High Energy Emission from short GRBs

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Motivation

Recent detection by the AGILE and Fermi satellites of high energy emission from short GRBs calls for a reconsideration of this type of bursts as high energy sources:

❑ Before AGILE/Fermi observations, high energy emission was expected to be more likely detected in coincidence with long GRBs, because of the higher equivalent isotropic energy and ISM number density (e.g. Nakar 2007).

❑**GRB 081024B, GRB 090510**: these short GRBs point to the existence of a longer-lasting high energy tail (GeV range), following the main event.

This talk

Under what conditions the observations can be accommodated within the most popular models for GRB emission?
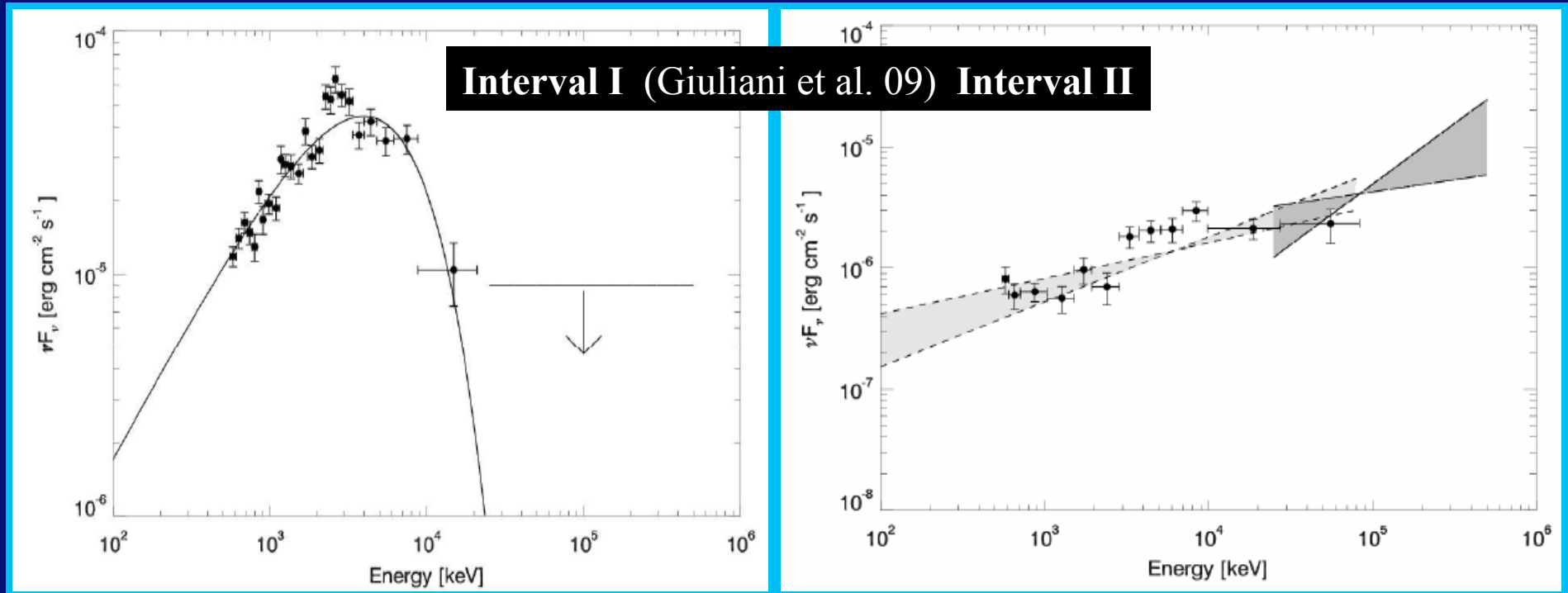
GRB 090510: emission during the first 1s

☐ Interval I: $[T_0, T_0+0.2$ s$]$ (see Giuliani et al. 2009)

