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Status of the ROTSE-III telescope network

S.A. Yost[1,⋆], **F. Aharonian**[2], **C.W. Akerlof**[1], **M.C.B. Ashley**[3], **S. Barthelmy**[4], **N. Gehrels**[4], **E. Göğüş**[5], **T. Güver**[5], **D. Horns**[6], **Ü. Kızıloğlu**[7], **H.A. Krimm**[4], **T.A. McKay**[1], **M. Özel**[8], **A. Phillips**[3], **R.M. Quimby**[9], **G. Rowell**[6], **W. Rujopakarn**[1], **E.S. Rykoff**[1], **B.E. Schaefer**[10], **D.A. Smith**[11], **H.F. Swan**[1], **W.T. Vestrand**[12], **J.C. Wheeler**[9], **J. Wren**[12], and **F. Yuan**[1]

[1] University of Michigan, 2477 Randall Laboratory, 450 Church St., Ann Arbor, MI, 48104
[2] Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
[3] School of Physics, University of New South Wales, Sydney, NSW 2052, Australia
[4] NASA Goddard, Greenbelt, MD 20771
[5] Sabancı University, Orhanlı-Tuzla 34956 Istanbul, Turkey
[6] Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany
[7] Middle East Technical University, 06531 Ankara, Turkey
[8] Çanakkale Onsekiz Mart Üniversitesi, Terzioğlu 17020, Çanakkale, Turkey
[9] Department of Astronomy, University of Texas, Austin, TX 78712
[10] Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803
[11] Guilford College, Greensboro, NC 27410
[12] Los Alamos National Laboratory, NIS-2 MS D436, Los Alamos, NM 87545

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ROTSE-III is a homogeneous worldwide array of 4 robotic telescopes. They were designed to provide optical observations of γ-ray burst (GRB) afterglows as close as possible to the start of γ-ray emission. ROTSE-III is fulfilling its potential for GRB science, and provides optical observations for a variety of astrophysical sources in the interim between GRB events.

1 Introduction

ROTSE-III is the successor to the ROTSE-I instrument of the 1990s, designed to hunt for long-wavelength counterparts to the brief, intense flashes of γ-rays (GRBs) (for an overview of GRB properties and models see a recent review by Piran 2005). GRB models predicted "afterglow" light at longer wavelengths, surviving to later times than the energetic events themselves (e.g., Rees & Meszaros 1992). The Compton Gamma-Ray Observer (1991–2000, see http://cossc.gsfc.nasa.gov) provided prompt but highly uncertain GRB positions, several degrees across. This drove the ROTSE-I design to a wide field of view (FOV) system, 16 degrees across (see Akerlof et al. 2003).

While a wide FOV required design tradeoffs in the instrument sensitivity, it had advantages, including the ability to observe a large fraction of the sky every night, leading to the Northern Sky Variability Survey (Wozniak et al. 2004). The survey is still being mined for data. This includes student projects studying bright variable stars (e.g., Cepheids, RR Lyrae stars associated with high velocity clouds), as well as the production of a catalog of contact binary stars (Gettel et al. 2005), and studies to correlate X-ray emission with contact binaries (Geske et al. 2005).

⋆ Corresponding author: sayost@umich.edu

Given ROTSE-I's success, while ROTSE-III was designed in response to improvements in GRB positions, it kept a wide FOV (1.85 degrees) to continue searches for untriggered optical transients. The four ROTSE-III instruments are at Siding Springs Observatory, Australia, McDonald Observatory, Texas, the H.E.S.S. site near Mt. Gamsberg, Namibia, and Bakirlitepe, Turkey. With their global distribution, it is always night at at least one ROTSE-III site, leading to the motto that "the sun never rises on the ROTSE empire". Each telescope has a 0.45 m aperture and operates unfiltered (with a peak sensitivity at red wavelengths), reaching a limiting magnitude of 17 in a 5-second exposure under good conditions. The custom mounts permit horizon-to-horizon slew and settling within 6–8 seconds. The clamshell enclosures are automated, with weather stations to indicate dangerous conditions. It is nevertheless important to have people on site regularly, and all collaborations were chosen to place ROTSE telescopes at observatories. For further details, see Akerlof et al. (2003).

2 ROTSE-III operation

ROTSE-III's rapid responses are designed to observe a large fraction of GRBs at early times and constrain, with the goal of understanding, the envelope of early behaviours.

