COBE OBSERVATIONS OF THE MICROWAVE COUNTERPARTS OF GAMMA RAY BURSTS

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Abstract:

We have used the data from the COBE satellite to search for delayed microwave emission (31 - 90 GHz) from Gamma Ray Bursts (GRBs). The large 7° beam of COBE is well matched to the large positional uncertainties in the GRB locations, although it also means that fluxes from (point source) GRB objects will be diluted. In view of this we are doing a statistical search of the GRBs which occurred during the currently released COBE DMR data (years 1990 and 1991), which overlap ~ 200 GRBs recorded by GRO. Here we concentrate on just the top 10 GRBs (in peak counts/second). We obtain the limits on the emission by comparing the COBE fluxes before and after the GRB at the GRB location. Since it is thought that the microwave emission should lag the GRB event, we have searched the GRB position for emission in the few months following the GRB occurrence.

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Towards the Source of Gamma Ray Bursts
1 Microwave Observations by COBE

One of the most important techniques which can be used to identify the sources of Gamma Ray Bursts (GRBs) is to find counterparts in other wavelength regimes. Here we focus on a search for delayed emission from GRBs in the microwave region of the spectrum. Such observations were made fortuitously by the COBE (COsmic Background Explorer) satellite with the Differential Microwave Radiometer (DMR) experiment. COBE observes the full sky every 6 months at 3 frequencies (31, 53, and 90 GHz) with 12 radiometers. (For a more complete description of the COBE mission, see e.g., Boggess, et al, 1992.) Some models of GRBs (e.g., Paczynski and Rhoads, 1993; Meszaros and Rees, 1993; Katz, 1994) predict microwave and radio emission which is delayed on time scales of hours to months. The best constraints on this type of delayed emission in the microwave regime can be found from the COBE database.

Unfortunately for this study, COBE was not designed for studying point sources. The radiometer horns have a FWHM of 7° to purposely dilute the effect of point sources and the radiometers have rms noises of $\sim 23 - 59$ mK antenna temperature. 1 mK corresponds to a point source emission of $\sim 1800 \left(\frac{\nu}{53 \text{ GHz}}\right)^2$ Janskys, so the best use of COBE data is for studying delayed emission on very long time scales where the noise can be reduced by integration to a useful level. The COBE data has also been used to put limits on prompt emission (see Bontekoe, et al., these proceedings). Another way to beat the radiometer noise is to average over a large ensemble of GRB. Currently only 207 GRBs were recorded by GRO during the period spanned by the publicly available COBE data. This number will be increased by a factor of $\sim 4$ when the remaining two years of COBE data is released. As a start towards this final goal we have analyzed the top ten GRBs (rated by peak count rates) which have been recorded in the released COBE data set.

2 Background Subtraction and Analysis

COBE measures the difference in antenna temperature between the GRB position and some reference point 60° away. This angle defines a ring of comparison points. COBE orbits along the Earth’s terminator, and as the Earth moves in its orbit, the COBE viewing pattern sweeps through the sky (and hence also the reference ring). This reference ring is not uniform; it usually slices through a portion of the galactic disk, which is a strong microwave emitter. This observing pattern therefore introduces a time dependent back-
ground noise into the GRB observations as COBE sweeps through the different portions of the reference ring. The reference ring is swept through twice per year, and the COBE orbit is slightly different in the biyearly observations, so the simplest way to model this time dependent reference signal is with two sine waves with a 1/2 and 1 (sidereal) year periods. We fit the sine waves to the data taken at the GRB location for at least one and a half years prior to the GRB event. These fits are then subtracted from the raw data. The residuals should contain only the GRB source emission. We compare the residuals before and after the GRB to see if they are different.

We want to use these residuals to look for delayed emission from the GRB source. Unfortunately, we must have some model in mind to test the data for goodness of fit. The model cannot be very complicated for testing against the limited sample here, because most of the GRB positions are only observed part of the year, and the time interval between the GRB and the end of the COBE data is different for each burst. When the full data set is analysed, we can test more sophisticated models, but for now we model the microwave GRB signal as a simple increase in emission coincident with the GRB event and which remains at a constant level thereafter.

