BOOTES: A STEREOSCOPIC AND ROBOTIC GROUND-SUPPORT FACILITY FOR INTEGRAL

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ABSTRACT

Since 1998 BOOTES has provided follow ups for more than 60 GRBs; the most important results obtained so far are the detection of an OT in the GRB 000313 error box and the non detection of optical emission simultaneous for several GRBs (either long/soft or short/hard events). With the recent instrumental and technical developments, BOOTES multiplies its science capabilities.

Key words: Wide-field monitoring; gamma-ray bursts; Galactic Plane.

1. INTRODUCTION

BOOTES, the **B**urst **O**bserver and **O**ptical **T**ransient **E**xploring **S**ystem, is mostly a Spanish-Czech international collaboration that works to fill the space that there actually exists in the rapid variability Astronomy. It is specially aimed towards the detection and study of the optical transients that are generated in conjunction with the elusive GRBs (Gamma Ray Bursts). It saw first light in 1998 (Castro-Tirado et al. 1996). A pioneer robotic observatory for OT (Optical Transient) follow ups (Castro-Tirado et al. 1998), it is also part of the ground segment for INTEGRAL (see also Castro-Tirado et al. 1999, Hudec et al. 1999).

Its main scientific objectives include:

- Simultaneous and quasi simultaneous observations of GRB error boxes.
- Detection of optical flashes of cosmic origin: either related to new astrophysical phenomena (i.e. large-amplitude flare stars and large-amplitude AGN flares) or to GRBs undetected from their gamma ray emission (orphan afterglows/transients).
- Sky monitoring in the I, R[1] & V bands.
- Discovery and study of meteors, asteroids, comets, variable stars, novae, supernovae ...

Although it was first thought of as a tool to perform rapid searches of GRB (Gamma Ray Burst) optical counterparts, BOOTES has also participated in the study of meteor storms. Additionally, it has accumulated an enormous database of sky images (Fig. 1) to study objects which exhibit short lived variations.

2. SCIENTIFIC RESULTS

Since 1998 BOOTES has responded to more than 60 GRB triggers with different results (Castro-Tirado et al. 2000a,b, Castro Cerón et al. 2001a,b,c). The

[1]BOOTES's CCD cameras have their peak response in the red, thus the reference to R band/magnitude for the unfiltered ones, which should not be taken as a standard filter. See http://laeff.inta.es/BOOTES/ for additional information.

Figure 1. One typical wide-field image obtained by BOOTES: a 50° × 32° field around the Galactic Centre region.

majority of the follow ups have provided upper limits to the GRB optical emission despite the prompt response, thus ratifying the elusiveness of these phenomena. Here we present three of the most significant GRB error zones exploration results:

2.1. Long duration GRBs

2.1.1. Simultaneous observations

GRB 010220 is the first time that a long/soft GRB error box is imaged by a CCD camera prior to the beginning of the burst as well as during and after it. The first of the recorded images began 52 seconds before the gamma ray event registered on 20^{th} February 2001 and covered the first 8 seconds of it. The second one covered from 68 to 128 seconds after the trigger. No OT was detected in any of these images. This can be attributed to the high extinction (A_V = 3.3 magnitudes) in this direction, at only 1.38° from the galactic plane (Castro-Tirado et al. 2001).

Upper limits of R = 10 and 11.5 were derived for GRB 030115 (Castro-Tirado et al. 2003a) and GRB 030226 respectively. In the latter case, an optical afterglow was discovered few hours after the event and it was possible to constraint the reverse shock emission (Castro-Tirado et al. 2003b) .

2.1.2. The GRB 030329/SN2003dh

The SN2003dh connected to the GRB 030329 was detected $\sim$ 30 hr after the event at the BOOTES-1B station, with the optical afterglow brightening at V $\sim$ 16.4 (Fig. 2). This is the nearest "classical" GRB detected so far, at z = 0.1685.

