# GRB 030913: HUNTING THE AFTERGLOW

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## ABSTRACT

Here we present the results of BOOTES-2 automatic response to GRB030913 and the further follow up observation at the 4.2m WHT where an optical candidate was initially reported. We evaluate the reality of the relation of this candidate with the GRB using all the available observations taken thereafter.

Key words: Gamma-Ray Burst; Wide Field Imaging; Galaxies.

## 1. INTRODUCTION

On 13 September 2003, at 17:06:57.52 UT, the HETE-2 FREGATE, WXM and SXC instruments detected a long duration (~10s) Gamma-Ray Burst (GRB). The position was reported as a GCN Position Notice (Suzuki et al., 2003) 37 seconds later. Due to some anomalous behaviour of the spacecraft during the burst, the notice was retracted the same day, at 21:18 UT. At that time several robotic observatories were already in operation.

After a more detailed ground analysis, 2.3 days later, the trigger was confirmed and the hunt for the afterglow resumed. Images of the first day where reanalysed without success, and a deeper image was obtained with the 4.2m William Herschel Telescope (WHT) at La Palma (Spain) as a last chance of localizing the optical counterpart of the burst. On this deep image a previously undetected source appeared and was postulated as the possible afterglow (Guziy et. al 2003).

## 2. OBSERVATIONS

BOOTES-2 is a robotic observatory located in the south of Spain (Castro-Tirado et al. 2004). It is provided with several "wide field cameras" (16ºx11º field of view) and a "narrow field camera" (30'x30' through a 30cm telescope). As soon as observations became possible from the observing location, 122 minutes after the burst, BOOTES-2 automatically pointed its cameras towards the field specified by the alert. In Fig. 1 we can see the first images obtained at the observatory, with both the wide and the narrow field cameras. With these images, BOOTES-2 established an unfiltered limiting magnitude of 17.5 on 70% of the refined error box and a limiting magnitude of 12 on 100% (de Ugarte Postigo et al. 2003). Other observatories imposed additional limits, being the strongest one R>19.5 210 minutes after the burst (Henden et al. 2003). After the retraction of the alert, and the non detection of a possible counterpart, no further observations where undertaken.

On September 16.01 UT (2.29 days after the burst) the trigger is confirmed by Suzuki et al. (2003) ensuring that the initial alert was, in fact, real. Work was then resumed and further observations were scheduled for the following night. Two hours later, Donaghy et. al (2003) provided a refined position reducing the error box down to 12' in radius.

*Proc. 5th INTEGRAL Science Workshop, 16-20 February 2004, Munich, Germany (ESA SP-552)*

