knee’’ region of the cosmic ray energy spectrum. The instrument will consist of two detecting parts: a calorimeter to measure hydrogen, helium, and other light elements, and a transition radiation detector (TRD) to measure heavier elements through iron. ACCESS is planned to replace AMS on Space Station in 2005. Goddard scientists involved are Drs. Streitmatter (Study Scientist), Barbier and Christian (Deputy Study Scientists), Ormes (calorimeter study team leader), Mitchell (accelerator test team leader), and Moiseev who is working on instrument simulations. In June 1999, Dr. Mitchell led a test of two ACCESS calorimeter prototypes at the CERN SPS accelerator. In these tests the prototypes were exposed to protons and negative pions at 375 GeV/c and to electrons between 20 and 250 GeV/c.

4.11 SWIFT

The Swift gamma-ray burst MIDEX proposal was selected for Phase A study in January 1999. It is an international payload consisting of wide and narrow field-of-view instruments with prompt response to gamma-ray bursts. A 2-steradian wide-field gamma- ray camera will detect and image $\sim$ 300 gamma-ray bursts per year with 1-4 arcmin positions. The Swift spacecraft then slews automatically in 20-70 seconds to point narrow- field X-ray and UV/optical telescopes at the position of each gamma-ray burst to determine arcsecond positions and performs detailed afterglow observations. The goal of the mission is to determine the origin of gamma-ray bursts and to use bursts to probe the early universe. The mission is managed at Goddard. Dr. Gehrels is the PI, Dr. White is the Project Scientist and Dr. J. Nousek is the lead scientist at Penn State, the prime US University partner. Key hardware contributions are made by international collaborators in the UK and Italy.

5. INSTRUMENTATION, SUB-ORBITAL, AND NON-FLIGHT PROGRAMS

5.1 High Energy Astrophysics Science Archive Research Center (HEASARC)

The High Energy Astrophysics Science Archive Research Center, HEASARC, provides the astrophysics community access to archival data from X-ray and Gamma-ray missions and to provide the maximum scientific capability via the provision of appropriate multimission analysis software. Highlights from the past 12 months include: a total data volume of 1.5 Terrabytes (TB), 1.2 TB downloaded via anonymous ftp, and 0.45 TB downloaded via the web, the opening of the BeppoSAX archive, the completion of the restoration of several data sets including OSO-8, HEAO-1 and Copernicus.

Ginga data restored by Penn State and Leicester U. was also ingested. The only data restoration effort left is the EXOSAT data, which will be complete at the end of 1999. The HEASARC database system was converted from ingres to sybase, and this has resulted in a major increase in performance. The HEASARC has supported several efforts to give cross-discipline access to OSS data sets. The AstroBrowse interface is a notable effort in that it provides the first seamless access to all the worlds astronomical resources on the Web. The HEASARC has also used its CD ROM mastering facility to exchange data sets with other data centers. The ASCA and ROSAT data have been sent to Leicester U. and the BeppoSAX data centers. The HEASARC's multi-mission Web catalog service, W3Browse, supported 156,000 queries. The SkyView facility uses existing large area surveys to display images in various projections in all wavebands. Over the past year 386,000 images were served.

5.2 High Resolution Detector Development

The X-ray Astrophysics Branch, together with the Goddard Detector Systems Branch, continues to develop high resolution, high quantum efficiency X-ray spectrometers by improving X-ray microcalorimeters. Currently we are concentrating on microcalorimeters with superconducting transition edge thermometers, or transition edge sensors (TES). This type of thermometer offers a number of fabrication and performance advantages over devices with semiconductor thermometers, such as a larger allowable heat capacity for the same energy resolution. The goal of this work is to produce large format arrays (1000 pixels or more) with 2 eV resolution at 6 keV for possible use on the Constellation X-Ray mission. Dr. Stahle is leading this effort at Goddard along with Drs. Finkbeiner, Kelley, Szymkowiak, and graduate student Ms. Mattson from the University of Maryland. Mr. Figueroa, a graduate student at Stanford University is also involved in the TES work and will soon be spending most of his time at Goddard. We are working in collaboration with Dr. K. Irwin and his colleagues at NIST/Boulder, who have pioneered the TES work. Dr. Stahle spent a productive two month period at NIST as part of a Goddard outreach program.

There has been much progress in the last year. At Goddard we have set up a dilution refrigerator for reading out transition edge devices. We identified molybdenum/gold bilayer films as a robust superconducting film and fabricated numerous test devices with good superconducting transitions. We have also begun working on fabricating working devices by depositing such films on thin silicon nitride membranes. The results are encouraging at this early phase of development and further progress should be rapid. In parallel, we have been working on the problem of X-ray absorbers that are deposited on the array during the device fabrication. To do this we are sequentially depositing bismuth on silicon wafers where the bismuth has a base and a top that overhangs to form a mushroom-like structure. This will allow large arrays to be fabricated with high filling factor. So far, the test samples have been excellent and the yield of fully intact arrays (32 x 32) has been very high. Our colleagues at NIST have produced the best energy resolution yet with a microcalorimeter (2.4 eV at 1.5 keV and 4.5 eV at 6 keV) using Mo/Cu TES. We will be working with them in the coming year to fabricate small arrays with integral Bi absorbers.

5.3 X-Ray Quantum Calorimeter (XQC) Sounding Rocket Program

Drs. Szymkowiak, Porter, Kelley and Stahle with D. McCammon (U. Wisconsin) have been developing high resolution, high throughput X-ray spectrometers for astrophysical observations. The techniques on which we have been focusing involve single photon calorimetry, which requires cryogenic operation. One important testbed for this technology has been our X-ray Quantum Calorimeter (XQC) sounding rocket payload.

On March 28, 1999, this payload was flown from the White Sands Missile Range, configured to observe an ~ 1 steradian section of the soft diffuse X-ray background. The instrument functioned well, and we were able to collect pulse height information for all 34 active detectors. A preliminary analysis of the spectrum clearly shows characteristic emission lines from highly ionized oxygen. After further work on data reduction and on our model of the instrumental responses, we will begin analysis of the implications of our spectrum for our understanding of the local ISM.

After some rework of the instrument, which suffered some slight damage due to a rather hard landing, we plan on re-configuring the instrument by placing the calorimeters at the focus of a thin foil X-ray telescope. The new payload would be used in a future flight to study the composition and conditions in the plasma of a supernova remnant, such as the Cygnus Loop.

5.4 Future Hard X-ray Detector Development

The research and development of new detector and optics technologies for future hard X- ray astrophysics instrumentation has long been an important endeavor in the LHEA. Drs. Parsons, Barbier, Barthelmy, Gehrels, Palmer, Teegarden and Tueller of the Low Energy Gamma-Ray Group (LEGR) have continued their highly successful technology development program to produce new cadmium zinc telluride (CdZnTe) and cadmium telluride (CdTe) detector arrays and focal plane sensors for balloon and spacecraft applications. Improvements in the availability of high quality room temperature semiconductors such as CdZnTe and CdTe have made it possible to produce large, convenient, light-weight detector arrays for hard X-ray imaging and spectroscopy. The advantages of CdZnTe and CdTe detectors include good energy resolution in the 5-300 keV energy range without the complexity of cooling and high-Z for greater stopping power with a thinner, more compact instrument. Working with Dr. C. Stahle and P. Shu in the GSFC Detector Systems Branch (Code 553), the LEGR group has developed the capability to design, process and package CdZnTe and CdTe detectors and readout electronics for a variety of space applications. Detector systems fabricated in the past include double-sided CdZnTe strip detectors with 100 micron pitch that would allow fine (arcsecond) imaging of hard X-ray sources and gamma-ray bursts. A 6x6 array of such strip detectors has been assembled at GSFC with over 500,000 separate resolution elements. The LEGR group has also flown CdZnTe detectors at balloon altitudes to investigate the CdZnTe detector background dependence on the active shielding configuration. The baseline detector systems for many future missions described elsewhere in this report depend on detector technologies that were developed through this program such as the proposed Swift Gamma-Ray Burst Explorer; InFOCμS, a balloon-borne hard x-ray focusing telescope; and the Hard X-ray Telescope for the Constellation-X program.

