The origin of GeV emission in Gamma-Ray Bursts

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Common properties of the high-energy emission:

- ✓ during the usual prompt emission (=emission seen in the keV-MeV range)
- ✓ small delay (few seconds or less) compared to the prompt
- ✓ long lasting

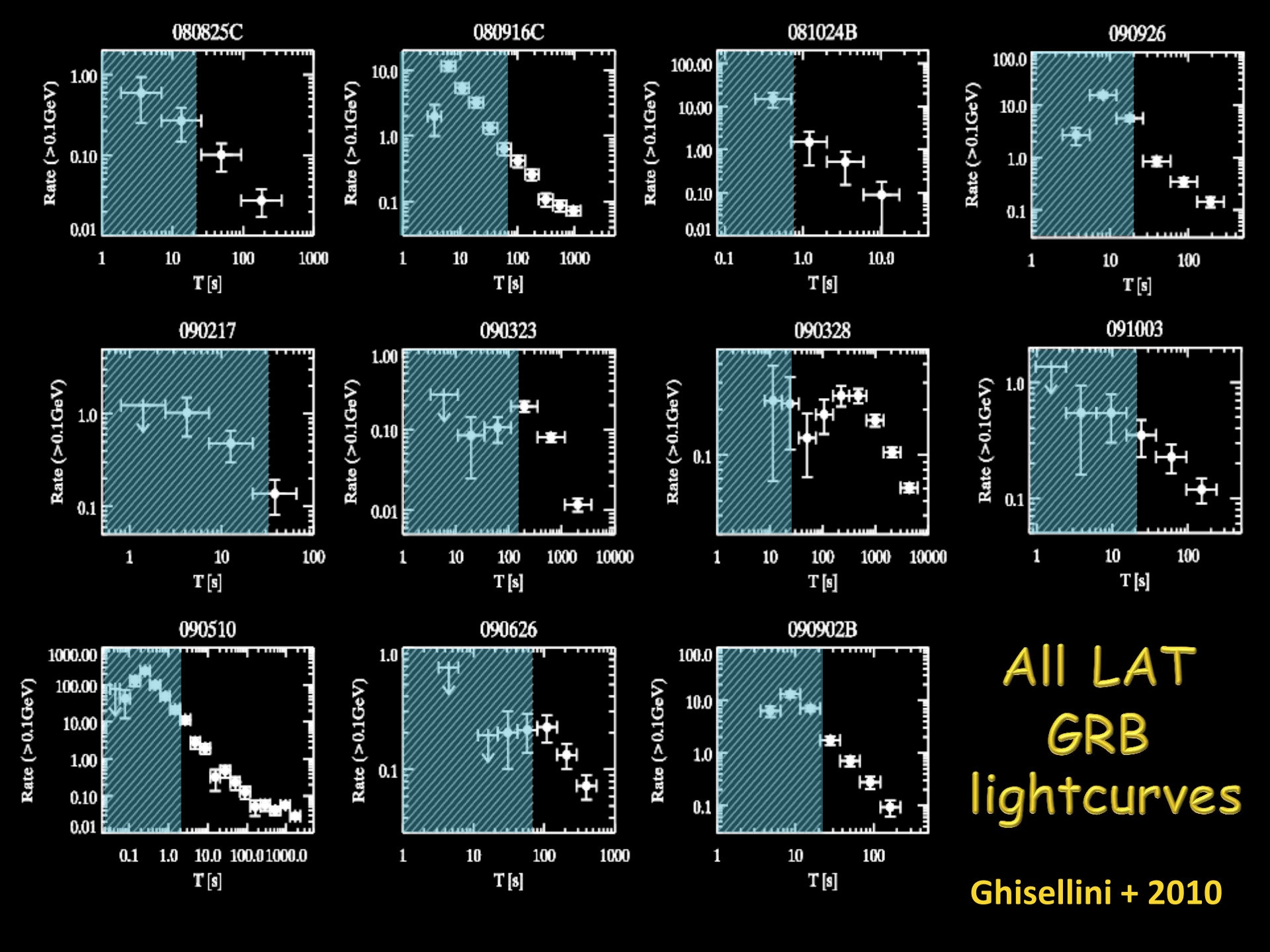
Origin of the high-energy emission?

Other common features?

