Searching for Gamma-Ray Burst Progenitors Using TESS FFIs

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Introduction

Gamma-ray bursts (GRBs) are the brightest electromagnetic events known to occur in the universe, and are characterized by brief flashes of gamma-ray energy concentrated from 0.1 to 1 MeV. The commonly-accepted model for GRBs involves the formation of an accreting compact object, beginning from an initial event such as the collapse of a massive star, in the case of long GRBs, or the coalescence of two compact objects (neutron stars) for short GRBs (Azzam et al. 2017).

In some models of long GRBs (Vietri & Stella 1998, Levan et al. 2016) the supernova is assumed to leave behind a rotationally supported supramassive neutron star which then slowly shrinks through angular momentum loss via a wind. After a time period typically anticipated to be weeks to months, the configuration becomes unstable and collapses to a black hole, leading to the GRB. The possibility of such a SN progenitor to the (delayed) GRB motivates a search for such emission (see, *e.g.* Heyl 2003).

In the majority of cases, the progenitor must be inferred rather than observed, because the GRB field was not being monitored prior to the burst. We have begun to use the TESS fields to search for visible progenitors to GRBs.

No other available instrument is capable of performing this study. Kepler/K2 had an effective field of view of 90 deg^2 , only about 4% of what TESS offers. Roughly 30% of K2 pointings were also located near the galactic plane, making optical progenitor detection much more difficult due to extinction and crowding. Furthermore, until options such as LSST become available, no ground-based option is competitive in terms of coverage and cadence. The resulting GRB progenitor data set from TESS would be roughly an order of magnitude larger than that from any previous study. We further note that even a nondetection would be meaningful, as it would help to rule out some classes of GRB models.

Data Reduction & Analysis

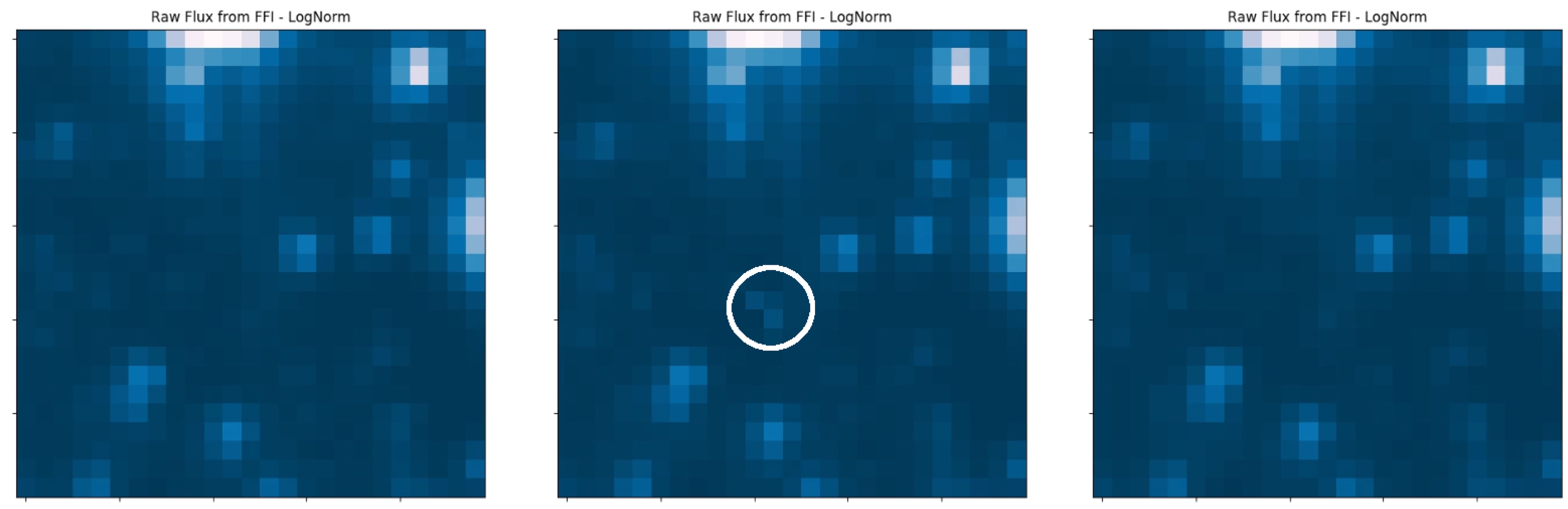

Fig. 1: A *TESS* FFI cutout around the location of GRB 181022A. The center frame shows that 63 hours prior to the *Swift* event an optical flash was visible for two consecutive frames (roughly an hour) at the burst location.