Future thrusts in the development of these technologies will be to improve spectroscopic performance throughout a more extended energy range (1 - 600 keV) with the use of both thicker CdZnTe detectors and stacked Si and CdZnTe detector arrays. As the angular resolution of hard X-ray optics improves, the trend in the development of future hard X-ray focal plane sensors will also be toward finer pitch detector arrays with an increasingly large number of pixels that must be read out within a physically small space. Small Application Specific Integrated Circuits (ASICs) provide each pixel with its own readout electronic circuit. One of the challenges of ASIC design is to fit the readout circuits with the required functionality into a space less than 400 microns square. While GSFC strip and pixel detectors have been read out using a variety of commercially available ASICs, GSFC engineers are currently developing an in-house low noise, lower power readout ASIC practical for future large area arrays.

5.5 Lobster-Eye All-Sky X-ray Monitor

Drs. Zhang, Petre, and Peele have continued their development of the lobster eye optics. They have adopted the silicon micro-machining technology to fabricate flat mirror holders. Compared to holders machined with the wire EDM technology, the silicon holders are lighter and their groves are much more accurately positioned. This accuracy translates directly into an improvement in the overall angular resolution. They expect they will assemble and test an X-ray optical module using thin glass sheets in the coming year with an angular resolution of $2'$.

5.6 Isotope Matter Antimatter eXperiment (IMAX)

The HECR group has continued working on data analysis from the IMAX (Isotope Matter Antimatter Experiment) that made measurements of antiproton, proton, deuterium, and helium isotopes fluxes in the energy range from a few hundred MeV/nucleon to three GeV/nucleon. Dr. Krizmanic has completed an analysis of the data from the IMAX experiment, which measured the atmospheric muon flux as a function of atmospheric depth. The results of the Super-Kamiokande experiment give strong evidence that neutrino oscillations are responsible for the atmospheric neutrino anomaly. However, the neutrino fluxes uncertainty lead to a large range of possible neutrino mass and mixing parameters. Measurements of the atmospheric muon flux by balloon-borne magnetic spectrometers provide an experimental measure of atmospheric neutrino production as the production of muons and neutrinos are kinematically related. The unique capabilities of the IMAX instrument enabled measurements which were uncontaminated by backgrounds in the momentum range 0.2 -> 0.45 GeV/c. These results, when compared to that of the Bartol Atmospheric Monte Carlo Predictions indicate good agreement at low atmospheric grammages, but demonstrate an over-prediction deeper in the atmosphere. The IMAX experiment is a collaboration among GSFC, Caltech (Drs. A. Davis, A. Labrador, R. Mewaldt, S. Schindler), New Mexico State U. (Drs. S. Stochaj, W. Webber), and U. of Siegen (Drs. M. Simon, M. Hof, W. Menn, O. Reimer).

5.7 International Focusing Optics Collaboration for μCrab Sensitivity (InFOCμS)

InFOCμS is a balloon-borne instrument incorporating recent breakthroughs in hard X-ray focusing optics and detectors to achieve order of magnitude improvements in both sensitivity ($\sim$ 100 μCrabs in 12 hours, 20 μCrabs for LDB) and imaging resolution ($\sim$ 1 arcmin), with high-resolution spectroscopy ($<$ 2 keV FWHM). Very low backgrounds achievable with this configuration will produce systematics-free results for very long, high sensitivity observations. Most traditional sources are so bright that background subtraction would be unnecessary. Exciting new results are expected, such as direct imaging of cosmic ray acceleration and nucleosynthesis (44Ti lines) in the Cas A supernova remnant and the first measurement of intergalactic magnetic field strengths by measuring the upscattering of the cosmic blackbody radiation by electrons in the radio lobes of AGN. This international collaboration (Drs. Tueller, Barthelmy, Gehrels, Palmer, Parsons, Petre, Serlemitsos, Stahle, Teegarden, White, and Mr. P. Shu at GSFC; Drs. H. Kunieda, Ogasaka, Y. Tawara, K. Yamashita at Nagoya U.; B. Barber, E. Dereniak, D. Marks, E. Young at U. of Arizona; W. Baumgartner, F. Berense, and M. Leventhal at U. of Maryland) includes world leaders in the development of foil mirrors, multicoated optics, segmented CdZnTe detectors, and balloon payloads with the experience and resources necessary to successfully exploit these promising new technologies for the future Constellation-X mission. Current activity concentrates on preparing for a balloon flight of the detector system to assess background levels.

5.8 Gas Micro-Structure Detector SR&T

Drs. Black, Deines-Jones, and Hunter have developed large area, high spatial resolution, one-dimensional and two-dimensional micro-well detectors (MWDs), a new type of gas proportional counter. These charge-sensitive detectors are being developed for astrophysical instrument applications requiring large area, low-power, two-dimensional position sensing. MWDs are similar in operation to micro-strip detectors. Unlike micro- strip detectors, however, the cathode of a MWD is raised above the anode, separated by a thin dielectric. This allows for two-dimensional readout if the anodes and cathodes are segmented into orthogonal strips. The MWD geometry also relies on a long avalanche region for gas multiplication rather than a small, wire-like anode. This aspect of the MWD geometry allows very robust, spark-tolerant construction.

The electrodes are commercially fabricated at very low cost as a flexible printed circuit board, using copper clad polymer substrates. The wells are then drilled at GSFC's UV laser ablation facility. The ablation process takes advantage of the fact that polymers are ablated by intense UV light, but the copper anode acts as a stop layer.

We have demonstrated 1) fabrication of 5 cm x 5 cm detectors with 400 um pitch, 2) stable proportional operation at a gas gain $>$ 30,000 in Ar- and Xe-based gases, 3) ability to sustain repeated breakdown with no performance degradation, 4) nominal proportional operation and good electron collection efficiency with FWHM energy resolution of 20% with 6 keV x-rays, and 10% resolution with 20 keV, and 5) $<$ 160 um x-ray spatial resolution.

5.9 Isotope Magnet Experiment (ISOMAX)

Some of the most significant questions in the field of particle astrophysics can be addressed by measurements of the isotopic composition of the cosmic radiation. In particular, measurements of the radioactive clock isotope ^{10}Be, which has a half-life of 1.6 million years, will allow strong constraints to be placed on models of cosmic ray transport in the galaxy. To make such measurements, the HECR group has developed a new magnetic rigidity spectrometer for balloon-borne flight, the Isotope Magnet Experiment (ISOMAX). ISOMAX is a collaboration of GSFC (Drs. Streitmatter, Barbier, Christian, Krizmanic, Mitchell, Moiseev and Ormes, and graduate student S. Geier) with Caltech (Drs. R. Mewaldt, S. Schindler and G. DeNolfo) and the U. of Siegen (Dr. M. Simon and students T. Hams and H. Goebel). After a successful first flight in the August 1998, a second flight in planned for the summer of 2000.

5.10 Trans-Iron Galactic Element Recorder (TIGER)

Dr. Christian has lead the HECR groups' efforts in a collaboration with Washington U. in St. Louis (Drs. R. Binns and P. Hink), U. of Minnesota (Dr. J. Waddington), and Caltech (Drs. R. Mewaldt, S. Schindler, and M. Wiedenbeck) on the Trans-Iron Galactic Element Recorder (TIGER), a balloon-borne instrument which will measure the elemental composition of the heavy component of the cosmic radiation for comparison with solar system abundances. TIGER has been selected as the first payload for the Ultra Long Duration Balloon (ULDB) program, with a 100-day flight planned for 2001.

5.11 Nightglow

The HECR group has begun work on a balloon instrument (called NIGHTGLOW) to measure the atmospheric UV background in the 300 - 400 nm range. The emission in this wavelength region is critical to the OWL mission - which images UHE air showers from nitrogen fluorescence. NIGHTGLOW (Dr. Barbier, PI) is a collaboration with the U. of Utah (Dr. E. Loh) and consists of 3 optical telescopes, which will monitor the UV emission during a two week around the world balloon flight planned for January 2001.

5.12 ENergetic Trans-Iron Composition Experiment (ENTICE)

The ENergetic Trans-Iron Composition Experiment (ENTICE) is an experiment that will detect fluxes of ultra-heavy nuclei with high charge resolution. This will allow definitive measurements on the nucleosynthesis origins of elements for $26 < Z < 83$. ENTICE was formerly a third part of ACCESS, but has been split off into a separate instrument. ENTICE is lead by Dr. R. Binns (Washington U. in St. Louis). Drs. Barbier and Christian lead the Goddard work on ENTICE.

