George Mason University
Center for Earth Observing and Space Research
Fairfax, Virginia 22030-4444

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This report covers the astronomy-related activities of the Center for Earth Observing and Space Research (CEOSR), a component of the Institute for Computational Sciences and Informatics (CSI) at George Mason University, for the period October 1, 1998 to September 30, 1999. Faculty and postdocs in the CEOSR program were J. Beall, P. Becker, R. Ellsworth, J. Guillory, P. Hertz, M. Kafatos, K. Olson, L. Ozernoy, P. Subramanian, M. Summers, L. Titarchuk, A. Vourlidas, J. Wallin, K. Wood, and R. Yang. S. Roy was a visiting faculty member. Further program information is available at http://www.ceosr.gmu.edu.

1. INTRODUCTION

The interdisciplinary doctoral program in Computational Sciences and Informatics recognizes the importance of numerical computation as a unifying theme in modern research and education. The doctoral program, begun in the Fall of 1992, focuses on a number of specialty areas, including bioinformatics, computational chemistry, Earth systems and global change, computational mathematics, computational physics, space sciences, and computational statistics. The program emphasizes three intellectual elements: a common computational sciences and informatics core; specialty tracks of computationally intensive courses; and doctoral research. CSI Space Sciences faculty are involved in many ongoing collaborations with scientists at the Naval Research Laboratory and NASA/Goddard Space Flight Center. CSI also maintains active relationships with a number of high-technology corporations in the Washington, D.C. area. Many members of CEOSR participate in the Washington Area Astronomers Association, a regional organization of professional astronomers stretching from Charlottesville to Baltimore.

2. OBSERVATIONAL ASTRONOMY & MULTIFREQUENCY DATA ANALYSIS

At CEOSR, work is continuing to extract information about the content of data in large data sets. Interactive, content-based data mining capabilities developed for earth science data systems can also be applied to space science data. Also, GMU's experience in federated data systems in the internet era (Kafatos *et al.* 1999) has application to distributed space sciences data systems.

A multi-institution collaboration involving George Mason University, the University of Puerto Rico at Cumacao, Penn State, and University of Crete is focusing on multifrequency observations of blazars. M. Kafatos, visiting faculty M. Roy and E. Ramos (University of Puerto Rico at Cumacao), R. Sambruna (PSU), K. Tsinganos (Crete) and Y. Papamastorakis (Crete), have carried out observations and data analysis related to the recent high state of the BL Lac object AO 0235+164. Cross-correlation analysis of optical and radio light curves has been performed using techniques developed at GMU.

A. Vourlidas worked under contract at the Large Angle and Spectroscopic Coronagraph (LASCO) project which is flown aboard the Solar Heliospheric Observatory (SOHO) satellite. LASCO is a Navy Research Labpratory (NRL) project and therefore he is stationed at NRL. His responsibilites at NRL include research and data analysis of solar observations obtained with the LASCO instruments, and operations and science support tasks such as instrument calibration and science planning. He also serves as the point of contact for researchers interested in using LASCO data products. A. Vourlidas is involved in several collaborative efforts with members from Nancay Radioheliograph, Potsdam Radioheliograph, DASOP, and WIND/WAVES. He has discovered 3 new sungrazing comets in the LASCO images which are documented in IAUC 7204, IAUC 6952, and Minor Planet Electronic Circ. 1999-A24, and is also leading the effort in the calibration and analysis of the LASCO/C1 coronagraph white-light images. He also derived a correction for the LASCO/C3 F corona data.

Student C. Bradshaw, along with B. Geldzahler and E. Fomalont, (NRAO) published a paper reporting the parallax of Scorpius X-1 with an uncertainty of 10%, representing the most precise parallax measurement to date for this source. The paper reports the results of eight VLBA observations at 5 GHz, spanning 3 years, that yielded a trigonometic parallax for Scorpius X-1 of 0.00036'' $\pm$ 0.00004'' corresponding to a distance of 2.8 $\pm$ 0.3 kpc. This precise distance has important implications for understanding the physics of low mass X-ray binary systems and their evolution and provides the basis for testing a fundamental prediction of the unified theory of these binary systems, namely that they radiate at the Eddington luminosity at a particular point in their X-ray cycle. The distance is also important for developing a clear understanding of these high-energy systems that represent unique laboratories for studying radiation and matter in the presence of strong magnetic and gravitational fields and at high temperatures and pressures.