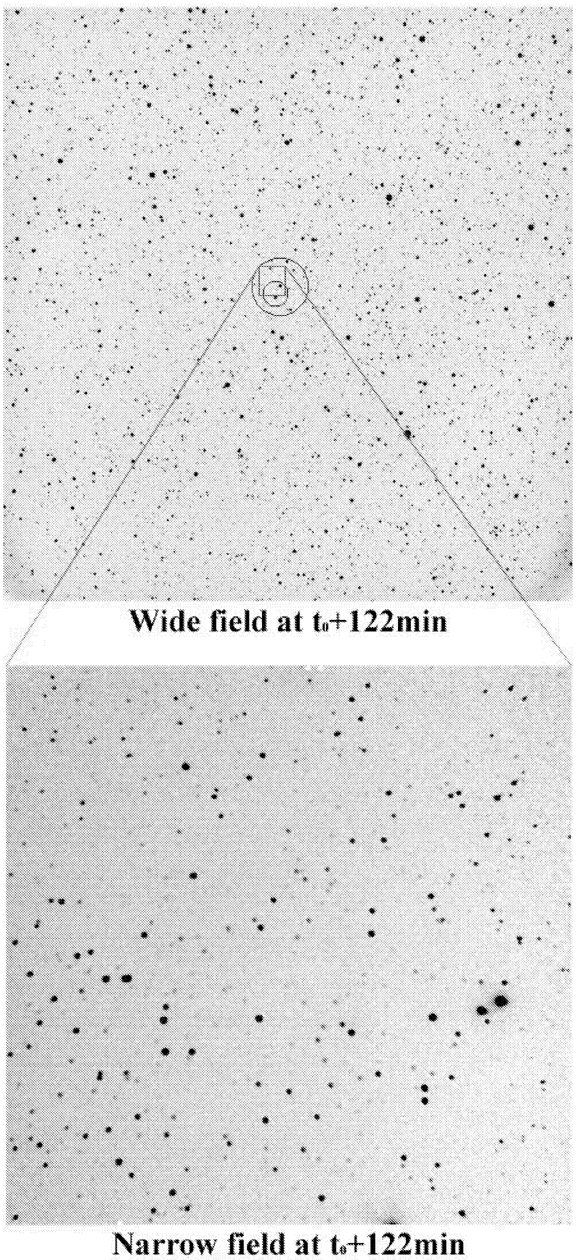


Fig. 1. First observations obtained with BOOTES-2. North is at the top and East at the left. Field is 9.5°x9.5° in the upper image and 36'x36' in the lower image. The two blue circles indicate the initial location provided by HETE-2 alert (large) and the later refined position (small).

As a result of the trigger confirmation, deep observations are requested at the 4.2m William Herschel telescope at La Palma. With four exposures obtained on September 18.04 UT we cover most of the error box. In one of the images, we detected a well sampled point-like source (see figure 2) at V=20.9±0.1 that was not present in the Digital Sky Survey. This optical candidate was reported in GCN 2391 (Guziy et al. 2003). Coordinates yielded R.A.(J2000): $20^h58^m46.5^s$ and Dec.(J2000): -02°20'59" with an uncertainty of 2".

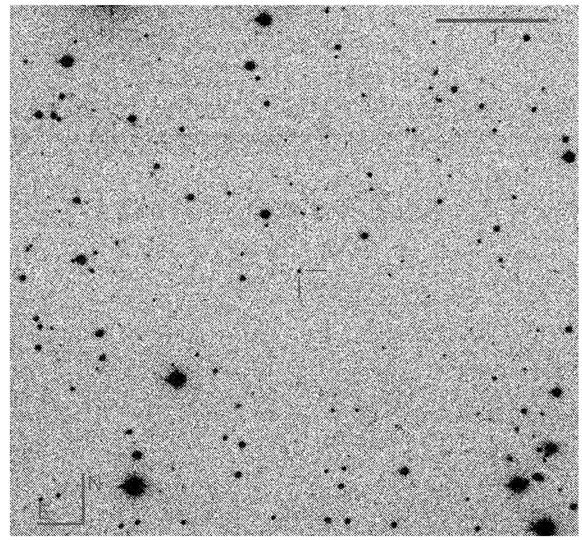

Fig. 2. V-band image of the optical candidate obtained with the 4.2m WHT

In order to confirm the reality of the new object detected from the 4.2m WHT images, a V-band image was requested with the 1.5m telescope of the Observatorio de Sierra Nevada (OSN), in Granada (Spain). The image, obtained on September 19.87 UT, revealed a very faint object at the same optical candidate position. The dimming of the object or the detection of an underlying galaxy would be the expected behaviour of a GRB event. However, if this was the afterglow of the GRB, it would have dimmed unexpectedly fast, with $\alpha \sim 5$ if $F \propto t^{-\alpha}$, while other observed bursts have values of $\alpha \sim 1$. Additional short exposures of standard stars where obtained with the same telescope in order to calibrate the field of our object in other bands.

On that same night, images on B and R bands where carried out at 4.2m WHT in order to explain the nature of the object we where observing. To complete the photometric curve and provide more colour information, V and I band exposures where performed at the 3.5m NTT (New Technology Telescope) in La Silla (Chile) on the context of a GRACE Target of Opportunity observations (ToO). This new set of images showed the object at the limit of detection, with a magnitude consistent with the one measured previously from OSN. This was suggestive of an underlying galaxy.

