On the properties of the z = 0.398 radio selected starburst galaxy in the error box of the dark GRB 001109*

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Received / Accepted

Abstract. We present optical and NIR (near infrared) follow up observations of the GRB 001109 from 1 to 300 days after the burst. No transient emission was found at these wavelengths within this GRB's (Gamma Ray Burst) 50" radius BeppoSAX error box. Strong limits (3σ) are set with: $R \gtrsim 21$, 10.2 hr after the GRB; $I \gtrsim 23$, 11.4 hr after the GRB; $H \gtrsim 20.7$, 9.9 hr after the GRB; and $K_S \gtrsim 20$, 9.6 hours after the GRB. We discuss whether the radio source found in the GRB error box (Taylor et al. 2000) might be related to the afterglow. We also study a reddened starburst galaxy, found coincident with the potential radio and the X ray afterglow. We show that our strong I band upper limit makes of the GRB 001109 the darkest one localised by the BeppoSAX's NFI (Narrow Field Instrument), and it is one of the most constraining upper limits on GRB afterglows to date. Further to it, the implications of these observations in the context of dark GRBs are considered.

Key words. Gamma rays: bursts - Galaxies: fundamental parameters - Techniques: photometric

1. Introduction

For the period spanning 1997–2001, approximately only one third of all GRBs (Gamma Ray Bursts) with well determined coordinates have had successful searches for optical counterparts (Greiner 2003). It is thought that extinction around the progenitor and in the host galaxy plays a role in the non detection of the optical counterpart associated with dark GRBs (Groot et al. 1998; Taylor et al. 1998). Several mechanisms (Lazzati et al. 2002; Ramírez-Ruíz et al. 2002) have been adduced to explain the lack of optical counterparts despite the prompt/deep observations carried out for some of them (Fynbo et al. 2001; Piro et al. 2002).

The GRB 001109 was detected on 09.391169 UT November 2000 (t_0 hereafter) by the BeppoSAX (Boella et al. 1997) with a refined uncertainty of 2.5' (Gandolfi et al. 2000a, 2000b). A BeppoSAX NFI (Narrow Field Instrument) observation at $t_0 + 16.5$ hr detected a previously unknown source inside the 2.5' radius WFC (Wide Field Camera) error box (Amati et al. 2000). The source, designated 1SAX J1830.1+5517, had R.A. (J2000) = $18^h 30^m 07.8^s$, Dec. (J2000) = $+55^\circ 17' 56''$ (error radius = 50'') and a 2–10 keV flux of 7.1 \pm 0.5 \times 10⁻¹³ erg cm⁻² s⁻¹. See Amati et al. (2003a, 2003b) for a detailed discussion of the X ray properties.

A radio source (dubbed VLA J1830+5518) was found within the NFI error box with R.A.(J2000) = $18^{h}30^{m}06.51^{s}$, Dec.(J2000) = $55^{\circ}18'35.7''$ (conservative errors of 0.1'' in each coordinate) and a flux of $236 \pm 31 \mu$ Jy at 8.46 GHz (Taylor et al. 2000). It seemed to decrease in brightness over a time span of 2 days (Rol et al. 2000), but further observations at the VLA for ~ 390 days failed to reveal a consistent decay (Berger & Frail 2001).

In this paper we report on the deep optical/NIR (near infrared) observations carried out for the GRB 001109 and their implications in the study of dark GRBs. Further we report on millimetre observations.

