Clues to the origin of X-ray flares with *Swift* and *Fermi*

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on behalf of the Fermi/LAT collaboration

The X-ray Flares Project

- **Open Issue**: do X-ray flares require a long duration and/or re-activation of the central engine activity? *Swift* observations alone can be explained by a variety of models.

- **Goal**: constrain the mechanism underlying the X-ray flare emission

- **Method**: broad-band analysis from optical to GeV energies: correlate the temporal and spectral behavior as observed by *Swift* and *Fermi*

The X-ray flares sample

- 140 *Swift* GRBs (2008 Aug - 2010 Aug) with rapid repointing
- 49 (35%) show bright X-ray flares at early times (<1000 s)
  - » only one short GRB
- 12 with good LAT observations: $\theta_{LAT} < 65°$ and $\theta_z < 95°$
- Only 4 bursts with known redshift, $<z>\sim 2.1$

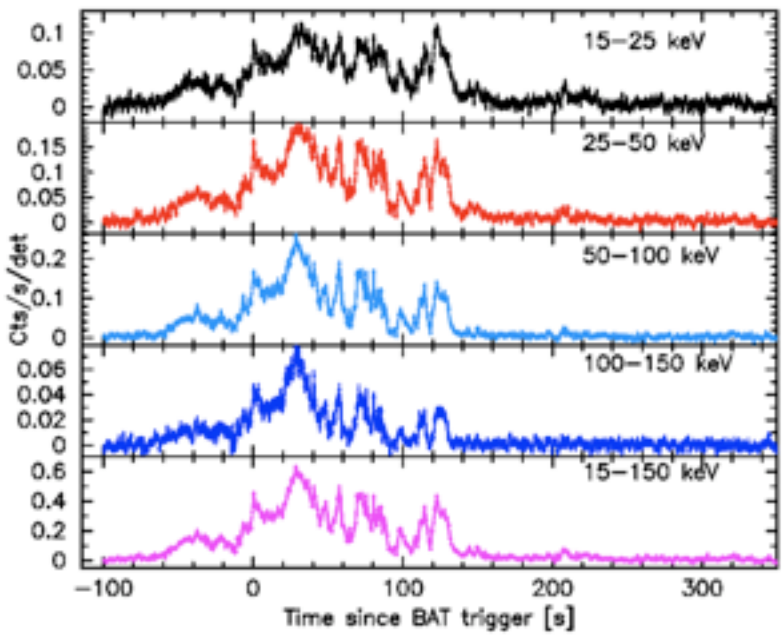
Final sample:

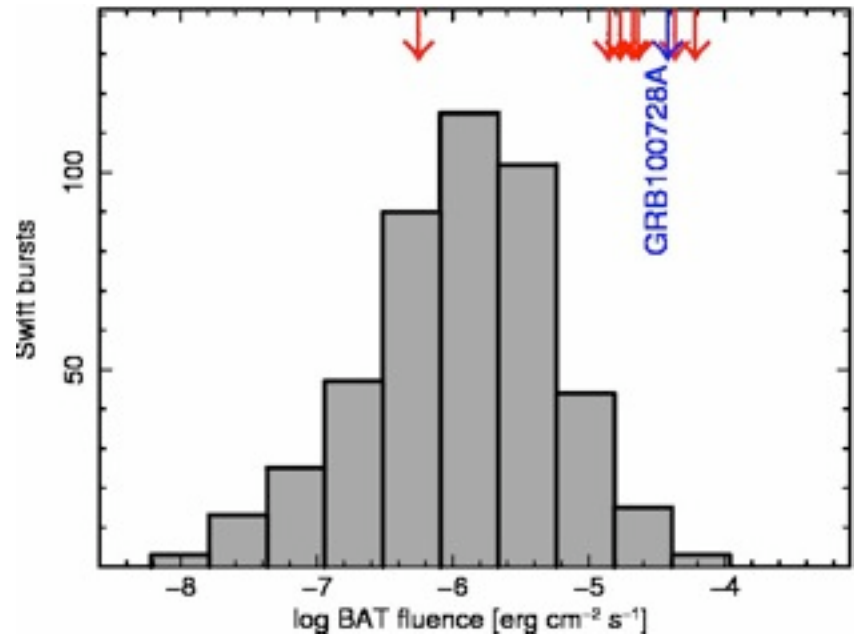
- 29 X-ray flares with simultaneous *Swift*/*Fermi* observations

