Gamma Ray Bursts: an observational overview

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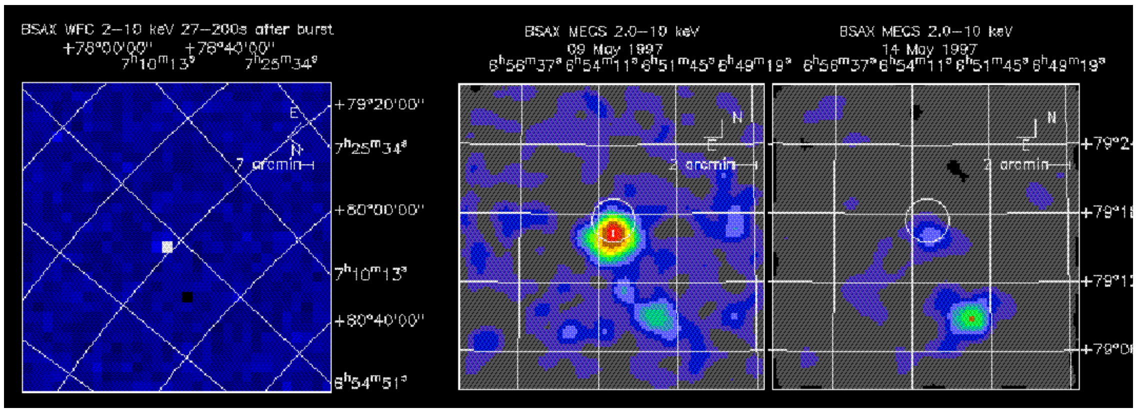
Summary

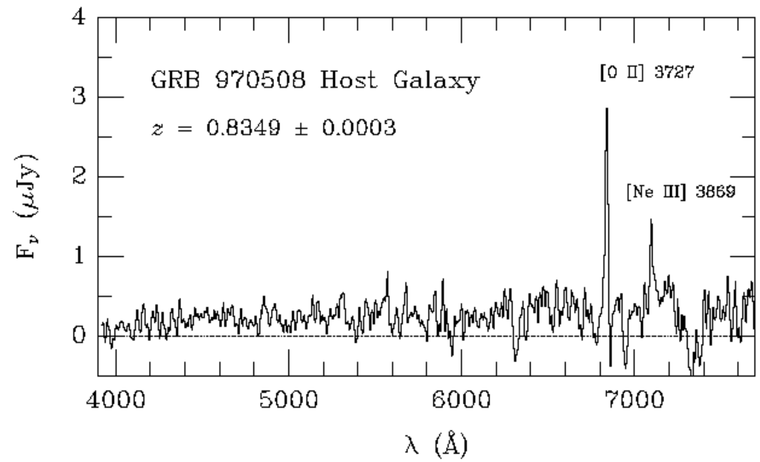
- The prompt and afterglow emission and the jet shock model vs the progenitor
- Off axis (short) GRBs
- High energy emission
- High-z GRBs and Ultralong GRBs

GB970508: the 1st redshift

- BSAX => Keck



Piro et al 98

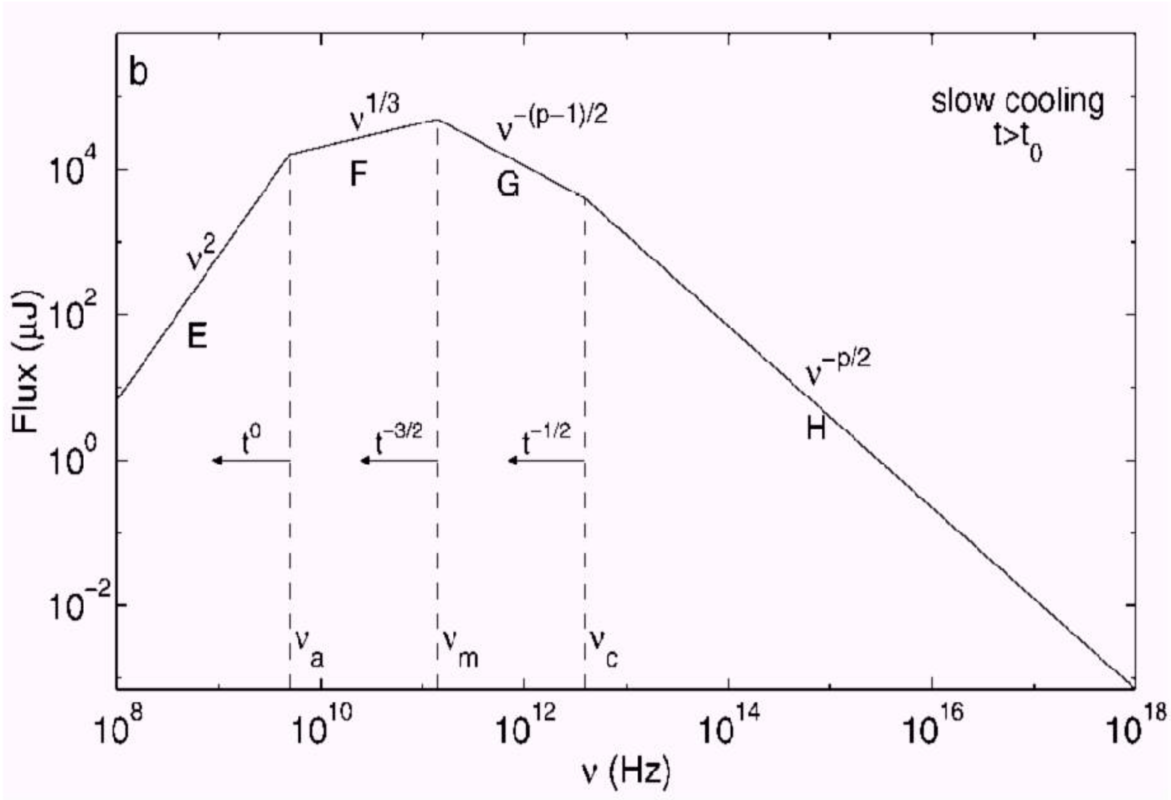


Bloom et al 98

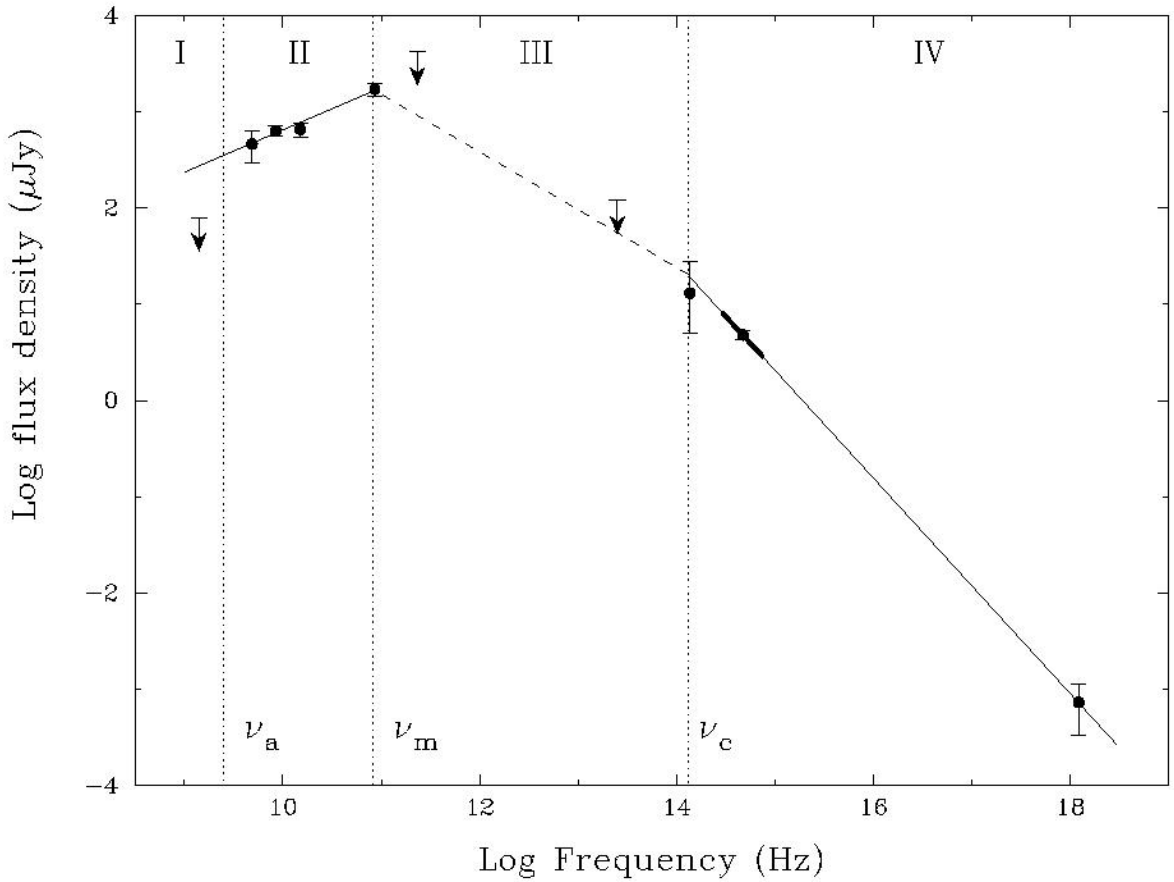
OT and redshift by absorption lines z=0.83: extragalactic(Metzger et al 97)

GRB970508: evidence of relativistic expansion by shock-driven synchotron emission

Sari et al 98



GRB970508: evidence of relativistic expansion by shock-driven synchotron emission