3. BLACK HOLE & NEUTRON STAR ACCRETION

M. Kafatos and P. Subramanian (1999) have analyzed the inner region of accretion flows onto black holes (BHs) and compared the predictions of differerent models with the observations. They examined both accretion onto stellar BHs and sypermassive BHs and the viability of scenarios such as the Advection Dominated Accretion Flow (ADAF). Most accretion scenarios such as two-temperature, ADAFs, and corona-disk flows predict very hot inner regions. They also found that a variety of physical mechanisms predict a viscosity value, $\alpha \lesssim 0.01$, which might be problematic for ADAFs.

M. Bautista and L. Titarchuk studied the formation of the H-like iron (Fe XXVI) Ly-alpha line at 6.97 keV in narrow-line Seyfert 1 galaxies in the framework of current models for black hole accretion. 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 in 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 specific observational tests to distinguish between collisional and resonant fluorescent excitation of the line.

The accretion proceeds almost in a free-fall manner close to the black hole horizon, where the strong gravitational field dominates the pressure forces. L. Titarchuk and P. Laurent used Monte-Carlo simulations to calculate 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 the observed spectra. They show that spectra in the soft state of black hole systems can be described as the sum of a thermal (disk) component and the convolution of some fraction of this component with the CI upscattering 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. They demonstrate the stability of the power law spectral index (alpha$=1.8\pm 0.1$) over a wide range of the plasma temperature (0-10 keV) and mass accretion rates (higher than 2 in Eddington units). The spectrum is practically identical to the standard thermal Comptonization spectrum when the CI plasma temperature approaches 50 keV. In this case one can see the effect of the bulk motion only at high energies where there is an excess in the CI spectrum with respect to the pure thermal one.

L. Titarchuk, K. Borozdin, M. Revnivtsev, S. Trudolyubov, and C. Shrader presented their analysis of the high-energy radiation from black hole 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 BMC model is characterized by three parameters: the disk color temperature, a geometric factor related to the illumination of the black hole 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, in particular, the assumption regarding the dominance of gravitational forces over the pressure forces within the inner few Schwarzschild radii. They have also examined the time behavior of these parameters which can provide information on the source structure.

Since the discovery of kHz quasi-periodic oscillations (QPOs) in neutron star binaries, the difference between peak frequencies of two modes in the upper part of the spectrum has been studied extensively. The idea that this difference is constant and (as a beat frequency) is related to the rotational frequency of the neutron star has been tested previously. The observed decrease of that differnce when the upper and low peak of kHz QPO increase has weakened the beat frequency interpretation. V. Osherovich and L. Titarchuk put forward a different paradigm: a Keplerian oscillator under the influence of the Coriolis force. For such an oscillator, the upper kHz QPO frequency and the assumed Keplerian frequency hold an upper hybrid frequency relation: the square of the hybrid frequency equals to sum of square of the Keplerian frequency and the square of the double rotational frequency of the magnetosphere. For three sources (Sco X-1, 4U 1608-52 and 4U 1702-429), they demonstrate that solid body rotation is a good first order approximation. Within the second order approximation, the slow variation of the rotational frequency as a function of the low kHz peak reveals the structure of the magnetospheric differential rotation. For Sco X-1, the QPO have frequencies around 45 and 90 Hz which they interpret as the 1st and 2nd harmonics of the lower branch of the Keplerian oscillations for the rotator not aligned with the normal of the disk.

L. Titarchuk and V. Osherovich 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 QPOs compare favorably with recent observations for the source 4U 1728-34.

C. Shrader and L. Titarchuk applied the bulk-motion Comptonization (BMC) model to observational data for LMC X-1, and Nova Muscae 1991. They extracted some physical parameters of these systems from observables (within the context of the BMC model), drawing from results on GRO J1655-40, for which they presented extensive analysis previously. They derived estimates of the mass (16 ± 1 solar masses) and mass accretion rate in the disk (roughly 2 in Eddington units) for LMC X-1, and mass (12 solar masses) and mass acretion rate (of order of 3) for Nova Muscae 1991. They discuss differences between these estimates and previous estimates (based on dynamical studies). It is further shown that the disk inner radius increases with the high-to-low state transition in Nova Muscae 1991. Specifically, their analysis suggests that the inner-disk radius increases to 17 Schwarzschild radii as the transition to the low-hard state occurs.