Spectral and temporal properties

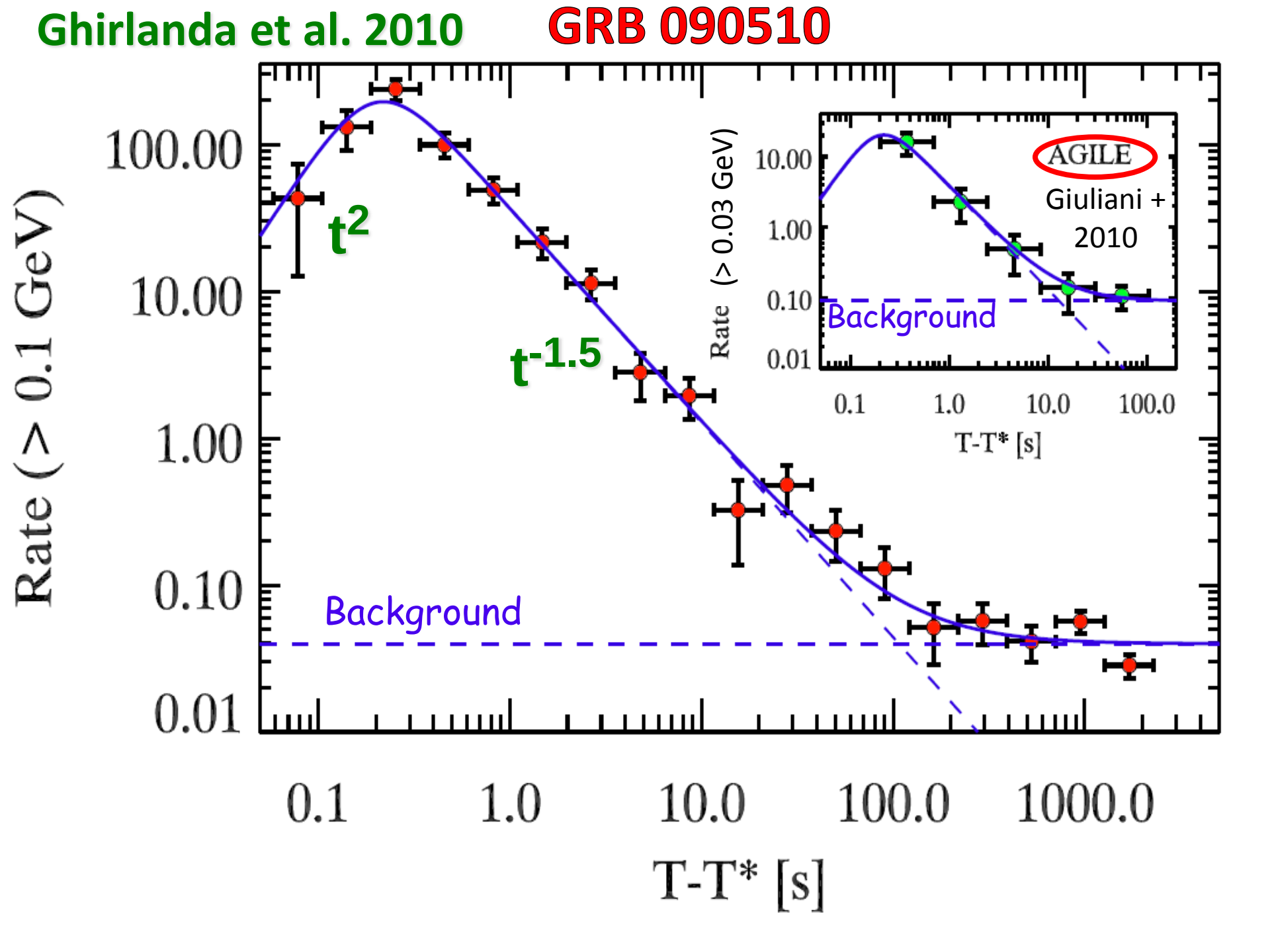
of all bursts with LAT detection
as of Oct. 2009 (11 GRBs - 9 long and 2 short)

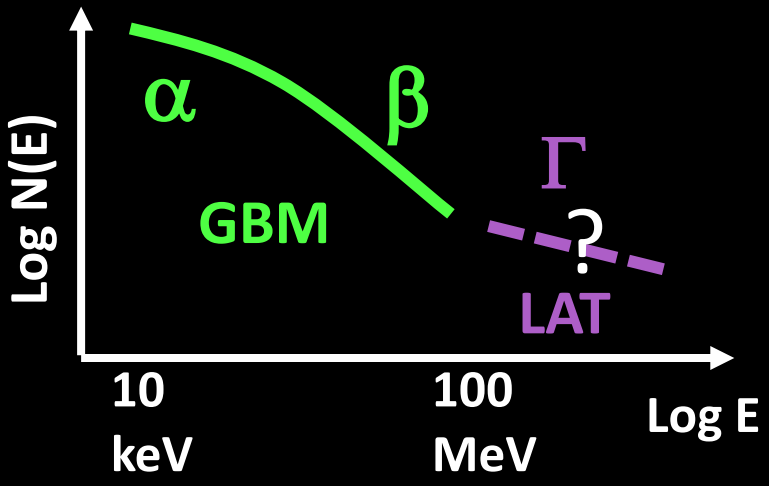
+ 080514B (AGILE/GRID)



