A search for Terrestrial Gamma-ray Flashes in the BeppoSAX Gamma-Ray Burst Monitor data archive

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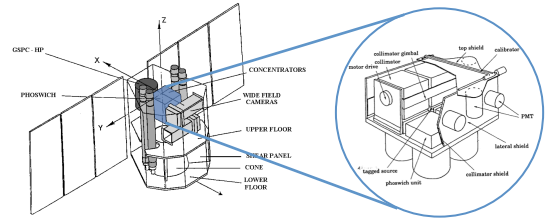
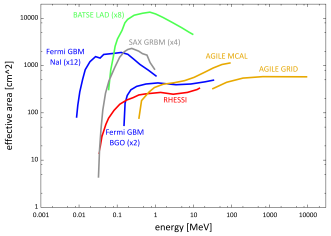
Serendipitously discovered 20 years ago by the BATSE experiment onboard the CGRO, Terrestrial Gamma-ray Flashes (TGFs) have been observed by several spacecraft, such as RHESSI, AGILE and the Fermi Space Telescope. The Italian/Dutch satellite BeppoSAX, operational in space during the period 1996-2002, represented one of the most important missions in the field of high-energy astrophysics. Its payload housed the Gamma-Ray Burst Monitor (GRBM), a segmented detector that can be considered a sort of "blood relative" of BATSE and that could, in principle, have observed TGFs as well. Motivated by this possibility, we carried out for the first time a systematic quest of possibly observed TGFs throughout the BeppoSAX GRBM data archive. After pointing out the major drawbacks of the GRBM for what concerned the TGF detection, we developed a search algorithm to look for events in the available dataset and performed a set of cross-checks to evaluate the goodness of the selected events. **Our search ended up with a sample of 12 TGF candidates**. Among these events, we also found a peculiar candidate occurring over Africa, whose temporal and directional features may be the signature of a mirrored electron TGF.

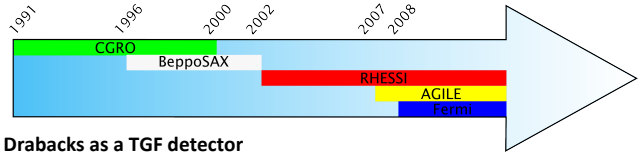
The BeppoSAX Gamma-Ray Burst Monitor (GRBM)





4 CsI(Na) scintillators
10 mm x 275 mm x 402 mm

GRBM band	AC band
40 keV ÷ 700 keV	> 100 keV
trigger mode 106 s (7.8 ms t res) 10 s (0.5 ms t res)	continuum acquisition (1 s t res)



Drabacks as a TGF detector

1) · long integration times (~ s)
· few counts (1 ÷ 11 cts/bin$_{7.8ms}$) expected for TGFs with fluence F = 0.1 ph/cm^2 (typical bkg = 6 ÷ 7 cts/bin$_{7.8ms}$)
→ **TGFs do not trigger the GRBM**

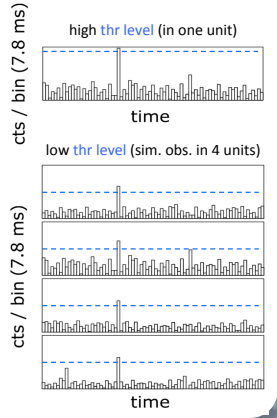
2) 7.8 ms time res » Δt_{TGF} → **TGF light curves look like spikes**

3) data in the AC band [> 100 keV] useless, due to the coarse time resolution (1 s) → **only one energy band [40 ÷ 700 keV] available for analysis**

The Search Algorithm

Spikes in the 7.8 ms light curves can be produced by:

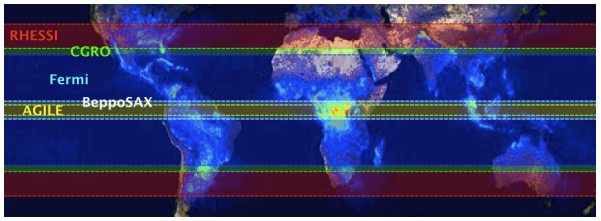
- TGFs
- statistical fluctuations of the background: discriminated by imposing a **threshold level**. Thresholds are chosen in order to select spikes with a **statistical significance of 5σ (or 4σ)** over the background.
- high-energy charged particles: discriminated by considering the GRBM as a **segmented detector**. Typically, a particle cannot cross more than 2 slabs out of 4. We just consider spikes simultaneously **occurring in all 4 units (or at least 3)**.



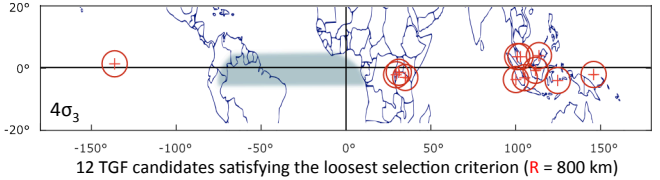
Expected number of detected TGFs

- Effective exposure time in 6 years activity of SAX: $\tau_{exp} = n_{trigger} \cdot \Delta t_{trigger} \sim 24$ d
- Geographic TGF density obs. by SAX and RHESSI: $\frac{n_{TGF}(\pm 3.9°)_{SAX}}{n_{TGF}(\pm 38°)_{RHESSI}} = 2.15$
- Minimum fluence needed to trigger the selection criteria: $F_{min} \sim 0.2$ ph/cm^2

→ **$N_{exp} < 10$**



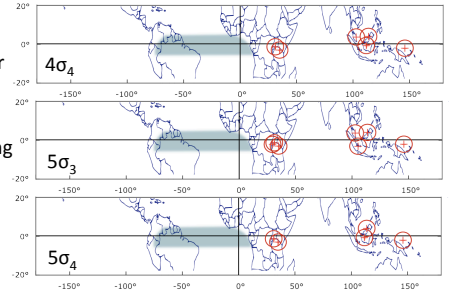
Results



12 TGF candidates satisfying the loosest selection criterion (R = 800 km)

evident **clustering** over continental regions;

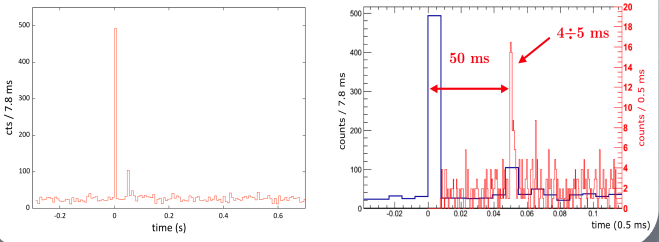
at least one unit pointing **towards the Earth** (± 30° from the nadir)



Event of March 8th 2000:

· over Africa
· double peaked time profile (1st peak from sky, 2nd peak from Earth)
· high intensity (only candidate that triggered the GRBM)

mirrored electron TGF?



References: *Frontera et al.* (1997), Astron. Astrophys. Suppl. Ser., vol. 122, n.2; *Grefenstette et al.* (2009), J. Geophys. Res., 114, A02314; *Briggs et al.* (2011), Geophys. Res. Lett., 38, L02808; *Østgaard et al.* (2012), J. Geophys. Res. 117, A03327