Highlight Results from the Watcher Robotic Telescope

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The Watcher Robotic Telescope

The Watcher Robotic Telescope is a fully automated 40 cm robotic telescope in South Africa whose primary goal is the rapid follow-up of Gamma-Ray Bursts (GRBs) in the optical band. Global Coordinate Network (GCN) alerts are distributed to participating observatories via an Internet socket connection. The alerts contain the locations of GRBs detected by orbiting gamma–ray satellites, along with other information about the bursts. Watcher can respond within ∼ 25-60 s upon receipt of a GCN, depending on how far across the sky it must slew. Since it began operation in mid-2006, it has followed up on 330 GRBs, 51 of which have been observed in under 2 minutes and 25 of which have been observed in under one minute.

Telescope site

Watcher is located at Boyden Observatory in Bloemfontein, South Africa (29° 02′ 20″ South, 26° 24′ 20″ East), at an altitude of 1387m.

On-site technical support is provided by the Physics Department of the University of the Free State, Bloemfontein.

The site has ∼70% clear nights, with the best observing window being during the austral winter. Summer tends to be stormy and has caused hardware problems due to lightning strikes, which have rendered the telescope inoperational at least twice.

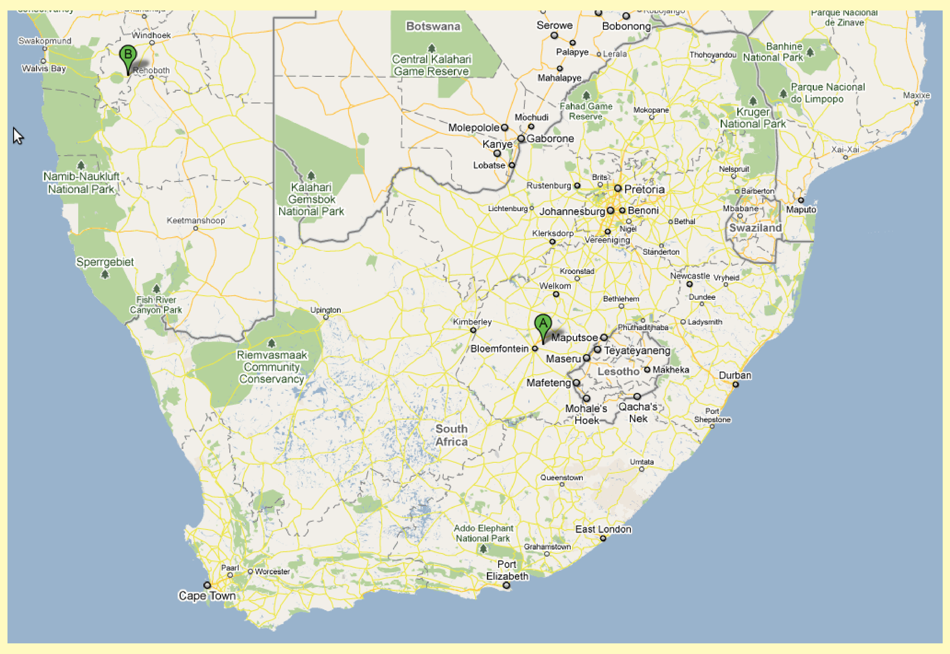

Figure 1: Watcher's location (A) relative to the HESS site (B) where ROTSE 3c is located

Hardware and Current Status

Watcher consists of a 0.4 m diameter primary mirror in a classical Cassegrain optical tube assembly, made by Optical Guidance Systems. The filter wheel is by Optek and uses standard Bessell UBVRI and clear filters.

The mount is a Paramount ME with a slew speed of up to 7° s^{-1} and a pointing accuracy of ∼30″. The Paramount has proved itself to be extremely reliable.

The camera used from commissioning to mid-2009 was an Apogee Ap6. In June 2009 this was replaced by an Andor iXon+ 1024 × 1024 pixel electron multiplying CCD (EMCCD). The current set-up gives a field of view of 8.02 × 8.02 arcminutes. The motivation for using the EMCCD was to achieve higher quantum efficiency (>90% compared to ∼ 60% for the Ap6), along with readout rates of up to 10 frames/sec without read-noise. The added complexity of this camera has been challenging to implement on a robotic system.

There have been some hardware problems since late 2010. The serial port on the mount was non-operational and has been repaired. The focuser has also been recently repaired.