☐ Interval II: $[T_0+0.2$ s, $T_0+1.2$ s$]$ (see Giuliani et al. 2009)
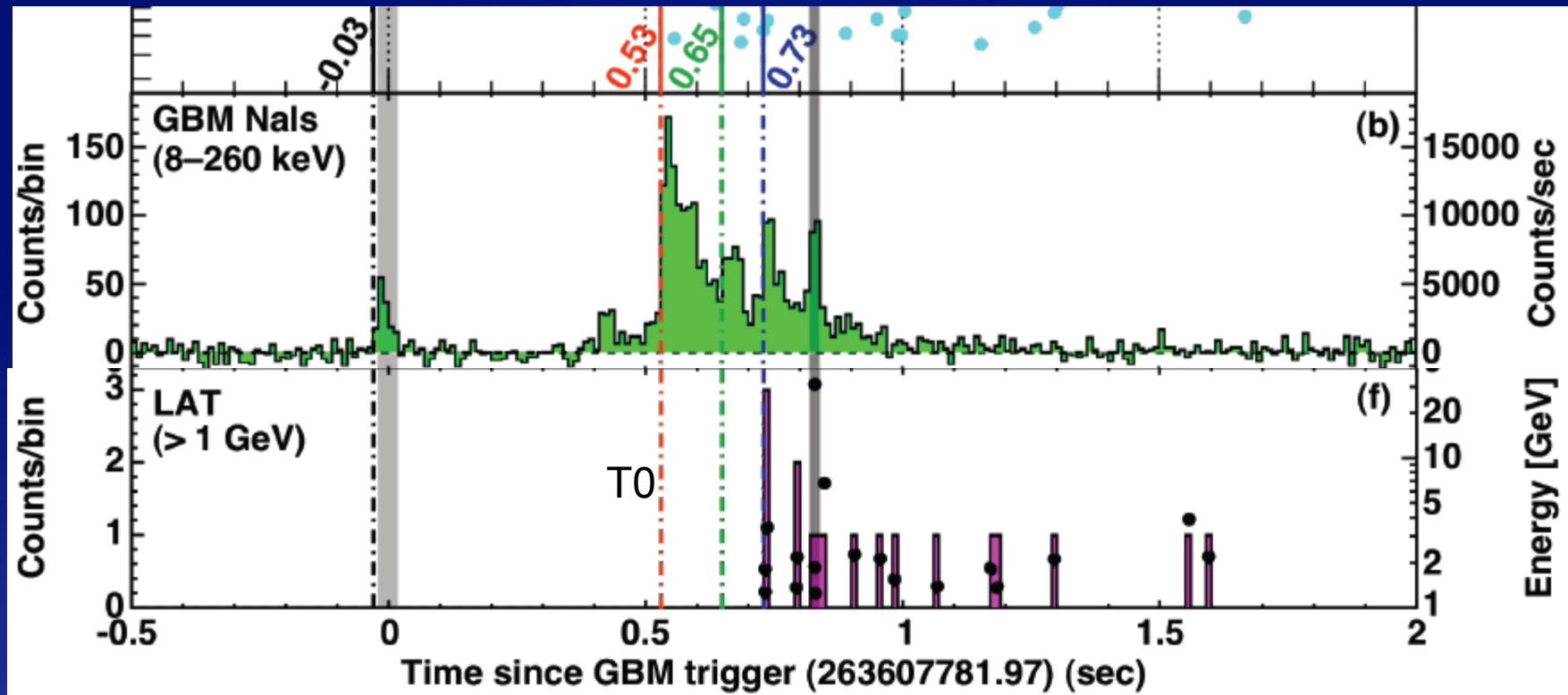
Abdo et al. 2009

GRB 090510: emission during the first 1s

Interval I (Giuliani et al. 09) Interval II

❏ **Optically thick in interval I:** power-law with exponential cutoff at 2.8 MeV (Giuliani et al. 2009) or Band model with E_{peak}=2.8 MeV, α=-0.59 and β<-5 (unusually small compared to typical values, Abdo et al. 2009). Steep high energy slope can be caused by pair production on an underlying Band spectrum with a more typical β=-2.5; this requires τ_{pair}~27 @ 100 MeV.

