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CHASING *FERMI*, *SWIFT*, AND *INTEGRAL* GRBS WITH THE T80 TELESCOPE OF JAVALAMBRE OBSERVATORY

J. Gorosabel,[1,2,3] W. Schoenell,[1] A. Fernández-Soto,[4,5] N. Benítez,[1] M. Moles,[6] A. J. Cenarro,[6] A. de Ugarte Postigo,[1] A. J. Castro-Tirado,[1] and C. Thöne[1]

RESUMEN

Presentamos el potencial que el telescopio T80 del observatorio de Javalambre atesora para el campo de los GRBs. Su rápida capacidad de apuntado unida al gran campo de visión de éste hacen del T80 una herramienta ideal para respuestas rápidas de GRBs. Hacemos hincapié en el uso del T80 para buscar contrapartidas ópticas en las gran zonas de error que proporciona *FERMI*. Una vez que se ha recibido una alerta, activaríamos ciclos de imagen *ugriz* con el fin de construir densas curva de luz en todo el rango óptico. El cartografiado JPAS, desarrollado también en el OAJ, nos brinda la posibilidad de utilizar imágenes pre-GRB tanto como patrones de subtracción como para estudiar las galaxias anfitrionas en 54 bandas estrechas. La sinergia del T80 con telescopios de gran apertura, como VLT o GTC donde disfrutamos de programas de oportunidad, puede ser realmente productiva.

ABSTRACT

We show the potential that the T80 telescope of the Javalambre observatory has for the GRB field. Its rapid pointing capabilities as well as its wide field of view makes the T80 an ideal tool for rapid GRB responses. We stress on using the T80 to search for optical counterparts in the the large error boxes provided by *FERMI*. Once an alert is received we would activate continuous cycles of *ugriz*-band images with the aim to construct dense lightcurves in the whole optical range. The JPAS survey, developed also at OAJ, opens the possibility of using pre-GRB host galaxy images, either as subtraction templates or to study the hosts in 54 narrow bands. The synergy of the T80 with large aperture telescopes, like VLT or GTC where we run spectroscopic target of opportunity programs, can be really productive.

Key Words: gamma-ray bursts — telescopes

1. INTRODUCTION

1.1. *The observatory of Javalambre*

The "Observatorio Astrofísico de Javalambre" (OAJ) is a new astronomical facility located at the Pico del Buitre, at the Sierra de Javalambre (Teruel), Spain. The observatory is placed 1957 m above the sea level, at 40°02′28.67″ North, 01°00′59.10″ West (Moles et al. 2011). The observatory shows excellent conditions for astronomical observations. The facilities are managed and operated by the Centro de Estudios de Física del Cosmos de Aragón (CEFCA[7]).

Site testing studies carried out during two years (2008-2009) yielded a median V-band seeing of 0.71″, with a mode of 0.58″ (Moles et al. 2010). In that run the fraction of totally (partially) clear nights was ∼53% (∼74%). The optical extinction (∼0.22 mag in the V-band) and sky brightness (moon-less night-sky surface brightness measurements were B=22.8 mag arcsec^{-2}, V=22.1 mag arcsec^{-2}, R=21.5 mag arcsec^{-2}, I=20.4 mag arcsec^{-2}), following the IAU[8] recommendations for a dark site.

The observatory is equipped by two main imaging facilities, the 2.55m (T250) and 0.82m (T80) telescopes. An additional set of small aperture telescopes are harboured in a dedicated building in order to monitor the extinction and seeing (see Fig. 1). OAJ is fully equipped with a wide equipment set, among others, a residence, a weather station, an alu-

[1]Instituto de Astrofísica de Andalucía (IAA-CSIC), Glorieta de la Astronomía s/n, E-18008, Granada, Spain.
[2]Unidad Asociada Grupo Ciencia Planetarias UPV/EHU-IAA/CSIC, Departamento de Física Aplicada I, E.T.S. Ingeniería, Universidad del País Vasco UPV/EHU, Alameda de Urquijo s/n, E-48013 Bilbao, Spain.
[3]Ikerbasque, Basque Foundation for Science, Alameda de Urquijo 36-5, E-48008 Bilbao, Spain.
[4]Instituto de Física de Cantabria, Avenida de los Castros s/n, 39005 Santander, Spain.
[5]Observatori Astronòmic, Universitat de València, C/ Catedrático José Beltrán 2, 46980 Paterna, Spain.
[6]Centro de Estudios de Física del Cosmos de Aragón, Plaza San Juan 1, 4400 Teruel, Spain.