The recent model of quasi-periodic oscillations in neutron star binaries (Osherovich and Titarchuk 1999, Titarchuk and Osherovich 1999) has suggested the existence of two branches of QPOs due to the influence of Coriolis force on the linear Keplerian oscillator: one branch with frequencies between 400 and 1200 Hz and another branch with frequencies an order of magnitude lower. The observations of the source 4U 1702-42 have shown that the centroid of the approximately 35 Hz QPO tracks the frequency of the kilohertz oscillations. V. Osherovich and L. Titarchuk interpret the 35 Hz oscillations as the low branch frequency and find that the angle between the rotational axis of the magnetosphere and the vector normal to the plane of Keplerian oscillations is 3.9 $\pm$ 0.2 degrees. Their results make 4U 1702-42 the second source (after Sco X-1) for which the theoretically derived lower branch is identified (within their model) and that angle is calculated. The inferred angle stays approximately the same over the significant range of the Keplerian freuqencies (650 - 900 Hz), as expected from the model. Based on their model, Osherovich and Titarchuk present a classification of QPO frequencies in the source 4U 1702-42 observed above and below the low branch frequency.

P. Subramanian, P. Becker, and D. Kazanas (NASA/GSFC) have continued to study the physical processes operative in viscous accretion disks surrounding rotating and non-rotating black holes. The most recent work has focused on the shear-induced Fermi acceleration of relativistic protons in the same scenario, due to collisions with the magnetic scattering centers (kinks) embedded in the Keplerian flow. The relativistic protons accelerated in the flow are postulated to feed a magnetically collimated jet, leading to the production of a strong gamma-ray flux when the jet collides with a distant cloud, possibly in the broad line region within one parsec of the central source. The calculations are relevant for simulations of accretion disks around compact objects, which are expected to have near-equipartition tangled magnetic fields embedded in them. This work is reported by Subramanian, Becker, & Kazanas (1999).

4. SOLAR PHYSICS

P. Subramanian has been working with members of the Solar Physics group at the Naval Research Laboratory on the physics of Coronal Mas Ejections (CMEs) from the Sun. Data from the Large Angle Spectroscopic Coronagraph (LASCO) aboard the Solar and Heliospheric Observatory (SOHO) reveal that CMEs have a variety of effects on the solar streamers that were not evident with previous observations. They shed light on the manner in which CMEs travel through and interact with the large scale magnetic field in the outer corona. He has also been studying the crucial subject of the photospheric magnetic field configurations that give rise to CMEs, using data from the Extreme Ultraviolet Imaging Telescope (EIT) instrument and the Michelson Doppler Imager (MDI) instrument aboard SOHO. Data from these instruments are providing valuable inputs to various theoretical models describing the initiation of CMEs in the lower corona. A. Vourlidas and P. Subramanian (in collaboration with other scientists at NRL) have investigated the energetics of CMEs using LASCO data. They have tracked the detailed temporal evolution of some of the basic physical parameters using direct observations, providing for the first time strong constraints on models of CME propagation.

5. RADIATION HYDRODYNAMICS

P. Becker has analyzed the structure of radiative, radiation-dominated shocks in accretion columns over the magnetic poles of bright X-ray pulsars. In pulsar accretion columns, the mass and momentum fluxes are conserved while the gas crosses the shock, but the energy flux is not. The loss of kinetic energy via the diffusion of photons through the walls of the column causes the gas to decelerate to rest at the stellar surface. By contrast, in the ‘‘standard’’ theory of adiabatic, radiation-dominated shocks, developed by Blandford and Payne in 1981, the energy flux is conserved, and the downstream flow velocity cannot vanish. Hence adiabatic shocks have no relevance for X-ray pulsar accretion flows. Becker (1998) obtained a new, analytical solution for the variation of the flow velocity above the polar cap of the neutron star including the dynamical effect of photon escape. This solution displays the correct ‘‘settling’’ character below the sonic point, and the flow velocity vanishes at the stellar surface as required. P. Becker, and D. Kazanas (NASA/GSFC) have expanded this work to include a consideration of the dynamical effects associated with the finite gas pressure.

J. Wallin began a sabbatical leave in the summer of 1999 at Los Alamos National Laboratory to work on improvements to Smoothed Particle Hydrodynamics (SPH). The direction of this work is twofold. First, methods to improve the consistency of SPH are being examined. Second, methods to eliminate artificial viscosity are being explored, including the use of flux limiters. It is hoped that this work will greatly improve the convergence rates of SPH in a number of astronomical applications.