RESULTS: first detection of HE emission in GRB 100728A

PRELIMINARY RESULTS, FURTHER VERIFICATION IS ONGOING

GRB 100728A: Prompt emission





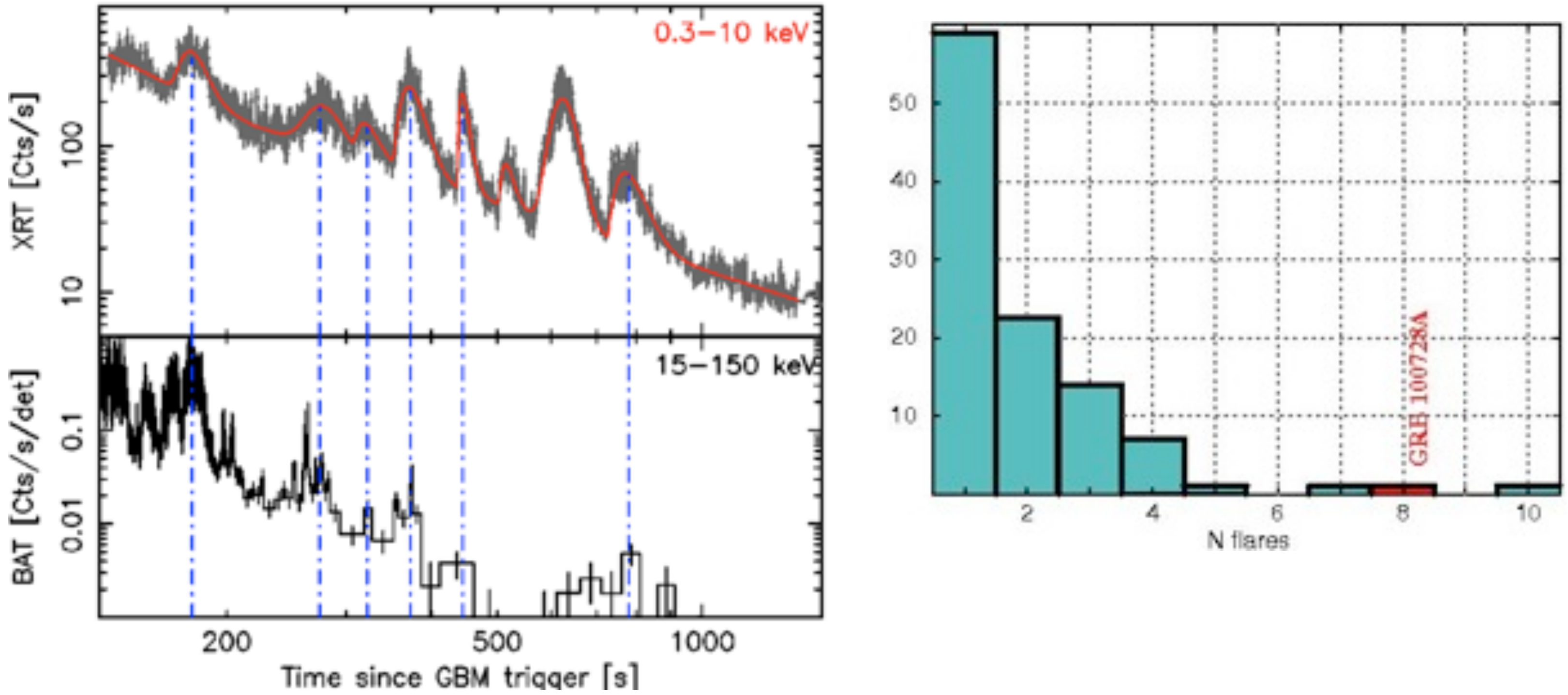
Sakamoto et al. 2010 - BAT 2nd GRB Catalogue
Swenson et al. 2010

