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Optical and near-infrared observations of the GRB 970616 error box⋆,⋆⋆

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Abstract. We report on near-infrared and optical observations of the GRB 970616 error box and of the X-ray sources discovered by ASCA and ROSAT in the region. No optical transient was found either within the IPN band or in the X-ray error boxes, similarly to other bursts, and we suggest that either considerable intrinsic absorption was present (like GRB 970828) or that the optical transient displayed a very fast decline (like GRB 980326 and GRB 980519).

Key words: methods: observational — gamma–rays: bursts

1. Introduction

The error box of the BATSE gamma-ray burst GRB 970616 (Connaughton et al. 1997) was scanned by RXTE four hours after the event (Marshall et al. 1997). Observations revealed a previously unknown X-ray source inside the error box whose position was consistent with the one provided later on by the Interplanetary Network (IPN), yielding a combined RXTE/IPN trapezoidal error box (Hurley et al. 1997). Four days later, the ASCA satellite observed the RXTE/IPN error box and detected four X-ray sources. One of them, A#1 according to the nomenclature of Murakami et al. (1997), was suggested as the X-ray counterpart to GRB 970616. Two candidates were initially proposed by Galama et al. (1997) and Udalski (1997), but other observers (Pahre et al. 1997; Dey et al. 1997; Wheeler et al. 1997; Castro-Tirado et al. 1997) failed to confirm these. Observations performed by ROSAT during June 23-25 revealed eleven faint X-ray sources, lying three of them within the RXTE/IPN error box. One of the three sources, R#2, following Greiner et al. (1997), was consistent with the ASCA variable source A#1, showing a flux five times lower than the one measured by ASCA. The 3σ upper limit to the unabsorbed ROSAT flux of the source A#4, implies a factor of seven lower than the previously measured by ASCA. The fading observed during the ASCA observation could suggest that A#1 is the X-ray counterpart to the GRB. However, the presence of another decaying X-ray source inside the RXTE/IPN error box keeps open the association with the GRB. A massive cluster of galaxies $2'$ away from the RXTE/IPN error box is reported by Benítez et al. (1999). Figure 1 shows the locations of the cluster and of the candidates proposed by Galama et al. (1997) and Udalski (1997).

2. Observations

2.1. Near-IR observations

Observations in the K'-band were performed with the 3.5-m telescope (+OMEGA) of the Calar Alto Observatory on 1997 June 21.18, 25.17 and 26.18 UT. Also J-band images were taken with the 2.2-m Telescope (+MAGIC) on June 25.14. The frames were centered on the candidate proposed by Galama et al. (1997). Additional K'-band observations were performed on 1998 Oct. 5.125 with the 3.5-m telescope.

2.2. Optical observations

Optical observations were mainly taken at La Silla with the Danish 1.54-m telescope equipped with DFOSC, whose field of view ($13'.6 \times 13'.6$) enabled us to cover the four ASCA sources (see Fig. 1). Table 1 displays the observing log.

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⋆ Based on observations collected at the German-Spanish Astronomical Centre, Calar Alto, operated by the Max-Planck-Institut für Astronomie, Heidelberg, jointly with the Spanish National Commission for Astronomy.
⋆⋆ Based on observations carried out at the Danish 1.54-m Telescope on the European Southern Observatory, La Silla, Chile.

Table 1. Observing log of the optical observations performed with the 1.54-m Danish telescope

Date of 1997	Exposure time (10^3 s) B	V	R	i	free
June 25	-	-	8.9	-	-
June 26	-	-	-	7.8	-
June 27	-	-	9.6	-	-
June 28	-	-	10.2	-	-
June 29	-	-	11.2	-	-
June 30	-	2.0	9.0	-	-
July 1	-	1.2	10.5	-	-
July 2	3.6	-	7.2	-	-
July 3	1.2	-	-	-	-
July 4	1.2	-	-	-	-
July 6	-	-	3.6	-	0.9
July 7	-	-	-	-	5.6
Total 26.02^h=	6.0	+3.2	+70.2	+7.8	+6.5

Additional R-band imaging was obtained on 1997 July 20.199, 20.207 and 20.257 with the 0.8-m IAC80 telescope at the Observatorio del Teide. A 1020 × 1024 pixels CCD provides a 7.′4 × 7.′4 field of view. Limiting magnitude was $R \sim 20$ on the 360-s exposures.