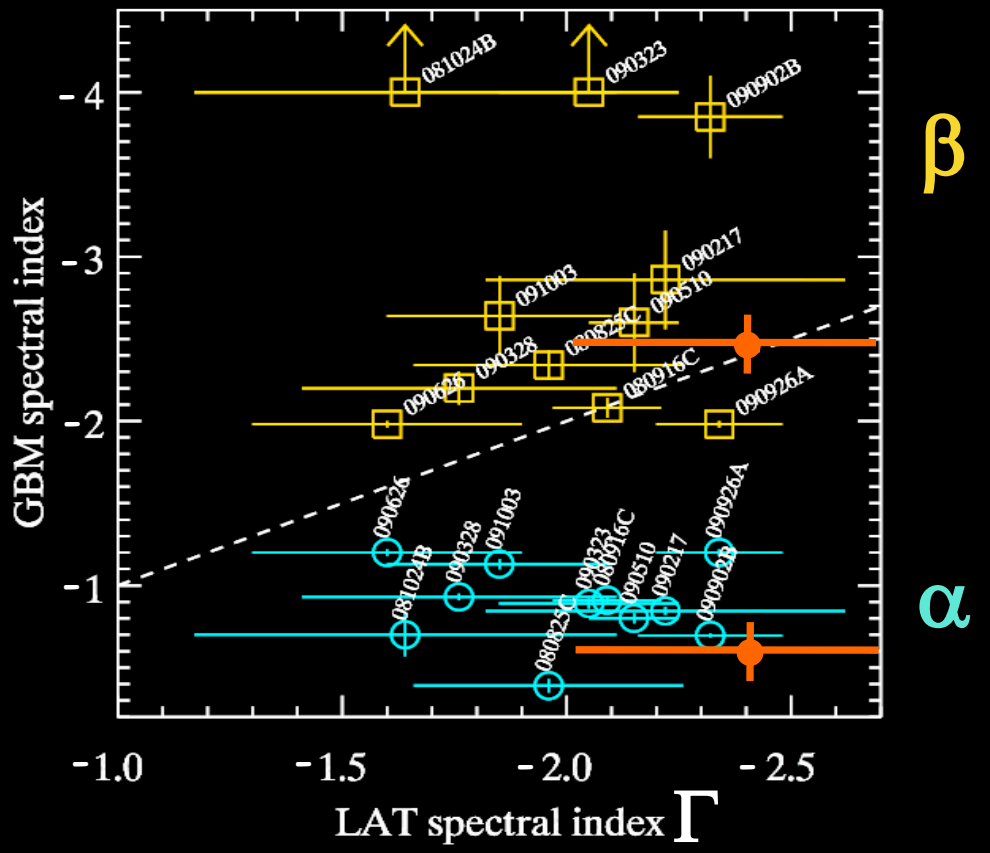
All LAT GRB lightcurves

Ghisellini + 2010

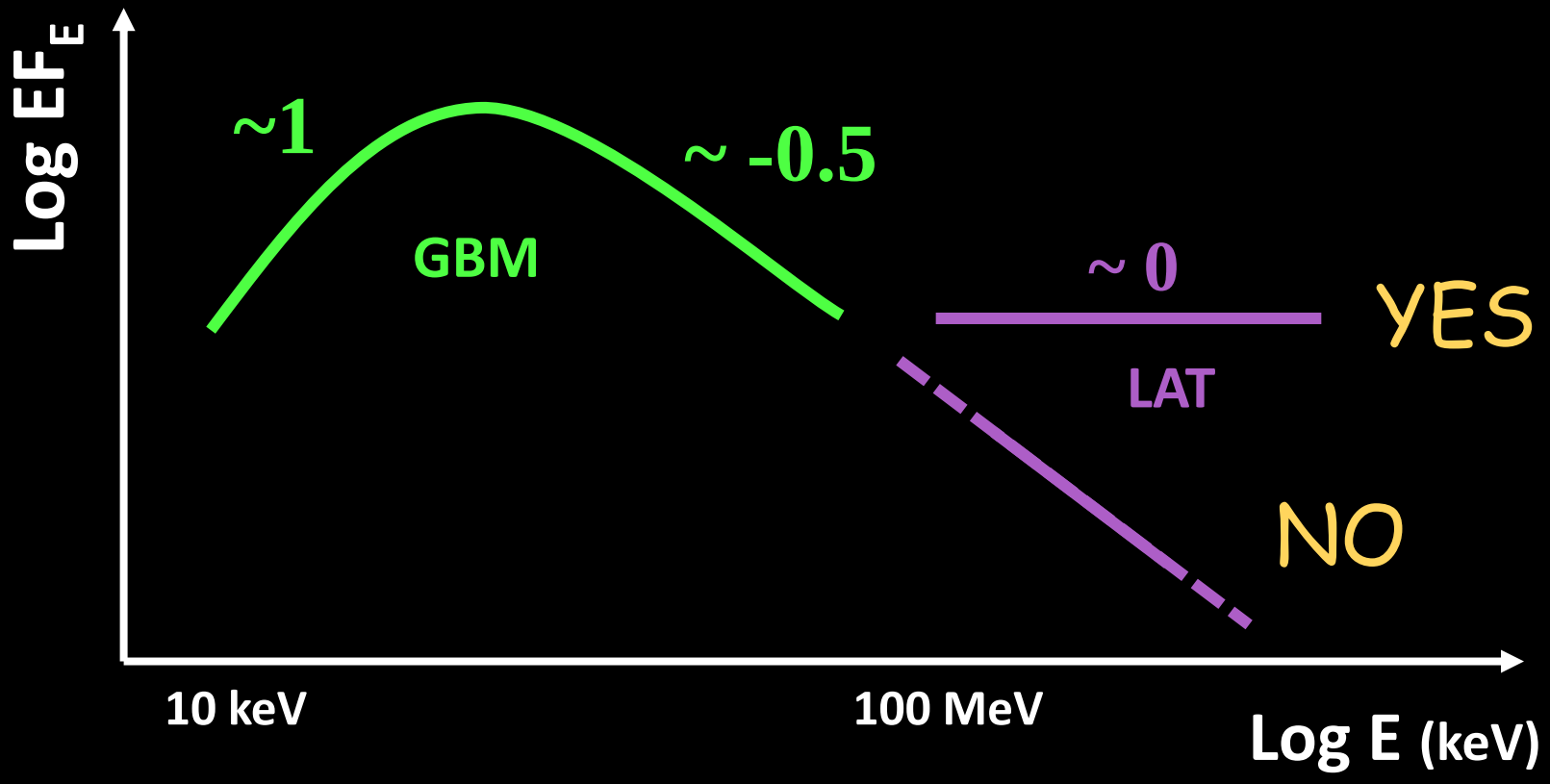

Ghirlanda et al. 2010
GRB 090510
Rate (> 0.1 GeV)
100.00
10.00
1.00
0.10
0.01
t2
t-1.5
Background
0.1
1.0
10.0
100.0
1000.0
T-T* [s]
Rate (> 0.03 GeV)
10.00
1.00
0.10
0.01
AGILE
Giuliani + 2010
Background
0.1
1.0
10.0
100.0
T-T* [s]