5.13 Extremely Heavy Cosmic-ray Composition Observatory (ECCO)

Dr. Barbier was the NASA Study Scientist for the Extremely Heavy Cosmic-ray Composition Observatory (ECCO) – an International Space Station mission. ECCO, Dr. Andrew Westphal(LBL) PI, is an extension of the TREK/MIR experiment that found that Pb is under abundant in the cosmic-rays. Since Pb is easily ionized, this contradicts standard models of the cosmic-ray source as being a solar-like, ionized medium. ECCO will measure the rare actinides (Th, U, Np, Pu, Cm) with high accuracy for the first time, which will help our understanding of the true cosmic-ray source.

5.14 Gamma Ray Burst Coordinates Network (GCN)

Dr. Barthelmy continues the development and operations of the GCN system (used to be called BACODINE). There are three parts to the GRB Coordinates Network: (1) the real-time distribution of GRBs detected by CGRO-BATSE (the original BACODINE system), (2) the near-realtime distribution of GRB locations detected by other spacecraft, and (3) the distribution of follow-up observation reports submitted by the GRB community (GCN Circulars).

The original BACODINE portion of the system is continuing to successfully send gamma- ray burst source coordinates to the community in real time. The BATSE portion of the telemetry from CGRO is monitored for the onset of a GRB, and its source coordinates are calculated in RA and Dec and are sent (as the burst may still be taking place) to sites that can make multi-band follow-up observations. The worst-case time delay is little over 5 seconds. The accuracy of the location depends on the intensity of the GRB and varies in radius over several degrees, depending on the burst brightness.

The GRB Coordinates Network (GCN) has generalized BACODINE by adding inputs from other GRB instruments/spacecraft, including the interplanetary network (IPN) and GRO-COMPTEL, RXTE-PCA/-ASM, BeppoSAX-WFC/-NFI, Wind-Konus, NEAR-XGRS, and extreme UV-transients from ALEXIS. These burst locations plus the BATSE- derived locations provide a wide range of time delays (seconds to hours) and range of error box sizes (arminutes to degrees). The global GCN client list includes over 70 optical, radio, x-ray, gamma-ray, and air-shower telescopes and instruments. The coordinates for all these sources are distributed via direct Internet socket connections, or by electronic mail, alpha-numeric pagers, cell-phones, and/or dedicated phone lines.

The GCN Circulars close the loop on the study of GRBs by allowing the follow-up observer to report his/her results to the scientific community in a rapid fashion. People are added to a distribution list which allows them to submit short reports (a few paragraphs) about their follow-up observations and these reports are automatically distributed to everyone on the list (within a minute).

5.15 Foil Mirrors for X-Ray Telescopes

The foil mirror group is led by Dr. Serlemitsos with collaboration by Drs. Soong and Chan. The technology of using thin-foil mirrors for space flight X-ray telescopes has been developed at Goddard for more than two decades. Two missions, BBXRT in 1990 and ASCA in 1993, were born out of this technology, and a third one, Astro-E, is scheduled to be launched in February 2000. These broad band (energy response up to 10 keV), high throughput, and light-weight telescopes provide the X-ray astrophysical community a powerful tool to probe deeper into space.

The aperture of the telescopes has steadily increased, as well as the sensitivity, while the image quality has improved from 3.5′ to the current 1.0′. The improvement came from reducing the surface roughness at millimeter spatial wavelengths on the mirror surface. The so-called orange-peel roughness on the 150-micron aluminum substrate was greatly reduced by the process of surface replication. We are now achieving 3-5 Angstrom RMS in surface roughness in the range between millimeter to sub-micron level. The mirrors use the conical approximation, which gives a theoretical limit of image half power diameter of about 0.3′ based on current telescope focal lengths of 4-5 m. There is still ground to be gained before the step to Wolter curved reflecting surface geometry. The residual errors are: 1) curvature of the foil along the optical axis, 2) round error of the foil, and 3) error of the holding fixture and the alignment procedure in general. Since delivery of five telescopes for Astro-E, work has proceeded on the above problems in order to advance into the next generation of X-ray telescopes of high sensitivity and better image quality.

The five telescopes on board of Astro-E spacecraft are in two groups. Four of them have a 4.75 m focal length and will be on top of four CCD detectors, which are provided by a group at MIT. The single one has a slightly shorter focal length of 4.5 m and will be on top of the microcalorimeter, which has an unprecedented 10 eV energy resolution, and thus will provide a powerful tool to study the emission processes of X-ray sources in detail.

Another front in high-energy astronomy is to broaden the energy band beyond 10 keV. We are currently engaged in multilayering of the reflecting surface for that purpose. The preliminary results show the feasibility of enhancing the response between 20-40 keV at different levels depending on the material and thickness arrangement of the layering process. A planned high altitude balloon flight with a telescope capable of focusing 20-40 keV photons will be started Fall 1999. The program is named InFOCμS (see Section 5.7).

5.16 Public and Education Outreach

The Laboratory for High-Energy Astrophysics continues its outstanding educational and public outreach program with the release of new products and strong representation at national and regional meetings.

The LHEA outreach group released, for the third year in a row, a CD-ROM capturing its educational web sites. This year's CD contains four sites, including Imagine the Universe!, StarChild, the Astronomy Picture of the Day, and the AstroCappella (a package of astrophysically correct songs by a professional a capella group, the Chromatics). Ms. M. Bene, Ms. M. Masetti, Ms. J.A. Hajian, Drs. Fantasia and Whitlock prepared and released Volume 3 of the CD-ROM. For this version, Ms. Bene converted all of the cgi activities to javascript, so that the interactive features were available in this format. The CD-ROM, which is given out free to educators and the public, is one of the LHEA outreach group's most popular items. It is both Mac and PC compatible and comes with all the necessary software. The LHEA outreach continues to expand our programs beyond the web site, with the development of a third set of posters and activity books, on the topic Gamma Ray Bursts. The outreach group produced a second CD-ROM this year, which includes 15 mission pages, three learning Centers (XTE, ACE, and Astro-E) and a Cosmic Distance Scale feature.

The LHEA outreach group represented the Structure and Evolution of the Universe theme at many national and regional meetings, including the National Science Teacher's Association and the National Council for Teachers of Mathematics annual meetings, the Science Teachers of New York State meeting, and two American Astronomical Society meetings.

PUBLICATIONS

Akerlof, C., Balsano, R., Barthelmy, S., Bloch, J., Butterworth, P., Casperson, D., Cline, T., Fletcher, S., Frontera, F., Gisler, G., Heise, J., Hills, J., Kehoe, R., Lee, B., Marshall, S., McKay, T., Miller, R., Piro, L., Priedhorsky, W., Szymanski, J., Wren, J. 1999, ''Discovery of Contemporaneous Optical Radiation from a Gamma-Ray Burst,'' Nature, 398, 400

Angelini, L., Church, M.J., Parmar, A., Balucinska-Church, M., Mineo, T. 1998, ''Discovery of a New 107s X-ray Pulsar 1SAXJ13244-6200,'' A&A, 339L, 41

Araya, R.A., Harding, A.K. 1999, ''Resonant Cyclotron Line Features from Near-Critical Magnetic Fields: The Effect of Optical Depth and Plasma Geometry,'' ApJ, 517, 334

Arnaud, K., Mushotzky, R. 1998, ''A Dusty X-Ray Absorber in the Perseus Cluster?,'' ApJ, 501, 119

Asai, K., Dotani, T., Nagase, F., Ebisawa, K., Mukai, K., Smale, A., Kotani, T. 1998, ''ASCA Observation of the Supersoft X-Ray Source CAL 87,'' ApJL, 503, 143

Baoezio, M., Carlson, P., Francke, T., Weber, N., . . . , Mitchell, J., Ormes, J., Streitmatter, R., Golden, R., Stochaj, S. 1999, ''New Measurement of the flux of Atmospheric Muons, '' Phys Rev Lett, 82, 4757

