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BOOTES-IR: Near IR follow-up GRB observations by a robotic system(*)

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Summary. — "BOOTES-IR" is the extension of the BOOTES experiment, which operates in Southern Spain since 1998, to the near IR (NIR). The goal is to follow up the early stage of the gamma ray burst (GRB) afterglow emission in the NIR, alike BOOTES does already at optical wavelengths. The scientific case that drives the BOOTES-IR performance is the study of GRBs with the support of spacecraft like *INTEGRAL*, *SWIFT* and *GLAST*. Given that the afterglow emission in both, the NIR and the optical, in the instances immediately following a GRB, is extremely bright (reached $V = 8.9$ in one case), it should be possible to detect this prompt emission at NIR wavelengths too. The combined observations by BOOTES-IR and BOOTES-1 and BOOTES-2 will allow for real time identification of trustworthy candidates to have a high redshift ($z > 5$). It is expected that, few minutes after a GRB, the IR magnitudes be H $\sim$ 7–10, hence very high quality spectra can be obtained for objects as far as $z = 10$ by larger instruments.

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1. – Introduction

BOOTES-IR, the *B*urst *O*bserver and *O*ptical *T*ransient *E*xploring *S*ystem in the *N*ear *I*nfrared(1) is the extension of the BOOTES project towards IR wavelengths thanks to a NIR camera developed in the context of Spain's Programa Nacional de Astronomía y Astrofísica AyA 2.002-0.802, in order to be placed in 2005 at the 60 cm telescope at the Observatorio de Sierra Nevada, under a controlled dome, also developed in the context of the Project. Sierra Nevada is an excellent site for NIR observing thanks to the height (2900 m above sea level) and the low H_20 (vapour) content.

The robotic operation of all subsystems will allow to achieve multifold scientific objectives that cannot be achieved with a more conventional instrumentation.

2. – Scientific objectives

Similarly to BOOTES in the optical range [1], the main BOOTES-IR scientific goal is the GRB follow-up observations of events detected with high-energy satellites like *INTEGRAL*, *SWIFT* and *GLAST*. All together they should provide around 100 detections/y, but none of these missions carry instrumentation devoted to the NIR, that could complete the observations at longer wavelengths. Following the detection of a bright, prompt optical flash for GRB 990123 with $M_V = -36$ [2], such events are also expected to occur at NIR wavelenghts. Although now it is widely accepted that the long-duration GRB are related to massive star deaths, about 50% of the events are not detected in the optical, and this latter population of dark GRB should contribute significantly to the hidden star formation rate in the Universe [3]. Thus, the BOOTES-IR scientific goal is doublefold: the study of dark GRBs and the "hunt" for high-z events.

2˙1. *Dark GRB*. – About 50% of events are not detected in the optical in spite of deep observations being performed minutes/hours after the event. This can be partly explained if the GRB do occur in a high-density region in the host galaxy which will extinct the optical emission. Thus, even with no optical afterglow being observed, a bright NIR transient might be recorded by BOOTES-IR and, together with the BOOTES observations (in optical) might allow to determine the intrinsic extinction (as was done in GRB 980703 [4]). In fact, it is expected that most of the dust will be sublimated by the prompt UV/optical emission, *i.e.* it is foreseen that the NIR flash should be observed prior to the optical one, allowing to determine an upper limit to the amount of dust in the surroundings of the GRB progenitor.

2˙2. *High-z GRB*. – There will be a small fraction of events not detected in the optical due to a high redshift (with $z > 6.5$), *i.e.* with the Lyα break in the I band (0.9 μm)

(1) See http://www.iaa.csic.es/BOOTES-IR.html

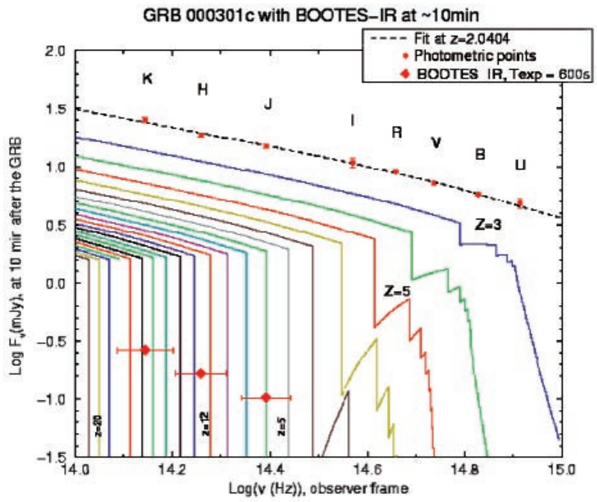

Fig. 1. – The GRB 000301c afterglow extrapolated at various redshifts, in case that it would have been observed 10 min after the event.

at that particular redshift. As BOOTES-IR will cover a redshift range $7 \leq z \leq 15$ (see fig. 1), part of these high-z population should be unveiled if prompt observations are conducted soon after the events. As it has been already pointed out, GRB are a powerful tool for the study of the high-z Universe. The importance of prompt observations is based on the fact that the photons arrival time should be divided by a $(1 + z)$ factor. That is, that the elapsed time since the onset of the event has to be accounted for in the framework of the source. Thus, a GRB at $z = 4$ being observed 10 min after the event means that is being detected $10/(1 + z) = 2$ min after the explosion, when the source is extremely bright. Thus, we can say that z might be an advantage, with a favourable K correction (see [5] for more details).