❏ **Optically thin in interval II:** power-law spectrum with β=-1.58 (Giuliani et al. 2009). Compatible with the Fermi/LAT spectrum. Fermi also detects a 30 GeV photon (Abdo et al. 2009), thus $\tau_{pair}\leq1$ @ 30 GeV.

❏ **Hard-to-soft** evolution ($E_{peak} \sim$ **2.8 MeV in I and $\geq$ 1 GeV in II).**

GRB 090510: pair production

$$\tau_{pair} \sim 0.1 \, \sigma_T \, N_{E>Ean}/(4\pi R^2)$$

❑ Radius of the emitting region: function of Γ → $R \sim 2 \, c \, \Gamma^2 \delta t_{obs}/(1+z)$

❑ E_{an} lowest energy of photons that can form pairs with a photon of energy E_{max}
$$E_{an} \sim (\Gamma m_e c^2)^2/[E_{max}(1+z)^2]$$

❑ $N_{E>Ean}$ num. of photons with $E>E_{an,}$ where $N(E) \propto E^\beta$

$$\Gamma \propto [\tau^{-1} \, E_{max}^{(-1-\beta)} \, \delta t_{obs}^{-1}]^{1/(2-2\beta)}$$

$$\rightarrow \tau_I > \tau_{II} \Rightarrow \Gamma_I < \Gamma_{II}$$

Generally speaking, $\Gamma_I \neq \Gamma_{II}$ could be explained in the IS scenario : we can think the high energy tail being generated by a lately emitted shell, with a **higher** Lorentz factor.

GRB 090510: synchrotron IS model

We need $\tau \sim 27$ @ E_{max}=100 MeV during interval I, and $\tau < 1$ @ $E_{max} \sim 30$ GeV during interval II. Setting δt_{obs}=10 ms, z=0.903, d_L=1.86x10^{28} cm, we get:

$$\Gamma_I \sim 190 \qquad \Gamma_{II} \geq 780$$

In the IS model, this increase in Lorentz factor does not agree with the observed soft-to-hard evolution: E_{peak} =2.8 MeV in I and $E_{peak} \geq 1$ GeV in II. In the IS model **$E_{peak} \propto \Gamma^{-2}$** (e.g. Guetta & Granot 2003), **so $\Gamma_I \leq \Gamma_{II}$ implies hard-to-soft!** NO CONSISTENT WAY TO EXPLAIN THE SPECTRA OBSERVED IN INTERVALS I AND II as SYNCHROTRON radiation by IS.

GRB 090510 : syn+SSC IS model?