Barbier, L.M., Birsa, F., Odom, J., Barthelmy, S.D., Gehrels, N., Krizmanic, J.F., Palmer, D., Parsons, A.M., Stahle, C.M., Tueller, J. 1999, ''XA Readout Chip Characteristics and CdZnTe Spectral Measurements,'' IEEE Trans Nucl Sci, 46, 7

Baring, M., Harding, A. 1998, ''Radio-Quiet Pulsars with Ultrastrong Magnetic Fields,'' ApJL, 507, 55

Baring, M., Harding, A. 1998, ''Pair Production Opacities for Gamma-Ray Burst Spectra in the 10 GeV-1 TeV Range,'' AdSpR, 22, 1115

Baring, M., Harding, A. 1998, ''Numerical Evaluation of Magnetic Photon Splitting Rates via a Proper-Time Technique,'' AdSpR, 22, 1121

Baring, M.G., Ellison, D.C., Reynolds, S.P., Grenier, I.A., Goret, P. 1999, ''Radio to Gamma-Ray Emission from Shell-Type Supernova Remnants: Predictions from Non-Linear Shock Acceleration Models,'' ApJ, 513, 311

Bautista, M., Kallman, T., Angelini, L., Liedahl, D., Smits, D. 1998, ''Hydrogen-Like Ion Emission in the Spectra of Low-Mass X-Ray Binaraies,'' ApJ, 509, 848

Bautista, M.A., Romano, P., Pradhan, A.K. 1998, ''Resonance-Averaged Photoionization Cross Sections for Astrophysical Models,'' ApJS, 118, 259

Bautista, M.A., Titarchuk L. 1999, ''H-Like Iron Emission in Narrow-Line Seyfert 1 Galaxies as a Temperature Diagnostic of Accretion Flows,'' ApJ, 511, 105

Bautista, M.A. 1999, ''Atomic Data from the Iron Project XXXIX. Photoionization Corss Sections and Oscillator Strengths for NiII,'' A&AS 137, 1

Baykal, A., Swank, J., Strohmayer, T., Stark, M. 1998, ''Spin-Down Rate of 1E 2259+586 from RXTE Observation,'' A&A, 336, 173

Berdichevsky, D., Bougeret, J.-L., Deladoudiniere, J.-P., Fox., N., Kaiser, M., Lepping, R., Michels, D., Plunkett, S., Reames, D., Reiner, M., Richardson, I., Rostoker, G., Steinberg, J., Thompson, B., von Rosenvinge, R. 1998, ''Evidence for Multiple Ejecta: April 7-11, 1997, ISTP Sun-Earth Connection Event,'' GRL, 25, 2473

Bildsten, L., Strohmayer, T.E. 1999, ''New Views of Neutron Stars,'' Physics Today, 52, 2, 40

Blandford, R. and Gehrels, N. 1999 ''Revisitng the Black Hole,'' Physics Today, 52, 6, 40

Boer, M., Lewin, W., Cline, T., Hurley, K., Niel, M., Kouveliotou, C., Harmon, A., Fishman, G., Briggs, M., Van Paradijs, J., Kommers, J. 1998, ''Verifying the Accuracy of the Third Interplanetary Network: Localization of the Bursting Pulsar GRO J1744-28 by Triangulation,'' AdSpR, 22, 1125

Boeziio, M., Carlson, P., Francke, T., Weber, N., Suffert, M., . . . , Mitchell, J.W., Ormes, J.F., Streitmatter, R.E., Golden, R.L., Stochai, S.J. 1999, ''New Measurement of the Flux of Atmospheric Muons,'' Phys Rev Lett, 82, 4757

Borozdin, K., Revnivtsev, M., Trudolyubo , S., Titarchuk, L., Shrader, C. 1999, ''Do Soft X-Ray Transients Reveal Bulk-Motion Inflow Phenomenon?,'' ApJ, 517, 36

Cane, H., Richardson, I., St. Cyr, O. 1998, ''The Interplanetary Events of January-May, 1997, as Inferred from Energetic Particle Data, and their Relationship with Solar Events,'' GRL, 25, 2517

Cane, H., Richardson, I., von Rosenvinge, T. 1998, ''Interplanetary Magnetic Field Periodicity of ~ 153 Days,'' GRL, 25, 4437

Cane, H.V., Wibberenz, G., Richardson, I.G., von Rosenvinge, T.T. 1999, ''Cosmic Ray Modulation and the Solar Magnetic Field,'' GRL, 26, 565

Cannizzo, J., Mattei, J. 1998, ''A Study of the Outbursts in SS Cygni,'' ApJ, 505, 344

Chen, W., Gehrels, N. 1999, ''The Progenitor of the New COMPTEL/ROSAT Supernova Remnant in Vela,'' ApJL, 514, 103

Cheng, L., Leventhal, M., Smith, D., Gehrels, N., Tueller, J., Fishman, G. 1998, ''BATSE All-Sky Search for Transient Gamma-Ray Lines Between 300 and 550 keV,'' ApJ, 503, 809

Cohen, C., Cummings, A., Dwyer, J., Gold, R., Krimigis, S., Leske, R., Mazur, J., Mewaldt, R., Mobius, E., Popecki, M., Stone, E., Stone, E., Von Rosenvinge, T., Wiedenbeck, M. 1999, ''Particle Acceleration and Sources in the November 1997 Solar Energetic Particle Events,'' GRL, 26, 141

Cohen, C., Cummings, A., Leske, R., Mewaldt, R., Stone, E., Dougherty, B., Wiedenbeck, M., Christian, E., Von Rosenvinge, T. 1999, ''Inferred Charge States of High-Energy Solar Particles from the Solar Isotope Spectrometer on ACE,'' GRL, 26, 149

Contopoulos, I., Kazanas, D. 1998, ''A Cosmic Battery,'' ApJ, 508, 859

Contopoulos, I., Kazanas, D., Fendt, C. 1999, ''The Axisymmetric Pulsar Magnetosphere,'' ApJ, 511, 351

Corbet, R., Finley, J., Peele, A. 1999, ''Evidence for a Very Slow X-Ray Pulsar in 2S 0114+650 from Rossi X-Ray Timing Explorer All-Sky Monitor Observations,'' ApJ, 511, 876

Corbet, R.H.D., Marshall, F.E., Peele, A.G., Takeshima, T. 1999, ''RXTE Observations of the X-ray Pulsar XTE J1855-026 - A Possible New Supergiant System,'' ApJ, 517, 956

Cui, W., Barret, D., Zhang, S., Chen, W., Boirin, L., Swank, J. 1998, ''Evolution of Aquila X-1 During the Rising Phase of Its 1998 Outburst,'' ApJL, 502, 49

Cui, W., Morgan, E., Titarchuk, L. 1998, ''Soft Phase Lags in the Millisecond X-Ray Pulsar SAX J1808.4-3658,'' ApJL, 504, 27

Cui, W., Zhang, S., Chen, W., Morgan, E. 1999, ''Strong Aperiodic X-Ray Variability and Quasi-Periodic Oscillation in X-Ray Nova XTE J1550-564,'' ApJL, 512, 43

Dahlem, M., Weaver, K., Heckman, T. 1998, ''An X-ray Minisurvey of Nearby Edge-on Starburst Galaxies. I. The Date,'' ApJS, 118, 401

Della Ceca, R., Griffiths, R.E., Heckman, T.M., Lehnert, M.D., Weaver, K.A. 1999, ''ASCA Observations of the Starburst-Driven Superwind Galaxy NGC 2146: Broadband (0.6-9 keV) Spectral Properties,'' ApJ, 514, 772

Edelson, R.A., Nandra, K. 1999, ''A Cutoff in the Fluctuation Power Density Spectrum of the Seyfert 1 Galaxy NGC 3516,'' ApJ, 514, 682

Elitzur, M. 1998, ''Polarization of Astronomical Maser Radiation. IV. Circular Polarization Profiles,'' ApJ, 504, 390

Ellison, D. C., Jones, F. C., Baring, M. G. 1999, ''Direct Acceleration of Pickup Ions at the Solar Wind Termination Shock: the Production of Anomalous Cosmic Rays,'' ApJ, 512, 403