Galama et al 98

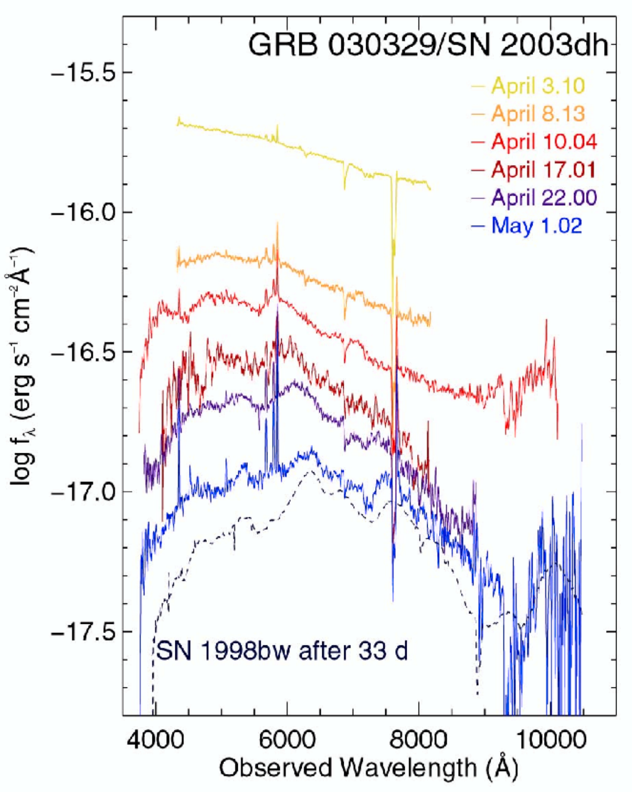
GRB progenitors and and (CC) Supernovae

- GB980425 discovered by BeppoSAX => SN1998bw in a nearby galaxy (Galama etal.98, Pian et al.98)

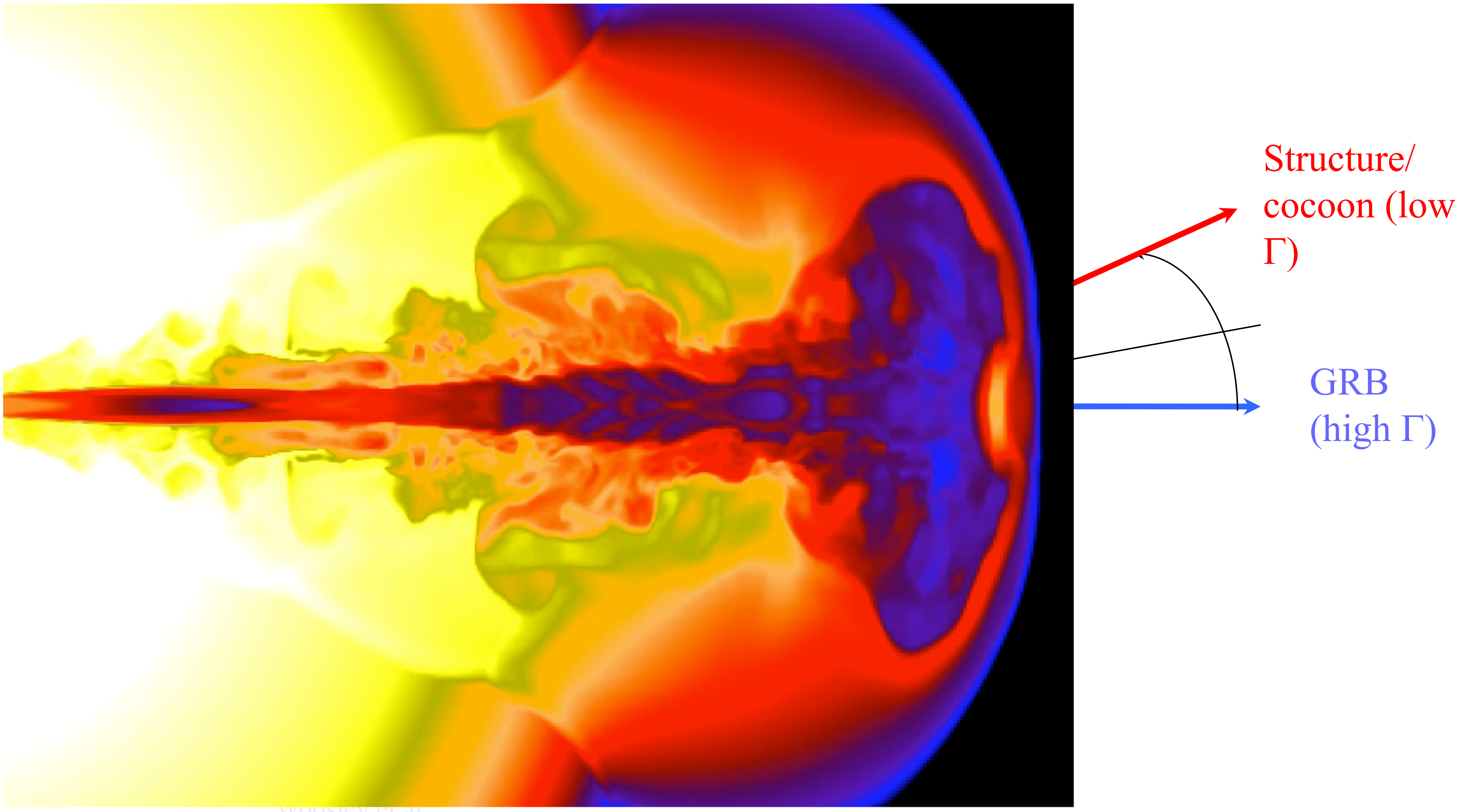
SN 1998bw in Spiral Galaxy ESO184-G82

ESO PR Photo 39a/98 (15 October 1998)

GRB030329: HETE2 GRB) z=0.168
SN spectrum (similar to 1998bw) emerging at about 10 days (Matheson et al 03, Hjorth et al 03).

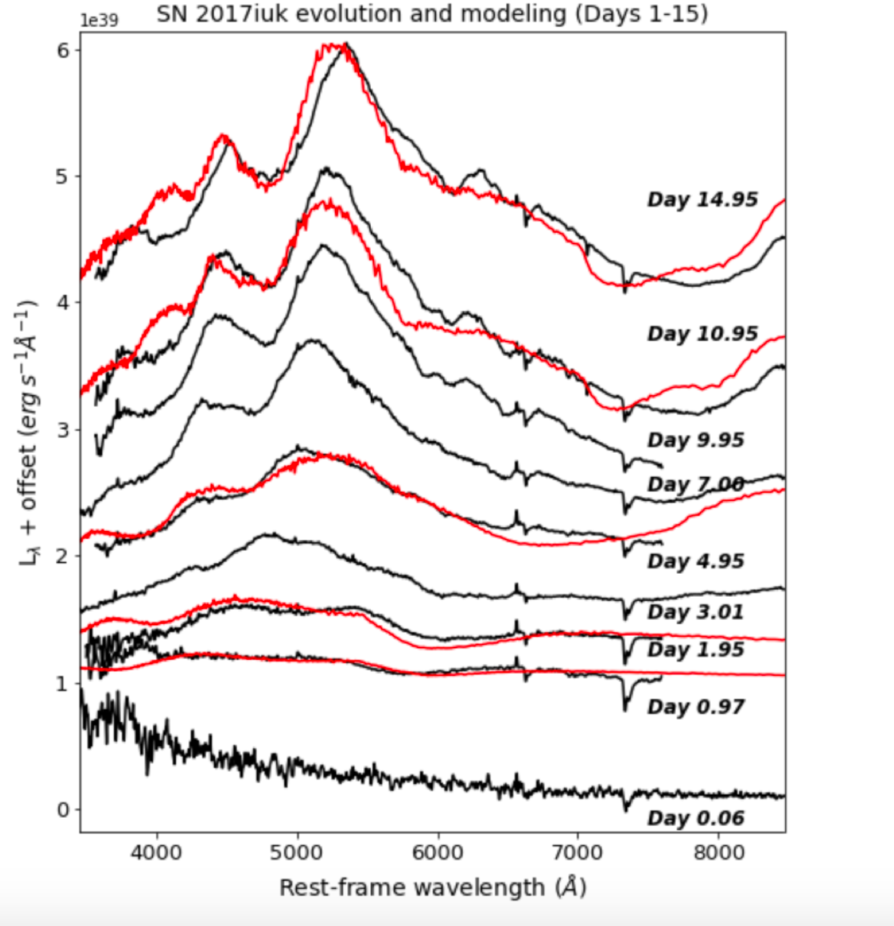


From the progenitor to the jet



Cocoons from Jet-ISM

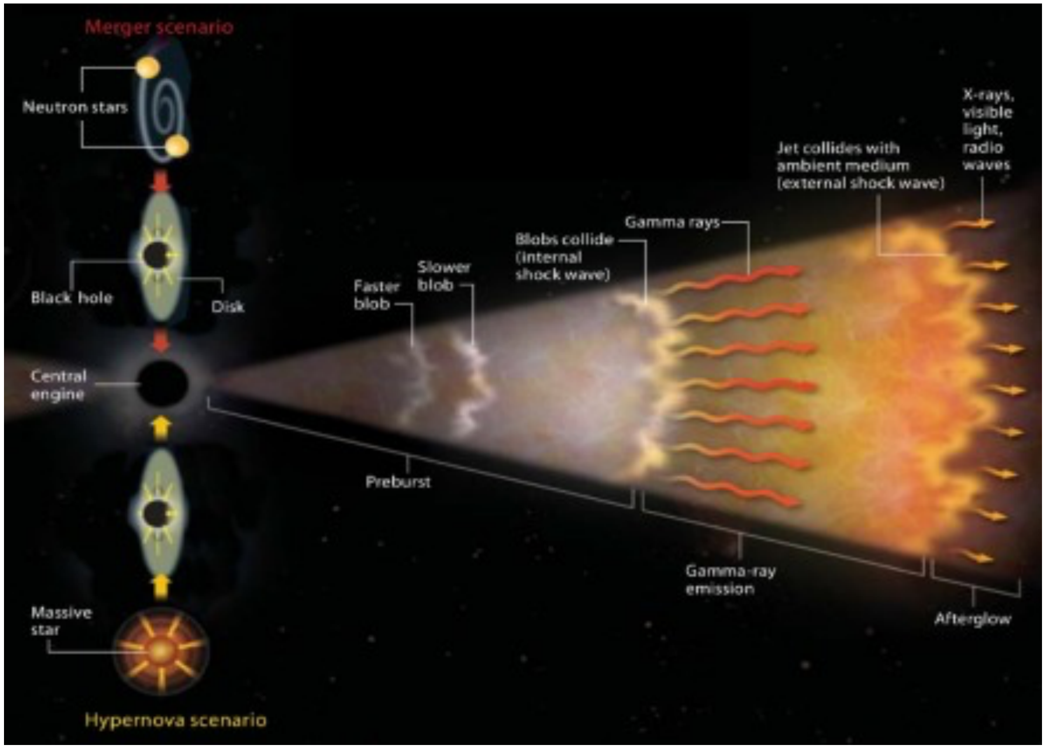
- SN 2017iuk, GRB 171205A
- extremely high expansion velocities of ~ 100,000 km s−1 within the first day
- characterized by chemical abundances different from those observed at later times
- originating from a hot cocoon generated by the energy injection of a mildly-relativistic GRB jet expanding into the medium surrounding the progenitor star