2. Observations

Table 1 displays the observing log. Target of Opportunity observations started at $t_0 + 9.1$ hr (referred to the start time of the first frame reported by Greiner et al. (2000), taken with the 1.23CAHA). We performed aperture photometry using SExtractor¹ (Bertin & Arnouts 1996) to study the contents of

* Based on observations made with telescopes at the Centro Astronómico Hispano Alemán (1.23 m + 3.50 m), at the Observatorio del Roque de los Muchachos (NOT + WHT), at the United States Naval Observatory (1.00 m) and at the Russian Academy of Sciences's Special Astrophysical Observatory (6.05 m). The NOT is operated on the island of San Miguel de la Palma jointly by Denmark, Finland, Iceland, Norway and Sweden, in Spain's Observatorio del Roque de los Muchahos of the Instituto de Astrofísica de Canarias. The Centro Astronómico Hispano Alemán is operated in Calar Alto by the Max-Planck Institut für Astronomie of Heidelberg, jointly with Spain's Comisión Nacional de Astronomía.

http://terapix.iap.fr/soft/sextractor/



Fig. 1. The contents of the BeppoSAX error box for the GRB 001109 field. This *R* band image was taken with the 2.56NOT (+ALFOSC) on 14.0524–14.0734 UT August 2001. The source in between ticks is the galaxy coincident with the VLA J1830+5518 and consistent with the position of the *X* ray afterglow. The numbered stars are the secondary standards indicated in Table 2. The large circle represents the refined WFC error box (Gandolfi et al. 2000b) and the small one the NFI error circle (Amati et al. 2000). The field of view covered by the figure is $5.1' \times 4.3'$. North is upwards and East is leftwards.

the BeppoSAX error box. The field was calibrated observing the Landolt field SA113 (Landolt 1992) in the *UBV RI* bands (*R* and *I* in the Cousins system), at airmasses similar to that of the GRB field, in only one night. Table 2 shows the positions and magnitudes of several secondary standards in the GRB field (see Fig. 1). Spectroscopic observations were made at the 6.05SAO telescope (12×600 s exposures; see Fig. 2) with SCORPIO and a 300 lines/mm grating. The spectral resolution (FWHM) obtained was ~ 20 Å and the effective wavelength coverage was 3500-9500 Å (Afanasiev et al. 2001). Millimetre observations were carried out at the 30.0IRAM telescope (see Sect. 3.5).

3. Results and analysis

3.1. Content of the BeppoSAX NFI error box

No optical afterglow was detected in the first 1.23CAHA (Greiner et al. (2000); $R_{lim} > 20.9$ mag at 10.2 hr after the GRB) and 2.56NOT ($I_{lim} > 22.9$ mag at 11.4 hr after the GRB) frames. Strong limits come from the deep NIR observations. The *H* and *K'* 3.50CAHA images (Greiner et al. (2000)) reported the value of *H*) have been compared to the *H* and K_S 4.20WHT ones reported by Vreeswijk et al. (2000). We derived the following upper limits² for any NIR transient emission within the NFI error box: K' > 19.9, H > 20.7 and J > 21.3, ~ 10 hr after the GRB, all of them with a 3σ confidence level.

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² We have assumed $K' \sim K_S$