Gamma–Ray Bursts

Gamma–Ray Bursts (GRBs) are extremely energetic events that take place at cosmological distances. The isotropic energy release of a GRB is 10^{51}–10^{53} ergs over some tens of seconds, roughly equivalent to the total energy emitted by the sun in its lifetime. GRB durations vary from under a second to thousands of seconds and they occur roughly once per day. Burst durations of less than two seconds are defined as short and are associated with compact object mergers while bursts longer than two seconds are thought to be associated with type Ib/c supernovae.

The mechanism for production of GRBs is well explained by the fireball model, shown in Figure 2. The processes involved in the formation of the prompt and afterglow emission can be seen. In both long and short GRBs a black hole is formed along with two jets which contain matter accelerated to highly relativistic velocities. This matter is emitted in a number of shells which collide, shock-heating matter and producing gamma–rays via the synchrotron process and creating the 'prompt' emission. There may be an additional reverse shock component as the ejecta plough into the stellar remnant, which may be seen as a bright optical flash. The shells will continue to expand out into the interstellar medium, heating it as they decelerate and causing it to emit at x–ray and optical wavelengths. This is known as the 'afterglow' phase.

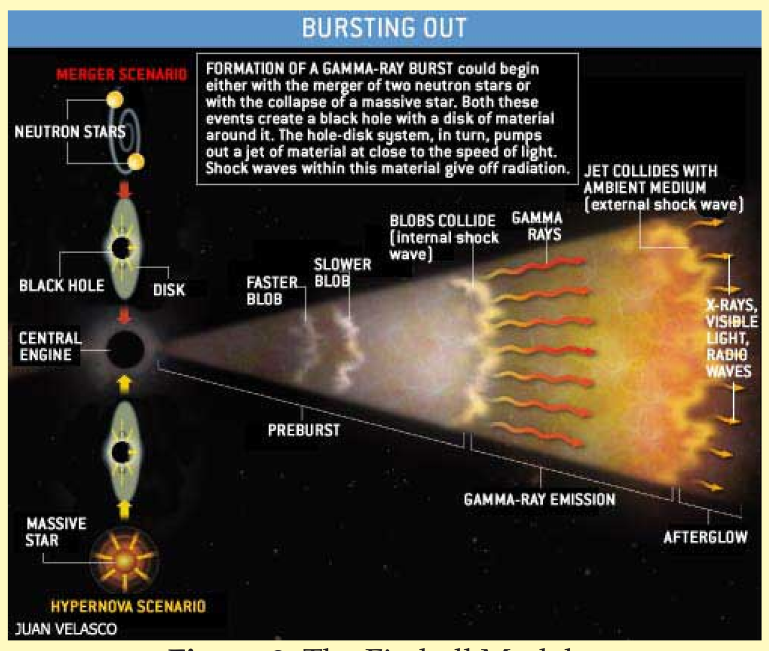

Figure 2: The Fireball Model

The Role of Robotic Telescopes in GRB Studies

The rapid response capability of dedicated robotic telescopes offers a powerful tool for GRB studies. In about a dozen cases to date robotic telescope detections have been made during the 'prompt' gamma–ray phase. Some examples are shown in Table 1. Observed patterns of optical emission include an early peak, followed by decay, or just the rapid decay phase (slope $\propto t^{-2}$). The variety of possible early behaviour necessitates the fastest possible response. In some cases there is a temporal correlation between the variable optical flux and the gamma–ray pulses, suggesting the same dynamical process is responsible for both. However, GRB 080319B showed an excess of the optical flux in comparison to the extrapolated γ–ray, suggesting a different spectral origin for the 2 components in that case.

Telescope	GRB	T90 (s)	Δ Opt (s)	Peak mag.	Δ Peak (s)	Ref.
ROTSE-I	990123	63	22	8.95	29	GCN 205
ROTSE-IIIb	041219A	520	74	14.9	2880	GCN 2868
Watcher	060526	275.2	36	15.5	112	GCN 5165
PROMPT	060607A	100	40	14.5	140	GCN 5236
Watcher	060904B	172	62	17.1	507	GCN 5510
TORTORA	080319B	50	0	5.3	23	GCN 7502
Watcher	080905B	128	43	15.8	75	GCN 8207

Table 1: Sample of GRBs observed during the γ-ray phase. Δ Opt (Δ Peak) is the start time of the first (peak) optical exposure relative to the burst trigger time.