Izzo+19

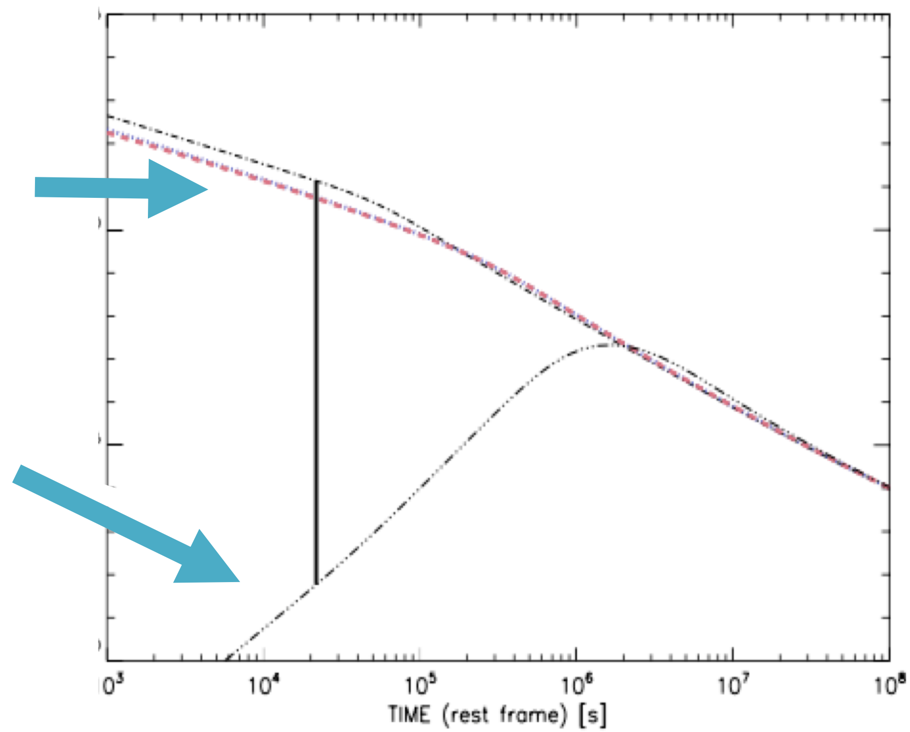
On and off-axis afterglow

- Beaming angle ~ $1/\Gamma$



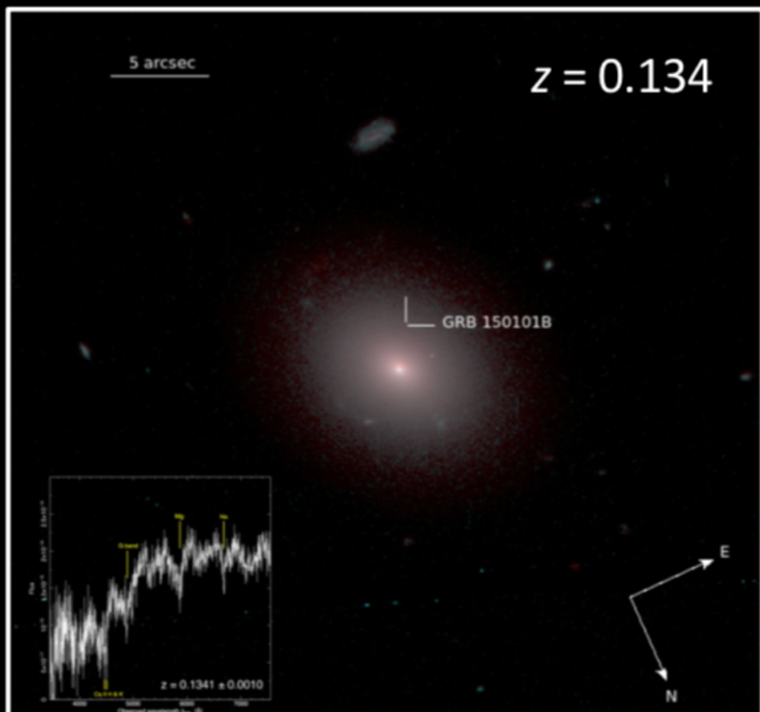
N. Gehrels, LP & P. Leonard 2004

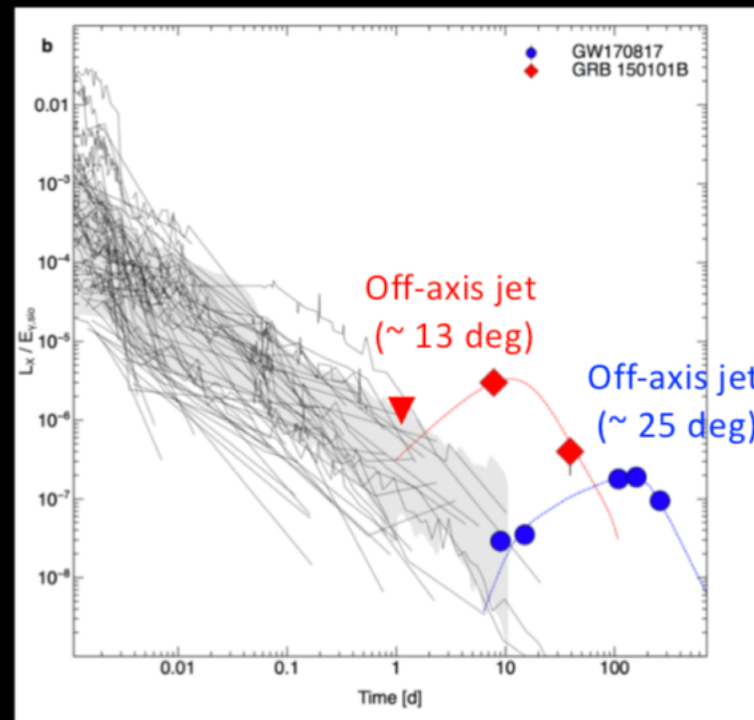
$\theta_V \sim 30$ deg



D'Alessio, LP & Rossi 2006

Off-axis SGRBs: A cosmological analogue to GW170817



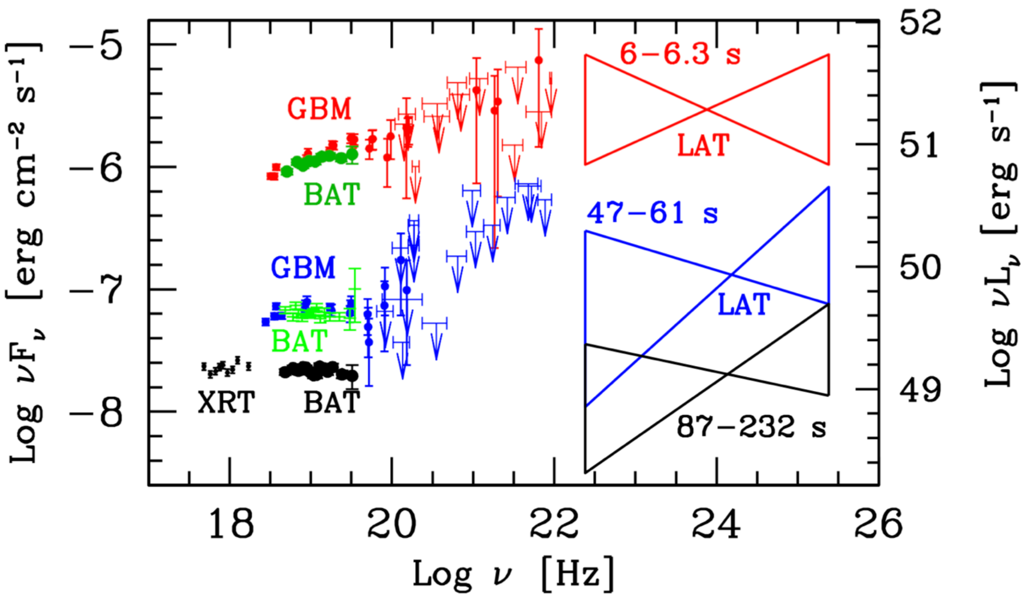


Troja, Ryan et al., *Nature Communications*, 2018

High energy emission

GRB190114C: the First VHE detection

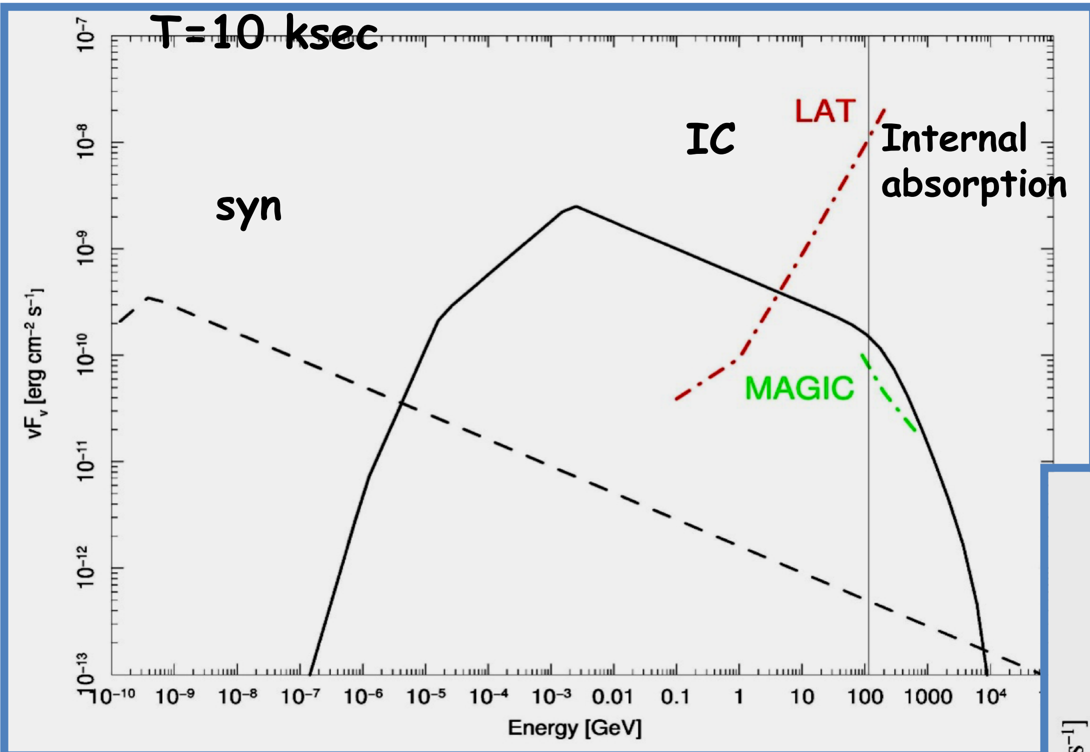