6. COSMIC RAY ACCELERATION

P. Becker and D. Kazanas (NASA/GSFC) have studied the acceleration of cosmic rays due to repeated scattering across a supernova-powered shock wave, using the ‘‘two-fluid’’ model of diffusive shock acceleration. This scenario remains an attractive model for the production of very energetic cosmic rays. When the acceleration process is efficient, a large fraction of the incident gas momentum flux is converted into cosmic ray pressure. In this case, the dynamical structure of the shock must be treated self-consistently, including the modifications due to the cosmic ray pressure. The upstream boundary conditions are stated in terms of the incident total Mach number and the incident ratio of the cosmic-ray pressure divided by the total pressure. It is well known that for certain combinations of these two parameters, 1, 2, or 3 distinct solutions are can be found for the shock structure. However, the precise nature of the constraint curves in the parameter space describing the number of possible solutions for given upstream conditions has remained unclear. P. Becker and D. Kazanas have derived new, exact critical constraints by reformulating the upstream conditions in terms of the two individual Mach numbers defined with respect to the cosmic-ray and gas sound speeds. Their results allow for the first time a systematic understanding of the parameter space and the implications for the resulting shock structure.

7. EXTRAGALACTIC ASTRONOMY & COSMOLOGY

M. Kafatos and visiting faculty member S. Roy have examined the broadening of spectral lines due to dynamic multiple scattering as applicable to quasar spectra (Roy, Kafatos, & Dutta 1999). The Wolf effect deals with the correlation-induced spectral change and explains both the broadening and shift of the spectral lines. In this framework, a relation between the width of a spectral line and the redshift z applies. For smaller values of z a relation similar to the Tully-Fisher relation can be obtained and for larger z a more general relation can be constructed with observational consequences for distant galaxies.

R. Amoroso (Noetic Institute), M. Kafatos, and P. Ecimovic (Univ. of Ljubljana, Slovenia) have examined the origin of the Hubble redshift as arising from anisotropic coupling to vacuum zero point fluctuations through harmonic structure described in terms of the Wheeler-Feynman absorber theory of radiation. This applies in the contect of a Dirac vaccum and compactification dynamics and supports the Vigier ''tired light'' theory (Amoroso, Kafatos, & Ecimovic 1998). They have also proposed a geometrodynamic model of the gravitational pinch effect also known as the Vigier Pinch from a modified Tolman-Ehrenfest-Podolsky calculation of the gravitational field of a photon-pulse pencil (Ecimovic, Kafatos, & Amoroso 1998).

M. Kafatos (1998) has developed the thesis that nonlocality is a fundamental property of the universe. He presents evidence of quantum-like correlations in the early universe and has constructed Universal Diagrams involving different physical quantities in multi-dimensional space. He then applies these ideas (Kafatos 1999) to the problem of consciousness, and examines the possibility that underlying foundational principles apply from the microcosm (quantum) to the macrocosm (cosmological) realms.

S. Roy and M. Kafatos (1999) have applied the above ideas to the large-scale of the universe. They find that Bell-type correlations may be prevalent in the early universe arising from the all-pervasive electron- positron annihilations. They extend the two-particle correlation to N-particle states, implying that frozen correlations may be used to explain the large scale structure of the present universe.

L. Ozernoy analyzed the formation of so-called ''super star clusters'' (SSCs) from shock-compressed giant molecular clouds (GMCs). Depending on the environment, parameters of the forming SSCs can vary. Three different environments are analyzed: (I) the central part of an isolated galaxy; (II) colliding galaxies; and (III) protogalactic clouds. Dependence of cluster parameters upon various gas cloud characteristics (velocity, density, temperature, and chemical abundance) is discussed. Case I is exemplified by a collisionally-induced star formation in the central part of the Milky Way Galaxy, which is characterized by relatively low velocities of colliding GMCs. Case II concerns starburst galaxies and is modelled by head-on collisions of galaxies (oblique collision case is examined as well). The cloud-cloud collisions trigger, during the time when the central parts of galaxies cross each other, gravitational instability in the bulk of the GMCs. Case III deals with globular cluster formation prior to, or in parallel with, galaxy formation via collisions of protogalactic clouds. The proposed model explains the basic observational features of SSCs.

