Rapid Optical Follow-up Observations of SGR Events with ROTSE-I


Abstract. The primary mission of the Robotic Optical Transient Search Experiment (ROTSE) is to search for contemporaneous optical emission from GRBs. Among the triggers ROTSE receives via the GRB Coordinates Network (GCN), there are a number from Soft-Gamma Repeater (SGR) events. Since beginning operations in March 1998, ROTSE-I has triggered on 16 observable SGR events. Ten of these events had useful data, eight events from SGR 1900+14 and two events from SGR 1806-20.

The error regions for these SGRs are a small fraction of the ROTSE 16° x 16° field of view and have been searched for new or variable objects. Limits on optical transient counterparts are in the range $m_{\text{ROTSE}} \approx 12.5 - 15.5$ during the period 10 seconds to 1 hour after the observed SGR events.

INTRODUCTION

There is currently nothing known about the emission of Soft Gamma-ray Repeater (SGR) bursts at energies below a few keV. In this paper we present the first known attempts to detect optical emission from SGRs in the period just following SGR bursts. The Robotic Optical Transient Search Experiment (ROTSE) [1] is configured to respond to transient events from the Gamma-Ray Burst Coordinates Network (GCN) and is capable of rapidly slewing to the coordinates of a transient event such as an SGR burst. Since beginning operations in March 1998, the first generation system, ROTSE-I, has triggered on 16 SGR events, ten of which had useful data.
## TABLE 1. Summary of ROTSE-I SGR Observations

<table>
<thead>
<tr>
<th>SGR</th>
<th>Date</th>
<th>Trigger</th>
<th>BATSE Delay before first usable exposure (s)</th>
<th>Number of usable images</th>
<th>Comments^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900+14^b</td>
<td>980530</td>
<td>6798</td>
<td>168</td>
<td>4</td>
<td>tiles</td>
</tr>
<tr>
<td></td>
<td>980607</td>
<td>6809</td>
<td>19</td>
<td>13 direct</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1023</td>
<td>4</td>
<td>tiles</td>
</tr>
<tr>
<td></td>
<td>980719</td>
<td>6932</td>
<td>226</td>
<td>1</td>
<td>tiles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>669</td>
<td>4</td>
<td>tiles</td>
</tr>
<tr>
<td></td>
<td>980790</td>
<td>6934</td>
<td>316</td>
<td>23 direct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>980921</td>
<td>7107</td>
<td>682</td>
<td>22 direct</td>
<td></td>
</tr>
<tr>
<td>1806-20</td>
<td>990429</td>
<td>7124</td>
<td>153</td>
<td>4</td>
<td>tiles</td>
</tr>
<tr>
<td></td>
<td>980908</td>
<td>7073</td>
<td>425</td>
<td>6</td>
<td>direct, first images cloudy</td>
</tr>
<tr>
<td></td>
<td>990429</td>
<td>7537</td>
<td>933</td>
<td>2</td>
<td>tile</td>
</tr>
<tr>
<td></td>
<td>980922</td>
<td>7109</td>
<td>174</td>
<td>4</td>
<td>tiles</td>
</tr>
</tbody>
</table>

^a “Direct” means the SGR was in direct exposures, “tiles” that it was only in tiles.

^b For three triggers, a second GCN trigger was received at a new location.

^c This does not include 6 frames in which only half of the SGR error region was covered.

### OBSERVATIONS

A typical ROTSE-I response to a GCN trigger consists of a series of direct exposures centered at the trigger coordinates followed by a series of tiled exposures with the mount shifted by ±8° (half the total FOV) in both right ascension and declination to extend the ROTSE-I coverage of the GCN error box. ROTSE-I SGR responses are summarized in Table 1. The durations of the SGR bursts were all < 1 s with the exception of BATSE trigger 6798 which was a series of bursts lasting 350 s. ROTSE generally begins observations ~ 10 s after receiving a GCN trigger. However, the first useful image may be taken up to several minutes later if the SGR position is only in tiled images. Six of the 16 SGR responses have no useful data, either because they occurred during twilight or in cloudy conditions (3 of 6), because the GCN trigger positions differed from the SGR location by more than 16 degrees (2 of 6) or because a software failure occurred (1 of 6).

### Data reduction

All images have been dark-corrected and flat-fielded. Examples of corrected images are shown in Figure 1. Parameters for all objects in an image are measured using SExtractor [2]. The object lists are photometrically and astrometrically calibrated against the Tycho Reference Catalogue [3]. Since ROTSE-I uses an unfiltered CCD, the photometry is color corrected using Tycho $B - V$ to produce a ROTSE-I equivalent V-band magnitude, $m_{\text{ROTSE}}$. 

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Extinction

Indices the limits agree to within 25% for the two methods.

Previously, the authors performed a cross-check of their extinction on a subset of the data.

For a number of spectral features, the extinction is evident, as is shown in Figure 2, where the extinction coefficient is determined for each of the SGRs.

![Image of extinction data for SGR 1906+14 and SGR 1806-20]
FIGURE 2. Limits for the 10 triggers with useful data. Each plot gives the limits, \( m_{\text{ROTSE}} \), as a function of delay since the SGR trigger.
to SGR 1900+14 of $A_V \approx 13$ mag. This agrees well with the extinction value found above for a distance of $2.2 - 6.6$ kpc, so we adopt $A_V \approx 13$ mag. For SGR 1806-20, $n_h \approx 6 \times 10^{22}$ cm$^{-2}$ [9,10] gives $A_V \approx 30$. This large value, if indicative of the true extinction to SGR 1806-20, would make it impossible to see this source in the optical.

With the calculated extinction to SGR 1900+14, we can now address how bright an optical transient would have to be for ROTSE-I to detect it. Accepting the distance of 5 kpc for SGR1900+14, the ROTSE-I limits of $m_{\text{ROTSE}} \approx 14$ mag give absolute magnitude limits of $M_{\text{ROTSE}} \approx -1$. The extinction of $A_V \approx 13$ mag reduces this to $M_V \approx 14$, roughly between a nova and supernova in brightness.

With the large extinction in the direction of the known SGRs, a campaign specifically designed to detect SGRs would utilize a rapid-response detector sensitive in the 1 - 10 $\mu$m region of the spectrum. However, ROTSE-I will continue to observe SGR triggers since doing so is a simple extension of ROTSE’s main GRB response program. To improve the chances that ROTSE-I observes an SGR event in the future, we may point to the coordinates of a particular SGR based on classification information in the GCN trigger and the position of the event as given by GCN. Furthermore, the ROTSE collaboration is developing several 45 cm aperture telescopes which should reach several magnitudes deeper than ROTSE-I. It is possible that this increased sensitivity will be enough to overcome the very large extinction in the direction of SGR 1900+14.

CONCLUSION

We have presented limits on optical emission in the period immediately following SGR bursts for a total of ten events. Limits on optical transient counterparts are in the range $m_{\text{ROTSE}} \approx 12.5 - 15.5$ during the period 10 seconds to 1 hour after the bursts.

REFERENCES