X–RAY COUNTERPART SEARCHES OF CLASSICAL GAMMA-RAY BURSTS WITH ASCA

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Abstract

ASCA has performed several observations of classical gamma–ray bursts (GRBs), in search for their X–ray counterparts. Among these, two small GRB error boxes, of GRB 920501 and GRB 781119, have been observed and X–ray sources were confirmed in both cases. We find that the probabilities of a chance association between the X–ray sources and the GRB error boxes are small to consider them as possible counterparts to the burst sources. We present ASCA images and spectra of these objects, and discuss the possible connections between the GRBs and the X–ray sources. Other GRB searches are also reported separately in this volume.

1. Introduction and Analyses

The origin of GRBs is still an open question. Recently, two members of a family of high energy transients, soft gamma repeaters (SGRs), have been identified with the SNR G10.0-0.3 in our Galaxy and N49 in the LMC Cloud [1,2,3,4]. However, the origin of the classical GRBs has not yet been determined. Based on the successful identifications of the two SGRs, X–ray counterpart searches of the classical GRBs with small error boxes are of particular interest in identifying the origin of the GRBs. We report two observations, of GRB 920501 and GRB 781119, with ASCA.

The GRB of 1992 May 1 (GRB 920501) was observed first with BATSE, PVO, and Ulysses, and was rapidly localized to the small–error region of about 2.7 arcmin^2 in size [5]. A VLA snapshot observation revealed no bright radio source and, 9 months after the burst, a three-hour search at 3.6 cm and 20 cm similarly revealed no sources [6]. 18 days after the burst, a ROSAT ToO observation was carried out, and a weak X–ray source was discovered in the error box. A year and half after the burst, a deeper ROSAT PSPC observation was made, and detected a source in the 0.07–2.4 keV energy band [7]. The ROSAT spectrum was best explained by an optically thin thermal bremsstrahlung (TB) function with a temperature of 7×10^6 K (or 0.6 keV), and, more importantly, heavy absorption from a column density of about 10^{22} hydrogen atoms cm^{-2}, roughly equivalent to the total galactic hydrogen column density in this direction, suggesting a distant source[7].

The GRB 781119 was the first GRB to be precisely localized. Using the spacecraft of the first interplanetary network (IPN), Cline et al. derived an arcmin^2 error box for it[8], which was subsequently observed in the optical, radio, and X–ray [9,10,11,12]. The detection of an optical transient within the error box by Schaefer defined a ~ 140 arcsec^2 region which was thought to contain the true counterpart[13]. The GRB 781119 was known for another reason: the spectrum revealed two possible emission lines, at 420 and 740 keV, which could be interpreted as redshifted positron–electron annihilation and nuclear iron lines, respectively [14], reinforcing the widely held idea that gamma–ray bursts originated on galactic neutron stars.

The Einstein detection, which was only in the high energy band (0.5–3 keV), took place in 1980 [11,12]. Boer et al. observed the region with EXOSAT, but failed to detect the source[15]. Thus, the rather weak (3.5 σ) Einstein detection could have been a statistical fluctuation.

1.1. Image and Spectrum of GRB 920501

An ASCA SIS image is superimposed on the error box of the GRB 920501 in fig 1. There are at least two X–ray point sources within the SIS FOV. Taking a typical systematic attitude uncertainty determination of 1' in diameter, one of the X–ray sources (the brighter one) is within the error box of the 1992 May 1 burst. A more accurate, 6" position for this X–ray source was reported using the ROSAT HRI observation[7]. The two X–ray sources in the SIS FOV above the 3 sigma flux level and the 2.7 arcmin^2 error box size for GRB 920501 simply give a probability of finding an X–ray source of 1.1×10^{-2} by chance.

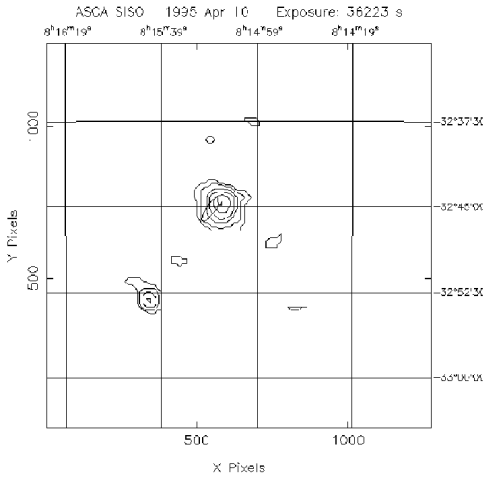

Fig. 1. ASCA SIS image of the GRB 920501 field. The 3rd IPN error box of GRB 920501[7] is superimposed. There are at least two X-ray sources in the 22' x 22' SIS FOV.

The galactic coordinates of GRB 920501 are (l, b) = (251.°16, +1.°21), which is very close to the galactic plane, where source confusion might be expected. A spectrum of the X–ray source has been derived with great care. The derived SIS spectrum can be described by the best-fit model, a power–law with an index of -2.3. However, due to the poor S/N ratio of the spectrum, any type of model, such as a power–law, TB or a Raymond–Smith model, gives an acceptable fit[17]. Interestingly enough, independent of the above continuum models, all of the models require a hydrogen column density of $\sim 10^{22}$ cm^{-2}, which corresponds to the total amount of the galactic column density in this direction [16]. The spectral shape and temperature of the ASCA fits indicate a hard spectrum, and might argue against an interpretation of the low temperature sources as being a field star or an old SNR[17].