Table 1. Journal of observations of the GRB 001109 field

Date UT	Telescope	Filtre	Exposure Time	Limiting Magnitude			
			(seconds)	(3σ)			
09.7708-09.8590/11/2000	1.23CAHA (CCD)	R	7×500	20.9*			
09.7847-09.8854/11/2000	1.23CAHA (CCD)	B	3×600	20.3*			
09.7848-09.7961/11/2000	4.20WHT (INGRID)	Ks	750	19.9**			
09.7968-09.8081/11/2000	4.20WHT (INGRID)	H	750	21.0**			
09.8083-09.8128/11/2000	4.20WHT (INGRID)	J	300	21.3**			
09.8447-09.8845/11/2000	2.56NOT (StanCam)	Ι	4×600	22.9			
10.0876-10.1084/11/2000	1.00USNO (CCD)	Ι	1 800	21.0^{*}			
10.7363-10.7883/11/2000	3.50CAHA (OMEGA Prime)	H	10×300	20.5*			
10.7618-10.8417/11/2000	1.23CAHA (CCD)	R	9×500	20.9*			
11.8191-11.8281/11/2000	4.20WHT (INGRID)	H	600	20.7**			
11.8292-11.8383/11/2000	4.20WHT (INGRID)	Ks	600	19.4**			
11.8423-11.8514/11/2000	4.20WHT (INGRID)	J	600	21.4**			
13.0560-13.0768/11/2000	1.00USNO (CCD)	Ι	1 800	21.0*			
22.1590-22.1938/11/2000	2.56NOT (ALFOSC)	B	600	23.0			
22.8278-22.8444/11/2000	2.56NOT (ALFOSC)	U	2×600	24.0			
23.8035-22.8194/11/2000	2.56NOT (ALFOSC)	B	2×600	23.5			
26.7576-26.7618/11/2000	3.50CAHA (MOSCA)	R	120	22.0			
27.7514-27.7556/11/2000	3.50CAHA (MOSCA)	R	180	22.3			
22.1590-22.1938/05/2001	4.20WHT (PF)	В	3×900	24.0			
22.1951-22.2079/05/2001	4.20WHT (PF)	V	3×450	23.5			
29.1249-29.1795/05/2001	2.56NOT (ALFOSC)	U	3×1500	23.5			
30.1249-30.1723/05/2001	2.56NOT (ALFOSC)	V	900 + 300	23.5			
31.0468-31.0548/05/2001	2.56NOT (ALFOSC)	V	600	22.0			
18.0361-18.0924/06/2001	4.20WHT (PF)	U	5×900	23.5			
30.0583-30.1361/06/2001	3.50CAHA (OMEGA Cass)	K'	120×60	21.0^{\dagger}			
01.0354-01.1181/07/2001	3.50CAHA (OMEGA Cass)	K'	120×60	21.0^{\dagger}			
24.8655-24.8828/07/2001	6.05SAO (SCORPIO)	R	3×180	25.5			
14.0524-14.0734/08/2001	2.56NOT (ALFOSC)	R	600 + 900	23.8			
14.9983-15.0223/08/2001	2.56NOT (ALFOSC)	R	2×900	24.0			
16.0571-16.1169/08/2001	2.56NOT (ALFOSC)	В	4×1200	25.0			
16.9835-17.0570/08/2001	2.56NOT (ALFOSC)	U	5×1500	24.1			
17.0148-17.0720/08/2001	2.56NOT (ALFOSC)	V	5×900	24.5			
17.0720-17.1148/08/2001	2.56NOT (ALFOSC)	Ι	6×600	23.7			
05.9503-06.0220/08/2002	2.20CAHA (BUSCA)	y	6×900	22.5			
* Greiner et al. (2000).	Their BRI band limiting mag	nitudes ha	ave been shifted to	our zero point.			
** Vreeswijk et al. (2000). Their JHK_S band limiting magnitudes have been shifted to our zero point.							
† The images from 30/6–	[†] The images from $30/6-01/07/2001$ were coadded in just a single limiting magnitude, $K' = 21.0$.						

Table 2. Photometric secondary standards in the GRB 001109 field

	RA(J2000) h m s	Dec (J2000)	U	В	V	R	Ι
1	18 29 52.55	55 16 37.8	18.62 ± 0.03	18.53 ± 0.08	17.95 ± 0.02	17.58 ± 0.02	17.25 ± 0.02
2	18 30 18.61	55 16 46.6	21.02 ± 0.17	19.57 ± 0.04	18.49 ± 0.02	17.79 ± 0.02	17.16 ± 0.02
3	18 30 02.94	55 17 03.2	19.24 ± 0.06	18.48 ± 0.07	17.55 ± 0.02	16.90 ± 0.02	16.36 ± 0.02
4	18 30 04.05	55 17 33.7	21.31 ± 0.17	19.99 ± 0.05	18.97 ± 0.02	18.16 ± 0.02	17.52 ± 0.02
5	18 29 48.91	55 19 20.5	20.26 ± 0.12	19.27 ± 0.06	18.33 ± 0.02	17.73 ± 0.02	17.25 ± 0.02
6	18 30 22.09	55 19 36.9	19.16 ± 0.06	19.45 ± 0.02	19.03 ± 0.07	18.77 ± 0.02	18.45 ± 0.02
7	18 30 20.65	55 19 40.7	20.63 ± 0.15	20.49 ± 0.08	20.05 ± 0.02	19.68 ± 0.03	19.27 ± 0.04
8	18 30 14.57	55 20 43.3	19.54 ± 0.08	18.62 ± 0.03	17.28 ± 0.02	16.33 ± 0.02	15.30 ± 0.02