On the basis of observations taken at the 8.2m Subaru telescope at Mauna Kea at September 22.40 UT, Kosugi et al. (2003) announced the detection of a galaxy at the optical candidate location and a point-like source 1.5" north of it. The position of the point-like source was inconsistent with the astrometrical position derived for the object.

On the nights of 22-23 of September, deeper images obtained at the 6.0m BTA (Bolshoi Azimuthal Telescope) telescope of the SAO (Special Astrophysical Observatory) in Mt. Pastukhova (Russia) allowed a more accurate determination of the R, V and B magnitudes of the underlying galaxy (see Fig. 3 and table 1) in order to construct the Spectral Energy Distribution (SED).

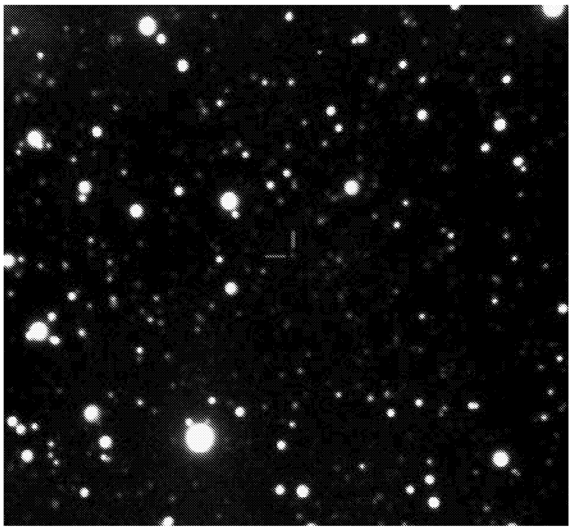

Fig. 3. BVR-bands colour composite obtained with the 6.0m SAO.

A final deep image was obtained 12 days after the burst (25th September) with the 3.5m NTT and the same band (V) as the one used in the initial optical candidate detection. This photometric point confirmed a constant magnitude, i.e. an underlying galaxy.

Using the standard stars imaged with the 1.5m OSN telescope, a calibration of the field was performed in B, V, R and I bands. We selected 8 stars of different colours and brightness that were used for obtaining the photometry of the object. Table 1 displays the list of observations performed by our team.

Table 1. Observing log

| Date (Sep 2003 UT) | Filter | Magnitude | Telescope |
|---|---|---|---|
| 13.817 | Unfiltered | <17.5 | BOOTES-2 |
| 18.040 | V | 20.9±0.1 | 4.2m WHT |
| 19.875 | V | 23.6±0.5 | 1.5m OSN |
| 19.971 | B | 24.4±0.15 | 4.2m WHT |
| 19.929 | R | 23.0±0.15 | 4.2m WHT |
| 21.187 | V | 24.3±0.4 | 3.5m NTT |
| 21.187 | I | 22.4±0.3 | 3.5m NTT |
| 22.80 | R | 23.0±0.1 | 6.0m SAO |
| 23.750 | V | 23.6±0.1 | 6.0m SAO |
| 23.750 | B | 24.6±0.1 | 6.0m SAO |
| 25.000 | V | 23.9±0.1 | 3.5m NTT |

A study of the resulting data revealed that after the first detection only the underlying galaxy was detected at V~23.7 (Fig. 4).

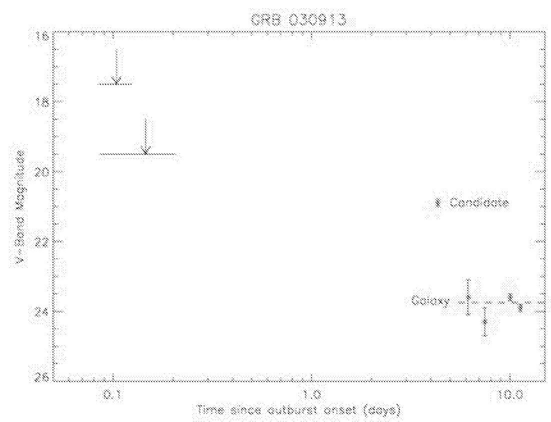


Fig. 4. V-band light-curve of the event. The two upper limits correspond to de Ugarte Postigo et al. (2003) and Henden et al. (2003).

