# A ROSAT Look for the Source of keV Emission following GRB 780506

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**Abstract**

We have re-analyzed HEAO 1 A-2 data of ~hour–long 2-6 keV emission following a $\gamma$-ray burst, GRB 780506, in order to take advantage of the Rev 2 analysis of a ~3000 s ROSAT Class C observation. The new, more realistic position constraints exclude all but four of the ROSAT sources from the combined GRB and X–ray "afterglow" 99% confidence contours. None of these four faint ($\leq 10^{-12}$ ergs-cm$^{-2}$-s$^{-1}$) sources is a clear candidate for either the GRB counterpart or for an X–ray transient.

## 1 Introduction

During a 6 hour pointed observation at a blank region of the Galactic plane near the Carina arm, the HEAO 1 A4 scintillation detectors 0.1-3 MeV and A2 2–60 keV proportional counters observed GRB 780506, a $\sim 7 \times 10^{-7}$ erg-cm$^{-2}$-s$^{-1}$ $\gamma$-ray burst [1]; [2]; [3]. The burst exhibited two peaks, roughly a minute apart, which were brightly visible in the A2 X–ray proportional counters. Several minutes after this emmission had faded to background, the A2 detectors recorded a slow increase in count rate in the 2–6 keV band, lasting for at least 30 minutes, and possibly as long as several hours. (This increase was visible only in the offset detectors, and not in a a nearly identical detector pointed 6°away, and so was not likely to be particle background: [2]; [3]. However the A2 detector field of view was $\sim 6° \times 6°$ FWHM, and the instrument was pointed along the Galactic plane. This raised the possibility that the ~ hour long emission could have been due to an unrelated X–ray transient such as those observed by GINGA and ROSAT (see [4], [5] and references therein).

To test his, we proposed two 6 ksec ROSAT exposures to cover the two ends of the best position error-boxes then available, in order to search for any sources with ~20 minute pulse periods similar to X Per. One was scheduled, covering the North Lobe of the combined GRB 780506 and X–ray "afterglow" emission error box. To take advantage of this, we re–calculated the position constraints from the HEAO1 A2 data using a Bayesian approach [6]. This allowed us to calculate the probability of its position on the sky without making any assumptions about source variability. As a result, this more realistic error box is smaller, and it is more probable that the ~ hours–long X–ray emission came from the source of GRB 780506. Four faint sources fell within the 99% confidence contours of both GRB 780506 and of the ~ hours long X–ray emission. None of them is an outstanding candidate for a GRB counterpart.

In the following section we describe the ROSAT observation and list the observed point sources in more detail.

## 2 ROSAT Observation

On April 19–20, 1991, ROSAT pointed at $(l^{II}, b^{II})$ of $(257°02'6.5'', -07°16'0.71'')$, along the Galactic plane near the Carina arm. This was the North side of the original HEAO 1 A-2 X–ray transient error boxes [2]. The observation was broken up into two sections: April 19 23:26:29 – 23:51:23 and April 20 04:15:09 04:32:45 – 04:47:28, for a total of 3058s of observation spread over 5.5 hours. ROSAT observed with the PSPC, with no filter, for an energy range of ~0.07-2.4 keV. We compared the HEAO 1 A–2 error–boxes with the results of the Standard Data Analysis Software (SASS of December 1994) for point sources.

Sixteen point sources were identified as significant. The light curves of two of the brighter sources (**A** and **P** in Table 1 below) showed weak evidence for time–variablity. All were considered too faint to do spectral fitting, so instead we have listed two hardness ratios. The first uses bands A and B, where A $\sim 0.1 - 0.5$ keV and B $\sim 0.5 - 2$ keV, while the second uses bands C and D, with C $\sim 0.5 - 0.9$ keV and D $\sim 0.9 - 2$ keV.