Very bright burst: *S* (10-1000 keV) ~ 1.3 x 10^{-4} erg/cm^2/s → *Fermi* ARR

T_{90}~200 s, faint emission seen up to ~750 s in BAT

Typical GRB spectrum: Band (or Cutoff) with peak energy ~300 keV

GRB 100728A: X-ray flares



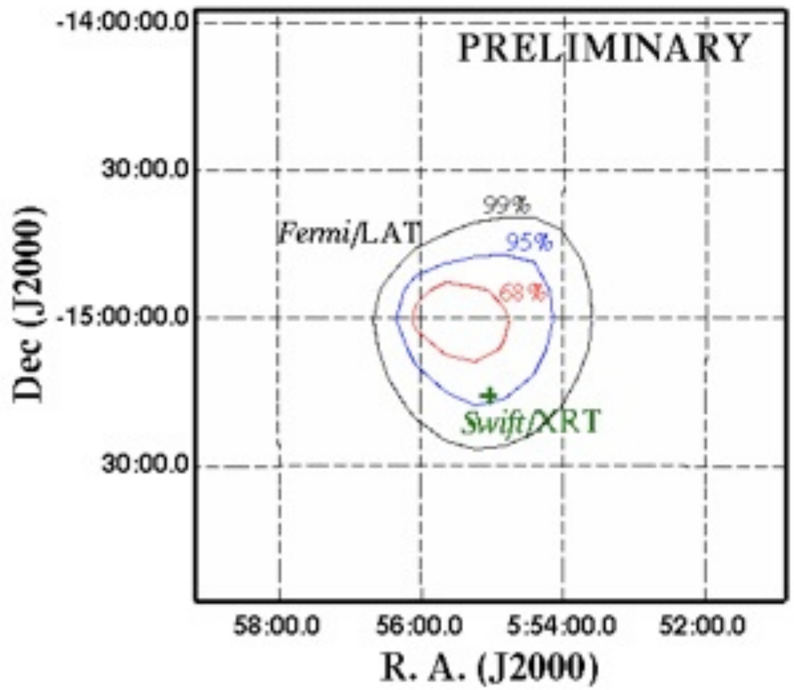
8 bright flares in XRT (from ~150 s to ~850 s) with several peaks visible in BAT
GRB afterglows commonly show one or two flares *(Chincarini et al. 2007,2010)*

FRED profiles, $0.04 < \Delta t/t < 0.2$

<u>Spectra</u>: Band (E_{pk} ~1 - 7 keV) or simple power law (Γ~2), first flare harder