Comparison
α vs Γ and β vs Γ

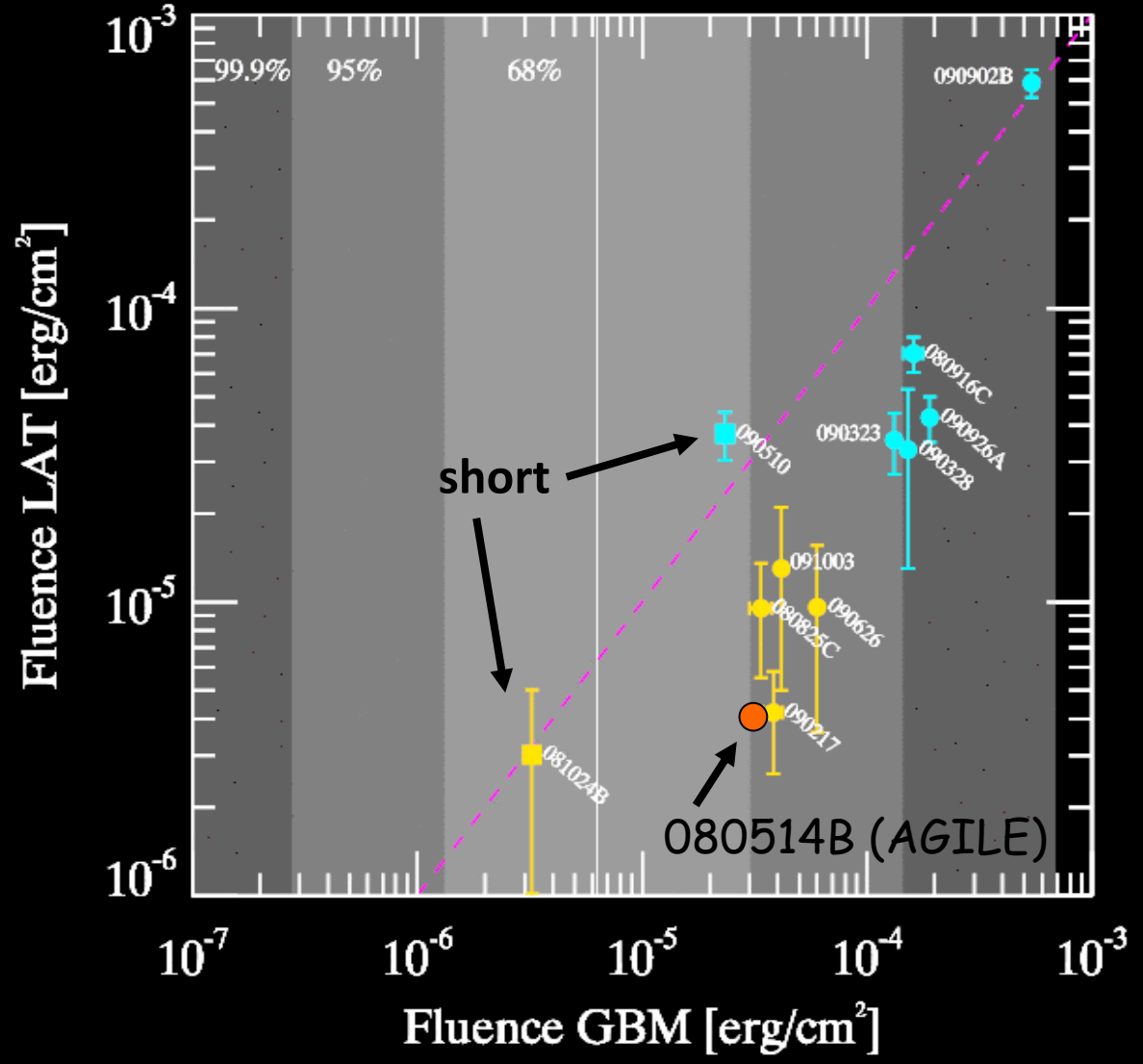


GBM and LAT spectra



Two different components !

GBM vs LAT fluences



Grey regions: GBM fluence distribution of all Fermi bursts

Bursts with redshift

Bursts without redshift

Ghisellini et al. 2010

Spectra

GBM and LAT *inconsistent* → suggest *different component*

Light curves

✓ *smooth* ✓ *peaked* ✓ *similar decay* ✓ *long lasting*

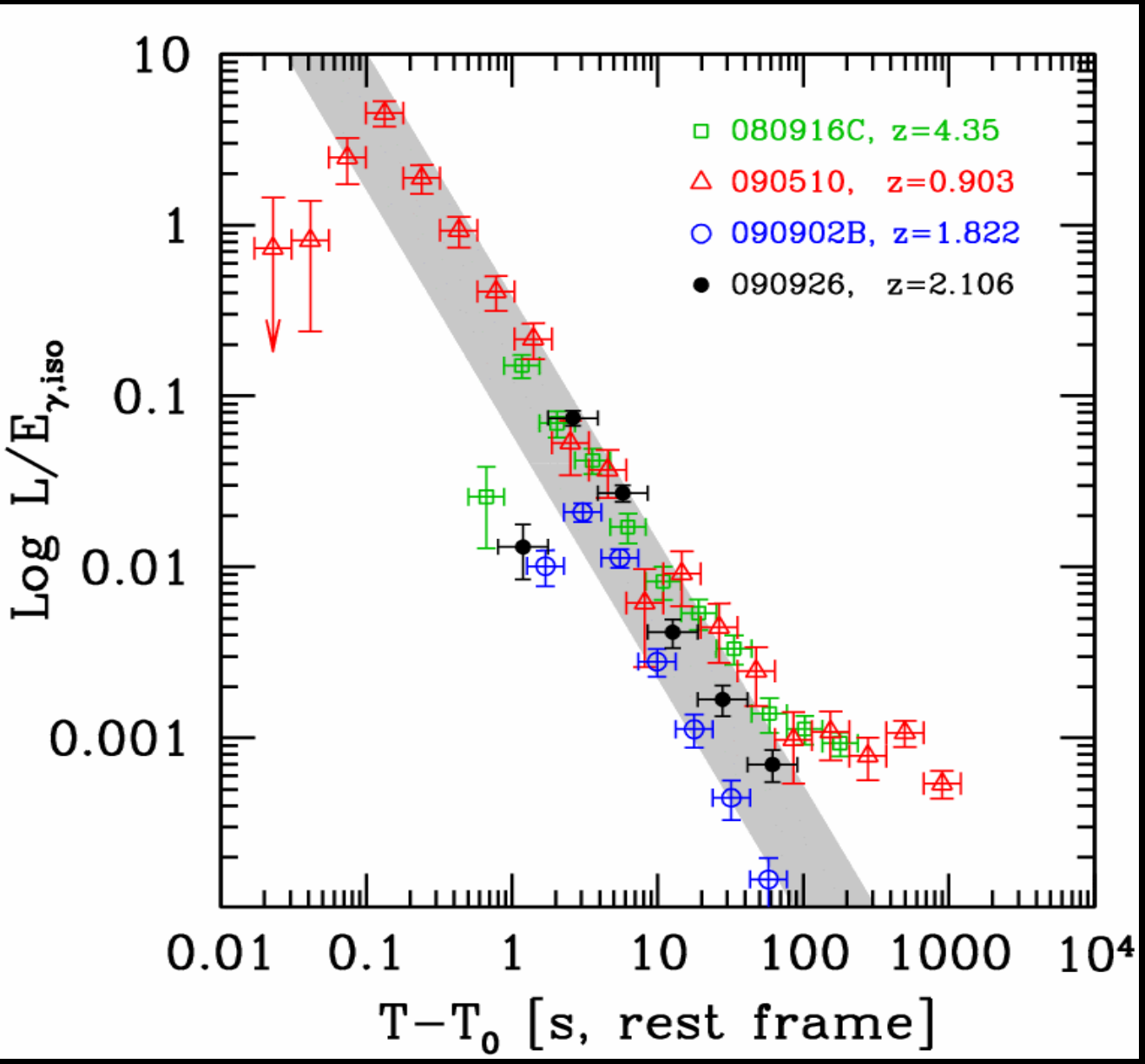
same origin as the X-ray and Optical afterglow:

-- External Shocks --

synchrotron emission from forward shocks

(Kumar & Barniol Duran 2009, 2010; Gao et al. 2009;
Corsi, Guetta & Piro 2010; De Pasquale et al. 2010)

Consistency check 1 - Peak time



4 brightest GRBs (with redshift)

t_{peak} (rest frame) all between 0.15 - 3 sec

Consistency check 1 - Peak time

$$t_{peak}^{rest} \approx 0.3 \left(\frac{E_{k,53}}{\Gamma_3^8 n} \right)^{1/3} seconds$$

E_k = initial kinetik energy of the fireball

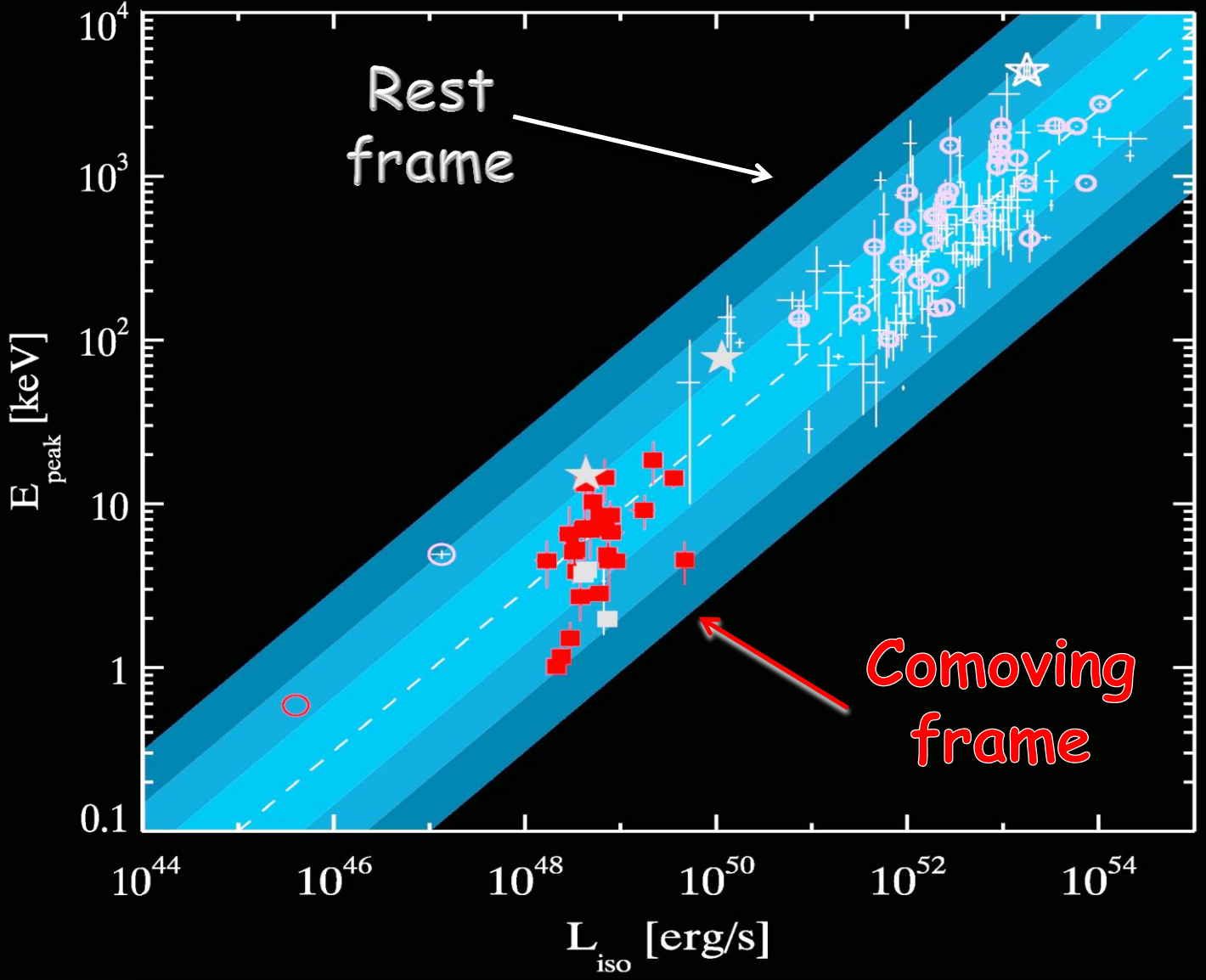
Γ = initial bulk Lorentz factor

n = ISM number density (uniform medium)