Table I. Summary of X–ray properties of 16 ROSAT sources

| | R.A, Dec 2000<br>h m s , ° ' " | Cts/Sec $\pm 1\sigma$<br>$0.07 - 2.4$keV | Ratio$\pm 1\sigma$<br>$\frac{B-A}{A+B}$ | Ratio$\pm 1\sigma$<br>$\frac{D-C}{D+C}$ |
|---|---|---|---|---|
| **A** | 7 52 14.5 , -42 19 16 | 0.024 0.003 | 0.37 0.13 | 0.11 0.15 |
| **B** | 7 52 43.3 , -42 21 10 | 0.002 0.0009 | 1.75 0.72 | −0.93 1.70 |
| **C** | 7 52 58.3 , -42 22 04 | 0.003 0.001 | 0.68 0.37 | 0.19 0.39 |
| **D** | 7 53 44.3 , -42 22 54 | 0.003 0.001 | 0.72 0.36 | −0.58 0.32 |
| **E** | 7 53 10.9 , -42 23 53 | 0.008 0.002 | 0.57 0.23 | −0.16 0.24 |
| **F** | 7 52 28.2 , -42 25 49 | 0.004 0.001 | −0.14 0.35 | −0.75 1.91 |
| **G** | 7 54 40.7 , -42 26 49 | 0.022 0.003 | — | — |
| **H** | 7 54 2.2 , -42 27 20 | 0.005 0.002 | 0.97 0.42 | 0.47 0.28 |
| **I** | 7 53 4.5 , -42 28 07 | 0.004 0.001 | 0.13 0.36 | −0.47 0.38 |
| **J** | 7 53 5.3 , -42 30 15 | 0.005 0.001 | 0.33 0.33 | 0.53 0.30 |
| **K** | 7 53 14.4 , -42 31 33 | 0.003 0.001 | 0.08 0.41 | — |
| **L** | 7 53 17.8 , -42 35 10 | 0.004 0.001 | 0.01 0.35 | — |
| **M** | 7 51 28.5 , -42 37 26 | 0.014 0.003 | 0.87 0.15 | 0.31 0.18 |
| **N** | 7 52 17.0 , -42 39 24 | 0.006 0.002 | 0.49 0.44 | 0.16 0.46 |
| **O** | 7 52 23.6 , -42 40 00 | 0.006 0.002 | −0.12 0.38 | 2.10 1.77 |
| **P** | 7 51 33.7 , -42 45 28 | 0.047 0.006 | 0.26 0.13 | −0.02 0.15 |

We have plotted their positions in Figure 1. On these we have superposed HEAO 1 A-2 position constraints for GRB 780506 (shaded) and the ~hour long afterglow (unshaded). These are contours of constant log Bayesian likelihood, $\log[\mathcal{L}] = \log[p(\alpha,\delta|\mathrm{Data})/p_{MAX}]$ [6]. We chose to plot $2\log[\mathcal{L}] = 4.6$ and 9.2 to be analogous to $\Delta\chi^2$ 90% and 99% confidence contours for 2 degrees of freedom [7]. There was some indication from comparing the HEAO 1 A-4 and A-2 spectra that the source of GRB 780506 was located $\pm 2°$from the center of the error box, along the long axis [3], so the ROSAT pointing covered one of the two combined A-2/A-4 best–fit positions.

Only four ROSAT sources fall within both the GRB 780506 and ~hour long transient $2\log\mathcal{L} = 4.6$ contours: **L**, **M**, **N**, and **O**. The HEAO 1 A-2 afterglow spectrum was consistent with a ~few keV blackbody, with no evidence of cooling [3]. None of these sources seems a good match to this spectrum.

ROSAT sources observed in the neighborhood of GB 780506

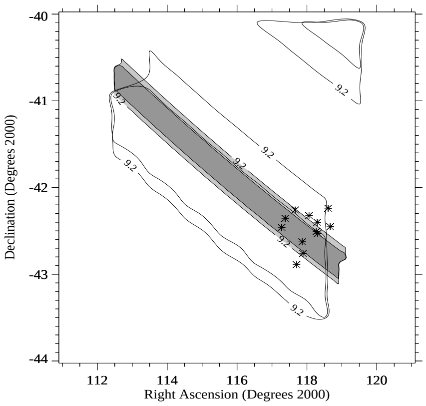


*Figure 1: ROSAT Sources observed in the neighborhood of GRB780506*

To check optical identifications, the ROSAT sources were compared with those of optical sources in catalogs compiled into the SIMBAD database system. Two of the four ROSAT sources which fell within the error box (**N** and **O**) had positions consistent with that of an A0 V star (HD 64505). were identified with known stars.

