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GAMMA–RAY BURST AFTERGLOWS WITH THE WATCHER ROBOTIC TELESCOPE

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RESUMEN

El objetivo científico principal del telescopio Watcher son las observaciones de seguimiento rápido de posluminiscencias de estallidos de rayos gamma (GRBs). Algunos ejemplos de observaciones recientes, incluyendo GRB 120327A y GRB 130606A, a un redshift de 5.9, son presentados. El telescopio ha sido integrado recientemente con éxito a la red de telescopios global GLORIA, que permite a sus usuarios hacer uso de la red para sus proyectos científicos propios.

ABSTRACT

The main scientific goal of the Watcher robotic telescope is the rapid follow-up observation of gamma–ray burst afterglows. Some examples of recent observations, including GRB 120327A and GRB 130606A, at a redshift of 5.9, are presented. The telescope has recently been successfully integrated into the GLORIA global robotic telescope network, which allows users to use the array for their own scientific projects.

Key Words: telescopes — gamma-ray bursts — follow-up

1. WATCHER TELESCOPE DESCRIPTION

The Watcher robotic telescope is located at Boyden observatory close to Bloemfontein in South Africa (29°02′20″ S, 26°24′17″ E) therefore covering the southern hemisphere (Topinka et al. 2013). Meteorological conditions allow observations for ~ 200 nights per year. Watcher had first light in 2006 and was built by a consortium led by Ireland, including as partners Spain, the Czech Republic and South Africa (French et al. 2004).

The primary scientific objective of Watcher is to observe the optical prompt and early afterglow emission from gamma–ray bursts (GRBs). The secondary scientific objective is to provide high cadence, multi-filter monitoring of a sample of optically bright Fermi blazars (Tisdall et al. 2014). The distribution of telescope time devoted to different tasks is shown in Fig. 1.

The telescope consists of a 40 cm primary mirror in the Cassegrain configuration (f/14.25) and a Paramount ME mount (with $\sim$ 60 s round-trip time). It is equipped with an Andor EMCCD camera, Optec filter-wheel (providing BVRI filters and clear) and a Robofocus focuser. The site includes UPS power backup, web-cam, cloud-meter, rain sensor, robotized Zelio roof controller and a Davis weather station.

Watcher's software runs on two Linux machines, a main control unit and a dedicated machine for the camera readout. The entire system is controlled by the open source `RTS2` software package, details of which can be found at *http://rts2.org* (Kubánek et al. 2004). The real-time astrometry of acquired images is achieved using the `astrometry.net` package (Lang et al. 2010) which is embedded in the data reduction pipeline.

2. PHOTOMETRY PIPELINE

An essential component in the data reduction pipeline is the photometry block, responsible for turning a sequence of images of a given source into a calibrated light curve. The current `walapi` pipeline (Ferrero et al. 2010), written in IRAF and Matlab, which determines the statistical zero-point for each image using all stars in the field, is being replaced by a much faster Python `watcher-pipeline` that uses several of the most suitable secondary standards within an image for calibration. The APASS catalogue (Henden et al. 2012) is now used for reference brightnesses, along with the USNO-B1 catalogue (Monet et al. 2003). Parameters used in the determination of the target's magnitude are adjusted in real-time based on current seeing, image quality and the nature of the source i.e. whether it is a known bright source or a faint GRB afterglow at the limit of detectability. Real-time online identification of an unknown transient source, based on a small

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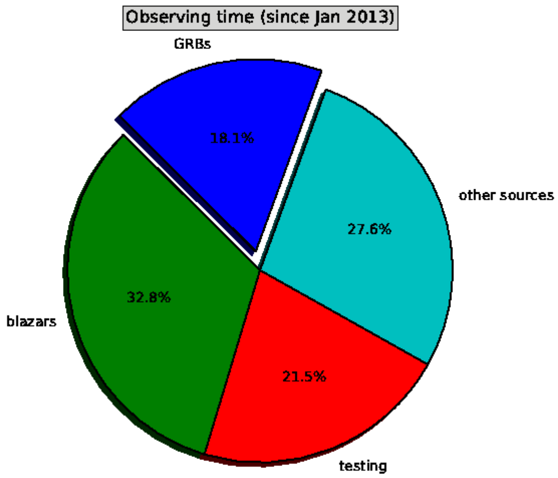

Fig. 1. The percentage of Watcher observing time dedicated to different target types: GRBs (18.1%), blazars (32.8%), other sources, including supernovae, asteroids, cataclysmic variables, etc. (27.6%) and maintenance and testing (21.5%).

number of images, is in development. This capability will ensure rapid identification and dissemination of new GRB afterglows.