Furuzawa, A., Tawara, Y., Kunieda, H., Yamashita, K., Sonobe, T., Tanaka, Y., Mushotzky, R. 1998, ''ASCA Observation of the Distant Cluster of Galaxies C1 0016+16 and Implication for H 0,'' ApJ, 504, 35

George, I., Turner, T.J., Mushotzky, R., Nandra, K., Netzer, H. 1998, ''ASCA Observations of the Ionized Gas in the Seyfert Galaxy NGC 3783,'' ApJ, 503, 174

George, I., Mushotzky, R., Turner, T., Yaqoob, T., Ptak, A., Nandra, K., Netzer, H. 1998, ''The X-Ray Spectral Variability of the Seyfert Galaxy NGC 3227,'' ApJ, 509, 146

Ghosh, P. 1998, ''Viscous Stability of Relativistic Keplerian Accretion Disks,'' ApJL, 506, 109

Ghosh, P. 1998, ''Lessons from QPOs in X-ray Pulsars,'' AdSpR, 22, 1017

Giles, A., Jahoda, K., Strohmayer, T. 1998, ''PCA Observations of Cyg X-1 from RXTE Using Fast Timing and High Telemetry Rates,'' AdSpR, 22, 965

Grove, J., Strickman, M., Matz, S., Hua, X.-M., Kazanas, D., Titarchuk, L. 1998, ''Timing Noise Properties of GRO J0422+32,'' ApJL, 502, 45

Guessoum, N., Kazanas, D., 1999, ''Lithium Production in Companions of Accreting X- Ray Binaries by Neutron Spallation of C, N, O Elements,'' ApJ, 512, 332

Haberl, F., Angelini, L., Motch, C. 1998, ''RXTE Observations of RXJ0146.9+6121: A New X-ray Outburst of the Be/X-ray Pulsar,'' A&A, 335, 587

Haggerty, D., Desai, M., Mason, G., Dwyer, J., Gold, R., Krimigis, S., Mazur, J., Von Rosenvinge, T. 1999, ''Simultaneous Observations of Energetic ($\sim$ 150 keV) Protons Upstream of the Earth's Bow Shock at ACE and Wind,'' GRL, 26, 169

Harding, A., Muslimov, A. 1998, ''Particle Acceleration Zones Above Pulsar Polar Caps: Electron and Positron Pair Formation Fronts,'' ApJ, 508, 328

Harris, M., Teegarden, B., Cline, T., Gehrels, N., Palmer, D.M., Ramaty, R., Seifert, H. 1998, ''Transient Gamma-Ray Spectrometer Measurements of the Positron Annihilation Spectrum from the Galactic Center,'' ApJL, 501, 55

Heckman, T.M., Armus, L., Weaver, K.A., Wang, J. 1999, ''An X-ray and Optical Investigation of the Starburst-Driven Superwind in the Galaxy Merger Arp 299,'' ApJ, 517, 130

Higdon, J., Lingenfelter, R., Ramaty, R. 1998, ''Cosmic-Ray Acceleration from Supernova Ejecta in Superbubbles,'' ApJL, 509, 33

Hua, X-M., Kazanas, D., Cui, W. 1999, ''Probing the Structure of Accreting Compact Sources through X-Ray Time Lags and Spectra,'' ApJ, 512, 793

Hurley, K., Kouveliotou, C., Fishman, G., Meegan, C., Briggs, M., Van Paradijs, J., Cline, T., Kommers, J., Lewin, W., Boer, M. 1998, ''Verifying the Accuracy of the Third Interplanetary Network: Localization of the Bursting Pulsar GRO J1744-28 by Triangulation,'' AdSpR, 22 (7), 1125

Hurley, K., Briggs, M.S., Kippen, R.M., Kouveliotou, C., Meegan, C., Fishman, G., Cline, T., Boer, M. 1998, ''The Ulysses Supplement to the BATSE 3B Catalog of Cosmic Gamma-Ray Bursts,'' ApJS, 120, 399

Hurley, K., Hartmann, D., Kouveliotou, C., Kippen, R.M., Laros, J., Cline, T., Boer, M. 1998, ''No Evidence for Gamma-Ray Burst/Abell Cluster or Gamma-Ray Burst/ Radio- Quiet Quasar Correlations,'' ApJ, 515, 497

Hurley, K., Cline, T., Mazets, E., Barthelmy, S., Butterworth, P., Marshall, F., Palmer, D., Aptekar, R., Golenetskii, S., Il'Inskii, V., Frederics, D., McTiernan, J., Gold, R., Trombka, J. 1999, ''A Giant, Periodic Flare from the Soft Gamma Repeater SGR1900+14,'' Nature, 397, 41

Hurley, K., Kouveliotou, C., Woods, P., Cline, T., Butterworth, P., Mazets, E., Golenetskii, S.D., Frederics, D. 1999, ''Reactivation and Precise Interplanetary Network Location of the Soft Gamma Repeater SGR 1900+14,'' ApJL, 510, 107

Hurley, K., Li, P., Louveliotou, C., Marakami, T., Ando, M., Strohmayer, T., van Paradijs, J., Vrba, F., Luginbuhl, C., Yoshida, A., Smith, I. 1999, ''ASCA Discovery of an X-Ray Pulsar in the Error Box of SGR 1900+14,'' ApJL, 510, 111

Hwang, U., Mushotzky, R.F., Burns, J.O., Fukazawa, Y., White, R.A. 1999, ''Mass and Metallicity of Five X-ray Bright Galaxy Groups,'' ApJ, 516, 604

Hynes, R., O'Brien, K., Horne, K., Chen, W., Haswell, C. 1998, ''Echoes from an Irradiated Disc in GRO J1655-40,'' MNRAS, 299, L37

Hynes, R., Haswell, C., Shrader, C., Chen, W., Horne, K., Harlaftis, E., O'Brien, K., Hellier, C., Fender, R. 1998, ''The 1996 Outburst of GRO J1655-40: The Challenge of Interpreting the Multiwavelength Spectra,'' MNRAS, 300, 64

In't Zand, J.J.M., Verbunt, F., Strohmayer, T.E., Bazzano, A., Cocchi, M., Heise, J., Van Kerkwijk, M.H., Muller, J.M., Natalucci, L., Smith, M.J.S., Ubertini, P. 1999, ''A New X-ray Outburst in the Globular Cluster NGC 6440: SAX J1748.9-2021,'' A&A, 345, 100

Israel, G.L., Stella, L., Angelini, L., White, N.E., Kallman, T.R., Giommi, P., Treves, A. 1998, ''The Discovery of 13s X-ray Pulsations from the Hydrogen Depleted Subdwarf O6 Star Binary HD49798,'' AdSpR, 22, 1035

Israel, G.L., Angelini, L., Campana, S., Giommi, P., Stella, L., White, N.E. 1998, ''The Discovery of 12-min X-ray Pulsations from 1WGA J1958.2+3232,'' MNRAS, 298, 502

Jahoda, K., Hink, P., Swank, J., Peterson, L., Rots, A., Marsden, D., Blanco, P., Gruber, D.E., Heindl, W., Pelling, M., Rothschild, R. 1998, ''Radio Pulsars Observed at X-Ray Energies by the X-Ray Timing Explorer,'' AdSpR, 22, 981

Jevremovic, D., Butler, C., Drake, S., O'Donoghue, D., Van Wyk, F. 1998, ''Ultraviolet and Optical Flares on G1866,'' A&A, 338, 1057

Jones, F., Jokipii, J., Baring, M. 1998, ''Charged-Particle

Motion in Electromagnetic Fields Having at Least One Ignorabale Spatial Coordinate,'' ApJ, 509, 238

Kallman, T., Boroson, B., Vrtilek, S. 1998, ''Simultaneous Hubble Space Telescope/Rossi X-ray Timing Explorer Observations of Scorpius X-1,'' ApJ, 502, 441

Kataoka, J., Mattox, J.R., Quinn, J., Kubo, H., Makino, F., Takahashi, T., Inoue, S., Hartman, R., Madejski, G.M., Sreekumar, P., Wagner, S. 1998, ''A Study of High Energy Emission from the TeV Blazar Mkn 501 during Multiwavelength Observations in 1996,'' ApJ, 514, 138