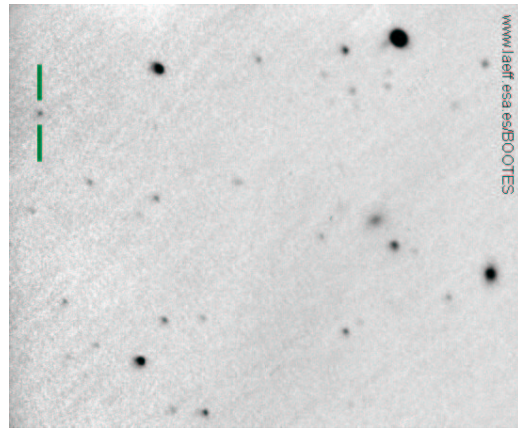

Figure 2. The GRB 030329/SN2003dh. Image taken with the 200 mm 1B-NFC on Mar 31.00 UT 2000 (1.5 days after the GRB), 1000 s R filter exposure. Limiting magnitude I $\sim$ 18. The frame reveals the very bright optical afterglow with R = 16.4 magnitude.

2.2. Short duration GRBs

2.2.1. Simultaneous observations

Excluding GRB 020531 (imaged under poor meteoroogical conditions, Castro-Tirado et al. 2002a), GRB 021201 was the first case for which a short/hard GRB error box was imaged by a CCD camera prior to the beginning of the burst as well as during and after it. The limiting magnitude was R = 10 (Castro-Tirado et al. 2002b).

2.2.2. GRB 000313: an OT in the follow up images

Besides a follow-up observation to the short/hard burst GRB 000607 (Masetti et al. 2002, Hurley et al. 2002), on 13^{th} March 2000 BOOTES responded to a GCN alert (Castro-Tirado et al. 2000c) and started exposing at the coordinates given, 4 minutes after the GRB was detected by the BATSE (Burst and Transient Source Experiment). The image was 5 minutes long with an *I* filtre, going down to 13^{th} magnitude.

A 9^{th} magnitude source, not present in the Digital Sky Survey, was found in the said image (Fig. 3). After the first one and, because of the big error box given by BATSE, BOOTES started a mosaic around this field, so no other image was taken at the original position until 55 minutes had elapsed since the trigger (Fig. 4). By then further imaging revealed that the source had faded away. The results are discussed in Castro-Tirado et al. (2002c).

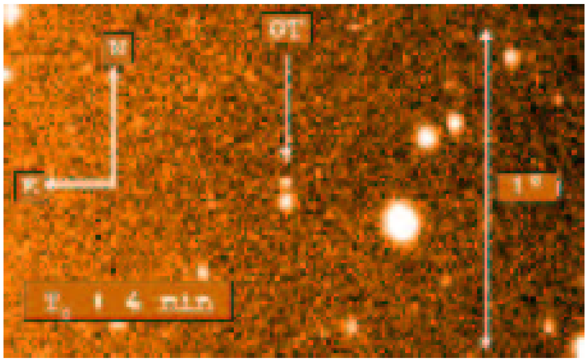

Figure 3. OT in the field of the GRB 000313. Image taken with the 50 mm 1A-WFC on Mar 13.88 UT 2000 (4 min after the GRB), 5 min I filter exposure. Limiting magnitude I ∼ 13. The frame reveals a bright new point like source of I = 9.4 magnitude.

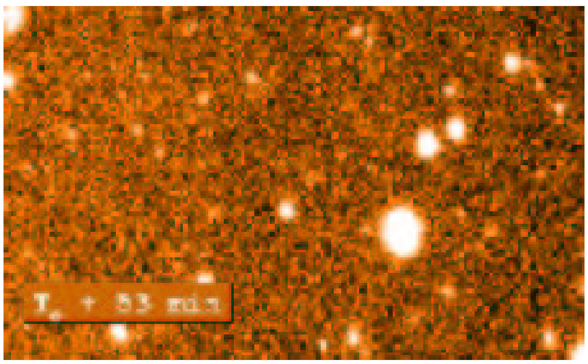

Figure 4. OT in the field of the GRB 000313. Image taken with the 50 mm 1A-WFC on Mar 13.923 UT 2000 (53 min after the GRB), 5 min I filter exposure. Limiting magnitude I ∼ 13. The optical transient is no longer detected. From Castro-Tirado et al. (2002c).