Other possibility: emission in I could be synchrotron from IS, while emission II (and up to 100 s) could be SSC from late IS (similarly to what proposed for GRB 081024B, Zou et al. 2009, Corsi et al. 2009). In such a case:
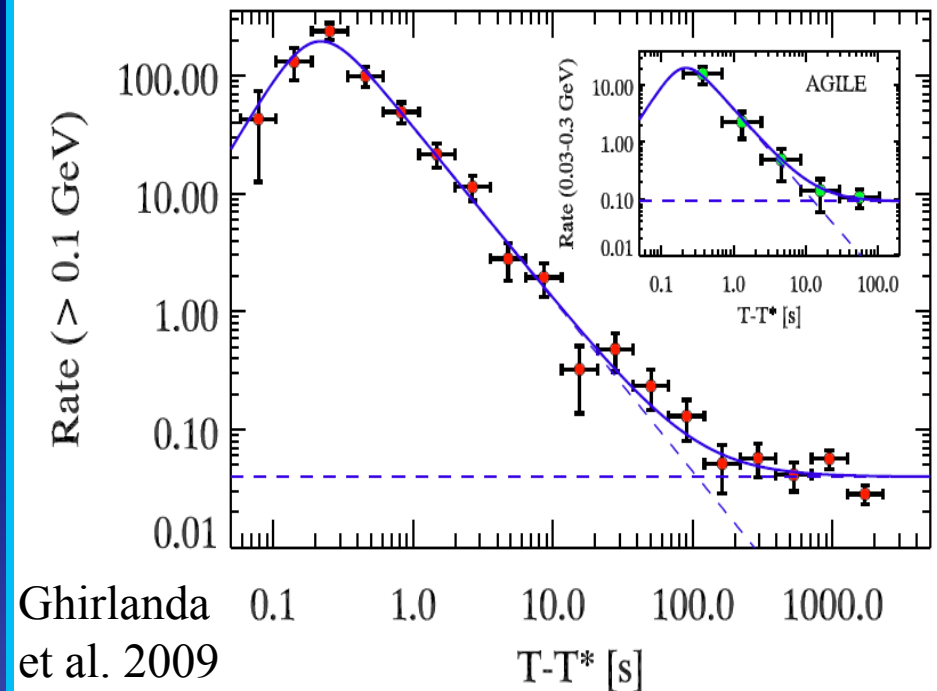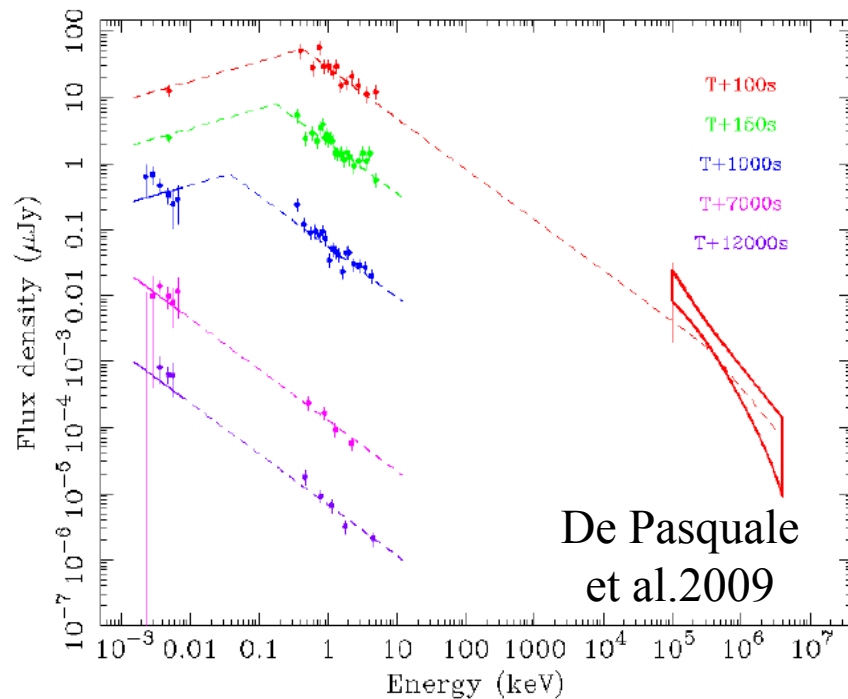
- during II the synchrotron component should be shifted at lower energies (and/or lower fluxes). Consistent with the fact that $E_{peak} \propto \Gamma^{-2}$ and Γ is required to increase from I to II in order to go from optical thick to optically thin.

- emission obse... ES afterglow, BUT the optical to Ge... spectrum!