Kazanas, D., Mastichiadis, A. 1999, ''Relativistic Electrons in Blazars: A Hadronic Origin?,'' ApJL, 518, 17

Keohane, J., Gotthelf, E., Petre, R. 1998, ''Evidence for Proportionate Partition Between the Magnetic Field and Hot Gas in Turbulent Cassiopeia A,'' ApJL, 503, 175

Konopelko, A.K., Kirk, J.G., Stecker, F.W., Mastichiadis, A. 1999, ''Evidence for Intergalactic Absorption in the TeV Gamma-Ray Spectrum of Markarian 501,'' ApJL, 518, 15

Kotani, T., Dotani, T., Nagase, F., Greenhill, J.G., Pravdo, S., Angelini, L. 1999, ''ASCA and Ginga Observations of GX 1+4,'' ApJ, 510, 369

Kouveliotou, C., Strohmayer, T., Hurley, K., Van Paradijs, J., Finger, M., Dieters, S., Woods, P., Thompson, C., Duncan, R. 1999, ''Discovery of a Magnetar Associated with the Soft Gamma Repeater SGR 1900+14,'' ApJL, 510, 115

Krizmanic, J.F. 1998, ''GLAST: The Gamma-Ray Large Area Space Telescope,'' NIM A418, 162

Kubo, S., Murakami, T., Ishida, M., Corbet, R. 1998, ''ASCA X-Ray Observations of Gamma Cassiopeiae,'' PASJ, 50, 417

Kubo, H., Takahashi, T., Madejski, G., Tashiro, M., Makino, F., Inoue, S., Takahara, G. 1998, ''ASCA Observations of Blazars and Multiband Analysis,'' ApJ, 504, 693

Laros, J., Hurley, K., Fenimore, E., Klebesadel, R., Briggs, M., Kouveliotou, C., McCullough, M., Fishman, G., Meegan, C., Cline, T., Boer, M., Niel, M. 1998, ''Gamma-Ray Burst Arrival Time Localizations: Simultaneous Observations by Pioneer Venus Orbiter, Compton Gamma-Ray Observatory, and Ulysses,'' ApJS, 118, 391

Laurent, P., Titarchuk, L.G. 1999, ''The Converging Inflow Spectrum is an Intrinsic Signature for a Black Hole: Monte-Carlo Simulations of Comptonization on Free-Falling Electrons,'' ApJ, 511, 289

Leske, R., Cohen, C., Cummings, A., Mewaldt, R., Stone, E., Dougherty, B., Wiedenbeck, M., Christian, E., Von Rosenvinge, T. 1999, ''Unusual Isotopic Composition of Solar Energetic Particles Observed in the November 6, 1997, Event,'' GRL, 26, 153

Loewenstein, M., White, R.E. III 1999, ''Prevalence and Properties of Dark Matter in Elliptical Galaxies,'' ApJ, 518, 50

Macomb, D.J., Gehrels, N., Shrader, C.R. 1999, ''A Gamma-Ray Flare from PKS 2255-282,'' ApJ, 513, 652

Macomb, D., Gehrels, N. 1999, ''A General Gamma-Ray Source Catalog,'' ApJS, 120, 335

Magdziarz, P., Blaes, O., Zdziarski, A., Johnson, W.N., Smith, D.A. 1998, ''A Spectral Decomposition of the Variable Optical, Ultraviolet and X-ray Continuum of NGC 5548,'' MNRAS, 301, 179

Mandzhavidze, N., Ramaty, R., Kozlovsky, B. 1999, ''Determination of the Abundances of Subcoronal He-4 and of Solar Flare Accelerated He-3 and He-4 from Gamma-Ray Spectroscopy,'' ApJ, 518, 918

Marani, G., Nemiroff, R., Norris, J., Hurley, K., Bonnell, J. 1999, ''Gravitationally Lensed Gamma-Ray Bursts as Probes of Dark Compact Objects,'' ApJL, 512, 13

Markwardt, C., Strohmayer, T., Swank, J. 1999, ''Observation of Kilohertz Quasi- Periodic Oscillations from the Atoll Source 4U 1702-429 by the Rossi X-Ray Timing Explorer,'' ApJL, 512, 125

Markwardt, C., Swank, J., Taam, R. 1999, ''Variable-Frequency Quasi-Periodic Oscillations from the Galactic Microquasar GRS 1915+105,'' ApJL, 513, 37

Marshall, F.E., Swank, J., Valina, A., Corbet, R., Takeshima, T., Barthelmy, S., Robinson, C., Koveliotou, C., Conaughton, V., Kippen, M., Preece, T.R., Bradt, H., Levine, A., Remilard, R., Smith, D., Hurley, K. 1998, ''RXTE Observations of GRB Afterglows,'' Nuc Phys B, 69, 640

Matsunaga, H., Orito, S., Matsumoto, H., Yoshimura, K., Moiseev, A., Anraku, K., Golden, R., Imori, M., Makida, Y., Mitchell, J., Motoki, M., Nishimura, J., Nozaki, M., Ormes, J., Saeki, T., Sanuki, T., Streitmatter, R., Suzuki, J., Tanaka, K., Ueda, I., Yajima, N., Yamagami, T., Yamamoto, A., Yoshida, T. 1998, ''Measurement of Low- Energy Cosmic-Ray Antiprotons at Solar Minimum,'' Phys Rev Lett, 81, 4052

Mayer-Hasselwander, H., Bertsch, D., Dingus, B., Eckart, A., Esposito, J., Genzel, R., Hartman, R., Hunter, S., Kanbach, G., Kniffen, D., Lin, Y., Michelson, P., Muecke, A., Von Montigny, C., Mukherjee, R., Nolan, P., Pohl, M., Reimer, O., Schneid, E., Sreekumar, P., Thompson, D. 1998, ''High-Energy Gamma-Ray Emission from the Galactic Center,'' A&A, 335, 161

Mazur, J., Mason, G., Dwyer, J., Von Rosenvinge, T. 1998, ''Solar Energetic Particles Inside Magnetic Clouds Observed with the Wind Spacecraft,'' GRL, 25, 2521

McKernan, B., Yaqoob, T. 1998, ''Occultation Mapping of the Central Engine in the Active Galaxy MCG-6-30-15,'' ApJL, 501, 29

Mewe, R., Drake, S., Kaastra, J., Schrijver, C., Drake, J., Guedel, M., Schmitt, J., Singh, K., White, N. 1998, ''Alpha Centauri: Coronal Temperature Structure and Abundances from ASCA Observations,'' A&A, 339, 545

Miller, S., Schlegel, E., Petre, R., Colbert, E. 1998, ''X-Ray Properties of NGC 1313: Second-Epoch PSPC Observations,'' AJ, 116, 1657

Miyaji, T., Connolly, A., Szalay, A., Boldt, E. 1998, ''ROSAT HRI Observations of Selected Area 57,'' Astron. Nachr., 319, 31

Miyaji, T., Ogasawa, Y., Boldt, E., . . . 1998, ''The Cross-Correlation of Faint QSOs with the Cosmic X-ray Background,'' Astron. Nachr., 319, 69

Moritz, P., Wennmacher, A., Herbstmeier, U., Mebold, U., Eggeer, R., Snowden, S. 1998, ''X-ray Shadows of the Draco Nebula. A New Method to Determine Total Hydrogen Column Densities,'' A&A, 336, 682

Morley, R., Church, M., Smale, A., Balucinska-Church, M. 1999, ‘‘Progressive Covering of the Accretion Disc Corona during Dipping in the LMXB XB 1916-053,’’ MNRAS, 302, 593

Murakami, T., Kubo, S., Shibazaki, N., Takeshima, T., Yoshida, A., Kawai, N. 1999, ‘‘Accurate Position of SGR 1900+14 by Bursts and Changes in Pulse Period and Folded Pulse Profile with ASCA,’’ ApJL, 510, 119

Nahar, S.N., Bautista, M.A., Pradhan A.K. 1998, ‘‘Electron-Ion Recombination of FeIV,’’ Phys Rev A, 58, 4593

Nahar, S.N., Bautista, M.A. 1999, ‘‘Electron-Ion Recombination of FeV,’’ ApJS, 120, 327