Future Work

Watcher will continue to observe GRB prompt and afterglow optical emission as rapidly as possible. The telescope uses the Swift pointing direction in its default observing plan, in order to minimise slewing time in response to a Swift burst. The telescope has recently joined the Sierra Stars Observatory Network (SSON) which sells telescope time to amateur astronomers and educational institutions. Watcher is a member of the EU FP7 'GLORIA' project which involves a network of 17 robotic telescopes around the world to enable Citizen Science and outreach projects. An automated pipeline for Watcher data is already in the advanced stages of development. The reduction aspects are largely completed, and the next phase is the automated analysis capable of accurate photometry and the detection of candidate optical transients, or of determining upper limits in the event of non–detections. The reduction scripts assemble the appropriate calibration frames, check their quality, and create master calibration frames. Object frames are then reduced using these calibration frames and passed to an automated analysis pipeline.

GRB 080905B

Watcher began observations of this GRB beginning at T_0+44.3 s, where T_0 is the Swift BAT trigger. Exposure times of 10s were taken from 44.3 s-656.3 s increasing to 30 seconds from 660.3-3591.3 s and 60 seconds from 3718.3-7264.3 s. All images were taken with the clear filter which corresponds to the R band due to the response of the CCD. The observed afterglow was blended with the 2MASS galaxy 2MASSX J20065732-6233465 located 4 arcseconds from the GRB. The contribution of the 2MASS galaxy was subtracted using images taken a long time after the trigger and standard aperture photometry was applied. The afterglow was also observed by UVOT (GCN 8182) and the VLT (GCN 8191).

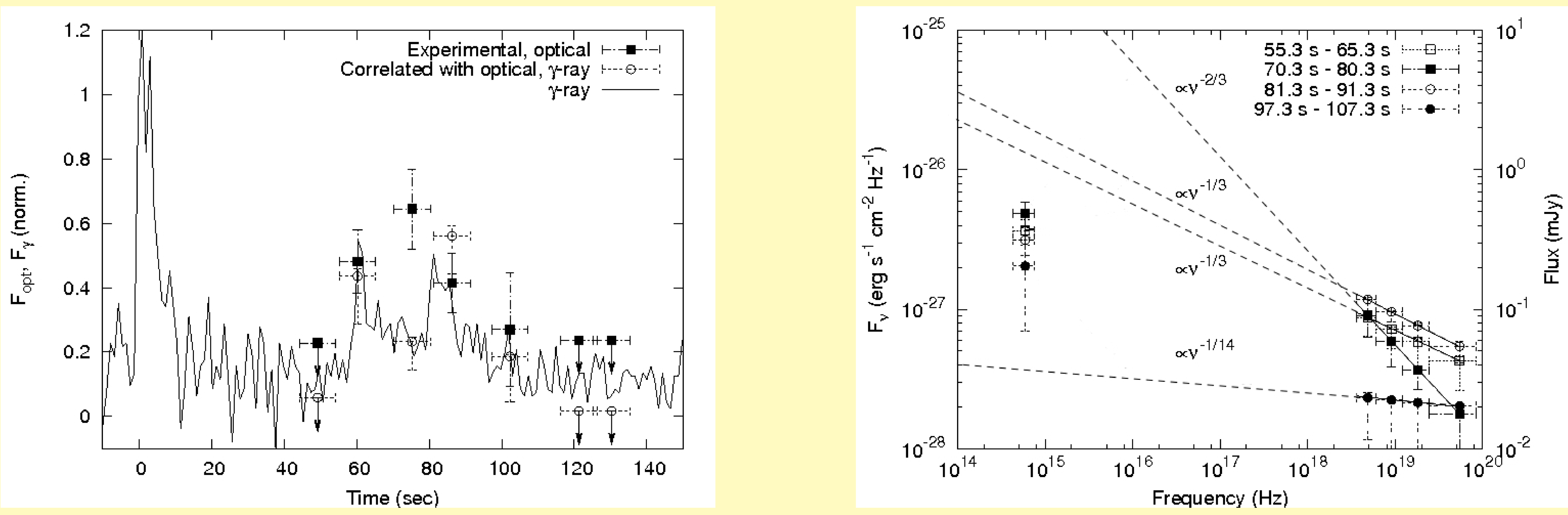

Figure 3: (Left) The BAT gamma–ray lightcurve overlaid with the Watcher optical data. (Right) The broadband spectrum from the γ–ray to the optical band for each optical exposure interval.

The white circles are the optical fluxes expected for a constant optical to γ–ray flux of $(2.5\pm0.5)\times10^{-5}$. These theoretical values are in good agreement with the observed values, except for the optical peak at 70.3-80.3 seconds. The optical flux from this time bin is larger than that predicted by the constant γ–ray to optical hypothesis, indicating a possible change in emission mechanism or the presence of an additional component (Figure 3 (right)).

Acknowledgements

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