[7]http://www.cefca.es
[8]http://www.iau.org

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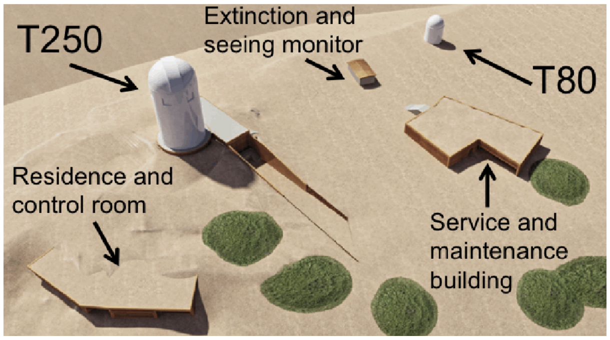

Fig. 1. Configuration of the OAJ. The different buildings are communicated by maintenance/evacuation tunnels not visible in the plot.

minizing plant and an emergency power generator support for possible electric grid failures. The OAJ is currently under construction, being the T80 partially operative.

The primary scientific project of the OAJ is to perform a multi-purpose 8000 deg^2 survey using the T250. The survey, named JPAS[9], will be based on 54 narrow-band filters, ranging from 3500Å to 10000Å, and 2 additional broad-band filters (still to be defined) mounted on the T250 (Benítez et al. 2014). The T250 assembly is close to be finished. The main T250 instrument will be an optical camera providing a field of view (FoV) of $\sim$ 7 square degrees ($\sim$ 3 degrees in diameter).

1.2. *The T80 telescope*

The T80 is based on a Ritchey-Chrétien f/4.5 optical configuration with an aperture of 82cm. The optical system hosts a field corrector which provides high optical quality and stability on a FoV of $\sim$ 2.3 square degrees ($\sim$ 1.7 degrees in diameter). The scale on the T80 focal plane is 55.67″/mm. The operation of the T80 will be totally autonomous, based on a telescope control system (TCS) developed at CEFCA. The T80 will be devoted mainly for calibration purposes of the survey, although secondary science would be carried out too. Fig. 2 shows two views of the T80.

The T80 will have permanently mounted a *ugriz*-band set of Sloan filters (Fukugita et al. 1996). In principle, the T80 GRB program would not use the JPAS narrow-band set. The T80 will be equipped with the T80Cam instrument on the Cassegrain focus based on a large format STA1600 CCD. This high-sensitivity CCD will contain 10560 × 10560 pixels of 9μm, enabling an almost entire coverage of the telescope FoV. The resultant T80Cam pixel scale on

