Final

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Dr. Jay P. Norris
Code 668.1
Laboratory for High Energy Astrophysics
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

Dear Dr. Norris:

This is the final report on CGRO Guest Investigator Program grant NAG5-2026 (PI: Mitchell C. Begelman, The Regents of the University of Colorado, Campus Box 19, Boulder, CO 80309-0019), covering the period 7/15/92–9/30/97. Attached please find a bibliography of the publications to date resulting from this grant. The following are highlights from the research supported by this grant.

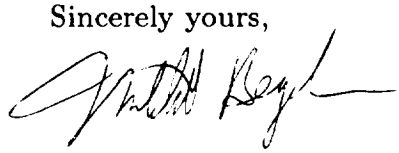
- *Theory of gamma-ray blazars*: We studied the theory of gamma-ray blazars, being among the first investigators to propose that the GeV emission arises from Comptonization of diffuse radiation surrounding the jet, rather than from the synchrotron-self-Compton mechanism. In related work, we uncovered possible connections between the mechanisms of gamma-ray blazars and those of intraday radio variability, and have conducted a general study of the role of Compton radiation drag on the dynamics of relativistic jets.

- *A Nonlinear Monte Carlo code for γ-ray spectrum formation*: We developed, tested, and applied the first Nonlinear Monte Carlo (NLMC) code for simulating gamma-ray production and transfer under much more general (and realistic) conditions than are accessible with other techniques. The present version of the code is designed to simulate conditions thought to be present in active galactic nuclei and certain types of X-ray binaries, and includes the physics needed to model thermal and nonthermal electron-positron pair cascades. Unlike traditional Monte-Carlo techniques, our method can accurately handle highly non-linear systems in which the radiation and particle backgrounds must be determined self-consistently and in which the particle energies span many orders of magnitude. Unlike models based on kinetic equations,

our code can handle arbitrary source geometries and relativistic kinematic effects. In its first important application following testing, we showed that popular semi-analytic accretion disk corona models for Seyfert spectra are seriously in error, and demonstrated how the spectra can be simulated if the disk is sparsely covered by localized "flares".

The funds were used primarily to support the visits of three senior scientists to JILA: Dr. Boris Stern (Institute for Nuclear Research, Moscow, Russia), the inventor of the Nonlinear Monte-Carlo method; Dr. Marek Sikora (Copernicus Astronomical Center, Warsaw, Poland), an expert on pair cascades, AGNs, and high-energy radiation processes; and Dr. Greg Madejski (NASA/Goddard Space Flight Center). It also supplied partial support for a postdoctoral research associate, Dr. Yueming Xu, and for two graduate students, Mr. James Dove and Mr. Joern Wilms.

Sincerely yours,



Mitchell C. Begelman
Principal Investigator

PUBLICATIONS SUPPORTED BY NASA GRANT NAG5–2026

Compton GRO Guest Investigator Program

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Principal Investigator: Mitchell C. Begelman

1. Papers in Refereed Journals (published, in press, and submitted)

Begelman, M. C., Mészáros, P., and Rees, M. J. 1993, "Gamma-Ray Bursts from Blast Waves around Galactic Neutron Stars," MNRAS, 265, L13-L16.

Begelman, M. C., Rees, M. J., and Sikora, M. 1994, "Energetic and Radiative Constraints on Highly Relativistic Jets," ApJ, 421, 153-162.

Dove, J. B., Wilms, J., and Begelman, M. C. 1997, "Self-consistent thermal accretion disk corona models for compact objects: I. Properties of the corona and the spectrum of escaping radiation," ApJ, 487, 747-758

Dove, J. B., Wilms, J., Maisack, M., and Begelman, M. C. 1997, "Self-consistent thermal accretion disk corona models for compact objects: II. Application to Cygnus X-1," ApJ, 487, 759-768

Dove, J. B., Wilms, J., Nowak, M. A., Vaughan, B. A., and Begelman, M. C. 1997, "RXTE observation of Cygnus X-1: I. Spectral analysis," MNRAS, submitted

Moderski, R., and Sikora, M. 1996, "On Black Hole Evolution in AGNs,", MNRAS, 283, 854-864.

Poutanen, J., Sikora, M., Begelman, M. C., and Magdziarz, P. 1996, "The Compton Mirror in NGC 4151," ApJ, 465, L107-L110.

Sikora, M. 1994, "High-Energy Radiation from Active Galactic Nuclei," ApJS, 90, 923-928.