8. GAMMA-RAY BURSTS

L. Ozernoy, jointly with V. Dokuchaev and Yu. Eroshenko (Inst. for Nucl. Research, Moscow) calculated the duration of the luminous quasar stage in relation to the initial mass of a newborn massive black hole (MBH) by comparing the observed luminosity and redshift distributions of quasars with the mass distribution of MBHs in normal galactic nuclei. It is assumed that, at the quasar stage, each MBH goes through a single (or recurrent) phase of accretion at or near the Eddington luminosity. The mass distributions of quasars is found to be connected with that of the MBHs residing in normal galaxies via a single-valued relationship through the entire mass range of the inferred MBHs, provided that the efficiency of accretion during the nearly Eddington luminosity phase is 10%. A number of consequences of these results for the current models of MBH formation and accretion have been discussed.

9. SOLAR SYSTEM & INTERPLANETARY DUST

L. Ozernoy, jointly with N. Gorkavyi, J. Mather (NASA/GSFC), and T. Taidakova (CCS), have developed a new numerical approach to the dynamics of minor bodies and dust particles, which enables one to increase, without using a supercomputer, the number of particle positions employed in each model up to $10^{10} - 10^{11}$, a factor of $10^6 - 10^7$ higher than previous numerical simulations. They applied this powerful approach, incorporating all relevant physical processes, to the high-resolution modeling of the structure and dynamics of cometary populations and dust in the solar system as well as to studying the structure and emission of circumstellar dust disks containing extra-solar planets.

L. Ozernoy, N. Gorkavyi, and T. Taidakova simulated a stationary distribution of test comets, which results from their gravitational scattering by the four giant planets and accounts for effects of mean motion resonances. Using these simulations, they reconstructed, in the space of orbital coordinates, the distribution function $n(a,e,i)$ for the population of scattered minor bodies beyond Jupiter. The simulations deal with 36 stationary distributions computed at different initial conditions for the dynamical evolution of comets, which start from the Kuiper belt and are usually traced until their ejection from the Solar system. These simulations include about 30×10^6 test bodies, which is comparable with the number of expected scattered comets (similar to Jupiter-family comets in their physical parameters). Two important new results have been found. First, the simulated comets are concentrated into four circumsolar belts, with a highly non-uniform and well structured distribution of the objects. Although these belts overlap, each belt can be associated with the orbit of the appropriate giant planet. Second, this huge population, with only a tiny fraction of its representatives presently known, is expected to have, like the simulations demonstrate, a rich structure containing (i) resonant gaps, (ii) diffusive accumulations, and (iii) near-resonance accumulations.

In another work, L. Ozernoy, N. Gorkavyi, J. Mather, and T. Taidakova have elaborated a physical model of the zodiacal cloud incorporating the real dust sources of asteroidal and cometary origin, which makes it possible to evaluate quantitatively the zodiacal light emission and scattering throughout the solar system. This model considerably improves the authors' 'reference model' based on the use of the continuity equation for the distribution function of dust particles and enables one to compute more reliable results than possible using phenomenological modeling of the zodiacal light. The improved model represents a 3D-grid containing $45 \times 180 \times 244 = 2 \cdot 10^6$ cells with a step in (heliocentric latitude φ, longitude λ, and radius R) equal to $(2°, 2°, 0.025R$ [AU]). Using the inferred distribution of the zodiacal dust, its thermal emission and scattering have been computed at several wavelengths (1.25, 5, and 20 μm) as a function of a space telescope location assumed to be at 1 AU or 3 AU. Areas on the sky with a minimum of zodiacal light are determined. These results are directly related to the currently discussed issue of where the Next Generation Space Telescope (NGST), which will replace the HST in the beginning of the next century, is to be be deployed. Further improvements in the physical modeling of the zodiacal light are feasible and could have important implications for extragalactic astronomy and cosmology.

L. Ozernoy, N. Gorkavyi, J. Mather, and T. Taidakova examined the resonant structure of a dusty disk induced by the presence of one planet with mass in the range $(5 \cdot 10^{-5} - 5 \cdot 10^{-3}) M_\odot$. It is shown that the planet, via resonances and gravitational scattering, produces (i) a central cavity, or 'hole', void of dust; (ii) a trailing (sometimes leading) off-center cavity or a few cavities; and (iii) an asymmetric resonant dust belt with one, two, or more clumps. These features can serve as indicators of planet(s) embedded in the circumstellar dust disk and, moreover, can be used to determine the mass of the planet and even some of its orbital parameters. The results of our study reveal a remarkable similarity with various types of highly asymmetric circumstellar disks observed with the JCMT around Epsilon Eridani and Vega. The crucial test of the above picture would be the discovery of the resonant asymmetric structure around the star. For circumstellar disks in ϵ Eri and Vega the asymmetric design is expected to revolve by, respectively, $(0.6 - 0.8)°$ and $(1.2 - 1.6)°$ annually.