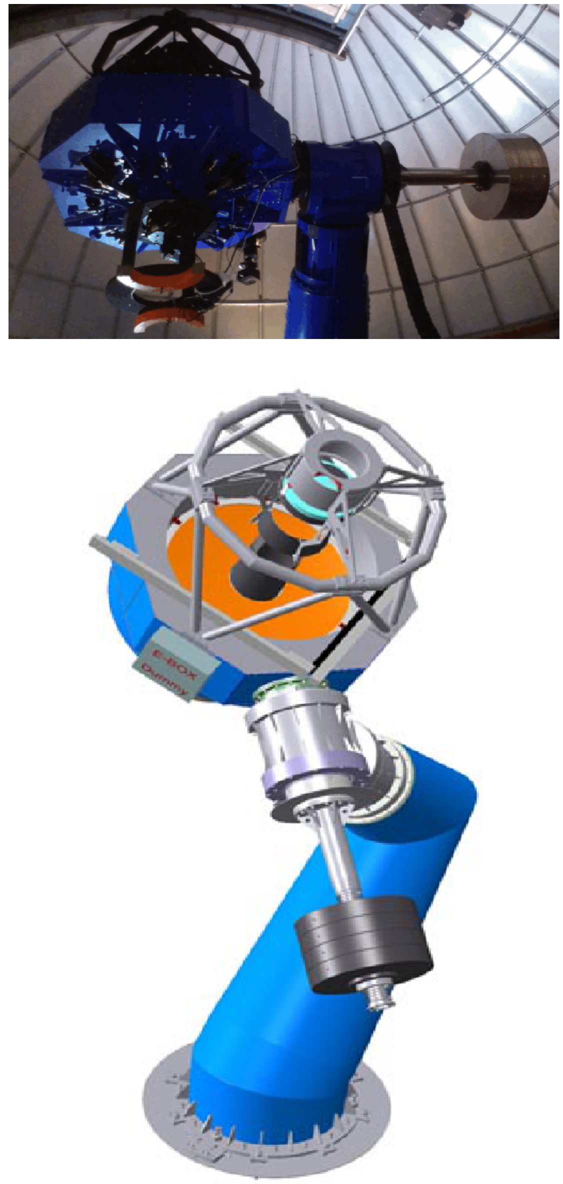

Fig. 2. *Upper panel:* T80 picture taken in Oct. 2013 inside the 6.2 diameter Ash-Dome dome. *Lower panel:* Plot of the T80 and its German mount. The total telescope mass is around ∼2500 kg, and can hold instrument weights up to ∼80 kg placed 25cm from the primary mirror flange. Plot adapted from `http://www.cefca.es`.

the focal plane will be 0.5″/pix. The readout will be carried out using 16 ports, allowing readout times of $\sim$ 20 s with a readout noise of ∼6 electrons. The sensitivity range of T80Cam would go from 3300 Å to 10000 Å, having a ∼95% sensitivity peak around 4500 Å. Currently the T80 is under testing phase using a commercial CCD camera. T80Cam is ex-

[9] `http://j-pas.org`

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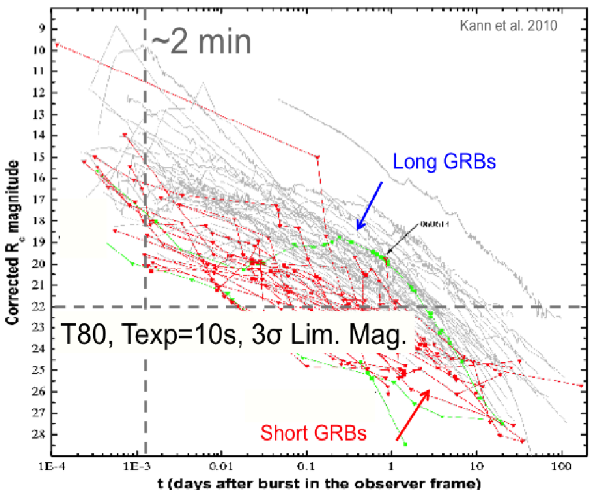

Fig. 3. The plot shows a collection of lightcurves of long and short GRBs detected by the *Swift* high-energy mission (Kann et al. 2011). The plot also displays the 3σ detection limit of the T80 for an exposure time of 10s, as calculated by the exposure time calculator. With a typical reaction time of ∼2 minutes the T80 will be sampling a diagram region which has been explored by very few telescopes so far, usually smaller than the T80, where the emission from the reverse-shock could be important.

pected to be fully operative for 2015. We note that the sensitivity of the STA1600 CCD at 10000Å its only a few percent, implying longer exposure times in the z-band with respect to the rest of Sloan filters.

2. FAST GRB REACTIONS WITH THE T80

The TCS, currently under development, will incorporate a GCN socket[10] so the T80 will be able to rapidly respond to Gamma-Ray Burst (GRB) alerts. The T80 slewing speed can be tuned, reaching a maximum speed of 20 deg per second. This reaction time is suitable for fast GRB reactions.

Fig. 3 displays the optical lightcurves for a large sample of long-duration (grey lines) and short-duration (in red) GRBs detected by *Swift* mission (Kann et al. 2011). According to the CEFCA exposure time calculator ETC[11] a 10s T80 exposure would reach a limiting magnitude of $R \sim 21$ (assuming grey-time and the average site-testing seeing of $0.7''$, Moles et al. 2010). The horizontal dashed line of Fig. 3 indicates this limiting magnitude. Assuming a very conservative reaction time of ∼2 minutes (dotted vertical line of Fig. 3), the T80 limiting magnitude would be sampling basically an almost unexplored region of the plot (shadowed). The early optical observations done so far seem to indicate that an essential physical component of this plot region is the short-lasting reverse shock which occurs during first stages of the GRB expansion into the interstellar medium/wind (Mészáros & Rees 1997).

It is worthwhile to point out that for GRBs longer than ∼ 60 seconds, even the earlier optical flash simultaneous to the gamma-ray emission could be also detected, as done in a handful of cases to date (Racusin et al. 2008). This would provide valuable physical information on the internal shocks colliding inside the GRB jet (Mészáros & Rees 1999).