2.3. Additional science

BOOTES collaborates with the "Sociedad de Observadores de Meteoros y Cometas de España" in the study of meteor showers, including double station observations and evolution of meteor trails in the upper atmosphere. For instance, see Trigo-Rodríguez et al. (2001, 2003) for a description of the double station observational set up and the results obtained so far, like a extraordinarily bright fireball imaged on 27 Jan 2003.

3. RECENT INSTRUMENTATION

BOOTES-1, the main BOOTES observatory, is located in Mazagón (Huelva), a very dark sky area in southern Spain, and is hosted by the INTA (Instituto Nacional de Técnica Aeroespacial) in its "Centro de Experimentación del Arenosillo". It has two domes (BOOTES-1A and BOOTES-1B) that shelter two Schmidt-Cassegrain telescopes and several wide field cameras. Following complementing schemes, all instruments carry out systematic explorations of the sky each night (Páta et al. 2001, Castro Cerón et al. 2003, de Ugarte et al. 2003) (Fig. 4) responding to GRB alerts at any time (Berná et al. 2003).

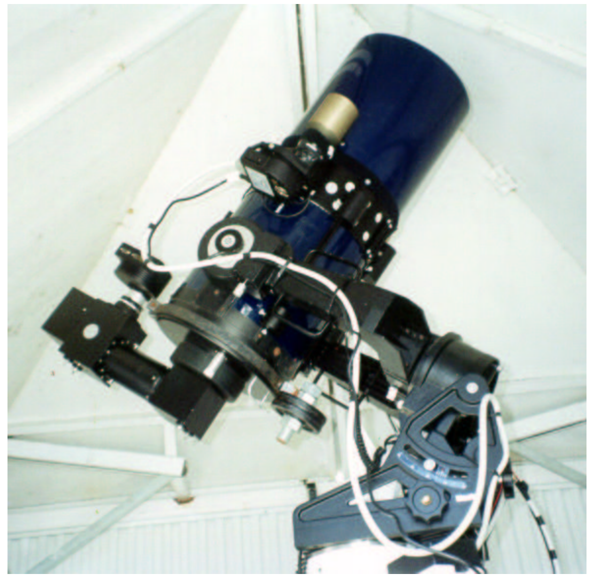

Figure 5. BOOTES-1B with the two wide-field cameras atop the telescope and the wide-field spectrograph at the Cassegrain focus.

A second observatory (BOOTES-2) is in operation since 2002 at a site 240 km East of BOOTES-1, at Málaga's "La Mayora", an experimentation centre property of the CSIC (Consejo Superior de Investigaciones Científicas), in order to observe simultaneously the same field of the sky from both locations BOOTES has a stereoscopic view. Thus, using parallax, it can discriminate against near Earth detected sources up to a distance of 10^6 km.

Amongst the recent instrumentation developed for BOOTES, we want to strengh a wide-field low-resolution spectrograph with a field of view of 30 arcmin, with a resolution of 50 Å in the red part of the spectrum, and 10 Å in the blue part. The limiting magnitude is R = 13 (Fig. 5). Additional details can be seen in de Ugarte Postigo et al. (2004).

4. TECHNICAL DEVELOPMENTS

One of the technical aspects that has been developed in BOOTES is a remote information and control system that, using GSM mobile communication tools, allows for full remote control of the observatories without needing any additional staff (Mateo Sanguino et al. 2003, 2004).

Before this, BOOTES already had a meteorogical station which was capable of deciding if the weather conditions were optimal for astronomical observations or not. This station controlled the aperture of the domes. The new remote information and control system adds the following functions:

1. On demand reports of the observatories's status, covering the position of the domes and complete meteorological information.
2. Alerts of system malfunctions such as problems while opening or closing the domes, adverse weather conditions or system breakdown due to power failures, etc.
3. Manual interaction with the system to open or close the domes at any moment.

In order to achieve these capabilities, a communication protocol between a personal computer and a GSM modem via RS 232 has been developed. It is based on the SMS (Short Message Service) standard (version 03.40) and programmed in the LabView environment.

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