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Follow up ability for GRB observations on Swift(*)

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Summary. — Swift is the first satellite to autonomously select its own targets and slew to them. To test the ability of the narrow field of view instruments (NFIs) to follow up gamma ray burst (GRB) triggers, we simulate a series of randomly positioned bursts. This allows us to explore how the follow up observations of the NFIs will proceed. Each located burst in the simulation is followed by four hours without bursts, to allow for the NFIs to follow up the GRB triggers. We simulated 50 bursts that were triggered and located by the Burst Alert Telescope (BAT) and observed by the NFIs to probe the follow up parameter space. The discovery orbit (when the burst is first observed after the trigger) has NFI observation durations that are random in duration, while the average observation per full-orbit (the orbits after the discovery orbit) is approximately 2500 seconds, which would then take four full orbits to fulfill the autonomous observation requirement. The NFI observations can only begin after Swift has settled on the GRB's location, which takes about a hundred seconds. This average hundred seconds limits to rapid follow up observations by the NFIs, leaving the earliest optical observations to ground-based robotic telescopes.

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1. – Introduction

Swift [1], the next satellite to study gamma ray bursts (GRBs), was sucessfully launched November, 2004. Swift has three instruments to detect and observe GRBs: the Burst Alert Telescope (BAT), the X-Ray Telescope (XRT), and the UltraViolet and

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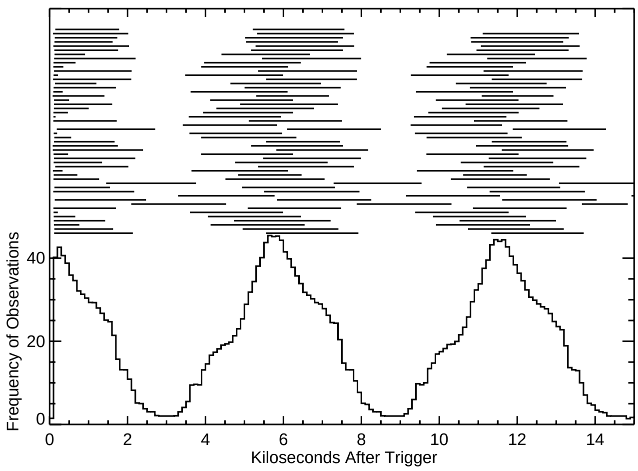

Fig. 1. – Swift's NFI observations as a function of time after trigger. The function in the lower half of the graph is the frequency of observations per time after the trigger for 50 simulated bursts. The lines above are indications of when Swift observes each burst, which are on different horizontal levels. The discovery orbit, (orbit in which BAT triggers) has random observation durations. However, the second and third orbits have almost identical peaks, which indicates that subsequent observations of the same burst have similar durations.

Optical Telescope (UVOT). Swift will be the first satellite to autonomously choose its own targets and point to them, thus observing GRBs as soon as possible. To detect and locate GRBs, first BAT must detect a significant statistical increase in the observed counts via the triggering algorithm [2]. Then, the on-board software [3] images the detector plane to locate a new point source in the sky. Swift then sends that location to the ground through TDRSS which is then sent out to the scientific community through the Gamma ray burst Coordinates Network (GCN) [4] in about 18 seconds after the trigger. After Swift has slewed to the GRB, XRT sends a more precise location then UVOT sends a finding chart to the ground in approximately 270 seconds after the trigger. The tests in [5] probed Swift's follow up abilities with 10 minutes between bursts. This paper goes into greater depths of Swift's behavior for extended observations.

2. – Simulations

We run the tests to explore how the NFIs observe GRBs on the "hotbench" (a set of computers which simulate the full spacecraft software and hardware, including actual pointing constraints and real slewtimes). Swift cannot point near certain areas, such as the Sun, Moon, and Earth, because of the sensitivity of UVOT and XRT; pointing near those bright sources would damage those telescopes. These constraints limit how long Swift's NFIs can observe a burst since the constraints will innevitably slide between Swift and the GRB during orbit. With Swift changing the location to which it points on orbit, accurate slewtimes are critical to determine the duration that the NFIs observe a GRB.