Table 2. Summary of potential optical IDs for 16 ROSAT sources

| | $10^{-14}$erg/cm$^2$-s$\pm 1\sigma$ 0.07–2.4 keV | | OpticalID SIMBAD | Type | $m_V$ $m_B$ | $f_{bol}$ erg/cm$^2$-s |
|---|---|---|---|---|---|---|
| **A** | 7.2 | 0.9 | HD64458 | B7IV | 7.7 7.2 | 4.4 $10^{-7}$ |
| " | " | " | HD64441 | B9III | 8.4 7.7 | 1.3 $10^{-7}$ |
| **B** | 0.69 | 0.27 | — | — | — | — |
| **C** | 0.9 | 0.3 | — | — | — | — |
| **D** | 0.9 | 0.3 | — | — | — | — |
| **E** | 2.4 | 0.6 | — | — | — | — |
| **F** | 1.2 | 0.3 | — | — | — | — |
| **G** | 0.65 | 0.9 | HD64954 | M1III | 7.5 8.6 | 9.9 $10^{-8}$ |
| **H** | 1.5 | 0.6 | — | — | — | — |
| **I** | 1.2 | 0.3 | — | — | — | — |
| **J** | 1.5 | 0.3 | HD64623 | F5IV | 9.4 9.0 | 4.5 $10^{-9}$ |
| **K** | 0.9 | 0.3 | — | — | — | — |
| **L** | 1.2 | 0.3 | — | — | — | — |
| **M** | 4.2 | 0.9 | — | — | — | — |
| **N** | 1.8 | 0.6 | HD64505 | A0V | 9.4 8.8 | 1.1 $10^{-8}$ |
| **O** | 1.8 | 0.6 | HD64505 | A0V | 9.4 8.8 | 1.1 $10^{-8}$ |
| **P** | 14. | 1.8 | CD-42 3600 | A0 | — 10.0 | 3.6 $10^{-9}$ |

We list properties of the potential optical counterparts to the ROSAT sources in Table 2. For the X–ray flux, we estimated roughly $3\times10^{-12} ergs/cm^2$ per 0.07–2.4 keV count. This is consistent with convolving a range of spectra, such as the spectrum one expects from the active corona of a normal star (roughly a $10^7$K thermal spectrum) through the telescope + PSPC response. Along with the statistical uncertainty, which is listed in in Table 2, we expect an overall systematic uncertaintly of roughly a factor of three, due to the uncertainty in the true shape of each spectrum. The bolometric luminosty was estimated from [8].

Notice that **A**, the second–brightest source, is positionally coincident with two B stars, both of which could have contributed to its flux. The X–ray flux is probably too low for either to be an accretion–powered X–ray binary such as an active Be–neutron star system. Even in its low state, systems such as X Per have a luminosity of $\sim 10^{34-35}$ ergs/s [4],[5]. This would imply X–ray fluxes an order of magnitude brighter than those listed in Table 2, even if the source were at the distant edge of the Galaxy (roughly 10 kpc). Instead, it looks more probable that the X–ray flux is from coronal emission. For stars of type O and B, one expects $\log[L_x/L_{bol}] \sim -7$, but dropping to much less for A–type stars, unless they are peculiar [9]. This is consistent with the suggestion that both B stars contribute some flux to **A**. For those of types M–F, one expects to find active coronae with $\log[L_x/L_{bol}] \sim -3$ [9]. This is consistent with the remaining suggested optical IDs in Table 2, except for source **P**.

This sample is also consistent with what was found by [4] in ROSAT observations of 225 sources in 200 square degrees along the Galactic plane. About 40% could be associated with normal stars. Based on their sample, they suggest roughly 10% of their sources not identified through SIMBAD should be faint red dwarfs with active coronae. This is consistent with an estimates of X–ray luminosites $\sim 10^{27-31}$ ergs/s; and number densities on the order of one per 25 pc$^3$ [9]. This suggests $\sim$ 1–3 of the 6 remaining unidentified sources is a red dwarf. Other possibilities include clusters of Galaxies, AGNs, and unidentified cataclysmic variables.

## 3 Conclusion

ROSAT observed one side of a $\gamma$-ray burst error box that was also apparently observed to have an ~hour long 2–6 keV afterglow. No compelling quiescent candidate was detected. The preliminary optical identifications of the sixteen ROSAT sources that were detected are consistent with the sample seen in other, larger, surveys of the Galactic plane.

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