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Multiwavelength chase of GRB 031220 afterglow(*)

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Summary. — Several gamma ray bursts (GRBs) with X-ray afterglow do not show any optical-IR afterglow. The nature of this class of events, the so-called *Dark Bursts*, is still not clear. The optical absorption could be due to the interstellar dust or to the high redshift of the event. Or, more simply, the non-detection of the optical transient should be due to the delay in the observation or to the rapid energy decaying of these events. High spatial resolution X-ray observations are the most promising tool to investigate on such kind of events. We have collected and analyzed X-ray data and images taken in different spectral bands (optical and infrared) for GRB 031220 and we present the results of the analysis of multiband observations on the field of this burst. Comparison between images taken at different epochs in the same filters did not reveal any strongly variable sources. Photometric analysis and photometric redshift estimation of all possible afterglow candidates suggest that this GRB can be classified as a *Dark Burst*.

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PACS 95.85.-e – Astronomical observations.
PACS 95.75.Mn – Image processing.
PACS 01.30.Cc – Conference proceedings.

1. – Introdution

The lack of optical afterglow for a large fraction (about 50%) of well localized X-ray afterglows and, sometimes, together with the detection of radio afterglow, leads to the

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definition of the phenomenological class of the so-called *Dark Bursts*. The nature of this class of events, bursts with no apparent optical afterglow, is still not clear but recent works have suggested some possible scenarios. In the *obscuration scenario* the failed detection of the optical afterglow is ascribed to the extinction by the dust of the host galaxy. Instead, in the *high-redshift* scenario, the afterglow emission is damped by the Lyman absorption redshifted to the optical-infrared bands. However, this kind of bursts could have an intrinsically fainter optical afterglow compared to the afterglow of other GRBs at all wavelengths [3] and this could happen if the afterglow decelerated in a low-density medium [12]. Obviously, also a combination of these effects can determine the *dark* nature of these events. However, for the few *Dark Bursts* of which the distance has been determined, the contribution of high redshift effects to the optical darkness of this events is very little or negligible and they are probably the result of dust extinction in the circum burst medium [5].

2. – Data analysis

2˙1. *X-ray data.* – X-ray observations of GRB 031220 were carried out with the Chandra space observatory 5.62 [4] and 28.47 [8] days after the burst, using the ACIS_I detectors. The exposure times were 40 and 20 kiloseconds respectively. In the Chandra field seven bright X-ray sources have been detected within the HETE2 error box. Source coordinates, official name and numerotation used in this work are reported in [4] and [8], togheter with coordinates and count rate for five fainter sources that were not detected in the second Chandra observation. A refined analysis of the X-ray data after the second Chandra observation excluded one of brighter sources (CXO source # 37) as a possible variable source in the field [8].

The X-ray analysis has shown that all candidates are compatible with a power law with photon index ~ 2–3. The data from the two Chandra observations have been used to extract also light curves in the 2.0–10.0 keV, using each observation as a single bin in the light curve, adding also the value of the prompt emission (Atteia, private comunication). Of the seven sources detected in the first Chandra observation only 2 of them show a flux decrease by more than a factor of 2 (at a 2 σ level of significance). In particular source # 1 is not detected and source # 7 is marginally detected and the flux variation factor is $>$ 2.6 and 2.3, respectively [8]. The decay index for the light curves of these two afterglow candidates are 1.3 ± 0.1 and $0.7^{+0.1}_{-0.5}$, respectively. We decided to promote source # 1 as the best candidate from its X-ray decay that is usual for observed afterglows.

2˙2. *Optical data and image photometry.* – Optical and infrared observations of GRB 031220 field have been performed in different epochs (from December 2003 to March 2004), in different spectral bands (UBVRIJHK'), with different telescopes and instrumentation (Subaru, TNG, CalarAlto3.5m and CalarAlto2.2m). As reported in table I the first follow-up observation analyzed started about 8 hours after the burst. First of all, we have investigated the field of GRB 031220 in order to check the possible presence of new variable sources, namely a possible optical afterglow without X-ray emission. We make comparison between Subaru observation and R band observation from TNG or CA2.2m I band observation.

Once checked the lack of any new variable object in the field, the photometric analysis of the six brighter Chandra sources within the HETE2 error box has been performed. The magnitudes reported in table I for the two best afterglow candidates (CXO sources # 1 and # 7) have been estimated making differential aperture photometry with the PHOT

TABLE I. – *Observation log for GRB 031220. Observing dates are listed chronologically starting from December 2003 to March 2004 and are referred to the beginning of the exposures. In this table we report only the magnitudes for our two best afterglow candidates, CXO sources # 1 and # 7.*