3. RECENT GRB AFTERGLOWS

GRBs are the most powerful transient events in the Universe believed to arise from the catastrophic core-collapse of massive stars or from a compact object merger (Piran & Fan 2007). Although the γ–ray 'prompt' emission lasts typically some tens of seconds, GRB counterparts called 'afterglows' appear at X–rays, optical and radio wavelengths in the subsequent minutes, days and months post-burst. In some cases, lower energy emission is observed simultanously with the *gamma*–ray burst itself. In rapid GRB follow-up observations it is essential to detect the early stage of the optical afterglow and/or the 'optical flash' phenomenon. In the fireball model, the peak in an afterglow light curve can represent a forward shock passing the observing band or it may be the signature of a reverse shock (Piran & Fan 2007; Zhang & Kobayashi 2005). Reverse shock emission is believed to last for only a short time due to the short crossing time of the thin ejecta. Since the reverse shock propagates backwards from the contact discontinuity, the emission peaks at energies lower by a factor of Γ^2 compared to the forward shock. However, the luminosity is $\sim \Gamma$ greater since the reverse

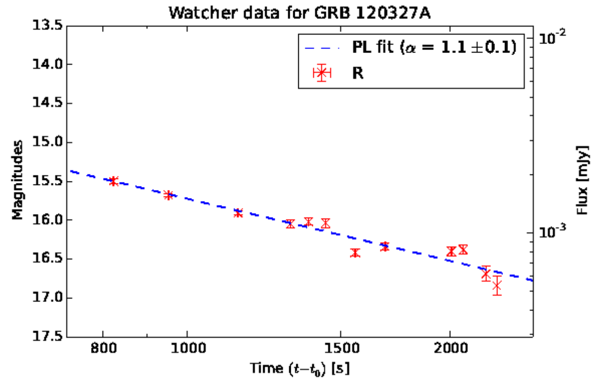

Fig. 2. The Watcher R-band light curve of the afterglow of GRB 120327A. t_0 denotes the satellite trigger time.

shock propagates into the jet, which has a higher density of the seed electrons responsible for the emission. The reverse shock emission can reveal properties of the jet, such as baryon loading. Moreover, by comparing the forward and reverse shock peaks, an estimate of the jet magnetization can be made (Harrison & Kobayashi 2013). Some recent Watcher observations of GRB afterglows are presented below.

3.1. *GRB 120327A*

GRB 120327A, at a redshift of 2.81 (D'Elia et al. 2014), was detected by Swift/BAT (Sbarufatti et al. 2012). The GRB had a duration of ~ 60 s and an X–ray afterglow was detected by the XRT at RA (2000): 16h 27m 27.14 s, Dec (2000): -29d 24′ 54.5″. The earliest ground-based optical observations of the afterglow were made by PROMPT (LaCluyze et al. 2012), 11 minutes after the Swift satellite trigger. Watcher also detected the optical afterglow, with a first detection at 11m 56s after the trigger. The light curve shows a power-law decay (slope $\sim 1.1 \pm 0.1$) of the source flux (Fig. 2) consistent with other observations e.g. (Klotz et al. 2012). The Watcher exposure time used for these R-band observations was 2 s, with an error of ~ 0.1 mag. Such a short exposure time is possible due to the use of the 'electron multiplying' mode of the Andor camera being used.

3.2. *GRB 130427A*

GRB 130427A, at a redshift of $z = 0.34$, had the largest GRB fluence ever recorded. The burst was accompanied by an underlying supernova, SN 2013cq, that was predicted and detected during the later stage of the afterglow (Xu et al. 2013). Unlike some other nearby GRBs with an underlying supernova, such as GRB 980425 with an energy of

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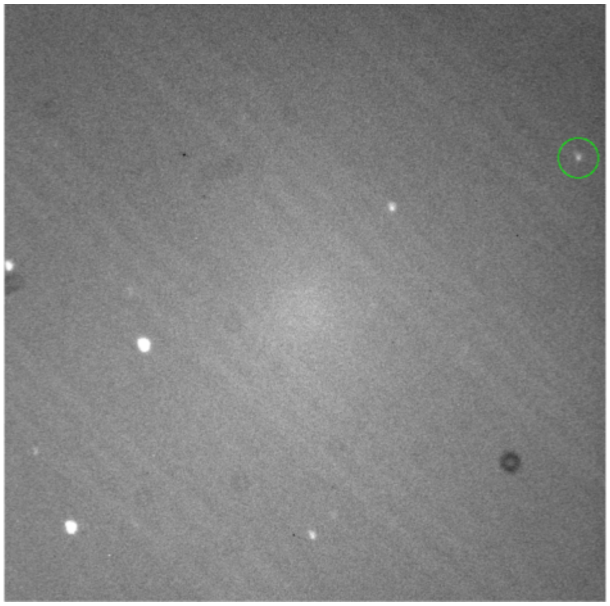

Fig. 3. The brightest GRB 130427A ever successfully confirmed in the image obtained by Watcher even +8h53m52s after the burst trigger. The position of the GRB afterglow is marked by the circle.