- MAGIC detection at ~50-100 sec at 300 GeV (Myrzoyan+19)
- Max Synchrotron energy (Acceleration scale/Larmor=radiation losses)= $m_e c^2/\alpha_F$= 70 MeV
- => IC component



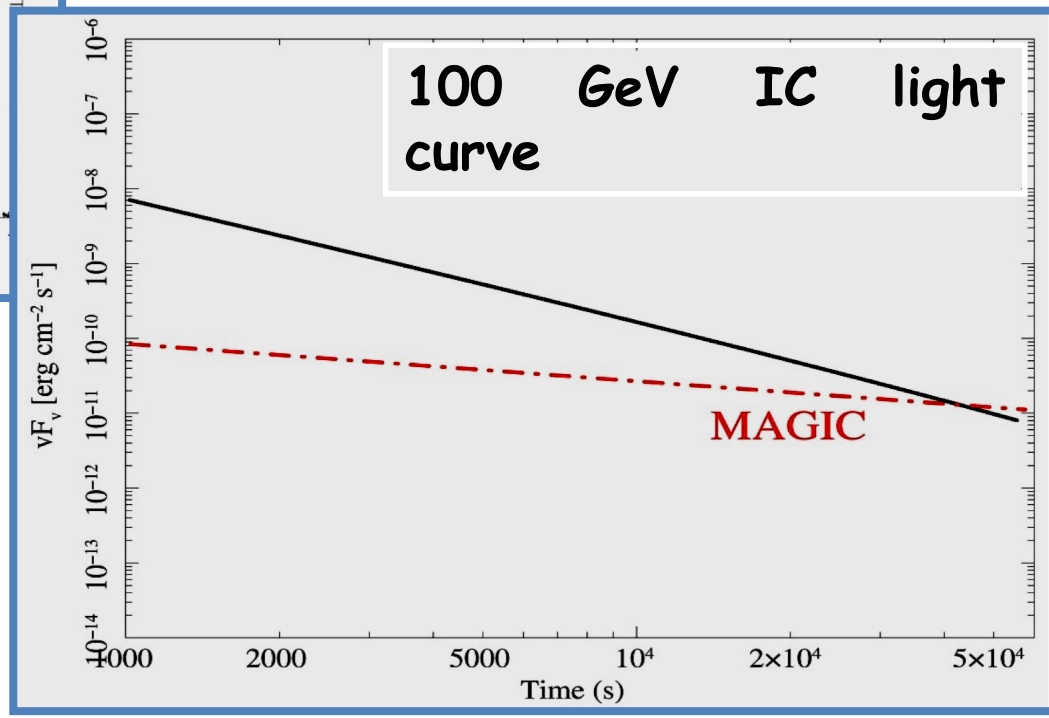
Ravasio et al 19, see also Wang et al 19)

Predictions for the afterglow phase

FAST COOLING: n>3



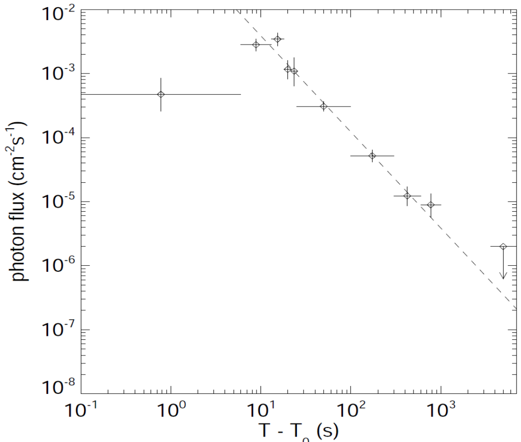
MAGIC can detect HE emission from the afterglow of a GRB (>100 s after the burst) in the 1-100 GeV range.



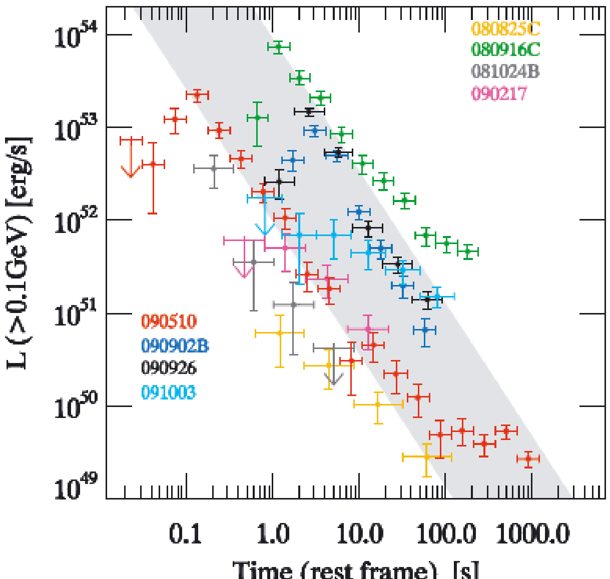
Galli&Piro (2008)

