N91-18984

1990

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA

BATSE SOFTWARE FOR THE ANALYSIS OF THE GAMMA RAY BURST SPATIAL DISTRIBUTION

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Contract No: NGT-01-002-099
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I. Introduction

The Burst and Transient Source Experiment (BATSE) on the Gamma Ray Observatory (GRO) is designed to study astronomical gamma ray sources and to provide better positional, spectral, and time resolution about these objects than has previously been possible from one experiment.

In particular, BATSE will study the phenomenon of the gamma ray bursts. These spurious high energy emissions have no known counterparts (either quiescent or variable) at other electromagnetic wavelengths, and their astrophysical sources have been difficult to identify. Much evidence exists (such as short-timescale variabilities indicative of compact emitting regions, emission lines characteristic of positron-electron annhilation, absorption features that seem to indicate cyclotron absorption corresponding to very strong magnetic fields, etc.) to suggest that the bursts arise from material accreting onto the surfaces or into the magnetospheres of Galactic neutron stars.

As suggestive as this evidence is of a Galactic origin for the bursts, distinct association of the burst spatial distribution with either the Galactic disk or the Galactic halo has not yet been verified. This is due to (1) the limited number of bursts known from balloon experiments and orbital satellites, (2) the inherent difficulties in measuring accurate burst positions, and (3) the severe selection effects present in attempting to observe bursts.

BATSE, with its four pi steradian sky coverage (over large timescales) to faint flux limits, should resolve the burst location problem within a matter of months. However, tests that measure and interpret isotropy and homegeneity of the spatial distribution must allow for unavoidable inaccuracies in measuring burst positions and account for the numerous selection effects that will be present due to inhomogenous sampling.

II. Overview of the Analysis Techniques and BATSE Software

The procedure to be used in the analysis of the gamma ray burst spatial distribution is depicted in figure 1. Data is input from BATSE via the Gamma Ray Burst Catalog (listing individual burst positions, flux values, and associated errors) and the Sky Sensitivity Map (which summarizes observational selection effects in table format).

A FORTRAN program generates Monte Carlo burst catalogs, which are models to be compared to the actual distribution. These models can be chosen to represent a number of spatial distributions (uniform, Galactic Disk, and Galactic Halo) while the source luminosities are selected from one of several luminosity functions (mono-luminosity, Gaussian, linear topheavy, linear bottomheavy, and power law). By this, many statistical selection effects (such as the Malmquist bias) are automatically included in the Monte Carlo data sets. The Monte Carlo models are then filtered through the Sky Sensitivity Map so that they suffer from the same selection effects as the actual catalog data. Additionally, each burst position is converted into a probability distribution to mimic BATSE positional sensitivity. In this manner the Monte Carlo models are created to suffer from many of the same systematic effects as the BATSE Burst Catalog so that statistical comparisons may be directly made between them.

The Burst Catalog, Monte Carlo burst catalogs, and Sky Sensitivity Map are then passed on to an IDL program that compares the catalogs for statistical significance. The Sky Sensitivity Map is used to estimate how often each sky area is observed above the minimum flux level in question. Each burst found in this sky area is then weighted according to the frequency with which this sky area is observed (such that a few bursts observed in a poorly-studied sky area are heavily-weighted).

The catalogs are then compared via tests of homogeneity (based upon their radial distributions) and isotropy (based upon their angular distributions). Among the statistical tests used to make these comparisons: The Log(N)_Log(N>S) test (which examines the homogeneity of the distribution), the <V/Vmax> test (which examines the sample's homogeneity based upon instrumental sensitivity), multipole analysis (which studies spatial isotropy of the sample), and a source cross-correlation analysis (another isotropy test). Errors are estimated concerning the validity of the comparisons by comparing many Monte Carlo burst catalogs (all generated from the same model) with the Burst Catalog via simple summaries (such as Kolmogorov-Smirnov estimators and the fractional or "tail-area" probabilities indicating that the two samples are drawn from the same parent distribution). The results of the statistical comparisons along with graphs and charts of the summaries, are output from the IDL program for study.

III. Current Status of the Analysis Programs, and Future Work

At the present time, the interactive FORTRAN Monte Carlo Burst Generation program is close to completion. It can effectively create the spatial distributions mentioned previously using any of the indicated luminosity functions. However, smearing of the point sources into probability distributions is dependent upon an as yet unmodeled functional form (to first order on the count rate of the source and to second order on the burst position in GRO coordinates). Before sources can be removed from the Monte Carlo burst catalogs via selection effects modeled in the Sky Sensitivity Map, a dummy Sky Sensitivity Map must be generated. The structure of this map is dependent upon the as yet unchosen format for the actual Sky Sensitivity Map.

The interactive IDL analysis program is not as close to completion as the Monte Carlo one. It is currently composed of a number of dissociated (and in some cases incomplete) modules. Tested FORTRAN code exists for the multipole analysis, and a rough IDL version of the Log(N)_Log(N>S) code is operational. The codes for <V/Vmax> and positional correlation do not yet exist (although the former is very easy to install). Summaries of model comparisons and associated IDL graphs are not yet coded.

IV. Acknowledgements

This analysis of the gamma ray burst spatial distribution was begun under the auspices of the NASA/ASEE Summer Faculty Fellowship Program and will continue as part of NASA's JOint VEnture (JOVE) Program. I would like to briefly (i.e. in the space provided) thank the many people who have given me the opportunity to work on and be involved in this exciting project: Chip Meegan, Gerry Fishman, and the entire Marshall Gamma Ray Group; Frank Six, Rick Chappell, Jerry Karr, Mike Freeman and all those connected to the Summer Faculty and JOVE programs; Richard Crofts, John Frey, Gloria Dimoplon, Jim Pierce, Steve Kipp, and the supportive faculty and administration of Mankato State University.

BATSE Analysis Software for Determining the Spatial Distribution of Gamma Ray Bursts