10. RELATIVISTIC JET INTERACTIONS

J. Beall and J. Guillory continue their collaboration with D. V. Rose, investigating the physics governing the propagation of jets of material originating in the centers of Active Galaxies (AGN), moving outward, and interacting with ambient material in the broad-line and narrow-line regions (BLR and NLR) of AGN. It is believed that the dominant energy loss mechanisms for such jets is via plasma (collective) processes (see, e.g., Rose *et al.*, 1984, ApJ, 280, 550; Rose *et al.*, 1987 ApJ, 314, 95; and Beall, 1990, in *Physical Processes in Hot Cosmic Plasmas*, ed. W. Brinkmann, F. Giovannelli, & A. Fabian, Kluwer Academic Publishers: Netherlands). In the regime of parameters likely for astrophysical processes, the research uses a 0-dimensional computer code that solves, time-dependently, a system of extremely stiff, coupled, differential equations. This code models the intensity of plasma waves generated by the jet as it propagates through the ambient medium. The code thus allows estimates of the propagation length and strength of the interaction of the relativistic jet. They have recently completed a series of ''benchmark'' tests by comparing the results of the 0-dimensional code with those obtained using 1-dimensional and 2-dimensional Particle-In-Cell (PIC) codes in parameter ranges where it is practicable to use such codes (Beall, Guillory, & Rose 1999).

J. Beall continues a collaboration with W. Bednarek at the University of Łódź, Łódź, Poland, modeling the gamma-ray emission produced by relativistic jets in AGN as they interact with the dense, compact clouds in the BLR and NLR of the galaxies. These results show that the plasma processes discussed above significantly change the low-energy portion of the gamma-ray spectrum and yield substantial improvement in the fits of hadronic collision models to the data for MKN 421 (Beall and Bednarek 1999).

PUBLICATIONS

Amoroso, R. L., Kafatos, M., & Ecimovic, P. 1998, ''The Origin of Cosmological Redshift in Spin Exchange Vaccum Compactification and Non-zero Rest Mass Photon Anisotropy,'' in Causality and Locality in Modern Physics, ed. G. Hunter, S. Jeffers and J. P. Vigier (Dordrecht: Kluwer Academic Publishers), p. 23

Aurass, H., Vourlidas, A., Andrews, M. D., Thompson, B. J., Howard, R. H., & Mann, G. 1999, ''Nonthermal Radio Signatures of Coronal Disturbances with and without Coronal Mass Ejections,'' ApJ, vol. 511, p. 451

Bacmeister, J. T., Siskind, D. E., Summers, M. E., & Zasadil, S. 1998, ''Age-of-Air in a Zonally Averaged Two Dimensional Model,'' J. Geophys. Res., vol. 103, p. 11263

Bautista M., & Titarchuk, L. G. 1999, ''H-like Iron Emission in Narrow Line Seyfert 1 (NLS1) Galaxies as Temperature Diagnostic of Accretion Flows,'' ApJ, vol. 511, p. 105

Bazell, D., & Geller, H. 1999, ''Simulation of the IARC NASDA Information System Archive and Analysis Subsystem Using Extend,'' Simulation, vol. 73, p. 111

Beall, J. H. 1999, ''Jets in Astrophysics,'' in Multifrequency Behaviour of High Energy Cosmic Sources, ed. F. Giovannelli and L. Sabau-Graziati, Mem. S. A. It. (in press)

Beall, J. H., & Bednarek, W. 1999, ''On the Hadronic Beam Model for Gamma-Ray Production in Blazars,'' ApJ, vol. 510, p. 188

Beall, J. H., Guillory, J., & Rose, D. V. 1999, ''Line Emission from Relativistic Jets,'' in Multifrequency Behaviour of High Energy Cosmic Sources, ed. F. Giovannelli and L. Sabau-Graziati, Mem. S. A. It. (in press)

Becker, P. A. 1998 ''Dynamical Structure of Radiation-

Dominated Pulsar Accretion Shocks,'' ApJ, vol. 498, p. 790

Becker, P. A. 1999, ''A New Perturbative Technique for Solving Integro-Partial Differential Equations,'' J. Math. Phy., vol. 40, p. 5224