3.2. Afterglow's SED

Fig. 3 displays selected detections and upper limits associated with the GRB 001109 (to keep the figure legible we have only plotted the most constraining measurement for each of the

optical and NIR bands). All plotted measurements have been shifted to a common epoch $[t = t_0 + 0.4 \text{ days}; \text{ epoch of the radio detection (Taylor et al. 2000)] assuming a power law decay index <math>\alpha = 1.27$ (suggested by the X ray observations reported in Amati et al. 2003a). As shown, the most constraining

Fig. 2. Optical spectrum of the galaxy coincident with the VLA J1830+5518, obtained with the 6.05SAO (+SCORPIO). It shows rest frame emission lines for H α (6 563 Å) and O[III] (4 959 Å, 5 007 Å).

upper limit corresponds to the 2.56NOT *I* band image taken on 9.8447–9.8845 UT November 2000.

This *I* band measurement allows us to impose an upper limit to the afterglow's optical to *X* ray spectral index: $\beta_{optical-X \text{ ray}} < 0.33 \pm 0.02$ (being the flux density given by $F_{\nu} \sim \nu^{-\beta}$).

Our *I* band limit is consistent with the non connection between the VLA J1830+5518 source and the afterglow of the GRB 001109 (Berger & Frail 2001). Had the radio detection (Taylor et al. 2000) been related to the afterglow, then our *I* band observation might have detected an optical counterpart (see Fig. 3). Nonetheless an extinction value of $A_I \sim 0.6$ (3.5 *muJy*) could loosen the constraint imposed by the *I* band upper limit (the corresponding intrinsic A_V depends on the unknown host galaxy redshift). The actual *I* band constraint (intrinsic extinction corrected value) would be above a power law stretch connecting the radio (Taylor et al. 2000) and *X* ray (Amati et al. 2003a) detections.

3.3. VLA J1830+5518

3.3.1. Astrometry

We performed astrometry on two different data sets to reveal the location of the VLA radio source. For the first data set, 10 USNO A2.0 stars, not saturated on the 6.05SAO images, were used. The astrometrical uncertainty was found to be ~ 0.5", including both, statistical and systematic errors (Sokolov et al. 2001). For the second data set, an independent astrometric solution, based on 50 USNO A2.0 stars, was obtained using the coadded *I* band image taken at the 2.56NOT (see the penultimate entry in Table 1). It yielded a similar uncertainty (0.57"). Both astrometric solutions showed, independently, that the radio source is consistent with the brighter component ($R = 20.65 \pm 0.06$, the object A hereafter) of a complex system (see Fig. 4). The second brightest component (the ob-



Fig. 3. Selected detections (*X* ray) and upper limits (*UBV RIJHKs*) associated with the GRB 001109. The most constraining upper limit corresponds to the 2.56NOT *I* band measurement. The optical to *X* ray spectral index upper limit ($\beta_{optical-X}$ ray < 0.33 \pm 0.02) is consistent with a non relationship between the VLA J1830+5518 and the GRB's afterglow (Berger & Frail 2001).

ject B hereafter) is located 1.25'' to the East of the object A. These two objects were independently detected in the optical and in the NIR, so we conclude that they are real objects.