$E_{53}=0.1, n=300, \varepsilon_e=0.2,$
$\varepsilon_B=10^{-3}, p=2.5, z=0.1$

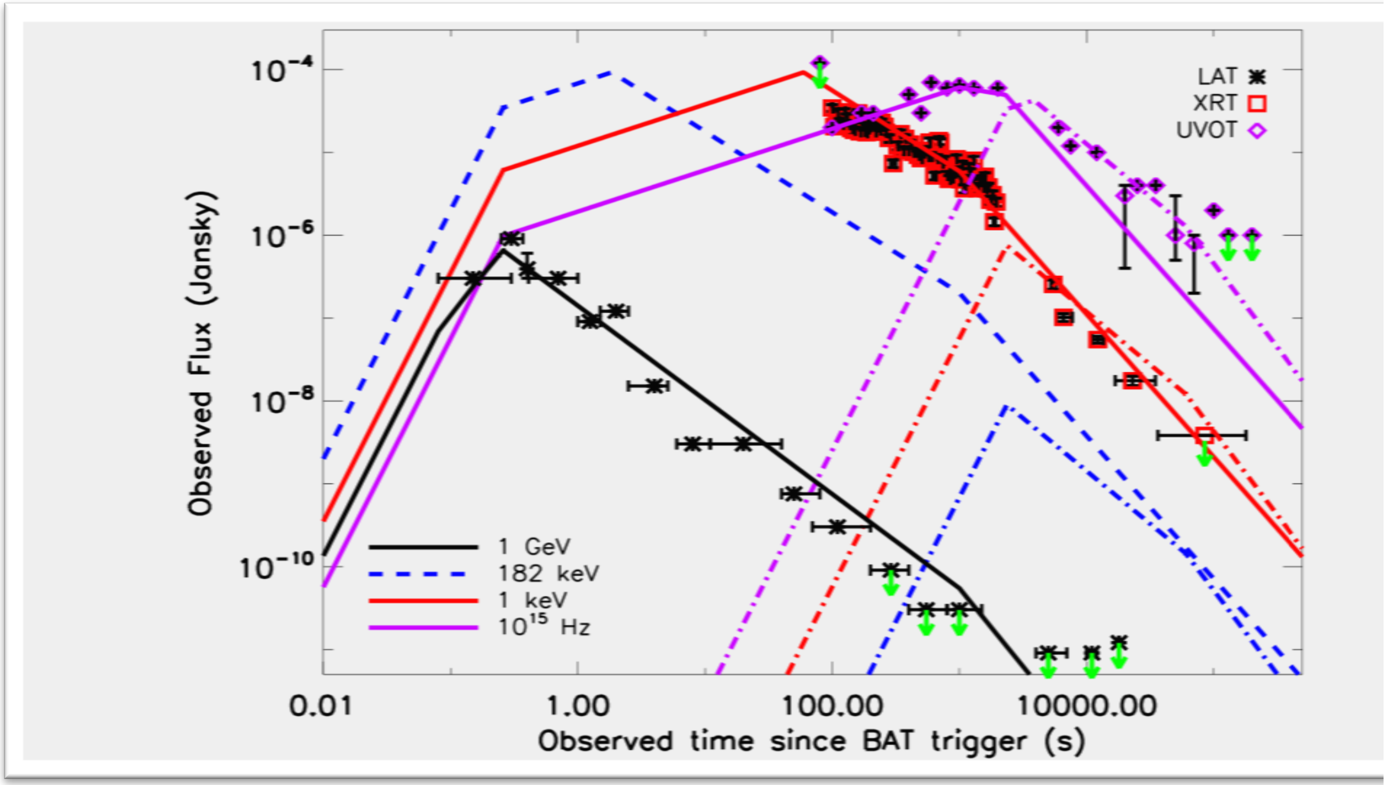
Delayed LAT emission as external shock



GRB 090902B
Abdo, A. A. et al. 2010



Ghisellini et al. 2010

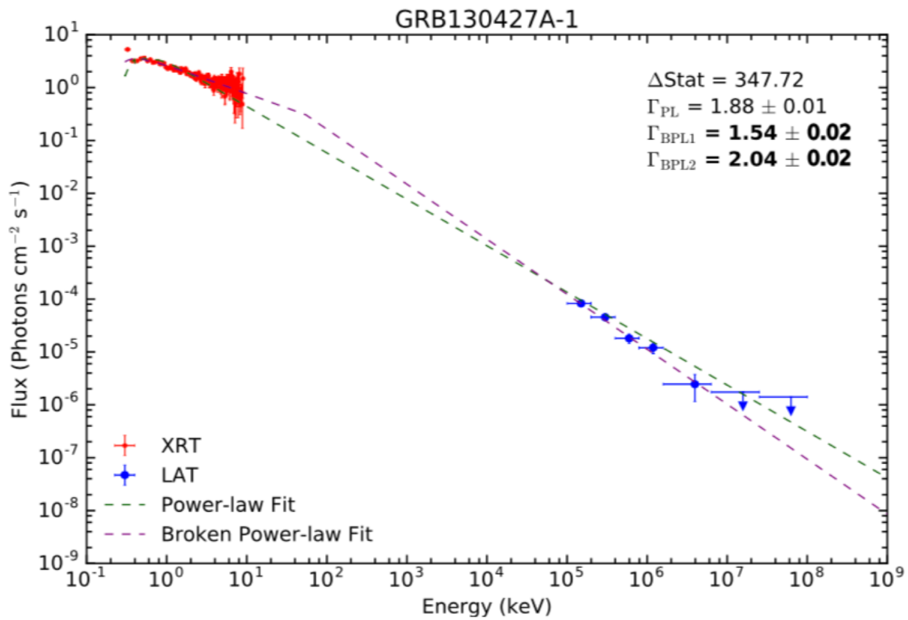


<u>GRB 090510 from Fermi (and AGILE) consistent with the External Shock model</u>

(Corsi, Guetta, Piro ApJ 2009; see also Kumar & Duran, 2009, De Pasquale et al 09, Ghrilanda et at 09).

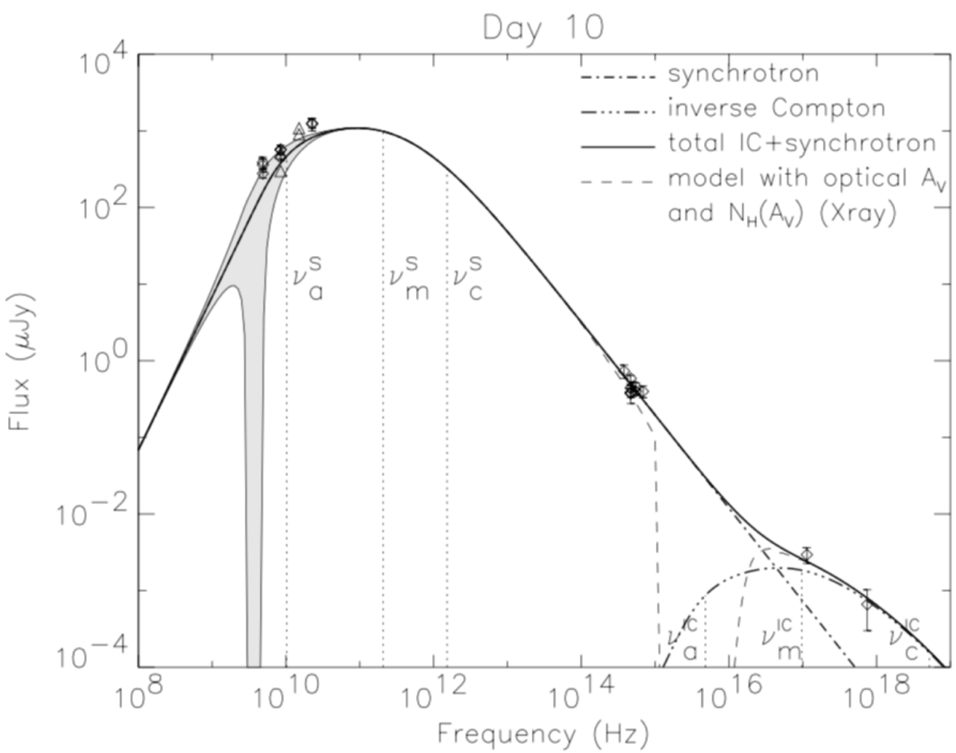
X-ray to Gev afterglow Spectrum

- Sample of XRT-LAT afterglow (Aiello+18)
- Afterglow (external shock): consistent with Synchrotron emission only (no IC) or peak above LAT