A combination of the BOOTES (optical) and BOOTES-IR (NIR) datasets will allow to distinguish a high z event. The identification of candidates in a color-color diagrame [6] will allow to discern the most interesting candidates allowing larger size instruments to point to the GRB afterglow while still is bright enough to ease spectroscopic observations. This will allow to study the distribution of Lyα clouds in the intergalactic medium as function of z, the metelicity, the interstellar medium in the host galaxy and the intergalactic medium reionization, expected in the $7 \leq z \leq 15$ range.

2·3. *Additional science*. – A significant fraction of observing time will be available for other scientific projects of interest, objects relatively bright and variable, like Solar System objects, variable stars, compact objects in binary systems and blazars.

3. – Hardware

3·1. *The telescope*. – The 0.6 m f/8 Richtey-Chretien telescope has been installed in Dec 2004. The sleewing speed is 20°/s with an acceleration of 2°/s^2 so it can reach any point of the sky in 10 s.

3·2. *The IR camera*. – The IR camera in the context of the BOOTES-IR project is based on a 1024 × 1024 HgCdTe detector (0.9–2.5 μm range) in a dewar cooled down

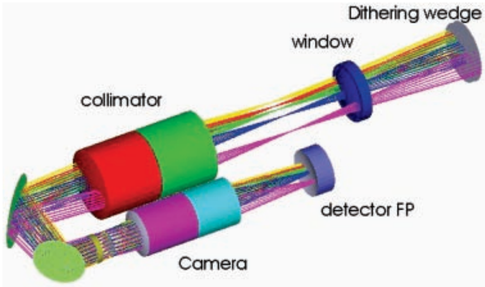

Fig. 2. – The BOOTES-IR camera optical train.

by a liquid N cooling system (fig. 2). The filter set contains three broad-band filters (JHK$_s$) and a JH grism (for low-resolution spectroscopy) plus 3 narrow band filters. The BOOTES-IR camera will be placed at the Nasmyth focal station of the 60 cm telescope. It has a high-transmission optics and it is equipped with a high readout speed controller. The field of view is $12'.7 \times 12'.7$ with a scale of $0.74''$/pix. Expected limiting magnitudes (300 s exposure time, $3\,\sigma$ detection level) are: 17.5 (J), 16.5 (H), 15.5 (K).

4. – Software

4·1. *The control system.* – The BOOTES-IR control system is based on RTS2 [7] which interacts with PILAR (the telescope software) and the telesurveillance module [8].

4·2. *The anaylisis software.* – The pipeline is based on JIBARO [9] and provides stacked images, background substracted, flat fielded in WCS format.

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REFERENCES

[1] Castro-Tirado A. J. *et al.*, *Simultaneous and optical follow-up GRB observations by BOOTES*, these proceedings.
[2] Akerlof C. *et al.*, *Nat*, **398** (1999) 400.
[3] Totani T., *ApJ*, **511** (1999) 41.
[4] Castro-Tirado A. J. *et al.*, *ApJ*, **511** (1999) L85.
[5] Lamb F. A. and Reichart D. A., *ApJ*, **536** (2000) L1.
[6] Gorosabel J. *et al.*, *A&A*, **384** (2002) 11.
[7] Kubánek P., Jélinek M., Nekola M. *et al.*, *RTS2: Remote Telescope System*, 2nd version, in *Gamma-ray bursts: 30 years of discovery*, edited by Fenimore E. E. and Galassi M. (American Institute of Physics, New York), *AIP Conf. Proc.*, **727** (2004) 753.
[8] Díaz-Verdejo J., García Teodoro P., López Soler J. and Martínez Pérez J. R., *El software de control del telescopio IR de 60 cm de Sierra Nevada*, in *Astrofísica Robótica en España*, edited by Castro-Tirado A. J., Morena B. A. and Torres J. (Equipo Sirius, Madrid) 2005, p. 201.
[9] de Ugarte Postigo A. *et al.*, *JIBARO: Un conjunto de utilidades para la reducción y análisis automatizado de imágenes*, in *Astrofísica Robótica en España*, edited by Castro-Tirado A. J., Morena B. A. and Torres J. (Equipo Sirius, Madrid) 2005, p. 35.