Measure of the peak time ⇨ Estimate of Γ

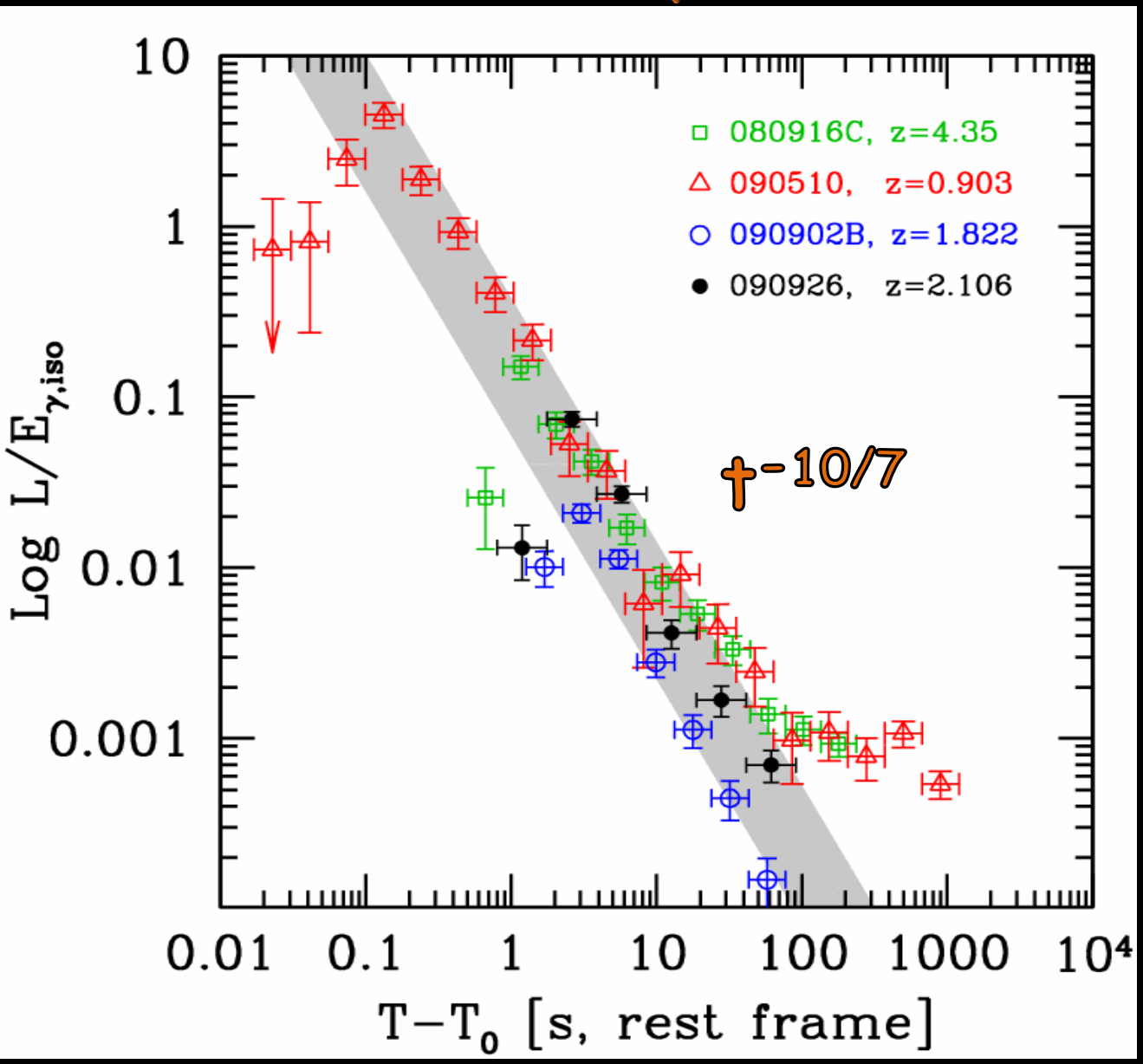
Γ between 600 and 1000 for the 4 brightest bursts

E_{peak}-L_{iso} correlation



Ghirlanda et al. 2012

Consistency check 2 - Decay



"standard" adiabatic afterglow:

t^{-1}

radiative afterglow:

$t^{-10/7}$

ISM pair enrichment
Beloborodov 2002

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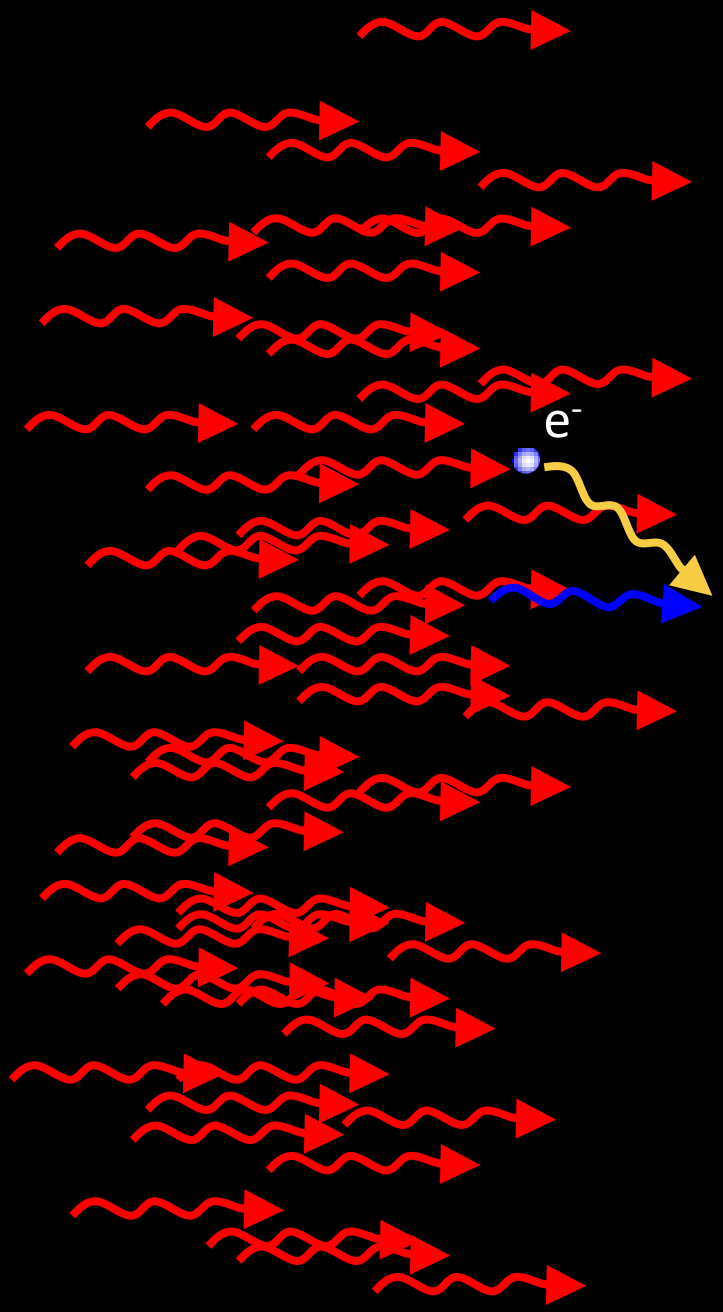
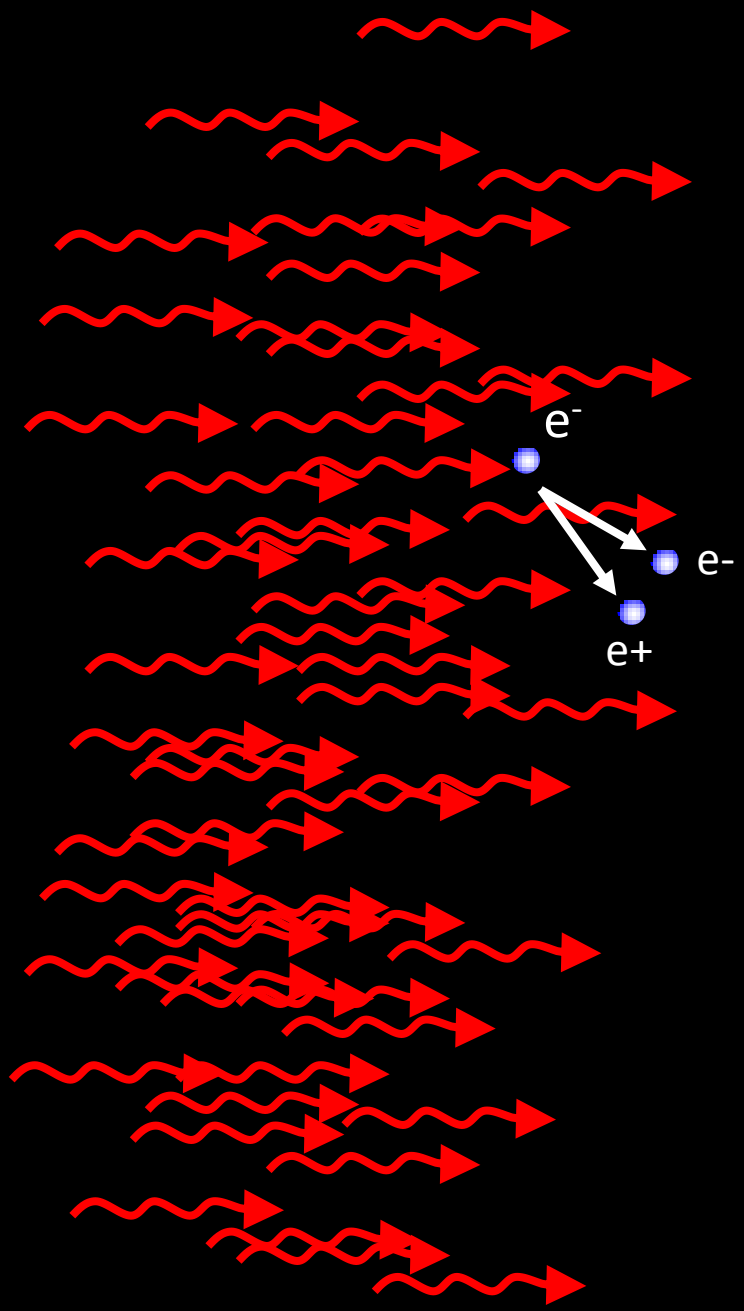
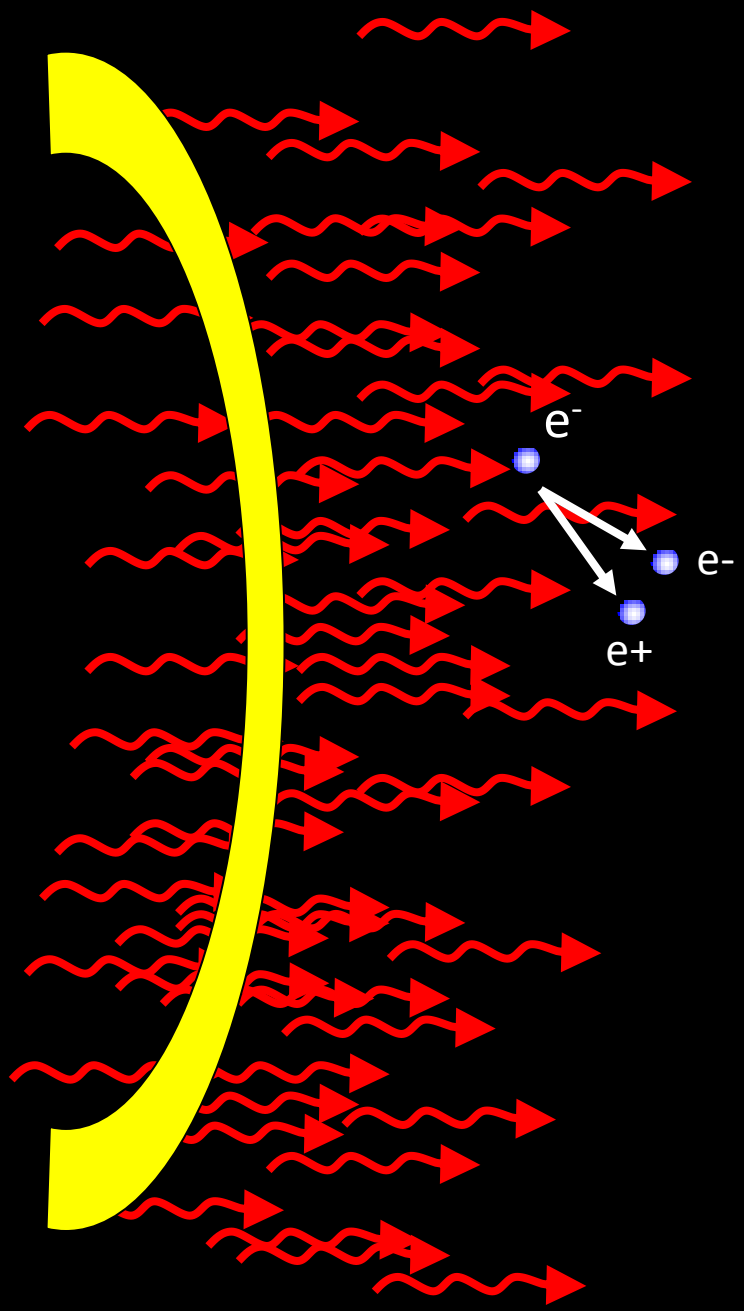