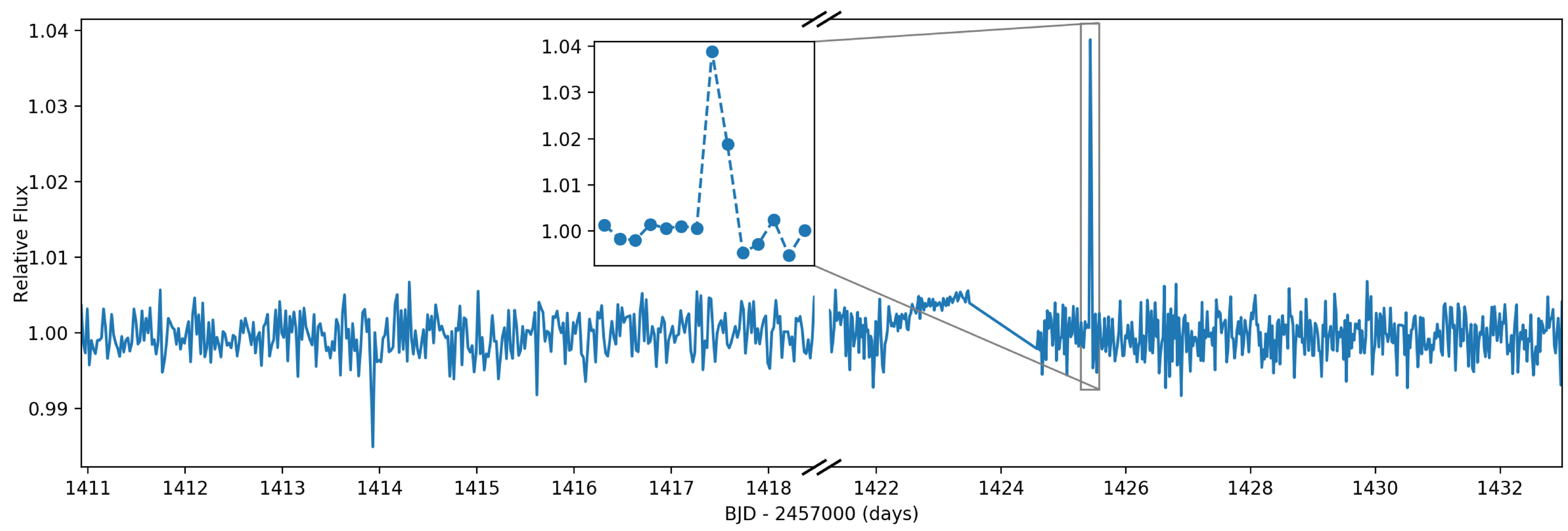

Fig. 2: Simple aperture photometry of the burst location showing the optical flash as a peak in the light curve beginning at *TESS* JD 1425.431.

We make use of Swift Burst Alert Telescope (BAT) GRB detections. Each GRB alert is assessed to determine if it lies within a sky region previously observed by TESS. If so, the positional accuracy ($\sim$ 4 arc min, or about 12 TESS pixels) of BAT will enable us to define an appropriate postage stamp for the TESS FFIs. These are typically $\sim 40 \times 40$ pixels, and we extract them using TESScut (Brasseur et al. 2019). We will then search for variability in the postage stamps to determine if a potential progenitor is present. For each of these, we produce afterglow light curves. Through Sector 11, 12 GRBs have occurred in TESS fields at times after TESS observed the field.

Figure 1 shows one such event, located at the reported position of GRB 180122A (https://gcn.gsfc.nasa.gov/gcn3/23364.gcn3). The event detected by TESS occurred 63 hours prior to the GRB detection, corresponds to Tmag $\sim$ 14, and was visible for two TESS frames. No afterglow was detected from the GRB itself. The most likely alternative explanation is a flare from a faint M dwarf; catalog searches reveal nothing at that location and nothing brighter than R = 20 within an arc minute, but further work is required. Figure 2 shows our preliminary light curve extraction for the event in Figure 1, detrended using the T'DA ensemble algorithm (see Poster 1).

Discussion

Few organized attempts have previously been made to search for GRB progenitors. Blake & Bloom (2004) made use of archival Near-Earth Asteroid Tracking (NEAT) images to search for optical progenitors for GRBs with known redshifts, with a limiting magnitude of $R \sim 20$. NEAT observed these fields for periods ranging from hours to years before the burst. This is comparable to the brightness expected for potential supernovae GRB progenitors. Blake & Bloom (2004) identified 11 potential targets, but failed to find evidence for significant detection of any progenitors. However, we note that their search was not systematic in the sense that it was dependent on the serendipitous timing of the NEAT observations, so that while some of their fields were well-sampled over long periods, others had only a few observations and any progenitors could easily have been missed. Piotrowski (2012) searched for an optical progenitor to the naked-eye GRB080319B without success as well, but his search only reached down to 12th magnitude.

We note that although our projected numbers of precursor detections for the entire TESS mission are low (<10 in the best case), **this is still a vast improvement over the current number of 0**. Successful detection would solidify the association of long GRBs with supernovae, as well as potentially discriminate between existing long-duration GRB models (as would plerion detection). Furthermore, establishing the length of the typical time delay (if any) between SN and GRB would further constrain long burst models.

References

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