Date (UT)	ΔT (days)	Filt.	Exp (s)	Telescope + Instrument	Source # 1	Source # 7	A_λ
Dec 20.47	0.32	I	5×600	Subaru + FOCAS	23.00 ± 0.26	21.83 ± 0.26	0.29
Dec 28.03	7.89	R	3600	TNG + DOLORES	23.61 ± 0.11	23.09 ± 0.11	0.38
Dec 30.96	10.81	K'	3600	TNG + NICS	18.57 ± 0.14	17.75 ± 0.10	0.08
Jan 04.86	15.72	H	4980	CA3.5m + ΩPrime	19.55 ± 0.14	19.87 ± 0.14	0.08
Jan 05.87	16.73	J	4500	CA3.5m + ΩPrime	20.52 ± 0.09	19.59 ± 0.05	0.13
Mar 20.80	91.66	B	3600	CA2.2m + BUSCA	23.77 ± 0.36	—	0.63
Mar 20.80	91.66	U	3600	CA2.2m + BUSCA	—	23.33 ± 0.17	0.72

routine of IRAF([1]). In particular, the magnitudes of a set of selected and not saturated stars have been estimated, compared with known catalog values for these stars and finally used to evaluate the magnitudes of all the candidates. All the magnitudes listed in table I have been corrected in each filter for the corresponding galactic extinction, A_λ, reported in the same table ($E(B-V) = 0.146$, [13]).

3. – Redshift estimation

For all the Chandra sources analyzed, photometric redshifts have been estimated by adopting a χ^2 minimization technique of the observed spectral energy distribution on a spectral library drawn from the Rocca-Volmerange synthesis models [10] as described by [7]. This method, taking into account the star formation history of each galaxy type, the reddening produced by internal dust and Lyman absorption produced by intergalactic dust, allows us to investigate the spectral evolution of galaxies at high redshift. This is a widely used and well tested tecnique for redshift determination [6, 11].

Follow-up observations started 8 hours after the burst did not reveal variable sources then we can assume that magnitudes reported in table I for our afterglow candidates must to be ascribed to the host galaxy of GRB 031220. In order to apply this method for photometric redshift search, we convert the estimated magnitudes in the Vega system into AB magnitudes. In fig . 1 we show the results of this analysis for our best afterglow candidate (CXO source # 1) for which we estimated a redshift $Z_{\rm phot}$ of 1.90 ± 0.30.

4. – Results and conclusion

We have performed a multiwavelength analysis of all the afterglow candidates of GRB 031220 inside the HETE error box. A deep inspection of optical-infrared images taken at different epochs did not reveal any new variable sources without X-ray emission. On the basis of X-ray data the most likely afterglow candidate for this burst is Chandra source

([1]) IRAF is the Image Reduction and Analysis Facility distributed by the National Optical Astronomy Bservatories (NOAO), which are operated by AURA Inc., under cooperative agreement with US National Science Foundation.

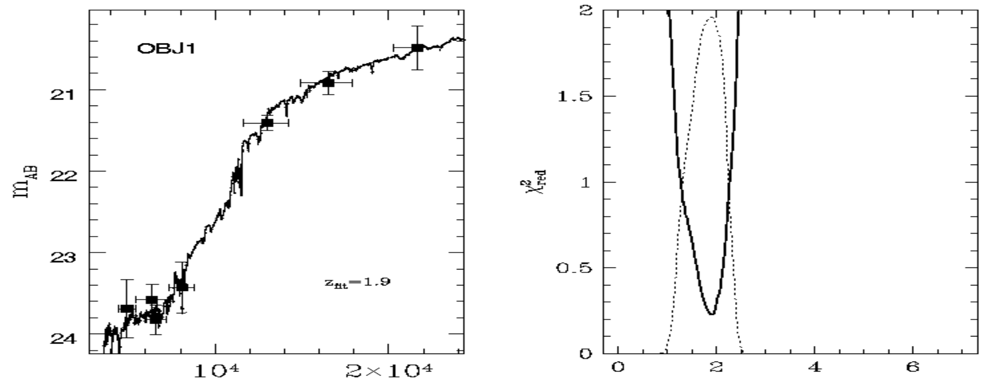

Fig. 1. – Magnitudes best fit *versus* wavelength (left) and $\chi^2_{\rm red}$ distribution *versus* redshift (right) for our best afterglow candidate (CXO source # 1). Filled squares represent the observed spectral energy distribution (horizontal bars show the amplitude of the filter while vertical bars indicate the errors in magnitude). Solid lines are the best-fit model that minimizes the $\chi^2_{\rm red}$.

1 that have a $Z_{\rm phot}$ estimated of 1.90 ± 0.30. This value of $Z_{\rm phot}$ for source # 1 is compatible with the value of 2.3 ± 0.5 found using the Boer & Gendre relationship [2] and also with the pseudo redshift of ~ 1.95 estimated from the prompt emission [1]. However, the other potential candidate, source # 7 got a flat decay ($0.7^{+0.1}_{-0.5}$) which is not common for the typically observed afterglows and it is not consistent with the decay inferred from the optical variation (0.21 ± 0.05, [9]). If Chandra source # 1 is the host galaxy of GRB 031220 it is evident that the optical-infrared flux extinction observed could not be ascribed to high redshift, because at $Z_{\rm phot} \sim 1.9$ the Lyman break is at ~ 2650 Å. On the basis of our multiwalength analysis we can conclude that this burst belongs to the class of *Dark Bursts* and its *darkness* is the result of dust extinction in the circum burst medium or inside the host galaxy. For a more detailed description of our multiwavelength analysis refer to Melandri *et al.* (2005, submitted to A&A).

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