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Final Technical Report For NASA Grant NAG-5-941

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This report describes the activities at Penn State University supported by NASA Grant NAG-5-941. During the period 10/90 to 12/91 work on HEAO-1 analysis of the Low Energy Detectors (LED) concentrated on using the improved detector spectral simulation model and fitting diffuse X-ray background spectral data. Most of this work was based on the work of Dr. Krishna Apparao, Visiting Adjunct Professor, on leave from the Tata Institute for Fundamental Research of Bombay, India, visiting Penn State through 8/91. Collaboration with Dr. Denis Leahy of the University of Calgary, Canada, lead to several joint publications.

More detailed descriptions of these activities are found in the following sections.

1 Spectral Fitting Results

The original calibration models from the HEAO-1 ground tests were found to give poor fits (reduced $\chi^2 > 10$). Response matrices made from these calibrations gave temperature and emission measure spectra for selected areas of the sky (North Ecliptic Pole, South Ecliptic Pole, and Crab supernova remnant) that were not compatible with those found by other spacecraft. This implied that additional work on counter fundamentals was necessary.

To test the effectiveness of these new calibrations the response matrix generation program and spectra generation programs were upgraded to allow production of time weighted response matrices. These matrices compensate for counter gain drift and allow better fits to sky spectra. These time weighted response matrices were applied to selected sky areas of interest.

Another important result arising from the improved detector simulation is the ability to completely reconcile the response of the front and back layers

(NASA-CR-194087) [HEAO-1 ANALYSIS OF LOW ENERGY DETECTORS (LED)] Final Report, Oct. 1990 - Dec. 1991 (Pennsylvania State Univ.) 3 p

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of the detector with the same spectral model parameters. This improvement gives us much greater confidence in establishing the absolute normalization level of the diffuse background, in particular the extra-galactic power law component. We find that the diffuse background between 1 and 2 keV is best described by a normalization of 10.4 ± 0.5.

The final summary results of the HEAO-1 LED observations of the diffuse soft X-ray background were presented by Garmire *et al* (1992). This paper also includes the maps of the diffuse sky intensity in four bandpasses.

2 X-ray Point Sources

Dr. Apparao wrote several contributions on X-ray sources during his short stay at Penn State (since July, 1990).

Apparao (1990a) has shown that six flares observed in EXO2030+375 with an average interval of about 4 h are due to Rayleigh-Taylor instabilities near the magnetospheric boundary of the neutron star when it reaches the equilibrium period.

It is generally thought that the circumstellar gas envelope around a Be star results from accretion of gas. Apparao (1990b) has pointed out that this is not tenable for Be star X-ray sources. The degenerate nature of the X-ray emitting companion precludes contribution of matter to the Be star. It is also shown that a triple system, where supposition is required to make the accretion hypothesis tenable, is not possible by calculation of the period of apsidal motion.

Apparao (1990c) discusses reasons for the non-detection of white dwarfs in Be star binaries. Possible signatures of their presence are presented.

Apparao, Berthiaume and Nousek (1992) discuss the X-ray emitting properties of two binary planetary nebulae.

3 Diffuse X-ray Sources

In similar work Leahy, Nousek and Garmire (1991) report diffuse X-ray emission which they interpret as being associated with the Gum Nebula, lending support to the origin of this nebula as a result of a supernova explosion.

Leahy, Nousek and Hamilton (1991, 1992) apply the improved spectral fitting results to more restrictively determine the characteristics of the supernova remnants SN1006 and the Lupus Loop.

Burrows *et al.* (1992) uses maximum entropy enhanced spatial resolution maps of the Eridanus X-ray enhancement to compare with radio and infrared data from the region. Through a comparision of the detailed morphology seen in various wavelengths they conclude the region most likely results from stellar wind bubbles, possibly reheated by a later supernova explosion.

4 Publications

4.1 Refereed Journals

Apparao, K.M.V. (1990a), "Flares in the X-ray Source EXO2030+375", Ap. J., submitted.

Apparao, K.M.V. (1990b), "White Dwarfs in Be Star Binary Systems", Astr. Astrophys., submitted.

Apparao, K.M.V., Berthiaume, G.D., and Nousek, J.A. "X-ray Observations of Planetary Nebulae with Binary Nuclei", Ap.J. submitted (1991).

Burrows, D.N., Singh, K.P., Nousek, J.A., Garmire, G.P., and Good, J. "A Multiwavelength Study of the Eridanus X-ray Enhancement", Ap.J. submitted (1992).

Garmire, G.P., Nousek, J.A., Apparao, K.M.V., Burrows, D.N., Fink, R.L., and Kraft, R.P. "The Soft X-ray Diffuse Background Measured by the HEAO-1 Low Energy Detectors", Ap.J. submitted (1991).

Leahy, D.A., Nousek, J., and Hamilton, A.J.S. "HEAO-1 A2 LED X-ray Spectra of the Lupus Loop and SN1006", Ap.J. 374, 218-226 (1991).

Leahy, D.A., Nousek, J., and Garmire, G. "Discovery of X-ray Emission Associated with the Gum Nebula" Ap.J. accepted (1992).

4.2 Conference Proceedings and Unrefereed Journals

Apparao, K.M.V. (1990c), "Origin of the Be Star Circumstellar Envelope", Be-star Newsletter (in press).

Leahy, D.A., Nousek, J., and Hamilton, A. "Non-equilibrium Ionization Models for X-ray Emission from the Lupus Loop and from SN1006", *Frontiers of X-Ray Astronomy* ed. Y. Tanaka and K. Koyama, Universal Academic Press, Inc., in press (1992).