3.3.2. Spectroscopy

Spectral measurements (performed with the slit aligned in the East-West direction) detected Balmer breaks and emission lines for sources A and B. Object A's redshift is z =0.398 ± 0.002 based on the identification of the H α (6563 Å) and O[III] (4959 Å, 5007 Å) emission lines (see Fig. 2 and Afanasiev et al. 2001). Object B's redshift is z = 0.3399± 0.0005 based on the identification of the H α (6563 Å) and H β (4861 Å) emission lines (Afanasiev et al. 2001). The redshift difference between sources A and B corresponds to a large relative expansion velocity of ~ 13000 km s⁻¹. Given that velocity dispersions in galaxy clusters are, at most, ~ 5000 km s⁻¹ (Fadda et al. 1996; Girardi et al. 1993), the alignment of both sources is likely the result of a chance projection. An HST high resolution deep image that might find signs of interaction would help to clarify this issue.

If the object A were the host of the GRB 001109, then the burst redshift would be $z = 0.398 \pm 0.002$. To further constrain this suggestion we calculate the probability to find a radio source with the brightness of VLA J1830+5518 in an error box with a radius of 50".

Following Fomalont et al. (2002) the density of radio sources detected at 8.4 GHz above a flux density S in microjanskys is given by:

$$N = (0.099 \pm 0.010) (\frac{S}{40})^{-1.11 \pm 0.13} \quad arcmin^{-2}$$

So we conclude that the chance probability of having a source brighter than $238 \pm 31 \mu J y$ inside the NFI error box is $3 \pm 0.9\%$ and thus, consider that the probability is not low enough to establish a physical relationship between the location of this radio source inside the GRB error box and the occurrence of the γ ray event.

3.4. Object A's SED

We have determined the flux distribution of the galaxy coincident (not necessarily related) with the VLA J1830+5518 by means of our UBVRI broad band photometric measurements together with the JHKs broad band measurements reported by Vreeswijk et al. (2000). The photometry was based on SExtractor (Bertin & Arnouts 1996), which allows to deblend entangled sources (this is specially relevant for cases like that of the objects A and B). The fluxes at the UBVRIJHKspassband wavelengths have been dereddened of Galactic extinction using a value of E (B - V) = 0.04 (DIRBE/IRAS dust maps: Schlegel et al. 1998).

The UBV RIJHKs passband fluxes (measured in units of 2×10^{-17} erg cm⁻² s⁻¹ Å⁻¹; see Fig. 5) correspond to the following values: 0.118 ± 0.014 , 0.234 ± 0.007 , 0.475 ± 0.012 , 0.684 ± 0.034 , 0.573 ± 0.030 , 0.526 ± 0.023 , 0.393 ± 0.018 and 0.315 ± 0.014 , respectively. We have modelled the SED using stellar population synthesis techniques (Bolzonella et al. 2000) leaving the extinction and the redshift as free parametres. For the extinction law we have used the one given by Calzetti et al. (2000), which is typical for starburst galaxies. The best fit is obtained with a dusty starburst galaxy SED at z = 0.381, with $A_V = 1.4$ mag and a starburst age of 0.25 Gyr (see Fig. 5).

Although the radio emission from the object A is not related to the afterglow of the GRB, the object A could still be the host galaxy of the burst. The estimated extinction ($A_V = 1.4$) might explain the lack of optical emission and agree with the non negligible $N_H = 2.83 \times 10^{22}$ cm⁻² (de Pasquale et al. 2003). This would also be consistent with the fact that the majority of the long duration GRB afterglows located so far have been linked to actively star forming galaxies.

3.5. Results of the millimetre observations

We observed the VLA J1830+5518 with the 117 channel Max Planck Millimetre Bolometre array (MAMBO, Kreysa et al. 1998) at the IRAM's 30 m radiotelescope on Pico Veleta, Spain, between 4 Mar 2003 and 12 Mar 2003. MAMBO has an effective centre frequency of ~ 250 GHz (1.2 mm) and a beam size of 10.6". The observations were done in standard on/off mode with 2 Hz chopping of the secondary mirror with a throw of 32". The flux was calibrated by performing observations on Mars and Uranus, which yielded a conversion factor of 30 000 counts/Jy with an estimated error of 15%. We did not detect any emission from the VLA J1830+5518 down to a rms noise level of 0.5 mJy.