ISM pair enrichment
Beloborodov 2002



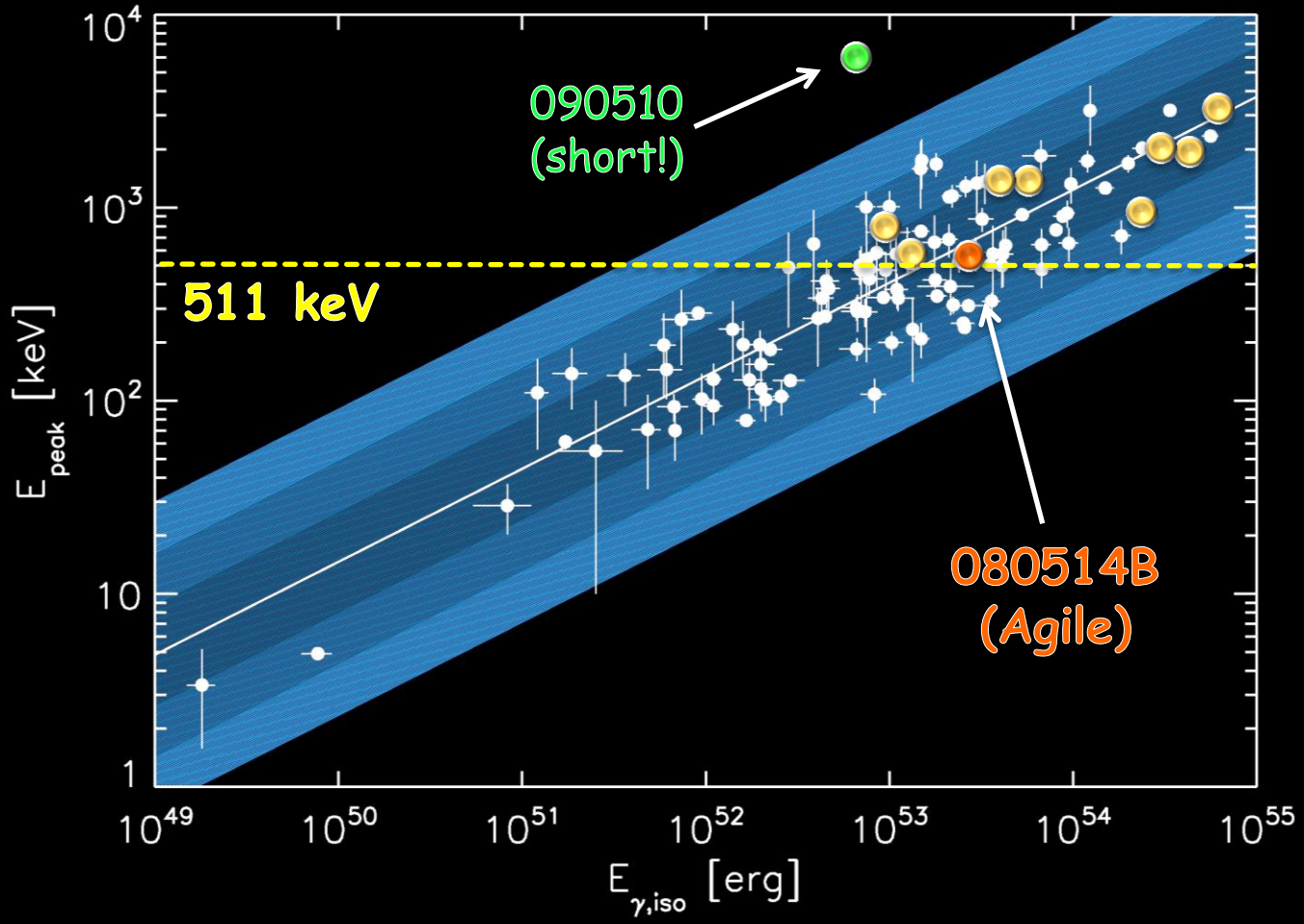
ISM pair enrichment
Beloborodov 2002



Consistency check 3 - Pair enrichment

If pair enrichment is required
GeV detected GRBs should be the ones with

$$E_{peak} > m_e c^2 > 511 \text{ keV}$$



Conclusions

- When Γ is large → early onset of the afterglow → very bright → Fermi/LAT detection
- Decay suggests radiative afterglows
- GeV preferentially in E_{peak}>511 keV GRBs
- E_{aft} increases: it helps to understand E_{prompt}/E_{aft}…but still it does not solve the problem