$\sim 10^{48}$ ergs, GRB 130427A had an isotropic equivalent energy $E_{iso} \sim 10^{52}$ ergs. The burst occurred during daytime in South Africa, however the image taken at+8h53m52s after the trigger clearly reveals the optical afterglow (Fig. 3).

3.3. *GRB 130606A*

GRB 130606A, at a cosmological redshift of $z = 5.91$, is Watcher's most distant GRB observed to date. Early time prompt optical observations were carried out by Watcher starting ~ 135 s after the first Swift/BAT trigger (T0 = 21:04:34 UT). The Watcher observations partially cover the second Swift/BAT peak. By capturing the rising part of the optical light curve and attributing the optical peak to the onset of forward shock emission, the initial bulk Lorentz factor can be constrained to ~ 185 (ISM case) or ~ 65 (WIND case) (Castro-Tirado et al. 2013).

4. OUTREACH AND GLORIA

Watcher is a founding partner of the GLORIA ('GLObal Robotic-telescopes Intelligent Array') project, an innovative citizen science astronomy initiative, which gives free and open access to a growing collection of robotic telescopes via a Web interface. In the initial phase, 17 telescopes around the world (Fig. 4) are being deployed for use by citizen and professional scientists (Hanlon 2013). Participation

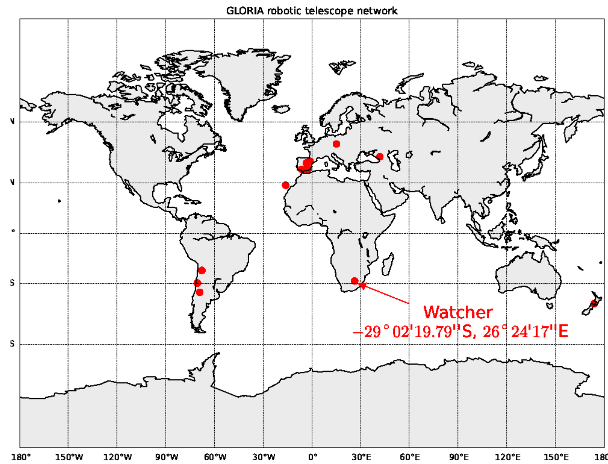

Fig. 4. The current GLORIA network covers 4 continents. Watcher's location in South Africa offers unique sky coverage within the network.

in GLORIA opens the door for a part of Watcher's time to be made available as an educational resource for citizens, schools and Universities. Watcher's integration into the GLORIA system has been completed and tested, offering the community observing time, both in interactive 'tele-operating' mode and in automatic 'batch' mode. Mainly due to the integration of the telescope into the GLORIA network, a significant fraction of Watcher's observing time has recently been devoted to testing and calibration (Fig. 1). More information about GLORIA can be found at *http://gloria-project.eu*

5. WATCHER ONLINE

To provide direct and easy access to the most common tasks and to monitor the telescope's behaviour the Watcher website has recently been redesigned (*http://watchertelescope.ie*), integrating a new set of features. The purpose of the website is two-fold: (i) To provide the current status of the telescope and (ii) To present technical information in a user-friendly interface for those who may wish to apply for time but have little experience in astronomy.

Current features include:

- The latest targets and the image quality, particularly for GRBs

- An annotated webcam image of the telescope itself

- Watcher's Twitter feed. The observational status and weather information for the site are tweeted regularly to *@WatcherTele*. The website displays the actual Twitter timeline where important messages about Watcher are circulated.

- Form for observing requests. Submitted requests are reviewed and evaluated and included into the Watcher observing plan.

- Detailed weather information and weather forecast, including visibility, pressure, humidity, temperature, wind speed and cloud level.

- Graphic of day/night on the globe, along with times of sunrise and sunset at Boyden.

- Access to the Watcher archive

- Up-to-date image gallery and further technical information related to Watcher.

6. CURRENT STATUS

The location of the site is very attractive for GRB follow-ups as there are relatively few robotic facilities at these longitudes. The African summer storms have recently caused serious problems, with electricity blackouts and network outages being a recurring problem. A chain of unlikely events in December 2013 conspired to cause the roof to be improperly closed and the telescope was flooded as a result. At the time of writing the damage to the equipment, especially the Andor camera, is still being assessed.

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