Further, we have estimated how "unusual" is a non detection with MAMBO in this case. This estimation is

Fig. 4. Contour plot displaying the galaxy coincident with the VLA J1830+5518. The figure shows the coadded I band image taken with the 2.56NOT (+ALFOSC) (17.0720–17.1148/08/2001) of the source coincident with the VLA J1830+5518. A seeing of 0.8" allowed us to separate the two components, the objects A and B. The centre of the circle marks the position of the radio source (Taylor et al. 2000), R.A.(J2000) = $18^{h}30^{m}06.51^{s}$, Dec.(J2000) = $55^{\circ}18'35.7"$. The radius of the circle is 0.57". The contours show the detection confidence level above the background in a logarithmic scale. North is upwards and East is leftwards.

based in a correlation between the far IR and the radio. Carilli & Yun (1999) give the correlation of the far IR/radio bands as a function of the redshift. Adapting this correlation to our frequencies we expect, for z = 0.398, the fluxes at 8.4 GHz and 250 GHz to be aproximately equal. We have that, for 8.4 GHz, flux = 0.2 mJy, and that, for 250 GHz, flux < 1.5mJy (3σ) , so our results agree with the expected ones. With a higher redshift the flux at 250 GHz is expected to rise as a function of the flux in radio. Our upper limit at 250 GHz and the correlation from Carilli & Yun (1999) give us an estimate of z = 1 as the maximum redshift allowed for the VLA source (taking the flux at 250 GHz to be less than 1.5 mJy at 3σ). This consistency with the far IR/radio correlation implies that the radio emission probably originates from star formation and not from an AGN. Such conclusion can be accomodated by our UBV RIJHK band SED of the object A (see Table 3 and Fig. 5). Additionally, the z = 1 upper limit for the VLA J1830+5518 is consistent with the object A's redshift.

Barnard et al. (2003) observed the GRB 001109 with the \sim 350 GHz photometry pixel on the Submillimetre Common User Bolometre Array (SCUBA, Holland et al. 1999), at the James Clerk Maxwell Telescope on Mauna Kea, United States. Their measurement yielded a flux of 1.89 ± 1.4 mJy, consistent with our upper limit at 250 GHz since the flux at 350 GHz is larger by a factor of 3–4.



Table 3. The object A's magnitudes

Band	Magnitude
U	23.31 ± 0.15
B	22.96 ± 0.04
V	21.61 ± 0.03
R	20.65 ± 0.06
Ι	20.11 ± 0.06
J	18.67 ± 0.05
H	17.95 ± 0.05
K	17.01 ± 0.05



Fig. 5. SED of the galaxy coincident with the VLA J1830+5518. The solid line is the SED of a dusty starburst galaxy at z = 0.381, with $A_V = 1.4$ mag and an age of 0.25 Gyr. The SED has been constructed with homogeneous data taken with the 2.56NOT (+ALFOSC) for the optical and with the 4.20WHT (+INGRID) for the NIR.

4. Discussion and conclusions

Our optical/NIR/millimetre observations are consistent with a connection between the VLA J1830+5518 and the object A. On the other hand, a connection between the object A and the GRB 001109 can not be established.