Borozdin, K., Revnivtsev, M., Trudolyubov, S., Shrader, C., & Titarchuk, L. G. 1999, ''Do the Spectra of Soft X-ray Transients Reveal Bulk Motion In Flow Phenomenon,'' ApJ, vol. 517, p. 367

Bradshaw, C. F., Fomalont, E. B., & Geldzahler, B. J. 1999, ''High-Resolution Parallax Measurements of Scorpius X-1,'' ApJ, vol. 512, p. L121

Cui, W., Morgan, E. H., & Titarchuk, L. G. 1998, ''Soft Phase Lags of Pulsed Emission from Millisecond X-ray Pulsar SAX J 18808.4-3658,'' ApJ, vol. 504, p. 27

Dokuchaev, V. I., Eroshenko, Yu. N., & Ozernoy, L. M. 1999, ''The Eddington Luminosity Stage in Quasars and AGN: Duration and Implications,'' in Cosmic Explosions, ed. S. Holt, AIP Conf. Proc. (in press)

Ecimovic, P., Kafatos, M., & Amoroso, R. L. 1998, ''The Vigier Pinch,'' in Causality and Locality in Modern Physics, ed. G. Hunter, S. Jeffers, & J. P. Vigier (Dordrecht: Kluwer Academic Publishers), p. 165

Gorkavyi, N., Ozernoy, L., Mather, J., & Taidakova, T. 1998, ''Structure of the Zodiacal Cloud: New Analytical and Numerical Solutions,'' Earth, Planets, and Space, vol. 50, p. 539

Gorkavyi, N., Ozernoy, L., Mather, J., & Taidakova, T. 1999, ''The NGST and the Zodiacal Light in the Solar System,'' AIP Conf. Proc., ed. E. P. Smith (in press)

Grove, J. E., Strickman, M. S., Matz, S. M., Hua, X.-M., Kazanas, D., & Titarchuk, L. G. 1998, ''Timing Noise Properties of GRO J0422+32,'' ApJ, vol. 502, p. L45

Kafatos, M. 1998, ''Non-Locality, Complementarity and Cosmology,'' in Causality and Locality in Modern Physics, ed. G. Hunter, S. Jeffers, & J. P. Vigier (Dordrecht: Kluwer Academic Publishers), p. 29

Kafatos, M. 1999, ''Non-locality, Foundational Principles and Consciousness,'' Noetic Journal, vol. 2, p. 21

Kafatos, M., El-Ghazawi, T., Wang, X. S., & Yang, R. 1999, ''Earth Observing Data Systems in the Internet Era,'' Photogrammetric Eng. & Remote Sensing, vol. 65, p. 540

Kafatos, M., & Subramanian, P. 1999, ''Inner Region Accretion Flows onto Black Holes,'' in The Neutron Star - Black Hole Connection, NATO Advanced Study Institute, ed. C. Kouveliotou, J. van Paradijs, & J. Ventura (Dordrecht: Kluwer Academic Publishers)

Kopeikin, S. M., & Ozernoy, L. M. 1999, ''Post-Newtonian Theory of Precision Doppler Measurements of Binary Star Orbits,'' ApJ, vol. 523, p. 771

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, vol. 511, p. 289

Lehnert, B., Roy, S., & Deb, A. 1999, ''An Extended Electromagnetic Theory,'' Apeiron (special issue)

Maia, D., Vourlidas, A., Pick, M., Howard, R., Schwenn, R., Magalh, E. S., & Atilde, A. 1999, ''Radio Signatures of a Fast Coronal Mass Ejection Development on November, 6, 1997,'' J. Geophys. Res., vol. 104, p. 12507

Osherovich, V., & Titarchuk, L. G. 1999, ''Kilohertz QPO in Neutron Star Binaries Modeled as Keplerian Oscillations in a Rotating Frame of Reference,'' ApJ, vol. 522, p. L113

Osherovich, V., & Titarchuk, L. G. 1999 ''Interpretation of $\sim$ 35 Hz QPO in Atoll Source 4U 1702-42 as a Low Branch of the Keplerian Oscillations under the Influence of the Coriolis Force,'' ApJ, vol. 523, p. L73

Ozernoy, L., Gorkavyi, N., Mather, J., & Taidakova, T. 1999, ''Signatures of Exo-Planets in Dust Debris Disks,'' ApJ, (in press)