GRB 081024B

Corsi, Guetta, Piro, arXiv:0905.1513
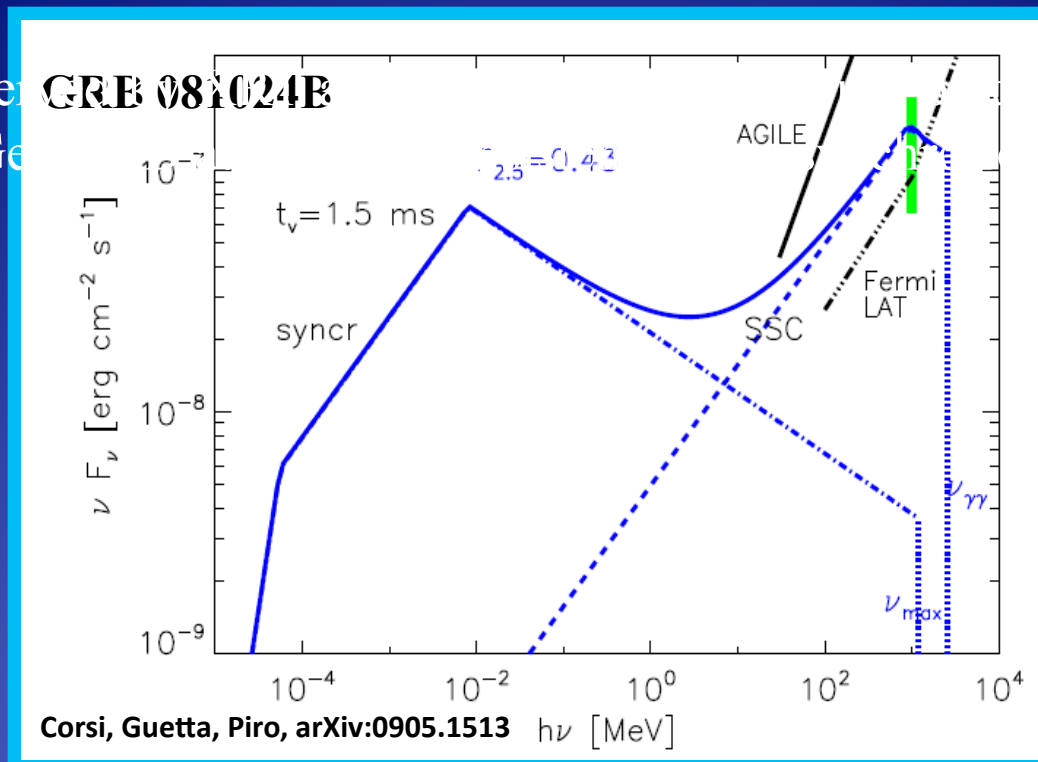
$L_{52}=10^{-3}$
tv=1.5 ms
$\varepsilon_e=0.45$
$\varepsilon_B=0.1$
p=2.5
z=0.1
$\Gamma_{2.5}=0.43$

GRB 090510 within the ES model

De Pasquale
et al.2009

Ghirlanda
et al. 2009

The high energy emission during interval II (and subsequent 100 s tail observed in the LAT) may be due to the ES:

- De Pasquale et al. 2009: broad-band spectral analysis (UVOT, XRT,LAT);

- Ghirlanda et al. 2009: the temporal behavior of the tail observed in the LAT;

- previous suggestions that HE emission could arise from ES (syn only or syn+SSC context, e.g. Sari & Esin 2001; Galli & Piro 2008; Zou et al. 2009 etc.)

GRB 090510: ES modeling

We have modeled the broad-band emission in the ES model (using the prescriptions by Sari et al.1998), to test the existence of a reasonable set of parameters (Corsi, Guetta, Piro in prep. 2009; see also Kumar & Duran, arXiv0910.5726).

-Low density (10^{-5} cm^{-3}), consistent with merger progenitor scenario (e.g. Belczynski et al. 2006)

- $\Gamma_0 = 7.3 \times 10^3$: Lorentz factor very high to have $t_{dec} \propto (E/n)^{1/3}\Gamma^{-8/3} \sim 0.2$ s

- Energy very high for a short. With a jet break @ 5×10^3s, one has $\theta \sim 0.34^o$ and E $\sim 6 \times 10^{48}$ erg, in the short GRB energy range.

GRB 090510: conclusion

❑ The emission during interval II (and the subsequent tail observed for about 100 s by the LAT) might be due to the ES (see Ghirlanda et al. 2009): a set of reasonable values for the fireball parameters can indeed be found to explain the broad-band observations (Corsi, Guetta, Piro in prep.).

❑ Other possible explanation: emission during I could be synchrotron from IS, while emission during II and the subsequent tail could be SSC from IS, emission observed by XRT and UVOT is the afterglow. However, too much of a coincidence having the SED at 100 s being consistent with a single synchrotron spectrum.

The End