ROTSE-III Performance in the Swift Era

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Abstract.
We report the successful performance of the Robotic Optical Transient Search Experiment (ROTSE) to promptly-disseminated Swift GRB triggers. ROTSE-III is a worldwide network of 4 unfiltered 0.45m optical telescopes. The telescopes operate robotically, automatically responding to GRB position triggers with a preset observations sequence. Including weather and other downtime, ROTSE-III can immediately respond to ∼40% of Swift trigger positions, with shutter open within approximately 6-8 seconds from the trigger dissemination. We discuss improvements made possible in the automated response the the small, accurate Swift error boxes. We report ROTSE-III's general results, including OTs discovered or confirmed, the distribution of imaging start times relative to the GRB duration, and an overview of OT lightcurves.

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RESPONSE CAPABILITIES

ROTSE-III is a global network of four 0.45 m robotic, automated telescopes, designed for fast (∼6 sec) responses to GRB triggers. They have a wide (1.85×1.85 deg) field of view, and operate without filters. Under good conditions, they reach an R-equivalent limiting magnitude of ∼17 in a single 5 sec exposure, and ∼18.5 in a 60 sec image. The 4 ROTSE-III telescopes are located at Siding Springs Observatory, Australia (A), McDonald Observatory, Texas (B), the H.E.S.S. site in Namibia (C), and the Turkish National Observatory near Bakirlitepe, Turkey (D). At any time, at least one ROTSE is in astronomical night. The ROTSE-III telescopes are described in detail in [1].

ROTSE-III has responded promptly to 30 of the 85 rapid triggers (coordinate distribution delay $<$ 1000 sec) since the *Swift* satellite went online in February 2005. Its response

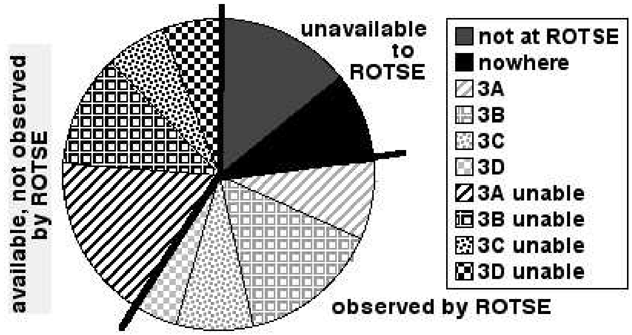

FIGURE 1. ROTSE-III's Responses by Telescope. Overall, ROTSE-III has responded promptly to 30 of the 85 rapidly-disseminated triggers since Swift went online (2005/02/15 – 2005/11/18), or 35%. The chart above shows the fraction of triggers promptly observed by each telescope, the location labelled by letters A-D (see text). Also indicated (darker slices) are the trigger fractions that could have been observed by the ROTSE sites if they had not been affected by weather or hardware downtime. When more than one site responded or was a potential responder, the trigger is subdivided to form the fractions given. Also indicated are the triggers that had a small ground window, not including the ROTSE sites, where the sun was down and the trigger was above the horizon at the burst time. The black slice indicates the triggers that could not be promptly observed from the ground (i.e., in the daytime sky).

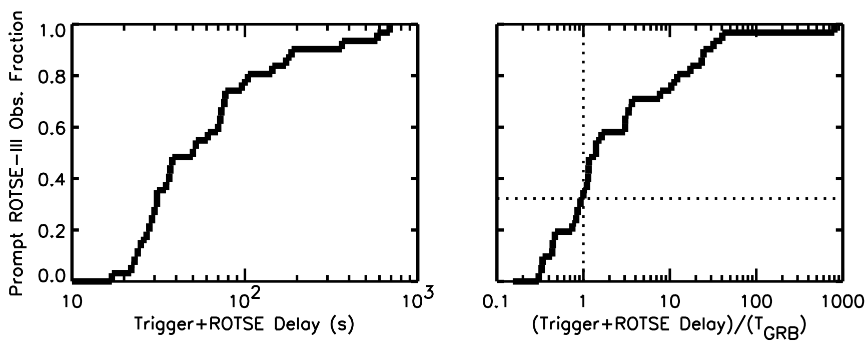

FIGURE 2. ROTSE-III Times From GRB Onset to Start of Imaging. ROTSE-III's 30 *Swift*-era rapid responses to non-delayed triggers are displayed as cumulative probability distributions. The delay from GRB onset to the distribution of a trigger is added to ROTSE's response time, and cases <1000 sec define a rapid response. The top panel gives the response in sec, showing typical responses are ~ 30 sec, with a broad tail at 100 sec and above. The lower panel gives these rapid responses in units of the GRB duration. Approximately $1/3$ of the responses begin during the GRB, and most have begun just after its end. The response at $\sim 800\times$ the GRB duration is an ordinary response to a short GRB.

fraction of 35% includes weather and hardware downtime, and the distribution of burst trigger positions, as some are too close to the Sun for ground-based optical observing.