Though we used very similar simulations to [5], we adjusted several parameters to focus on NFI follow-up observations. Between each burst, we let about four hours pass to learn how Swift behaves during subsequent orbits. We use random BATSE time

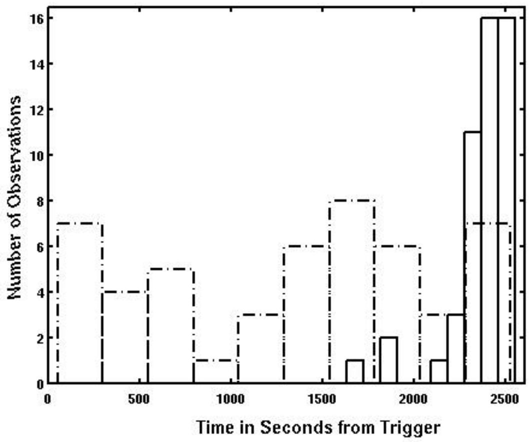

Fig. 2. – Observation durations per orbit. The dashed curve is the durations of observations from fig. 1 during the discovery orbit, observations that generally begin before 3000 seconds after the trigger. The solid lines are the observations during the first full orbit from fig. 1, the orbit immediately following the discovery orbit. The observations during the discovery orbit are near a uniform distribution in their durations. However, during the first full orbit, the majority of observations have durations around 2500 kiloseconds, thus only requiring four orbits to complete the autonomous observation requirement. Note that there were four bursts which were not observed during the discovery orbit, and three of those were not observed during the first full orbit.

histories, random positions in the sky, and high peak fluxes to generate each burst. This is a timing and operations test, rather than a sensitivity test, so we use the set of brightest bursts that would be observed in a typical year.

3. – Follow-up observations

Once Swift has detected and located a burst, the NFIs can continue observing that burst through the following orbits. In our simulation, we limit the time between bursts to four hours, so our test did not have time to collect the required seconds of autonomous data per burst. The NFI constraints and the orbit around the Earth set the limits on duration of observations per orbit. We have found that the duration of the discovery orbit has a uniform distribution between 0 and 2500 seconds.

However, the amount of time observing a burst after the discovery orbit remains constant in the second and third orbits, thus indicating that the duration of observations for a given burst will stay constant in the full orbits until the NFIs have accumulated 10^4 seconds of data, as seen in fig. 1. In an average full orbit, Swift can observe a GRB with the NFIs for approximately 2500 seconds.

The NFI constraints and the orbit around the Earth set the limits on duration of single observations. It would then take four subsequent orbits to fulfill the autonomous observation requirement, which translates to 6 hours of flight time to record 10^4 seconds of data.

After the trigger, the BAT's location algorithm can locate a burst within about 6 seconds. Though we have the location very soon to the peak of the burst, it takes about 100 seconds for Swift to slew to the GRB. During this lag between GRB location by

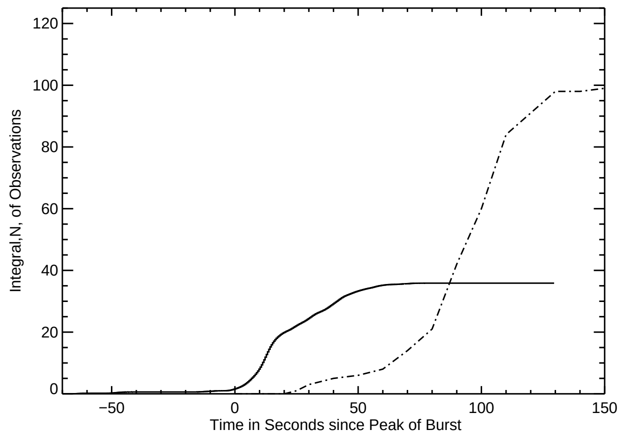

Fig. 3. – The integral number of bursts observed as a function of time after the peak of the burst. The solid line is the integral curve of Swift's location function with RAPTOR's [6] reaction function, with a three second delay for TDRS and GCN delays. The dashed line is the integral curve of the time it takes for Swift to observe the burst from the peak of the burst. We use the RAPTOR response curve as an example for any robotic telescope. Though RAPTOR will observe more bursts earlier than Swift, Swift will observe more bursts overall. This represents approximately a year of operation.

BAT and NFI observation, Swift transmits the position to the ground through TDRS thus reaching GCN in a few seconds. Robotic telescopes can capitalize on these prompt locations through GCN. As seen in fig. 3, there is a distinct lag between when robotic telescopes can begin observations, and when Swift begins observing the burst. Though Swift does observe more bursts overall (due to the limitations of ground effects such as weather and daylight), the robotic telescopes will observe more bursts until 80 seconds after the peak of the burst. Swift can observe many of the bursts it detects, but the time it takes to slew to GRB locations is a considerable delay to Swift's ability to observe early afterglows with the NFIs. The difference between when Swift can locate bursts and when the spacecraft can observe them potentially gives ground-based robotic telescopes the opportunity to make remarkable strides in early GRB observations.

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