FINAL REPORT
FOR
ADP STUDY OF GAMMA-RAY BURSTS
NASA GRANT NAG-51177

I. STRATEGY OF INVESTIGATION

This grant supported study of cyclotron scattering lines in the spectra of γ-ray bursts through analysis of Ginga and HEAO-1 archival data, and modeling of the results in terms of radiation transfer calculations of cyclotron scattering in a strong magnetic field. The grant partially funded work by the principal investigator, Don Q. Lamb; co-investigators John C. L. Wang (Chicago and the Canadian Institute for Theoretical Astrophysics, Toronto, Canada) and Geoffry J. Heuter (formerly at University of California, San Diego); and graduate students Carlo Graziani, Tom Loredo, and Peter Freeman (Chicago).

II. ACCOMPLISHMENTS

We have developed a Monte Carlo radiation transfer code with which we are able to calculate the expected properties of cyclotron scattering lines in the spectra of γ-ray bursts. We have also developed the extensive software necessary in order to carry out fits of these model spectra to γ-ray burst spectral data, including folding of the model spectra through the detector response functions. We have completed fits to Ginga satellite data on burst GB880205 and are in the process of carrying out fits to Ginga satellite data on burst GB870303. These fits have allowed us to test our software, as well as to garner new scientific results.

This work has demonstrated that cyclotron resonant scattering successfully accounts for the locations, strengths, and widths of the observed line features in GB870303 and GB880205. The success of the model provides compelling evidence that these γ-ray bursts come from strongly magnetic neutron stars and are galactic in origin, resolving longstanding controversies about the nature and distance of the burst sources. These results have been reported in two papers which are in press in the proceedings of the Taos Workshop on Gamma-Ray Bursts, and in a paper submitted for publication.

In a paper now in preparation, we report the results of fits to the HEAO-1 satellite data on GB780325, using the Monte Carlo radiation transport code and fitting software that we developed and tested on the Ginga satellite data. The most significant conclusion of this work is that the variations in the strengths and widths of the cyclotron lines observed in the spectra of GB780325 (and GB870303) are naturally accounted for by rotation of the magnetic neutron star.

III. PUBLICATIONS DURING THIS GRANT

The following is a list of papers supported by the grant and published during the past two years:

Cyclotron Lines in Gamma-Ray Burst Spectra: Signatures of Neutron Star Rotation (D. Q. Lamb, J. C. L. Wang, and I. Wasserman), in *Proceedings of the Taos Workshop on Gamma-Ray Bursts*, ed. R. I. Epstein, E. E. Fenimore, and C. Ho (Cambridge U. Press: Cambridge, England), in press (1991).

Energetics and Dynamics of Resonant and Nonresonant Scattering in Gamma-Ray Burst Sources (J. C. L. Wang, D. Q. Lamb, and I. Wasserman), in *Proceedings of the Taos Workshop on Gamma-Ray Bursts*, ed. R. I. Epstein, E. E. Fenimore, and C. Ho (Cambridge U. Press: Cambridge, England), in press (1991).

Cyclotron Line Variations in Gamma-Ray Burst GB870303: Possible Evidence of Neutron Star Rotation (C. Graziani, E. E. Fenimore, J. P. Conner, R. I. Epstein, R. W. Klebesadel, J. G. Laros, D. Q. Lamb, T. J. Loredo, J. C. L. Wang, T. Murakami, J. Nishimura, A. Yoshida, and I. Kondo), in *Proceedings of the Taos Workshop on Gamma-Ray Bursts*, ed. R. I. Epstein, E. E. Fenimore, and C. Ho (Cambridge U. Press: Cambridge, England), in press (1991).

Cyclotron Line Variations in Gamma-Ray Burst GB870303: Possible Evidence of Neutron Star Rotation (C. Graziani, E. E. Fenimore, J. P. Conner, R. I. Epstein, R. W. Klebesadel, J. G. Laros, D. Q. Lamb, T. J. Loredo, J. C. L. Wang, T. Murakami, J. Nishimura, A. Yoshida, and I. Kondo), in *Proceedings of the Taos Workshop on Gamma-Ray Bursts*, ed. R. I. Epstein, E. E. Fenimore, and C. Ho, *Ap. J.*, submitted (1991).

Cyclotron Line Variations in Gamma-Ray Burst GB780325: Possible Evidence of Neutron Star Rotation (D. Q. Lamb, C. Graziani, T. J. Loredo, J. C. L. Wang, and G. J. Heuter), *Ap. J.*, to be submitted (1991).