The Gamma-Ray Coordinates Network (GCN) (Barthelmy 1998) provides triggers and disseminates information from GRB observers, who may identify optical or radio counterparts. This drives other observations, such as spectroscopy, and acts as an informal network for one type of astronomical observation.

The ROTSE sites are quite remote, thus all communication with the telescopes is text-based and low-bandwidth. Large image files remain at the telescope until the data drive fills up and is swapped out. The images are reduced at the telescopes, with calibrated object lists and JPEG images sent to the University of Michigan for each exposure.

ROTSE's scheduler is dynamic, with a target file for the night. This includes a sky patrol and particular fields to monitor. Desired cadence and maximum number of exposures can be specified. After each exposure, the scheduler rechecks all target observabilities and priorities (including cadence) to determine the next target. ROTSE presently cannot schedule a timed observation.

All ROTSE operations are interruptible given a GRB alert that the control computer determines is above the minimum observable elevation. It will abort, dumping any previous exposure and slewing to new coordinates within 6–8 seconds. It then takes a preset series of exposures (10 5-second, 10 20-second, and then 3 hours of 60-second images). An old alert is overridden by a newer one.

ROTSE's operation is visible to the public on the Web at: http://www.rotse.net/

The /operation/ subpage shows the present status and allows access to the JPEGs or GIFs of images taken by the telescopes. There is a private area where collaborators can access webpages for responses to burst alerts. These pages show images of the GRB position, flagging any new and/or variable objects in the field. The telescopes generate match structures of objects in the images taken during an alert to determine such afterglow candidates, and to produce lightcurves from them. There is a further page comparing the error box to the DSS[1] archive image. These are used by ROTSE collaborators to identify optical counterparts to GRBs.

3 ROTSE Results

When not observing GRB positions, ROTSE-III performs its sky patrol and targeted observations. The sky patrol searches for untriggered GRB afterglows, using its automated data analysis pipeline to find candidates. The pipeline compares object lists for the night's patrol to the archival sky patrol history, and flags likely new objects that pass quality checks (see Rykoff et al. 2005a). The candidates must be checked by hand to determine whether they are asteroids, or non-GRB transients such as cataclysmic variables with a quiescent state below ROTSE's sensitivity. The patrol has not to date found any untriggered GRB afterglows. It has yielded supernovae discoveries in dwarf galaxies (SN2005cg, Rykoff et al. 2005b; SN2005ch, Rykoff 2005).

The targeted observations include a supernova search, yielding dwarf novae (Quimby et al. 2005b, 2005c), and several supernovae (e.g., SN2004gk, Quimby et al. 2004; SN2005cr, Quimby et al. 2005a). The global array has been used to observe a microquasar in outburst (Smith 2005), and comet 9P/Tempel for the Deep Impact project (Meech et al. 2005)

ROTSE-III is now fulfilling its promise, with *typical* responses to ordinary GRBs sometimes resulting in optical imaging during the prompt GRB γ-ray emission phase. These are possible when a trigger is promptly disseminated for a GRB of duration $\sim$ 30 s or greater, with 3 ROTSE-III cases to date: GRB 050401, GRB 051109A, and GRB 051111.

GRB 050401 further demonstrated the diversity in prompt GRB optical behaviour. There were two previous detections: the ROTSE-I observation of 990123 (an extraordinarily bright GRB), with a prompt optical excess *uncorrelated* with the GRB (Akerlof et al. 1999), and the RAPTOR detections or GRB 041219 (an extraordinarily long GRB), with prompt optical light *correlated* with the GRB lightcurve (Vestrand et al. 2005). GRB 050401 showed no optical excess relative to the later afterglow decay (Rykoff et al. 2005c). The more recent events are still being analyzed.

3.1 Future networking prospects

ROTSE is focused upon its primary (GRB) science goals for the duration of the *Swift* mission, which is expected to be for the next three years. Improvements in its network will be dedicated to accomplishing these goals. These could include automating some of its counterpart announcements to the GCN in the most definite cases, and networking with local collaborators at the ROTSE sites. An example of the latter would be sending an automated notice to the H.E.S.S. operators when the local ROTSE has detected a counterpart.

4 Conclusion

The ROTSE-III network is responding well to its goals for GRB optical studies, pushing back optical responses to the γ-ray emission. It performs scientifically interesting observations when not on GRB alert, with the network shared by the collaborators directly logging into the telescope computers and adding to the object queue list.

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[1] http://archive.stsci.edu/cgi-bin/dss_form

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