Nandra, K., Clavel, J., Edelson, R., George, I., Malkan, M., Mushotzky, R., Peterson, B., Turner, T.J. 1998, ‘‘New Constraints on the Continuum Emission Mechanism of Active Galactic Nuclei: Intensive Monitoring of NGC 7469 in the X-Ray and Ultraviolet,’’ ApJ, 505, 594

Netzer, H., Turner, T.J., George, I. 1998, ‘‘The Soft X-Ray Spectrum of Scattering- Dominated Active Galactic Nuclei,’’ ApJ, 504, 680

Norris, J., Bonnell, J., Watanabe, K. 1999, ‘‘Constraints on Association of Single-Pulse Gamma-Ray Bursts and Supernovae,’’ ApJ, 518, 901

O’Brien, P.T., Dietrich, M., Leighly, K., Alloin, D., Clavel, J., . . . , Netzer, H., Peterson, B., Reichert, G., . . . , George, I., . . . , Turner, T.J., . . . 1998, ‘‘Steps Toward Determination of the Size and Structure of the Broad-Line Region in Active Galactic Nuclei. XIII. Ultraviolet Observations of the Broad-Line Radio Galaxy 3C 390. 3,’’ ApJ, 509, 163

Orr, A., Yaqoob, T., Parmar, A., Piro, L., White, N., Grandi, P. 1998, ‘‘Quasi- Simultaneous Observations of 3C 273 by BeppoSAX and ASCA,’’ A&A, 337, 685

Palmer, D. 1999, ‘‘SGR 1806-20 Is a Set of Independent Relaxation Systems,’’ ApJL, 512, 113

Park, S., Finley, J.P., Dame, T.M. 1998, ‘‘Evidence for the Galactic X-ray Bulge. II.,’’ ApJ, 509, 203

Parsons, A., Gehrels, N., Paciesas, W., Harmon, B., Fishman, G., Wilson, C., Zhang, S. 1998, ‘‘Multiyear BATSE Earth Occultation Monitoring of NGC 4151,’’ ApJ, 501, 608

Peele, A., Zhang, W. 1998, ‘‘Lobster-Eye All-Sky Monitors: A Comparison of One- and Two- Dimensional Designs,’’ Rev Sci Instr, 69, 2785

Peele, A.G. 1999, ‘‘Investigation of Etched Silicon Wafers for Lobster-Eye Optics,’’ Rev Sci Instr, 70, 1268

Pittard, J., Stevens, I., Corcoran, M., Ishibashi, K. 1998, ‘‘The X-Ray Light Curve of Eta Carinae,’’ MNRAS, 299, 5

Ptak, A., Yaqoob, T., Mushotzky, R., Serlemitsos, P., Griffiths, R. 1998, ‘‘X-Ray Variability as a Probe of Advection-Dominated Accretion in Low-Luminosity Active Galactic Nuclei,’’ ApJL, 501, 37

Ragot, B.R. 1999, ‘‘Nongyroresonant Pitch-Angle Scattering,’’ ApJ, 518, 974

Ramaty, R., Vangioni-Flam, E., Casse, M., Olive, K. 1999, ‘‘LiBeB, Cosmic Rays and Gamma-Ray Line Astronomy,’’ PASP, 111, 651

Randich, S., Singh, K., Simon, T., Drake, S., Schmitt, J. 1998, ‘‘ROSAT HRI Observations of the Intermediate-Age Open Cluster IC 4756,’’ A&A, 337, 372

Ray, A., Harding, A.K., Strickman, M.S. 1999, ‘‘RXTE Observation of PSR1706-44 and Implications for Theoretical Models of Pulsar Emission,’’ ApJ, 513, 919

Reames, D., Ng, C. 1998, ‘‘Streaming-Limited Intensities of Solar Energetic Particles,’’ ApJ, 504, 1002

Reames, D.V. 1998, ‘‘Solar Energetic Particles: Sampling Coronal Abundances,’’ SpSci Revs, 85, 327

Reames, D.V. 1999, ‘‘Quiet-time Spectra and Abundances of Energetic Particles During the 1996 Solar Minimum,’’ ApJ, 518, 473

Rho, J., Petre, R. 1998, ‘‘Mixed-Morphology Supernova Remnants,’’ ApJL, 503, 167

Richardson, I.G., Cane, H.V., Wibberenz, G. 1999, ‘‘Corotating Cosmic Ray Depressions Near the Ecliptic During Five Solar Minima: Evidence for a 22-year Dependence,’’ JGR, 104, 12549

Rothschild, R., Band, D., Blanco, P., Gruber, D., Heindl, W., MacDonald, D., Marsden, D., Jahoda, K., Pierce, D., Madejski, G., Elvis, M., Schwartz, D., Remillard, R., Zdziarski, A., Done, C., Svensson, R. 1999, ‘‘Observation of Centaurus A by the Rossi X-Ray Timing Explorer,’’ ApJ, 510, 651

Rots, A., Jahoda, K., Macomb, D., Kawai, N., Saito, Y., Kaspi, V., Lyne, A., Manchester, R., Backer, D., Somer, A., Marsden, D., Rothschild, R. 1998, ‘‘Rossi X- ray Timing Explorer Absolute Timing Results for the Pulsars B1821-24 and B1509-58,’’ ApJ, 501, 749

Roy, A., Colbert, E., Wilson, A., Ulvestad, J. 1998, ‘‘The Compact Radio Sources in the Nucleus of NGC 1068,’’ ApJ, 504, 147

Saeki, T., Anraku, K., Orito, S., Ormes, J., Imori, M., Kimbell, B., Makida, Y., Matsumoto, H., Matsunaga, H., Mitchell, J., Motoki, M., Nishimura, J., Nozaki, M., Otoba, M., Sanuki, T., Streitmatter, R., Suzuki, J., Tanaka, K., Ueda, I., Yajima, N., Yamagami, T., Yamamoto, A., Yoshida, T., Yoshimura, K. 1998, ‘‘A New Limit on the Flux of Cosmic Antihelium,’’ Phys Lett B, 422, 319

Safi-Harb, S., Petre, R. 1999, ‘‘RXTE Observations of the Eastern Lobe of W50 Associated with SS433,’’ ApJ, 512, 784

Sambruna, R., Mushotzky, R. 1998, ‘‘X-Ray Absorption in the BL Lacertae Object PKS 0548-322,’’ ApJ, 502, 630

Schaefer, B.E., Cline, T.L., Hurley, K.C., Laros, J.G. 1998, ‘‘Gamma-Ray Counterparts: Optical Data,’’ ApJS, 118, 353

Shelton, R.L. 1998, ‘‘Simulations of Supernova Remnants in Diffuse Media and Their Application to the Lower Halo of the Milky: I. The High-Stage Ions,’’ ApJ, 504, 785

Shrader, C.R., Singh, K.P., Firoza, S., Macomb, D.J. 1998, ‘‘High-Energy Spectral and Temporal Properties of GRO J1008-57,’’ ApJ, 512, 920

Singh, K., Drake, S., Gotthelf, E., White, N. 1999, ‘‘X-Ray Spectroscopy of Rapidly Rotating, Late-Type Dwarf Stars,’’ ApJ, 512, 874

Smith, D., Main, D., Marshall, F., Swank, J., Heindl, W., Leventhal, M., In’t Zand, J., Heise, J. 1998, ‘‘XTE J1739-

302: An Unusual New X-Ray Transient,'' ApJL, 501, 181

Smith, M., Robinson, R., Corbet, R. 1998, ''A Multiwavelength Campaign on Gamma Cassiopeiae. I. The Case for Surface X-Ray Flaring,'' ApJ, 504, 877

Snowden, S. 1998, ''The Calibration of the ROSAT HRI Particle Background,'' ApJS, 117, 233

Stanimirovic, S., Staveley-Smith, L., Dickey, J., Sault, R., Snowden, S. 1999, ''The Large-Scale HI Structure of the Small Magellanic Cloud,'' MNRAS, 302, 417

Stecker, F.W., Salamon, M.H. 1999, ''Photodisintegration of Ultrahigh Energy Cosmic Rays: A New Determination,'' ApJ, 512, 521

Stecker, F.W. 1999, ''Intergalactic Extinction of High Energy Gamma-Rays,'' Astroparticle Physics 11, 3

