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USING CONTOUR MAPS TO SEARCH FOR RED-SHIFTED 511 keV FEATURES IN BATSE GRB SPECTRA

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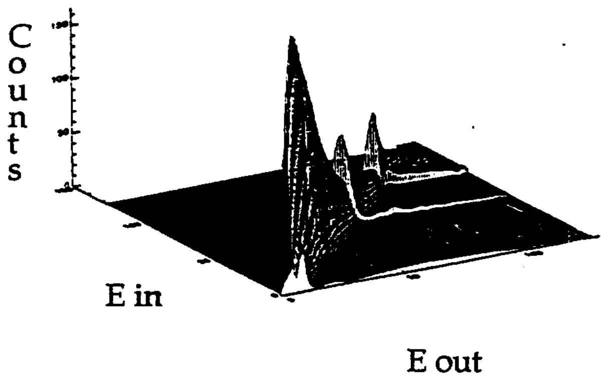
Since their discovery twenty years ago, the origin of gamma-ray bursts (GRB's) has remained an intriguing mystery. The quest to understand these objects has given rise to a plethora of competing theories. Several theories suggest that GRB's are galactic in origin while others suggest that GRB's are cosmological (Harding 1993).

One piece of evidence that might provide scientists with a key to understanding the origin of GRB's may be whether or not spectral emission and absorption features exist in burst spectra. If the features exist and can be attributed to either cyclotron lines or to red-shifted 511 keV annihilation lines then credence would be given to those theories that support a galactic origin, i.e. near neutron stars (Barat 1984, Mazets 1980, Mitrofanov 1984, Nolan 1984).

A method of searching for spectral features in burst spectra (BATSE HER data) will be outlined in this paper. The method was used to investigate the energy range between approximately 350 keV to 600 keV. This energy range was chosen because previous experiments have reported emission features in gamma-ray bursts around 400 keV to 500 keV. These features have been interpreted as gravitationally red-shifted 511 keV annihilation radiation produced near a neutron star (Barat 1984, Mazets 1980, Mitrofanov 1984, Nolan 1984).

The first step was to calculate a background model representing the ambient background radiation. The model was used to separate the burst spectrum from that of the background. Next, we construct the incident "photon" spectrum from the recorded "count" spectrum. To do this involves convolution with matrices that contain information on the detector's efficiency as a function of energy, as a function of angle of incidence of radiation, and also the detector's sensitivity to that fraction of the incident radiation caused by scattering off the Earth's atmosphere. The combination of all of these is called the detector response matrix (DRM) shown in Figure 1.

The BATSE HER data for a single burst can be binned into different time intervals and each interval forms a spectrum. Burst 1B 911221 was binned into 8 spectra each lasting approximately 9 secs. A fit of the spectrum that ranged in time from 9.7 secs to 18.2 secs produced the best fit results. Figure 2 shows the fit that was made to this spectrum using a Broken Power Law, the form of which can be seen in Equation 1.



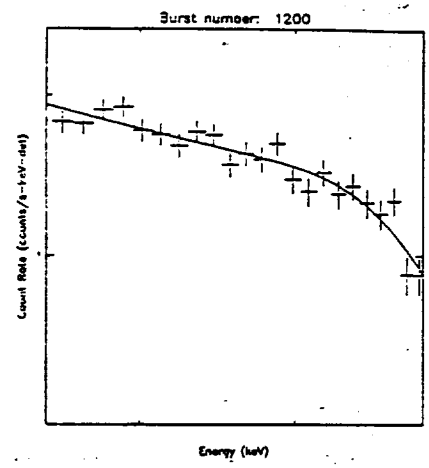


Figure 1 A detector response matrix. Figure 2 A fit using a Broken Power Law.

$$A\left(\frac{E}{Epivot}\right)^{\lambda_1} \text{ if } E \leq Ebreak$$

$$\text{or} \qquad [1]$$

$$A\left(\frac{Ebreak}{Epivot}\right)^{\lambda_1} \left(\frac{E}{Ebreak}\right)^{\lambda_2} \text{ if } E \geq Ebreak$$

The fit shown in Figure 2 produced a χ^2 of 23.4 with 22 degrees of freedom. After the initial fit was made to this spectrum, a batch fit was made to the other 7 spectra by adjusting the parameters of the first fit to find the best fit for each of the others.

The batch fits form the basis of a continuum model which was then subtracted from the data. These residuals were then divided by the standard deviation, σ, that was associated with each energy value. Contour maps of the residuals plotted against energy and time were then generated. Figure 3 shows the contour map that was generated for burst 1B 911221.

The contour lines are displayed for values of 2 σ, 3 σ, 4 σ, and 5 σ. When examining the structure in contour plots the resolution of the detector at the particular energy must be considered in order to determine whether the structure is real or not. Equation 2 gives the resolution of the detector as a function energy.

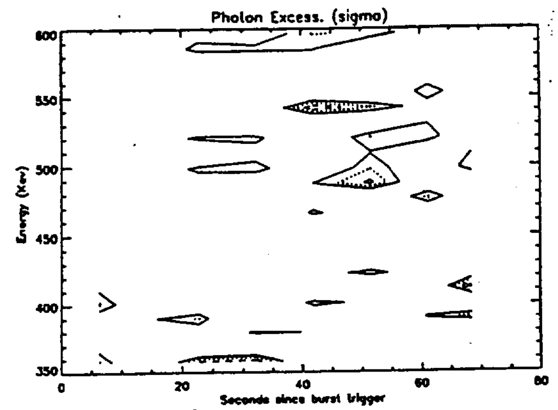


Figure 3 Contour map generated for burst 1B 911221.

$$\text{Res} = 0.079E\left(\frac{E}{511}\right)^{-0.42} \qquad [2]$$

At 545 keV the resolution is 42 keV. Therefore, the structure seen at 545 keV between 36 secs and 57 secs is probably a detector anomaly. The detector resolution at 490 keV is 39 keV. The observed structure ranges from 480 keV to 510 keV, so the feature is probably not real but further investigation is warranted. Figure 4 shows a plot over a larger energy range chosen to show the features at 490 keV in the context of a larger continuum. The figure shows that, in the energy range of 480 keV to 510 keV, there are no significant features.

The feature searching method described above provides a means of searching through a vast amount of data, looking for regions which warrant further and more thorough searches.

The new searching method also allows us to evaluate our background subtracting and fitting routines. For instance, if there were a lot of structure around 511 keV it might indicate that the background subtraction routines were not working properly.

Future work will be done to improve and enhance this searching method while analyzing GRB's for spectral emission features.

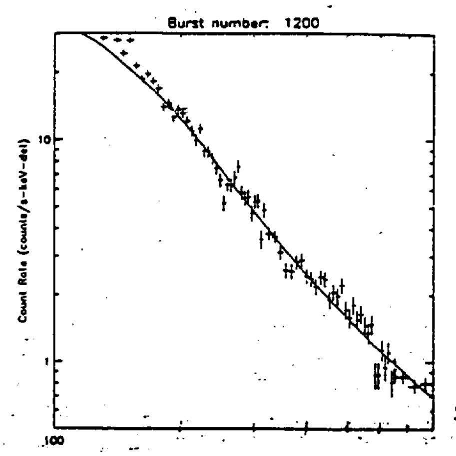


Figure 4 Fit of a broken power law over the energy range 170 keV to 900 keV.

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