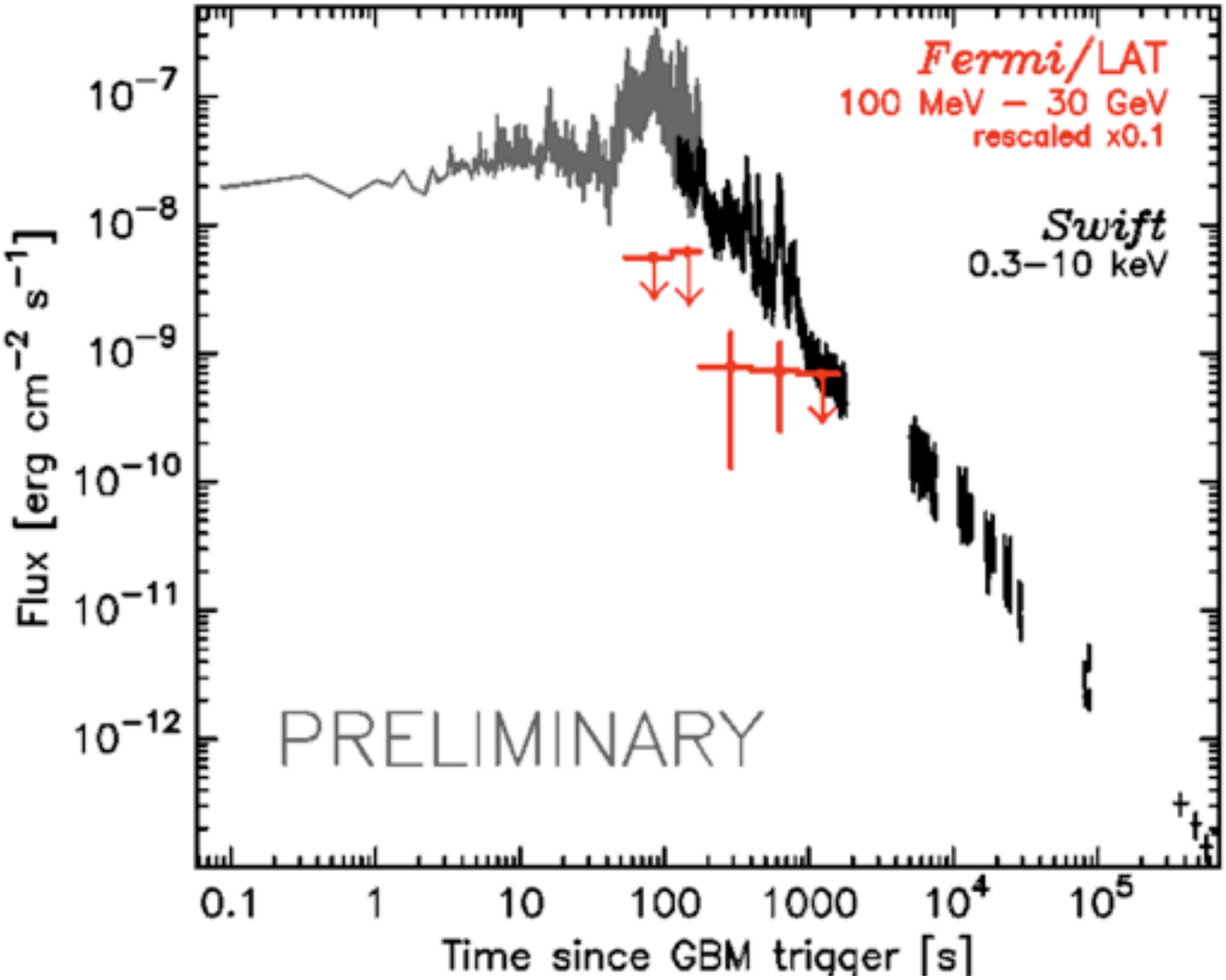
GRB 100728A: LAT detection

- **Time-resolved search**: no detection (TS<11; ~3σ)
- **Time-integrated search**: significant emission (TS~31; >5σ) is detected during the whole flaring duration. Coincident with the GRB position.



- Preliminary tests detected no substantial emission in the LAT energy range before (from T_0 to T_0+200 s) or after (from T_0+900s to T_0+1800 s) the flares. However, poor observations during prompt (θ_{LAT} ~ 58°)

Swift/*Fermi* light curve



Properties of the LAT emission

- **TEMPORAL**
  - temporally extended high-energy emission (under verification)
  - no significant correlation between the XRT and LAT light curves, however the sensitivity of the analysis is limited by the low statistics in LAT and the high duty cycle of flares.

- **SPECTRAL**
  - **hard spectrum: 1.4 +/- 0.2** (1 σ), while the average X-ray photon index is Γ_X=2.24
  - fluence [100 MeV - 30 GeV] ≈ 1.5 x 10^{-3} ph/cm^2, consistent with the extrapolation of the X-ray flares spectrum
  - *95% UL during prompt emission* ≈ 4.5 x 10^{-3} ph/cm^2 , consistent with the extrapolation of the Band spectrum

Some preliminary considerations

X-ray flares are usually associated to Internal Shock.

The observed GeV emission can in turn be produced:

- by the same IS process. The requirement on optical thickness for pair production ($\tau_{\gamma\gamma}<1$) requires a Lorentz factor **$\Gamma>50\ t_v^{-1/6}$**. In this context there are two solutions:
  - **Synchrotron:** the extrapolation of the X-ray spectrum into the GeV range appears consistent with the observed GeV flux level but only marginally with the LAT spectral shape;
  - **Inverse Compton:** the GeV spectral shape can be accounted by an IC component peaking in or above the LAT range. However $\nu_m(IC)=\gamma_m^2\nu_m(Syn)$ requiring $\gamma_m\geq 1000$. As $\gamma_m=1800\varepsilon_e$ this would imply ε_e **>0.6**
- External IC onto the electrons of the forward shock: we expect only a faint emission (anisotropy, dilution of target photons)

Conclusions

Detection of high-emission emission in GRB100728A during a period of intense X-ray flaring activity:

- *Fermi* Automated Repointing was fundamental for the detection
- suggestive of a connection between the two emission components, though other interpretations remain viable (low statistics in LAT)
- LAT extended emission: afterglow or central engine?
- simultaneous *Swift*/*Fermi* observations are crucial: *Swift* can greatly enhance the *Fermi* science and vice versa