If we define a dark GRB as one with no counterpart brighter than R < 23 at 24 hr from the onset, then the GRB 001109 is clearly a dark GRB, given the I > 22.9 limit imposed by the 2.56NOT 0.47 days after the γ ray event. We have used our 2.56NOT I > 22.9 upper limit (9.8447–9.8845/11/2000) to further constrain the luminosity of the GRB 001109 within the context of the BeppoSAX's NFI dark burst sample (see upper limits for dark bursts in Table 1 of de Pasquale et al. 2003). To do so we have (following the methodology described in de Pasquale et al. 2003) calculated the R band upper limit 11 hr after the GRB, from the 2.56NOT I band constraint. First, we calculated the R band flux associated with the I band limit using the spectral index $\beta_{optical-X ray} = 0.33 \pm 0.02$ (see Sect. 3.2). Then, the R band flux was rescaled from $t - t_0 =$ 11.3624 hr (9.8646 UT November 2000; mean 2.56NOT observing time) to $t - t_0 = 11$ hr (assuming a power law decay index $\alpha = 1.15$, adopted by de Pasquale et al. 2003). Further, the R band flux upper limit was corrected for Galactic extinction using a E (B - V) = 0.04 value (Schlegel et al. 1998). As a result we derived an unextincted R band flux upper limit of 1.80 μ Jy 11 hr after the γ ray event. This value reduces the previously reported optical flux constraint by a factor of ~ 7 (11.81 μ Jy in de Pasquale et al. 2003). Moreover, our I band image lowers the optical to X ray flux ratio (f_{oX}) from 0.59 to 0.09, making of the GRB 001109, by far, the darkest BeppoSAX NFI GRB. Consequently, the 2.56NOT I band measurement has impossed one of the most constraining upper limits on GRB afterglows to date.

The GRB 001109 belongs to the subsample of darkest BeppoSAX NFI bursts (~ 25% of the total BeppoSAX NFI dark GRB sample) which show f_{oX} values incompatible (at a 2.6 σ level) with optical transient GRBs (de Pasquale et al. 2003). For those objects the spectral index $\beta_{optical-X}$ ray \leq 0.62, so the GRB 001109 is clearly in this group, which is composed by the GRBs 981226, 990704, 990806 and 000210.

It is important to highlight that the GRB 001109 exhibited the brightest X ray afteglow among the dark BeppoSAX NFI bursts (de Pasquale et al. 2003). On the other hand it showed the lowest N_H reported for the dark BeppoSAX NFI GRBs (de Pasquale et al. 2003). In fact, the GRB 001109 N_H value is consistent with the ones measured for GRBs with detected optical transients. Thus, the bright X ray afterglow of the GRB 001109, its low N_H value (in comparison to the rest of the dark BeppoSAX NFI GRB sample) and the constraining optical limits imposed in the present work, might indicate that the GRB 001109 showed a spectrum intrinsically different from optical transient GRBs.

Acknowledgments

For their assistance during the observations we are grateful to, L. Montoya and A. Aguirre at the CAHA, A.A. Kass at the NOT and, I. Skillen, C. Benn, T. Augusteijn and C. Zurita at the WHT. Some images were taken under the auspices of the Isaac Newton Group's Service Observation Programme. Some of the data presented here have been taken using ALFOSC, which is owned by the Instituto de Astrofísica de Andalucía (IAA-CSIC) an operated at the Nordic Optical Telescope under agreement between the IAA-CSIC and the NBIfAFG of the Astronomical Observatory of Copenhagen. We thank E. Pérez Jiménez for fruitful discussions. JMCC and JG acknowledge a FPI doctoral fellowship from Spain's Ministerio de Ciencia y Tecnología and a Marie Curie Research Grant from the European Commission respectively. JMCC is grateful for the hospitality extended by the Danish Space Research Institute (DSRI), the Insituto de Astrofísica de Andalucía (IAA-CSIC) and the Astronomical Observatory of the University of Copenhagen, where part of this work was carried out. This research has been partially supported by Spain's Ministerio de Ciencia y Tecnología under programme AYA2002-082 (which includes FEDER funds). This work was supported by the Danish Natural Science Research Council. This research has made use of NASA's Astrophysics Data System. The work of the SAO team was supported by the Russian Astronomy Foundation and RFBR grant N01-02-17 106a. KAP acknowledges partial support by RFBR grants 00-02-17 164 and 99-02-16 205. UL acknowleges partial support from Spain's Ministerio de Ciencia y Tecnología under grant AYA 2 002-03 338, and from the Junta de Andalucía.

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