Another scientific goal is to monitor the optical peak due to the GRB forward shock. That would allow us to determine the initial Lorentz Factor (Γ_0) of the burst (see for instance Molinari et al. 2007).

The error boxes provided by both *Swift* (Gehrels et al. 2004) and *INTEGRAL* (Winkler et al. 2003) are much more reduced than the T80Cam FoV. So even the promptest GRB positions (available during the first second post burst) which have uncertainties of a few arcmin, will be well within the T80Cam FoV.

The *FERMI* mission provides larger error box than *Swift* and *INTEGRAL*. This fact is specially relevant for those GRBs only detected by the Gamma-Ray Burst Monitor (GBM) instrument which provides error boxes with several degrees in diameter (Meegan et al. 2009). However those *FERMI* GRBs detected also by the Large Aperture Telescope (LAT, Atwood et al. 2009) instrument show smaller error boxes, with radii of $\sim 30'$, which can be easily covered by a T80 single exposure.

Swift detects ∼ 90 GRBs per year. We estimate, based on our experience with the 1.23m telescope of Calar Alto (Gorosabel et al. 2010), that ∼18 GRBs/year would be visible in real-time from OAJ. If we correct this observability rate from the OAJ weather correction (62.2% of nights with clouds less than 50%, Moles et al. 2010) we would detect in real-time ∼ 11 *Swift* GRBs per year. If we also consider the GRBs detected by *FERMI*(+LAT) and *INTEGRAL*, we expect ∼13 GRBs pear year.

FERMI afterglows detected to date seem closer, and hence brighter, than *INTEGRAL* and *Swift* GRBs (Gorosabel et al. 2004; Jakobsson et al. 2006). So, in a future, once the project is running, we might consider to go also for the *FERMI* GRBs detected only by the GBM. This would imply more GRBs per year, although it would require to mosaic the error boxes. A potential intersection with a later error box provided by the Interplanetary Network of satellites (IPN; Hurley et al. 2013) might reduce the position uncertainty, and hence make a faster

[10] http://gcn.gsfc.nasa.gov/sock_pkt_def_doc.html
[11] `http://www2.cefca.es/jplusetc/`

afterglow search. A possible help could come from including a selection criteria in the T80 trigger algorithm based on GRB fluence. Hence, we would only mosaic the brightest *FERMI*(+GBM) events, which would have *i*) the smallest error boxes and *ii*) the brightest optical afterglows on average.

Another interesting aspect would be to identify the host galaxy in images taken casually at the GRB position before the explosion. These host galaxy images would be part of the regular JPAS survey carried out with the T250. In those fortunate situations, we would have host galaxy data in 54 narrow band filters, so the whole artillery of the JPAS survey could be applied. Most importantly, those pre-GRB images could be used as subtraction templates, specially relevant in the *FERMI*(+GBM) large error boxes where the afterglow search could be difficult.

The observing strategy would be based on continuous cycles in *ugriz* (in this order) so we could build the lightcurves in all the optical range. In order to enhance the time resolution of the lightcurves, the CCD might be windowed depending on the GRB error box size. In addition, this strategy could potentially bracket the Lyman-α break up to redshift $z{\sim}6$. In such cases we would use the T80 to activate low-medium resolution spectroscopic target of opportunity (ToO) programs, specially those we run in large aperture telescopes like GTC or VLT.

3. CONCLUSIONS

We report on the opportunity of using the rapidly-slewing 0.8m T80 telescope of the OAJ to respond to GRB alerts, mostly coming from *Swift*. The superb seeing conditions and the large number of clear nights at the OAJ makes the project attractive and realistic. The sensitivity of the T80 and the response times would put our project in an excellent condition to study the still enigmatic optical flash and the reverse shock. Once an alert is received by a dedicated socket, we would construct dense *ugriz* lightcurves, and if possible, estimate the photometric redshift using the Lyman-α break. In addition to *Swift* GRBs, the large field of view of the T80 makes it a very competitive telescope to respond to GRB alerts sent by *FERMI*. Those *FERMI* GRBs localized by its LAT instrument would be top priority targets, due to their expected low redshift. Once the T80 reaction system is well tested, we could extend the program to those *FERMI* GRBs localized exclusively by the GBM instrument. The T80 will be essential to feed our spectroscopic and polarimetric ToOs at GTC and VLT.

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