## 3. RESULTS AND DISCUSSION

### 3.1 The underlying galaxy

Using the data available in different bands, we have estimated the photometric redshift of the underlying galaxy using Hyperz (Bolzonella, Miralles & Pelló 2000). After executing the program with all available synthetic galaxies we determine that the best fit is obtained with a z=0.4 synthetic SED that would correspond to an irregular galaxy, as shown in Fig. 5.

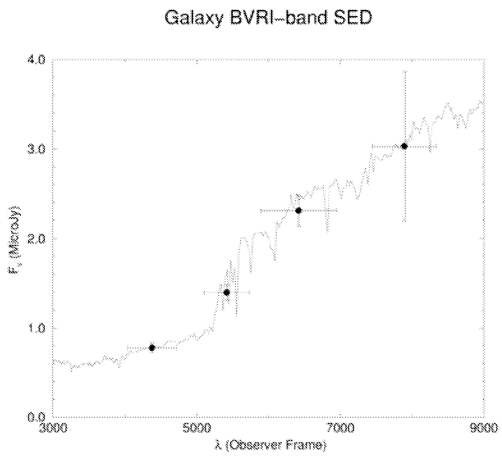


Fig. 5. Fit of the galaxy with a synthetic SED considering an irregular galaxy at z=0.4.

### 3.2 The optical candidate and its relation with the GRB

The decay between the optical candidate image and the next one would imply the fastest fading ever seen in a GRB afterglow. After considering all the available data and taking into consideration the unusual behaviour when compared with other GRB optical afterglows, the relation of the optical candidate with the GRB is under debate. The following arguments have been considered:

In favour of the afterglow relationship:

- Detection of a non catalogued transient object within the HETE-2 error box.
- The object has the expected magnitude for a bright GRB afterglow 4 days after the burst.
- A galaxy is found within 2" of the optical afterglow candidate.

Against the afterglow relationship:

- The disappearance of the object in such a short time (~2 days) implies a decay of $t^{-\alpha}$ with $\alpha \geq 5$, never seen before in a GRB afterglow. Taking into account the standard fireball model (Sari, Piran & Halpern 1999) after the light curve break (the steepest possible decay), an unrealistic value of p~5 would be derived, with $dN/d\Gamma \propto \Gamma^{-p}$ being the power law distribution of electrons with Γ the Lorentz factor.

With the doubts that arose from the afterglow hypothesis an additional explanation was considered. Given that the optical candidate appeared only in a single image with a short exposure time (120s), an alternative explanation is suggested considering a minor planet (MP) as the responsible.

A search in several databases[1] revealed that there was no known MP in the field at that time. However, we can make an estimate of the probability of this being a non catalogued MP, taking also into account the fact of the detection of an underlying galaxy, as has been observed in most GRBs once the optical afterglow has disappeared:

- The expected number of minor planets[2] in the HETE-2 error box with R<21 and moving at an apparent speed <1"/min would be ~1.
- The probability of finding an underlying galaxy, within 2”, and R<23 is ~0.01 (Koo & Kron 1992).
- This implies a non negligible probability of such a coincidence of ~1%.

## 4. CONCLUSION

The probability of the detected object being a MP is low but still significant to be taken into account. Therefore, we consider that a reasonable explanation for this event would have been a minor planet crossing the field, rather than a very unusual GRB afterglow.

This has implications for future searches in large error boxes in the sense that at least two images per field should be taken within the same night in order to rule out MPs crossing the field.

## 5. REFERENCES

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[1] MPChecker http://scully.harvard.edu/~cgi/CheckMP

[2] Main Belt Asteroids: *http://pan-starrs.ifa.hawaii.edu/ /project/people/magnier/rocks/*