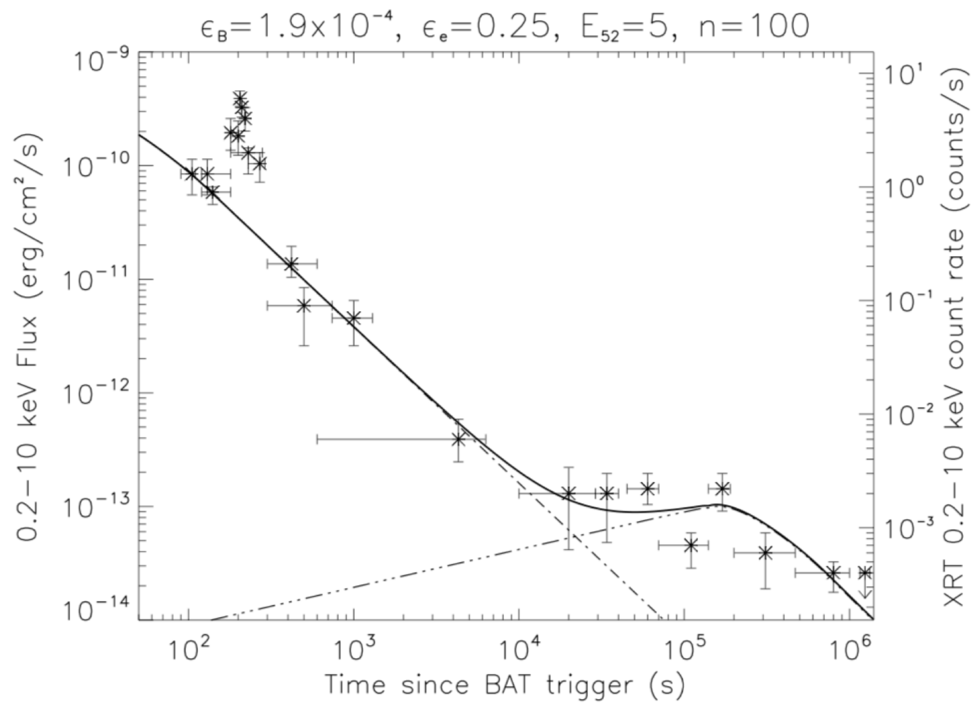


Evidence for IC emission

- Mostly from X-rays and hard X-rays



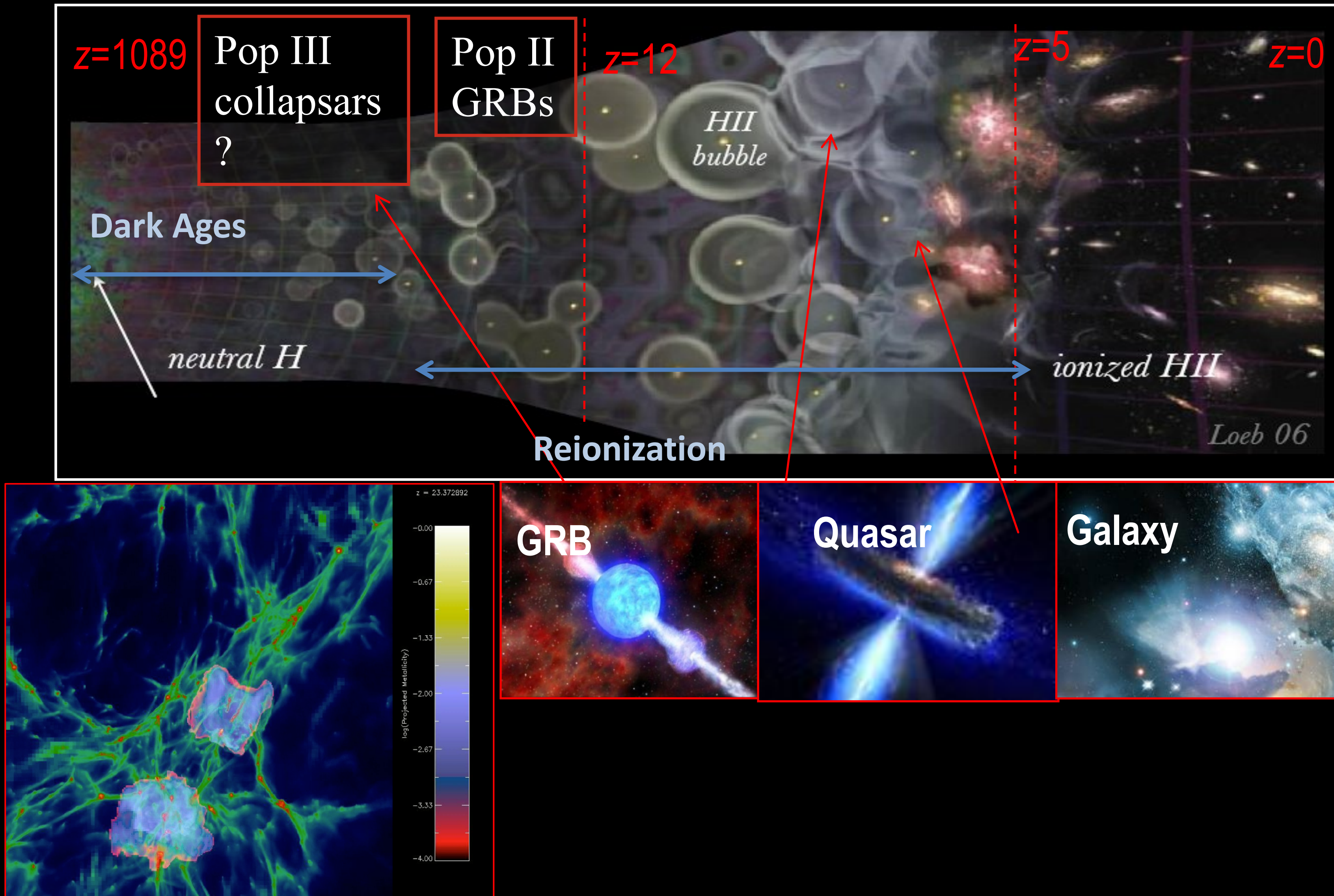
Harrison + 2001



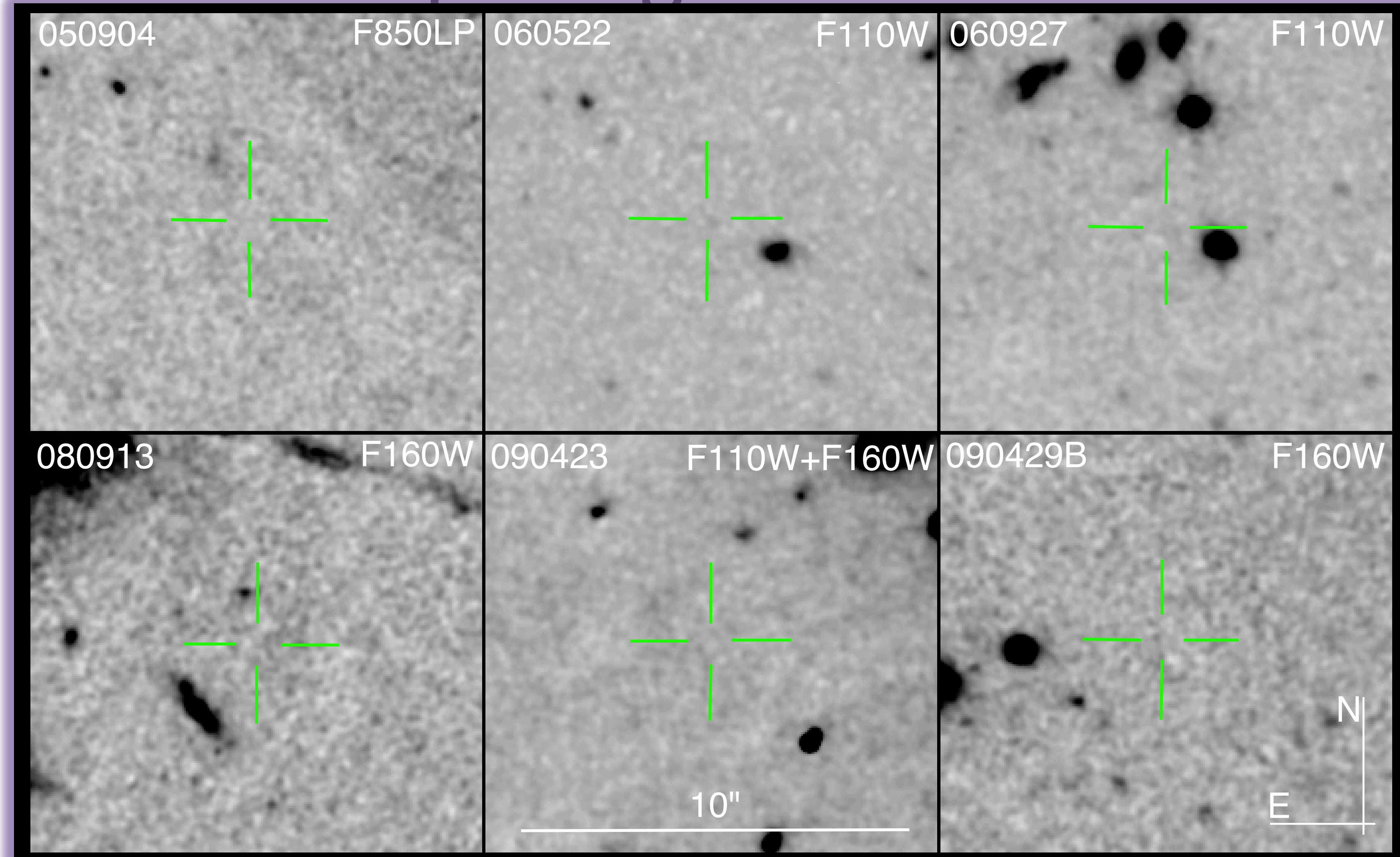
Corsi & LP 2006

High-z and ultralong GRBs

The first stars, the first BH, the first metals



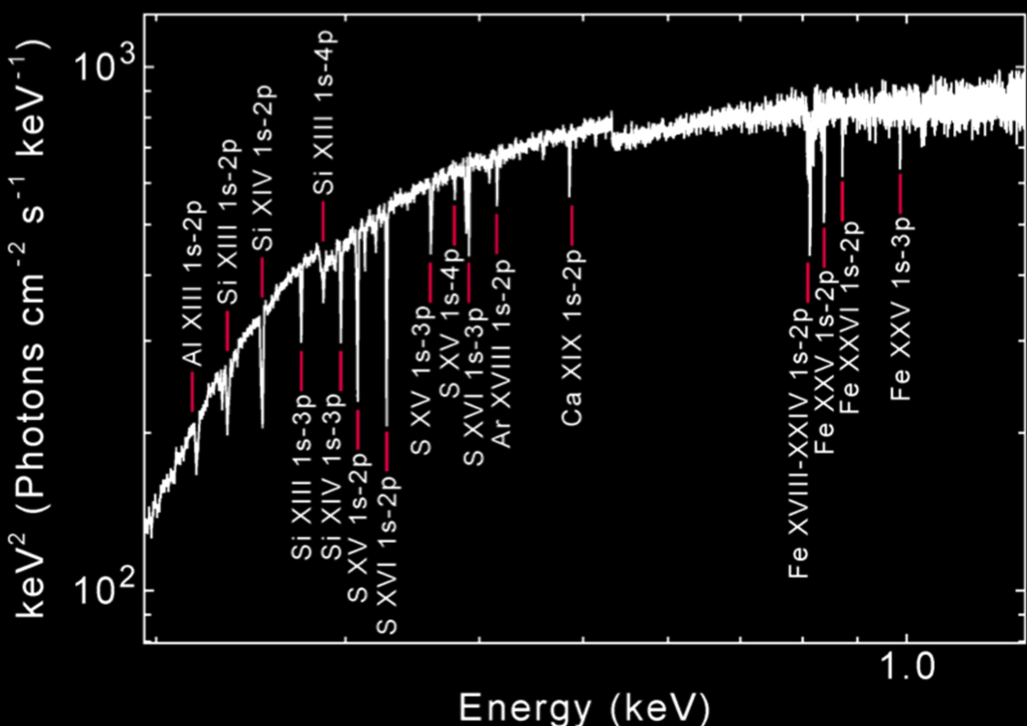
High-z GRBs: pathways to “unvisible” protogalaxies

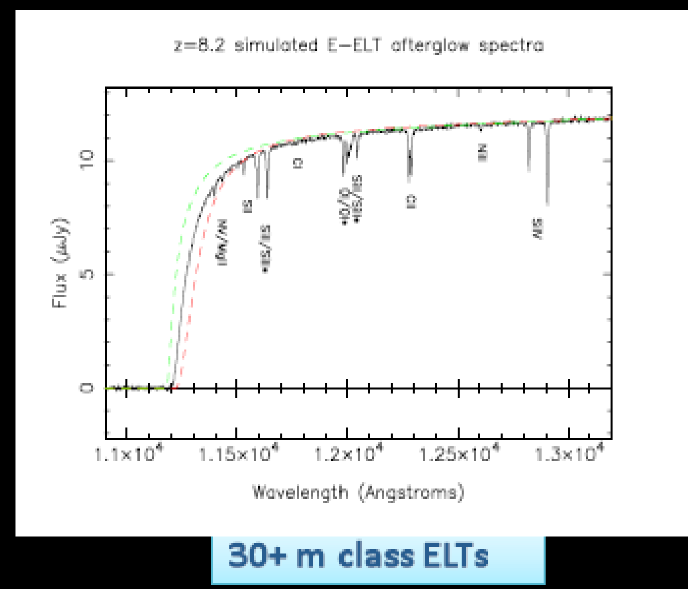


High-Z GRBs: The first stars and black holes

When did the first generation of stars explode to form the first seed black holes and disseminate the first metals in the Universe?