Fig. 1 charts the distribution of these responses among ROTSE sites. ROTSE-IIIB (Texas) has responded most frequently (12.5 times, note that responses by more than one telescope are divided between them), and ROTSE-IIID (Turkey) the fewest times (4). The observability distribution of rapid triggers has been uneven, with IIIC and IIID receiving fewer potential triggers than IIIA or IIIB. Approximately 10% of the rapid triggers have not been promptly observable from the ground, and a further 15% have had small prompt ground observability windows that did not include any ROTSE sites.

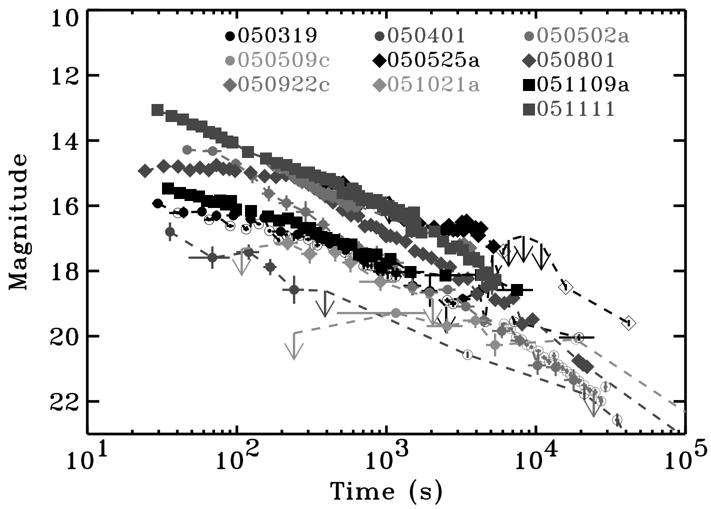

FIGURE 3. Early Lightcurves of OTs Detected by ROTSE-III in the *Swift* Era. ROTSE-III has detected 10 afterglows since February 2005. Their *R*-equivalent magnitudes are plotted here, with upper limits as arrows. ROTSE-III points are solid circles; in a few cases, additional data from the literature [3-11] are included as empty circles for comparison. The lightcurves are coded as indicated. Some show an underluminosity at the earliest times relative to the afterglow's subsequent evolution. There are no 990123-type cases with strong early overluminosity pointing to a reverse shock's emission.

RESPONSE AND REPORT SPEED

ROTSE-III's response speed, combined with promptly-disseminated GRB triggers (principally from *Swift*), facilitates early observations. As shown in Fig. 2 (top panel), a typical response time is 30-100 sec from γ-ray onset to the start of ROTSE's first 5 sec image. This total delay includes the computation and dissemination of the trigger position, as well as ROTSE's $\sim$6-8 sec slew & settle time. Only cases with a delay is < 1000 sec are considered. A response time > 1000 sec is delayed from ROTSE's perspective.

ROTSE-III's automated pipeline reduces images and flags potential optical counterparts. Collaborators then quickly evaluate candidates, allowing very rapid OT identifications. ROTSE-III presently holds the record for the fastest dissemination of an OT to the GCN Notices, just under 7 minutes from the GRB onset to the GCN submission (GRB 050801), as well as other cases with submission at $\sim$ 10 minutes. The next most-rapid cases are $\sim$ 1/2 hour from GRB to GCN.

ROTSE's typical response time is comparable to the duration of a long GRB. This capability yields cases of "prompt" optical observations, imaging of the GRB location while γ-ray photons are still being emitted. This is evident in the lower panel of Fig. 2, where the total delay as described above is given in units of the GRB duration (typically the reported T90). The response at 800$\times$ the GRB duration was for a normal $\sim$ 30 sec response to a short GRB.

ROTSE-III has detected optical photons contemporaneous with γ-ray emission for 3 GRBs of typical duration: 050401 [2], 051109A, and 051111 [Yost, Swan *et al.* in prep]. We have also observed 7 other GRB positions before the end of γ-ray emission, but no OTs were detected in those cases.

DETECTIONS

ROTSE-III has detected 10 OTs thus far in the Swift era. Their lightcurves in R-equivalent magnitudes are shown in Fig. 3. The earliest points are more densely sampled in the later events. *Swift*'s small, accurate error boxes have made an unjittered mode with only the central subframe read out possible, used for the first 10 (5-sec) exposures. This reduces the overhead from 9-10 sec to 2 sec per image.

There is significant lightcurve diversity, including a late rise (050509C), a long initial plateau (050801), and a steady decay connecting to observations by other instruments a day later (050401).

Some of these events are underluminous relative to back-extrapolations of later data. There is no strong evidence for early overluminosity like that expected from reverse shocks in these 10 cases. The bright reverse shock seen in 990123 remains unique among prompt GRB observations.

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