3 Results

All 10 of our selected GRBs are consistent with no change in emission after the GRB. We present our limits on the amount of emission after the event (in Jy) in Table 1. To insure that our background subtraction procedure is not affecting our results, we have done two things. 1) We fit sine waves on data only before the GRB and then subtract only the extrapolation from the raw data after the GRB. (This also reduces the accuracy of the fit slightly, because it reduces the number of periods spanned by the data.) This does not significantly affect our results. 2) We also break up the residuals data before the GRB into subsections and show that the pieces are also consistent with zero emission.

It would be useful to set fluence limits on these GRBs, but it is difficult to make sensible limits when there are gaps the size of months in the GRB coverage. However, for two of the top ten (910522 and 910609) we have almost “continuous” coverage (more than 200 1/2 second observations every day in the first three months following the GRB, and only one gap of 2 days in the remaining time because COBE was doing some internal calibration checks. For those two GRBs we calculate the fluence limits using the following...
Table 1: 95% Confidence Upper Limits on the Change in Emission Level Following the GRBs (integrated until the end of the COBE data–1/1/92).

| Rank | GRB   | 31 GHz U.L. (Jy) | 53 GHz U.L. (Jy) | 90GHz U.L. (Jy) |
|------|-------|------------------|------------------|-----------------|
| 1    | 910503| 210              | 320              | 1900            |
| 2    | 910601| 120              | 240              | 720             |
| 3    | 911118| 736              | 643              | 1140            |
| 4    | 910609| 290              | 240              | 830             |
| 5    | 910522| 80               | 400              | 760             |
| 6    | 910627| 330              | 360              | 540             |
| 7    | 910626| 330              | 320              | 1270            |
| 8    | 911109| 470              | 712              | 980             |
| 9    | 910421| 350              | 270              | 910             |
| 10   | 911104| 580              | 670              | 2180            |

Likelihood Ratio

| Ratio | All 10 | 206 | 415 | 620 |

Formula for microwave Fluence $F_\mu$:

$$F_\mu \equiv \delta t \sum_{i=1}^{3} \nu_i \langle F(\nu_i) \rangle,$$

where $\nu_i = 31$, 53 and 90 GHz, $\langle F(\nu_i) \rangle$ is the average (background subtracted) flux at frequency $\nu_i$ after the GRB. $\delta t$ is the length of time over which observations (used to find $\langle F(\nu_i) \rangle$) were made. The results for these fluences are given in table 2.

Table 2: 95% Confidence upper limits on fluence $F_\mu$ for two gamma ray bursters. The second column indicates how many days are used in the fluence calculation.

| GRB   | Number of Days | $F_\mu$ U.L. (ergs/cm$^2$) |
|-------|----------------|-----------------------------|
| 910609| 205            | $8 \times 10^9$             |
| 910522| 223            | $6 \times 10^5$             |
4 Conclusions

We have analyzed the top ten GRBs (rated by BATSE peak counts) for delayed emission in the 31-90 GHZ region as observed by COBE. We find rather high limits for the amount of possible microwave emission from these ten using a crude model of the microwave emission. Our results for the upper limits on flux are presented in Table 1 and the limits on fluence for two GRBs are presented in Table 2.

We have selected these GRBs for two reasons: 1) if there is any effect it is likely that the effect will be greatest in the most violent GRBs, and 2) we needed a small subset to examine in detail to prepare for a larger study of GRBs. We expect to have the complete set of 207 Gamma Ray bursts analysed soon. With the complete ensemble, we expect more stringent limits smaller by a factor of \(1/\sqrt{20}\) and more detailed models can be more realistically tested. The release of the final part of the COBE data will increase the number of Gamma ray bursts for study by a factor of 4, and will include such events as the “superbowl” burst.

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