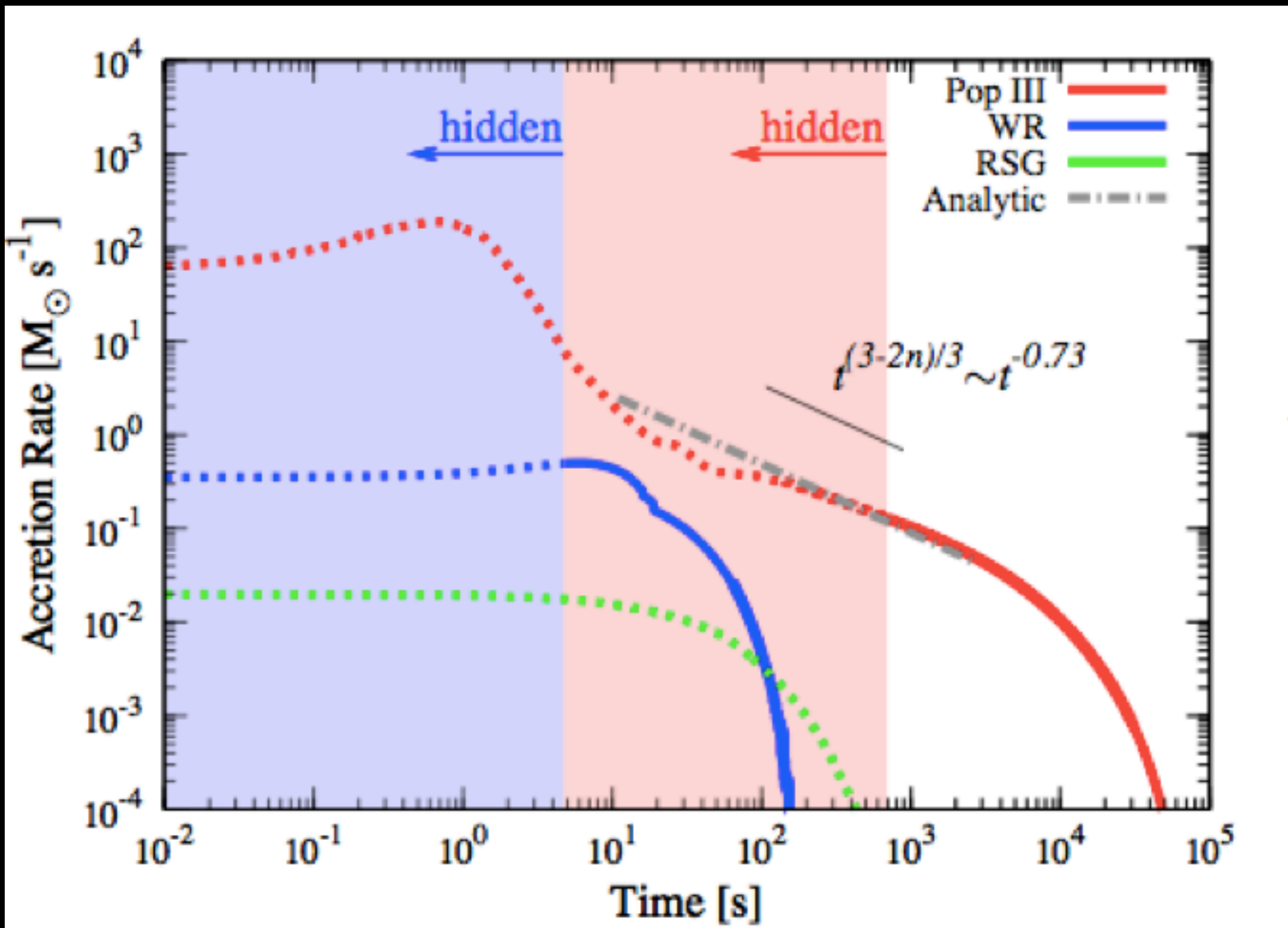
Gamma Ray Burst at z=7





Jonker, O'Brien et al., 2013 arXiv1306.2336

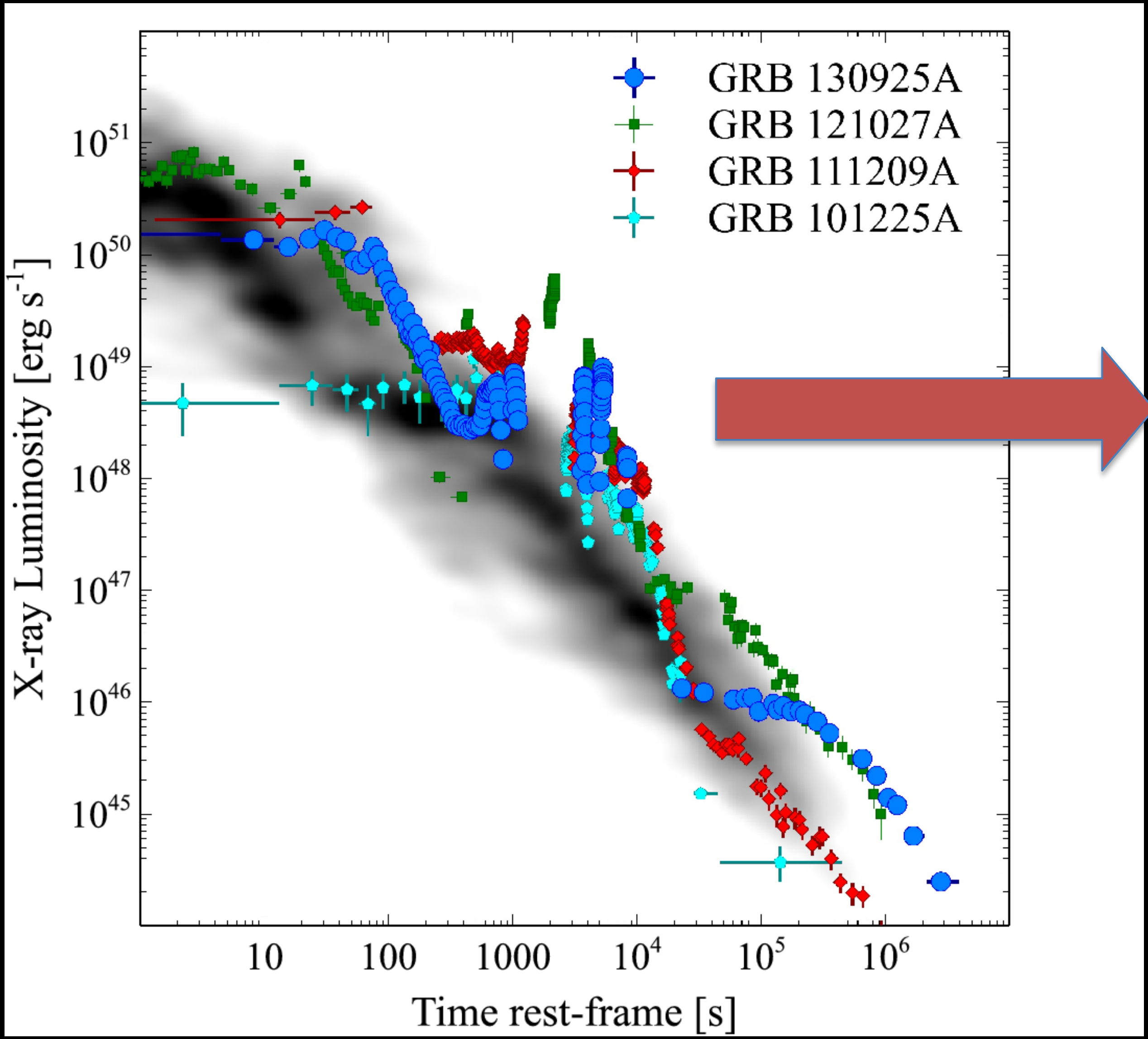
popIII GRBs



$T_{90}=10^4$ s
Eiso$=10^{55}$ erg
$L=10^{52}$ erg/s

Suwa&Ioka 2011

Ultralong GRB: a popIII analogue?