Sikora, M., Begelman, M. C., and Rees, M. J. 1994, "Comptonization of Diffuse Ambient Radiation by a Relativistic Jet: The Source of Gamma-rays from Blazars?" ApJ, 421, 153-162.

Sikora, M., Madejski, M., Moderski, R., and Poutanen, J. 1997, "Learning about active galactic nucleus jets from spectral properties of blazars," ApJ, 484, 108-117.

Sikora, M., Sol, H., Begelman, M. C., and Madejski, G. 1996, "Radiation Drag in Relativistic AGN Jets," MNRAS, 280, 781-796.

Stern, B. E., Begelman, M. C., Sikora, M., and Svensson, R. 1995, "A Large Particle Monte Carlo Code for Simulating High-Energy Processes Near Compact Objects," MNRAS, 272, 291-307.

Stern, B. E., Poutanen, J., Svensson, R., Sikora, M., and Begelman, M. C. 1995, "On the Geometry of the X-Ray Emitting Region in Seyfert Galaxies," ApJ, 449, L13-L17.

Wilms, J., Dove, J. B., Maisack, M., and Staubert, R. 1996, "The Broad-Band High-Energy Spectrum of Cyg X-1," A&AS, 120, 159-162.

2. Invited Review Articles

Begelman, M. C. 1997, "Black holes, jets, and accretion disks," in Proceedings of the 18th Texas Symposium on Relativistic Astrophysics," ed. A. Olinto, J. Frieman, and D. Schramm (Singapore: World Scientific), in press

Sikora, M., Madejski, G., and Begelman, M. C. 1997, "Variability, Power, and Pair Content of AGN Jets," in Relativistic Jets in AGNs, M. Ostrowski, M. Sikora, G. Madejski, and M. Begelman (eds.), in press (Cracow).

2. Contributed Papers

Dove, J. B., Wilms, J., Nowak, M. A., Vaughan, B. A., and Begelman, M. C. 1997, "RXTE Observations of Cygnus X-1: Spectral Analysis," in The Active X-ray Sky: Results from Beppo-SAX and Rossi-XTE, L. Scarsi, H. Bradt, P. Giommi, and F. Fiore (eds.), in press (Nuclear Phys. B Proceedings Supplements)

Nowak, M. A., Dove, J. B., Vaughan, B. A., Wilms, J., and Begelman, M. C. 1997, "The Physical Interpretation of X-ray Phase Lags and Coherence: RXTE Observations of Cygnus X-1 as a Case Study," in The Active X-ray Sky: Results from Beppo-SAX and Rossi-XTE, L. Scarsi, H. Bradt, P. Giommi, and F. Fiore (eds.), in press (Nuclear Phys. B Proceedings Supplements)

Rees, M. J., Mészáros, P., and Begelman, M. C. 1994, "Why 'Galactic' Gamma-Ray Bursts Might Depend on Environment: Blast Waves around Neutron Stars," in *Gamma Ray Bursts*, AIP Conf. Proc. 307, G. J. Fishman, J. J. Brainerd, and K. Hurley (eds.), 605-609 (New York: Amer. Inst. Phys.).

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Sikora, M., and Madejski, G. 1996, "Bulk-Compton Constraints on AGN Jet Models and 'Hot' Jet Scenario for MeV Blazars," in Gamma-ray Emitting AGN, J. G.Kirk, M. Camenzind, C. von Montigny, and S. Wagner (eds.) 153-160 (MPI H-V37-1996).

Sikora, M., Moderski, R., Madejski, G., and Poutanen, J. 1997, "Learning About Jet Physics from Gamma-ray Blazars," in The Transparent Universe, Proc. 2nd Integral Conf., in press (ESA).

Sikora, M., Sol, H., Begelman, M. C., and Madejski, G. 1996, "Propagation of Relativistic Jets Through Dense Radiation Fields in AGN," in Proc. 3rd Compton Symp., A&AS, 120, C579-C582.

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Wilms, J., Dove, J., Staubert, R., and Begelman, M. C. 1997, "Properties of Accretion Disk Coronae," in The Transparent Universe, C. Winkler, T. J.-L. Courvoisier, and P. Durouchoux (eds.), 233-236 (Noordwijk: ESA Publications Div., ESA SP-382).

3. Internal Reports

Xu, Y. 1994, "A New Monte Carlo Method for Non-Linear Problems and its Applications to the Cscade Spectrum of Pair Plasmas," JILA Internal Report.

4. Ph.D. Thesis

Dove, J. B. 1997, Self-Consistent Accretion Disk Corona Models: Application to Black Hole Candidates," Ph.D. Thesis, University of Colorado at Boulder