3. Discussion and conclusion

Optical and IR images of the RXTE error box were obtained starting 106 hours after the event. No variable optical counterpart was found within the A # 1 and A # 4 X-ray source error circles in the RXTE/IPN annulus, being the variation $\Delta B \leq 0.3$, $\Delta V \leq 0.2$, $\Delta R \leq 0.2$ and $\Delta i \leq 0.3$ for optical objects with $B \leq 23$, $V \leq 23$, $R \leq 24$ and $i \leq 22$. In fact, no objects brighter than $R = 24.2$ are seen within the error box of the ROSAT R # 2 source detected at the ASCA position, consistently with the magnitudes reported by Groot et al. (1997). Therefore, either there is a considerable intrinsic absorption (as in the case of GRB 970828, Yoshida et al. 1999) or the transient optical emission displayed a fast decline, as seen in GRB 980326 (Groot et al. 1998) and GRB 980519 (Hjorth et al. 1999).

No IR variability has been found in a 5′ × 4′ region centered at the position of the candidate proposed by Galama et al. (1997). This object was observed at $J = 18.3 \pm 0.2$, and $K' = 17.4 \pm 0.3$ and did not show any obvious IR/optical variation in the K'-band. The color is consistent with this of a late-type star, as suggested by Pahre et al. (1998) and it seems to be a non-variable star (Groot et al. 1997). Any fading or increase was ≤ 0.5 mag for $K' \leq 17.0$.

Concerning the above mentioned cluster of galaxies (the long arrow in Fig. 1), it is probably related to the X-ray source A # 2, which is outside the IPN band, and consequently not related to the GRB.

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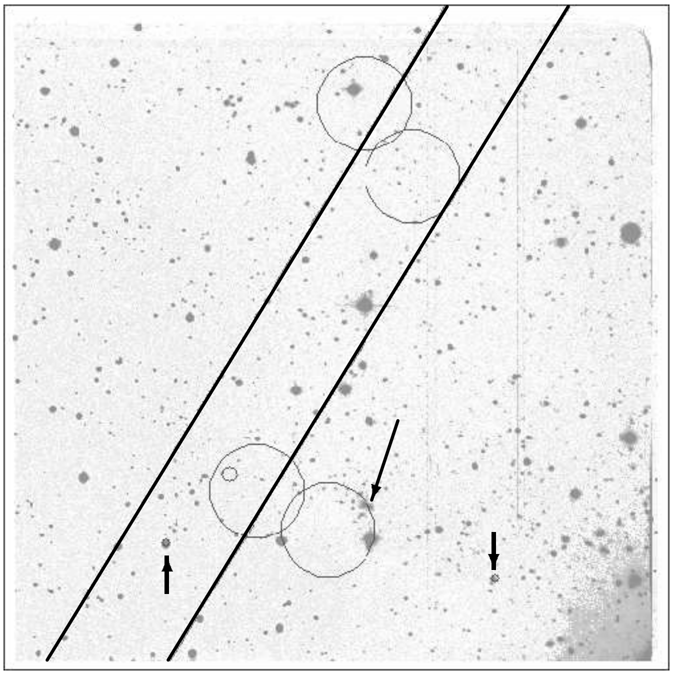

Fig. 1. A coadded R-band image of the field of GRB 970616 obtained with the Danish 1.54-m telescope. The total exposure time is 19.5 hours and the limiting magnitude $R = 24.2$. The straight thick lines represent the IPN arc determined by Ulysses and BATSE. The two circles fully included in the IPN band are A # 4 (large, at the top) and R # 2 (small at the bottom), whereas the circles partially included are A # 3 (top) and A # 1 (bottom). The circle totally outside the IPN band is A # 2. R # 1 and R # 3 are outside the field of view. The two short arrows show the variable objects proposed by Galama et al. (1997) -inside the IPN band- and Udalski (1997) -outside the IPN band-. The field of view is 13.′6 × 13.′6 and is totally within the RXTE/ASM error box. North is to the top and east to the left. The long arrow indicates the massive cluster of galaxies found by Benítez et al. (1999)

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