NASA CR-193368

Final Report for NASA grant NAG5-2056

176447
P. 7

J. J. Brainerd

University of Alabama in Huntsville

(NASA-CR-193368) [COSMOLOGICAL GAMMA-RAY BURST MODEL] Final Report (Alabama Univ.) 7 p

N94-10507

Unclas

G3/93 0176447

ABSTRACT

Dr. Brainerd developed a cosmological gamma-ray burst model that reproduces the observed gamma-ray spectra. This model, which is an outgrowth of work on synchrotron emission from cosmological sources, creates the observed spectra from a power law spectrum through Compton attenuation in dense molecular clouds. It restricts the burst source to the centers of galaxies, and it is easily tested through comparisons with time dependent burst spectra. Dr. Brainerd continued development of a Monte Carlo code that tracks the random walk of a gamma-ray through a plasma in a strong magnetic field and used this code to show that a two temperature plasma in a strong magnetic field can suppress soft x-ray emission.

1. RESEARCH

Between the time the research proposal for NASA grant NAG5-2056 was submitted and the time research under this grant began, the Burst and Transient Source Experiment (BATSE) on board the Compton Gamma-Ray Observatory (CGRO) released observations to the public showing that gamma-ray bursts are not from the Galactic plane and are most likely from cosmological sources. Therefore most of the work supported by this grant examined the mechanisms capable of creating gamma-ray burst spectra at cosmological distances.

The work on cosmological sources is built on research examining synchrotron emission as a source of gamma-rays. This research was part of the proposed research, although the rapid advances in gamma-ray burst research forced the commencement of this project before the commencement of funding. By examining the conditions required for synchrotron emission to produce bright non-thermal spectra, Dr. Brainerd showed that gamma-ray burst sources must travel with a Lorentz factor above 100 (Brainerd 1992). But this presents a great difficulty: if the Lorentz factor is large and unconstrained, why do all gamma-ray burst spectra break at several hundred keV? A possible solution is that the interstellar medium surrounding the source modifies the burst spectrum. Pursuing this hypothesis, Dr. Brainerd developed a theory in which gamma-rays are attenuated through Compton scattering in dense molecular clouds. This can reproduce the observed spectra if the unattenuated source emits a power law spectrum. The resulting color-color diagrams are similar to those found for the gamma-ray bursts detected by BATSE (Kouveliotou 1993). Members of the BATSE team have successfully fit this model to several gamma-ray burst spectra, and in the coming months Dr. Brainerd will make a systematic comparison of observed burst spectra to this model. The density of material required to attenuate the spectrum is characteristic of the density of molecular clouds at the center of the Galaxy. This implies that gamma-ray bursts originate from the cores of galaxies, because all bursts must be attenuated to explain the observations, so the most reasonable source is a massive black hole. This model eliminates many cosmological models, such as the colliding neutron star model, and it make predictions that are testable. From this work Dr. Brainerd wrote and submitted to the Astrophysical Journal the article "Producing the Universal Spectrum of Cosmological Gamma-Ray Bursts with the Klein-Nishina Cross Section." It has received a favorable referee's report and should appear in print within the next nine months.

A consequence of the theory outlined above is that the x-ray flux is coherently scattered by dust grains in molecular clouds (Overbeck 1965). This produces a delayed x-ray flux with a specific spectral shape. This type of effect is seen for x-ray pulsars (Day & Tennant 1990). Dr. Brainerd showed that such scattering in the gamma-ray burst model discussed above produces an afterglow similar to that observed by Ginga for GRB870303 (Murakami *et al.* 1990). These results are described in the article "A Theory for X-Ray Afterglow from Cosmological Gamma-Ray Bursts," which was recently submitted to the Astrophysical Journal Letters.

Dr. Brainerd continued to improve his Monte Carlo code that calculates the random walk of gamma-rays through a plasma in a strong magnetic field, where the predominate radiative process is resonant Compton scattering. At this point, the program handles propagation in the cyclotron line better than previously. This code was used to show that a plasma with the electron temperature describing the motion along the magnetic field larger than the electron temperature describing the population of the Landau levels can absorb soft x-rays, creating a much harder spectrum than one would expect from a plasma in thermal equilibrium. In the future this code will be applied to accretion and spin powered pulsars.

2. ARTICLE ABSTRACTS

Listed below are abstracts for the two papers written during the grant period.

Brainerd, J.J., 1993, "Producing the Universal Spectrum of Cosmological Gamma-Ray Bursts with the Klein Nishina Cross Section," ApJ, submitted.

A power law spectrum attenuated through Compton scattering by an optically thick medium produces spectra that have a characteristic energy of several hundred keV. Add a redshift, and one finds that this model can qualitatively reproduce the color-color diagrams found for individual gamma-ray bursts. This model is easily tested through model fits to burst spectra and through the comparisons of the parameters derived from model fits to the limits on parameters derived from the burst $\log N$–$\log P_{max}$ curve. The heavy attenuation makes the amount of energy released in the burst $\approx 10^3$ times larger than is inferred from the observed flux. The requirements of high optical depth and no photon-photon pair creation place a lower limit on the size of the scattering region. This size suggests that the attenuation occurs in giant molecular clouds in the cores of galaxies. This indicates that gamma-ray bursts are probably from supermassive black holes. If the Lorentz factor of the radiation source is large, the optical depth, and therefore the hardness ratio of a burst, can change over the duration of the burst.

Brainerd, J.J. 1993, "A Theory for X-Ray Afterglow from Cosmological Gamma-Ray Bursts," ApJ (Letters), submitted.

A recent article (Brainerd 1993, cited above) showed that gamma-ray burst spectra can be reproduced if one hypothesizes that the gamma-ray source is surrounded by a molecular cloud that is optically thick to Compton scattering. A consequence of this model is that dust particles within the cloud scatter x-rays, producing an extended x-ray afterglow. This letter presents the characteristics of the afterglow derived from analytic and Monte Carlo calculations. The x-ray afterglow is observable below ≈ 20keV and its temporal

and spectral characteristics are diagnostics of the size of the scattering region and the characteristics of the dust. Compton scattering produces an unobservable gamma-ray afterglow.

REFERENCES

Brainerd, J.J. 1992, ApJ, 394, L33.

Day, C.S.R., & Tennant, A.F. 1991, MNRAS, 251, 76

Kouveliotou, C., Paciesas, W.S., Fishman, G.J., Meegan, C.A., & Wilson, R.B. 1993, A&A, 97, 55

Murakami, T., Inoue, H., van Paradijs, J., Fenimore, E.E., & Yoshida, A. 1992, in *Gamma-Ray Bursts: Observations, Analyses and Theories*, ed. C. Ho, R.I. Epstein, & E.E. Fenimore (Cambridge University Press: Cambridge), p. 239

Overbeck, J.W. 1965, ApJ, 141, 864