Stephens, S., Streitmatter, R. 1998, ''Cosmic-Ray Propagation in the Galaxy: Techniques and the Mean Matter Traversal,'' ApJ, 505, 266

Strohmayer, T., Zhang, W., Swank, J., Lapidus, I. 1998, ''The Long-Term Stability of Oscillations During Thermonuclear X-Ray Bursts: Constraining the Binary X-Ray Mass Function,'' ApJL, 503, 147

Strohmayer, T. E., Markwardt, C. B. 1999, ''On the Frequency Evolution of X-Ray Brightness Oscillations during Thermonuclear X-Ray Bursts: Evidence of Coherent Oscillations,'' ApJL, 516, 81

Tatischeff, V., Ramaty, R., Kozlovsky, B. 1998, ''X-Rays from Accelerated Ion Interactions,'' ApJ, 504, 874

Tatischeff, V., Ramaty, R., 1999, ''Diffuse 0.5-1 keV X-Rays and Nuclear Gamma-Rays from Fast Particles in the Local Hot Bubble,'' ApJ, 511, 204

Taylor, J. 1999, ''Line Emission from Stellar Winds in Active Galactic Nuclei,'' PhD Thesis, Univ. of Maryland, College Park

Terashima, Y., Kunieda, H., Misaki, K., Mushotzky, R., Ptak, A., Reichert, G. 1998, ''Detection of an Iron K Emission Line from the LINER NGC 4579,'' ApJ, 503, 212

Thompson, D.J., Bailes, M., Bertsch, D.L., Cordes, J., D'Amico, N., Esposito, J.A., Finley, J., Hartman, R.C., Hermsen, W., Kanbach, G., Kaspi, V.M., Kniffen, D.A., Kuiper, L., Lin, Y.C., Lyne, A., Manchester, R., Matz, S.M., Mayer-Hasselwander, H.A., Michelson, P.F., Nolan, P.L., Ogelman, H., Pohl, M., Ramanamurthy, P.V., Sreekumar, P., Reimer, O., Taylor, J.H., Ulmer, M. 1999, ''Gamma Radiation from PSR B1055-52,'' ApJ, 516, 297

Titarchuk, L.B., Osherovich, V. 1999, ''Correlation Between Kilohertz Quasi-Periodic Oscillations and Low-Frequency Features Attributed to Radial Oscillations and Diffusive Propagation in the Viscous Boundary Layer Around a Neutron Star,'' ApJL, 518, 95

Treyer, M., Scharf, C., Lahav, O., Jahoda, K., Boldt, E., Piran, T. 1998, ''Large-Scale Fluctuations in the X-Ray Background,'' ApJ, 509, 531

Turner, T.J., George, I., Nandra, K. 1998, ''X-Ray Signatures of an Ionized Reprocessor in the Seyfert Galaxy Ton S 180,'' ApJ, 508, 648

Turner, T.J., George, I., Grupe, D., Nandra, K., Remillard, R., Leighly, K., Marshall, H., Kraemer, S., Crenshaw, D. 1999, ''X-Ray Observations of the Seyfert Galaxy LB 1727 (1H 0419-577),'' ApJ, 510, 178

Turner, T.J. 1999, ''X-Ray Observations of Markarian 231,'' ApJ, 511, 142

Valinia, A., Marshall, F. 1998, ''RXTE Measurement of the Diffuse X-Ray Emission from the Galactic Ridge: Implications for the Energetics of the Interstellar Medium,'' ApJ, 505, 134

Valinia, A., Henriksen, M.J., Loewenstein, M., Roettiger, K., Mushotzky, R.F., Madejski, G. 1999, ''Rossi X-ray Timing Explorer Hard X-ray Observation of A754: Constraining the Hottest Temperature Component and the Intracluster Magnetic Field,'' ApJ, 515, 42

Vangioni-Flam, E., Ramaty, R., Olive, K., Casse, M. 1998, ''Testing the Primary Origin of Be and B in the Early Galaxy,'' A&A, 337, 714

Waldron, W., Corcoran, M., Drake, S., Smale, A. 1998, ''X-Ray and Radio Observations of the Cygnus OB2 Association,'' ApJS, 118, 217

Wang, J.C.L., Link, B., van Riper, K., Arnaud, K.A., Miralles, J.A. 1999, ''RX J0720.4-3125: Implications for Neutron Star Cooling and the Dense Matter Equation of State,'' A&A, 345, 869

Watanabe, K., Hartmann, D., Leising, M., The, L. 1999, ''The Diffuse Gamma-ray Background from Supernovae,'' ApJ, 516, 285

Weaver, K., Yaqoob, T. 1998, ''On the Evidence for Extreme Gravity Effects in MCG-6- 30-15,'' ApJL, 502, 139

Weaver, K., Reynolds, C. 1998, ''Are the Nuclei of Seyfert 2 Galaxies Viewed Face-On?,'' ApJL, 503, 39

Wells, J., Moiseev, A., Ormes, J. 1999, ''Illuminating Dark Matter and Primordial Black Holes with Interstellar Antiprotons,'' ApJ, 518, 575

White, N.E., Ghosh, P. 1998, ''Low-Mass X-Ray Binaries, Millisecond Radio Pulsars, and the Cosmic Star Formation Rate,'' ApJL, 504, 31

Wilson, A.S., Roy, A., Ulvestad, J., Colbert, E., Weaver, K., Braatz, J., Henkel, C., Matsuoka, M., Xue, S., Iyomoto, N., Okada, K. 1998, ''The Ionization Fraction in the Obscuring 'Torus' of an Active Galactic Nucleus,'' ApJ, 505, 587

Wozniak, P., Zdziarski, A., Smith, D., Madejski, G., Johnson, W.N. 1998, ''X-Ray and Soft Gamma-Ray Spectra of Broad-Line Radio Galaxies,'' MNRAS, 299, 449

Yamashita, K., Serlemitsos, P., Tueller, J., Barthelmy, S., Bartlett, L., Chan, K-W., Furuzawa, A., Gehrels, N., Haga, K., Kunieda, H., Kurczynski, P., Lodha, G., Nakajo, N., Makamura, N., Namba, Y., Ogasaka, T., Okajima, T., Palmer, D., Parsons, A., Soong, Y., Stahle, C., Takata, H., Tamura, K., Tawara, Y., Teegarden, B. 1998, ''Supermirror Hard-X-Ray Telescope,'' Applied Optics, 37, 34

Yaqoob, T., George, I., Turner, T.J., Nandra, K., Ptak, A., Serlemitsos, P. 1998, ''A Peculiar Emission-Line Feature in the X-Ray Spectrum of the Quasar PKS 0637-752,'' ApJL, 505, 87

Yaqoob, T. 1999, ''On the Unusually High Temperature of the Cluster of Galaxies 1E 0657-56,'' ApJL, 511, 75

Yoshita, K., Tsunemi, H., Miyata, E., Gendreau, K.C., Bautz, M.W. 1999, ‘‘Improvement of the Position Resolution of the CCD for X-ray Use,’’ IEEE Trans Nuc Sci, 46, No 2, 100

Zdziarski, A., Poutanen, J., Mikolajewska, J., Gierlinski, M., Ebisawa, K., Johnson, W.N. 1998, ‘‘Broad-Band X-Ray/Gamma-Ray Spectra and Binary Parameters of GX 339-4 and Their Astrophysical Implications,’’ MNRAS, 301, 435

Zdziarski, A., Lubinski, P., Smith, D. 1999, ‘‘Correlation Between Compton Reflection and X-Ray Slope in Seyferts and X-ray Binaries,’’ MNRAS, 303L, 11

Zhang, B., Hong, B.H., Qiao, G.J. 1999, ‘‘Is Coherence Essential to Account for Pulsar Radio Emission?,’’ ApJL, 514, 111

Zioutas, K., Thompson, D.J., Paschos, E.A. 1998, ‘‘Search for Energetic Cosmic Axions Utilizing Terrestrial/Celestial Magnetic Fields,’’ Phys Lett B, 443, 201-208

Zycki, P.T., Done, C., Smith, D.A. 1999, ‘‘X-ray Spectral Evolution of GS 2023+338 (V404 Cyg) During Decline After Outburst,’’ MNRAS, 305, 231