1.2. Image and Spectrum of GRB 781119

In the SIS image, two sources were detected, and one, with 7 σ confidence was in the GRB error box. This source, at alpha(2000)=01h 18m 50.10s, delta(2000)= –28d 35m 32.62s (90 % confidence error radius 1'), probably corresponds to the Einstein source. Spectral fitting was done after carefully subtracting the background within a 2.2 arcmin radius. Power–law and TB fits both give acceptable reduced χ^2 values. The power–law index is $1.77^{+0.98}_{-0.43}$ (90% confidence), and the hydrogen column density is $3.2^{+45}_{-3.2} \times 10^{20}$ cm^{-2}. The latter is consistent with the total column density in this general direction of –84 degree in galactic latitude[18].

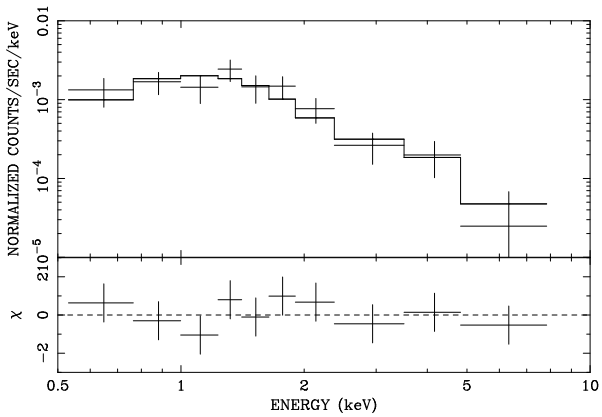

Fig. 2. SIS spectrum of the X–ray source in the GRB 781119 error box. A power-law fit with index 1.77 is shown.

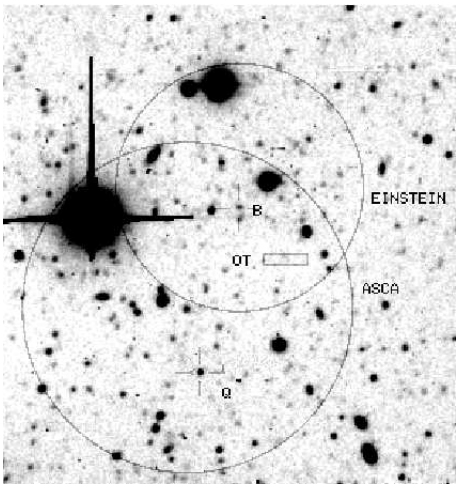

Fig. 3. The optical content of the region around the Einstein and ASCA 90% confidence error circles, from observations using the ESO telescopes. The positions of the radio source B and Q are also indicated.

2. Discussions

The probabilities that one of the two sources detected in the SIS field of views of GRB 920501 and GRB 781119 falls in the GRB error box are the order of $\sim 10^{-2}$. This is about the same as that which would be predicted using the ASCA X–ray source log N-log S relation,

which gives a probability $\sim 10^{-2}$ that a source with an intensity equal to or greater than the one observed here would fall into identical error boxes anywhere on the sky. Since there are two independent observations with low probabilities, we note that the combined probability is small enough to warrant their consideration as possible counterparts to the burst sources.

The observed fluxes of both were weak but the spectra were rather hard, extending to 8$\sim$10 keV with a power-law index, which is comparable to that of the Crab, suggest that the spectrum may not be due to coronal emissions from an ordinary field star, or to an old SNR with a low-temperature thermal plasma[17,18]. The point-like nature also argues against the possibility of an old extended supernova remnant in our galaxy. One striking feature of the spectrum, which is not in doubt for GRB 920501, is the strong absorption at low energies, which is consistent with a hydrogen-column density of $\sim 10^{22}$ cm^{-2} , and does not depend on the continuum model used in the ASCA fits[17]. If this is due to interstellar, as opposed to circumstellar, absorption, the distance to the X–ray source is large. There is no thick or peculiar molecular cloud was found in this direction [19]. Recently Blaes et al. observed the 6" ROSAT position in JHK bands at Keck Telescope and have found at least seven candidates around the ROSAT error circle[20]. Six are consistent with stellar objects in color and one is extended and might be a galaxy. The stellar objects can be rejected based on the ASCA hard X–ray spectrum and the estimated distance. A galaxy with a hard X–ray spectrum, which is observed through the galactic disk, is consistent with the ASCA observations.

Fig 3 shows the radio and optical image of the region around the ASCA and Einstein error circles. The QSO first noted by Pedersen et al. and the radio sources "B and Q" first noted by VLA are the candidates for the counterpart to the ASCA X–ray source[10,21]. Hurley et al. noted a possible optical counterpart to these radio sources [18]. They indicate that two optical objects in B are extended and possibly galaxies and the object in Q is star-like on exposure sums at ESO, having resolution of $\sim$1.6", with m_V=22.64, and B-V=0.46. If B or Q is the optical counterpart to the X–ray source, it would have a very high X–ray to optical luminosity ratio, found only in X–ray binaries and in some active galaxies. Further optical and X–ray observations will be required to confirm this association.

3. References

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