Ozernoy, L., Gorkavyi, N., & Taidakova, T. 1999, ''Large Scale Structures in the Outer Solar System: I. Cometary Belts With Resonant Features Associated With the Orbits of Four Giant Planets,'' Icarus (in press)

Ozernoy, L., Gorkavyi, N., & Taidakova, T. 1999, ''Four Cometary Belts Associated With the Orbits of the Giant Planets: A New View of the Outer Solar System Emerges From Numerical Simulations,'' Planetary Space Science (in press)

Ozernoy, L., Gorkavyi, N., Taidakova, T., & Mather, J. 1999, ''Four Circumsolar Dust Belts in the Outer Solar System Associated With the Giant Planets,'' Planetary Space Science (in press)

Roy, S., & Kafatos, M. 1999, ''Bell-type Correlations and Large Scale Structure of the Universe,'' in Instantaneous Action at a Distance in Modern Physics: Pro and Contra, ed. A. E. Chubykalo, V. Pope, & R. Smirnov-Rueda (New York: Nova Science Publishers)

Roy, S., Kafatos, M., & Dutta, S. 1999, ''Broadening of Spectral Lines due to Dynamic Multiple Scattering and the Tully-Fisher Relation,'' Phys. Rev. A, vol. 60, p. 273

Roy, S., & Kar, G. 1999, ''Quantum Cryptography, Eavesdropping and Unsharp Spin Measurement,'' Chaos, Solitons and Fractals, vol. 10, p. 1715

Roy, S. & Kar, G. 1999, ''Quantum Cryptogrphy and Unsharp Spin Measurement,'' Lecture Notes in Computer Science, vol. 1509 (Springer Verlag)

Saur, J., Neubauer, F. M., Strobel, D. F., & Summers, M. E. 1999, ''3D Simulation of Io's Interaction with the Io-Plasma Torus: Asymmetric Plasma Flow,'' J. Geophys. Res., in press

Shrader, C., & Titarchuk, L. G. 1999, ''Mass Determination of Black Holes in LMC X-1 and Nova Muscae 1991 from their High-Energy Spectra,'' ApJ, vol. 521, p. L121

Siskind, D. E., & Summers, M. E. 1998, ''Implications of Enhanced Mesospheric Water Vapor Observed by HALOE,'' Geophys. Res. Lett., vol. 25, p. 2133

Siskind, D. E., & Summers, M. E. 1998, ''Chemical Eddy Transport by Planetary Waves in the Mesosphere,'' Geophys. Res. Lett., vol. 103, p. 321

Subramanian, P., & Dere, K. P. 1999, ''Source Regions of Coronal Mass Ejections,'' Solar Physics, submitted

Subramanian, P., Dere, K. P., Rich, N. B., & Howard, R. A. 1999, ''The Relationship of Coronal Mass Ejections to Streamers,'' J. Geophys. Res., vol. 104, p. 22

Subramanian, P., Becker, P. A., & Kazanas, D. 1999, ''Formation of Relativistic Outflows in Shearing Black Hole

Accretion Coronae,'' ApJ, vol. 523, p. 203
Summers, M. E. 1999, ''Perspectives in Atmospheric Science: Vertical Couplings,'' Science, vol. 284, p. 1783
Summers, M. E., & Siskind, D. E. 1999, ''Surface Catalysis on Meteoric Dust as a Source of Mesospheric Water Vapor,'' Geophys. Res. Lett., vol. 26, p. 1837
Summers, M. E., Strobel, D. F., & Gladstone, R. G. 1998, ''Chemical Models and Constraints on Pluto's Atmosphere,'' invited chapter for the book Pluto and Charon, University of Arizona press, Space Science Series
Titarchuk, L. G., & Osherovich, V. 1999, ''Correlations Between Kilohertz Quasi-Periodic Oscillations and Low-Frequency Features Attributed to Radial Oscillations and Diffusive Propogation in the Viscous Boundary Layer around a Neutron Star,'' ApJ, vol. 518, p. L95
Titarchuk, L. G., Osherovich, V. A., & Kuznetzov, S. I. 1999, ''Timing Spectroscopy of Quasi-Periodic Oscillations in the Low-Mass X-ray Neutron Star Binaries,'' ApJ, in press
Vourlidas, A., Subramanian, P., Dere, K. P., & Howard, R. A. 1999, ''LASCO Measurements of Energetics of Erupting Flux Ropes,'' ApJ, submitted.

Peter A. Becker

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