Flux@z=10

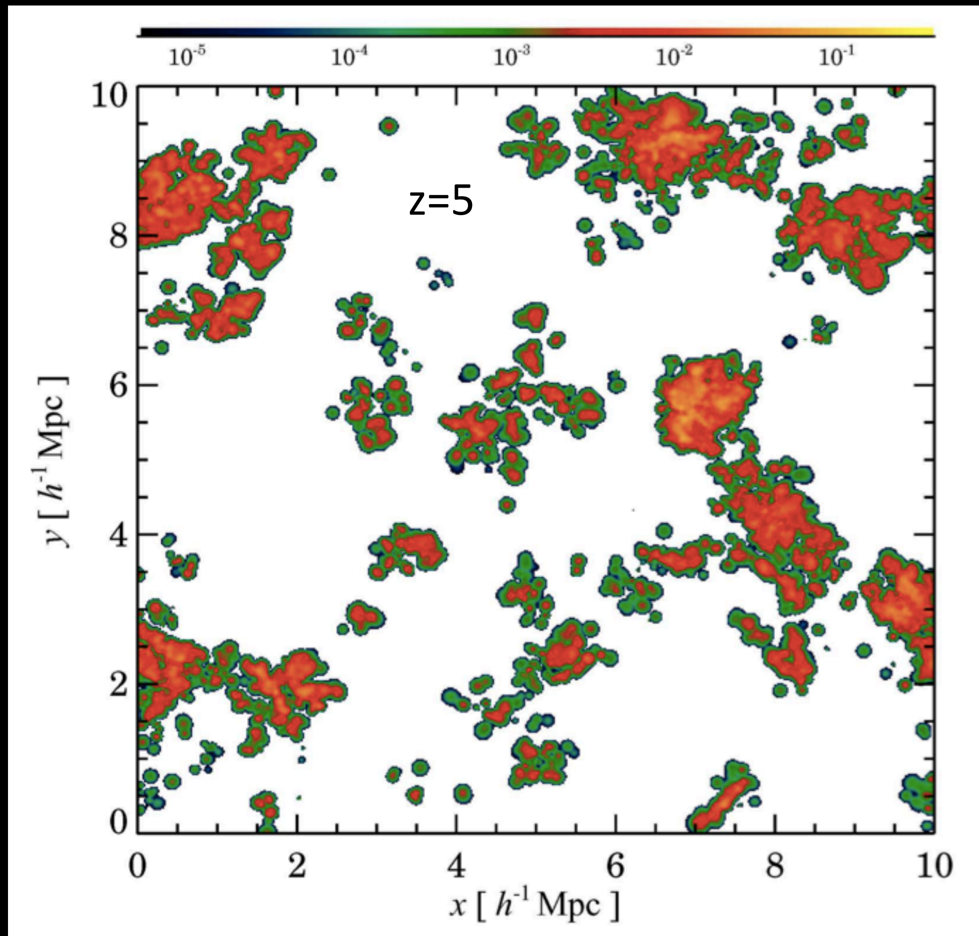
10^{-12-11} erg/cm^2/s

Piro+ 2014

end

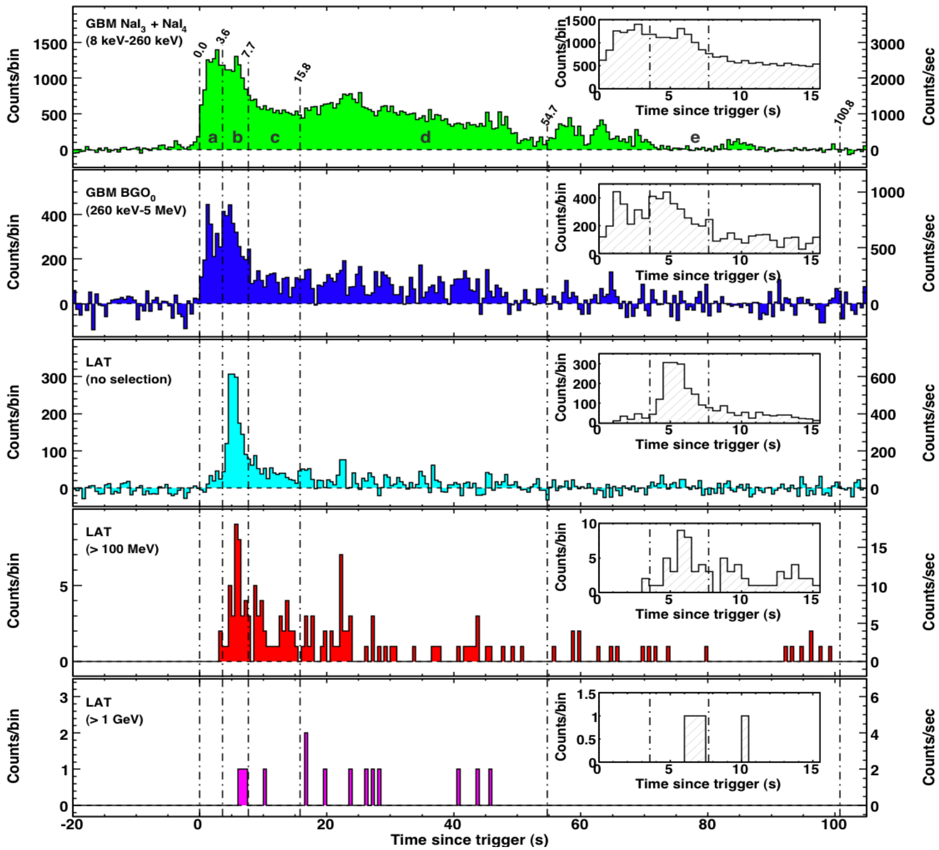
popIII-popII transition

Chemical enrichment is highly inhomengenous: popIII and popII coexhists for a long period

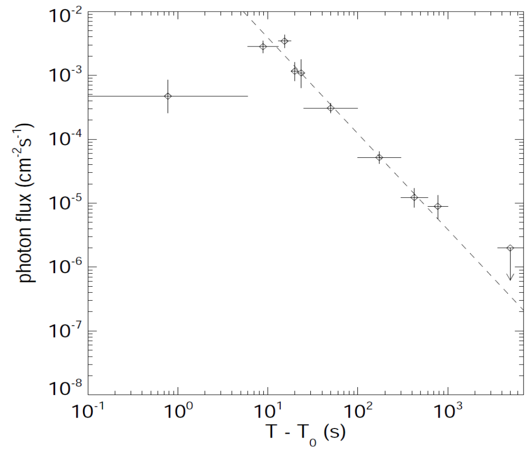


Tornatore et al 2007

Fermi GRBs

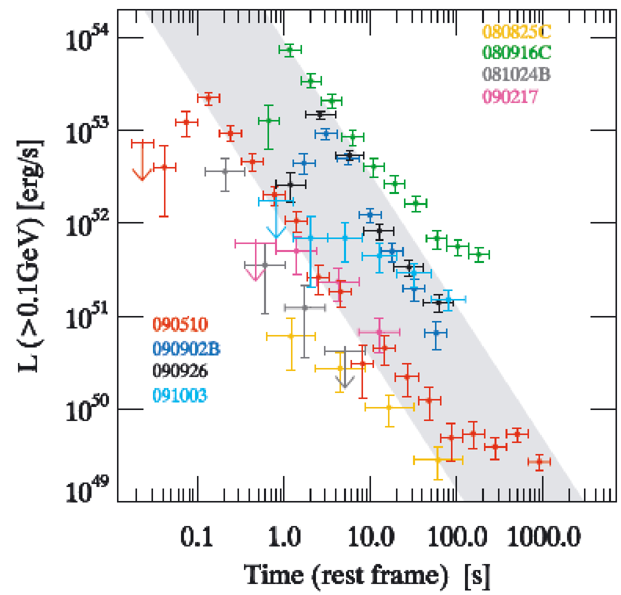


GRB 080916C
Abdo, A. A. et al. 2009



GRB 090902B
Abdo, A. A. et al. 2010

Ghisellini et al. 2010

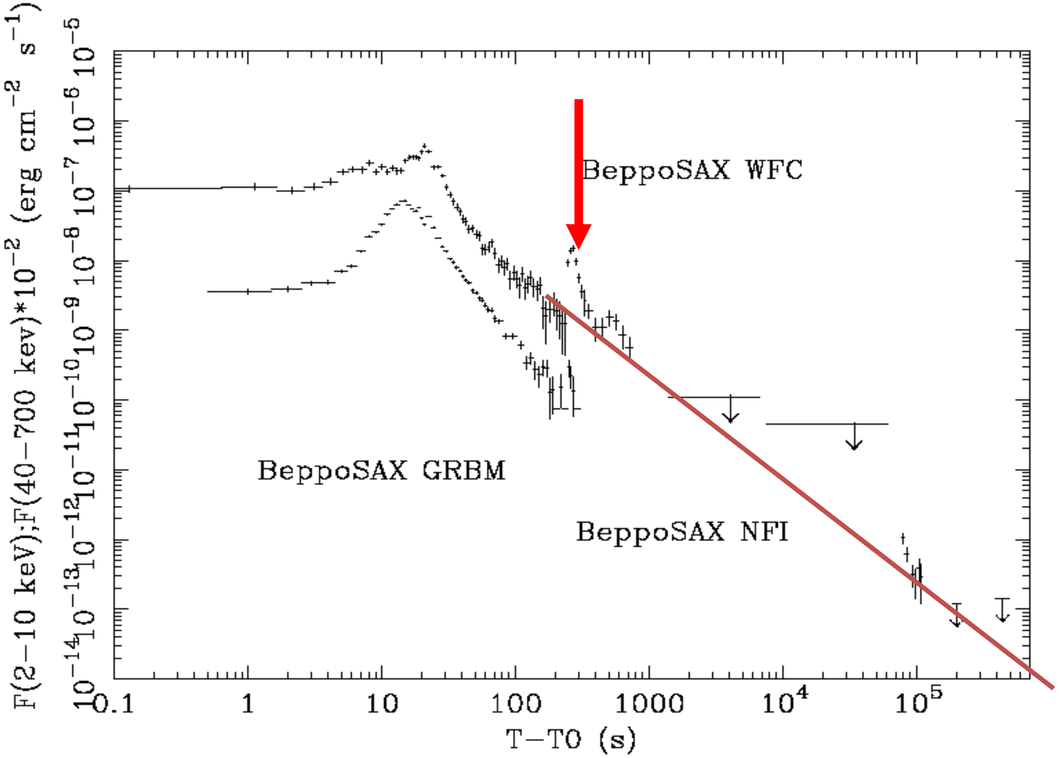


GeV emission is DELAYED with respect to the sub-MeV emission

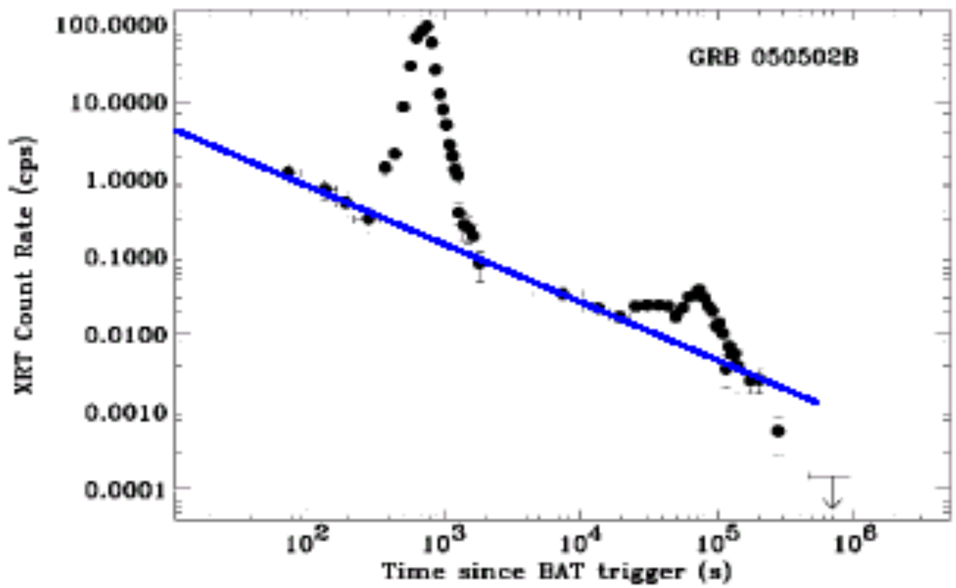
LONG LIV
most burst

X-ray Flares

BeppoSAX: Piro et al (2005)



SWIFT: Burrows et al (2005)

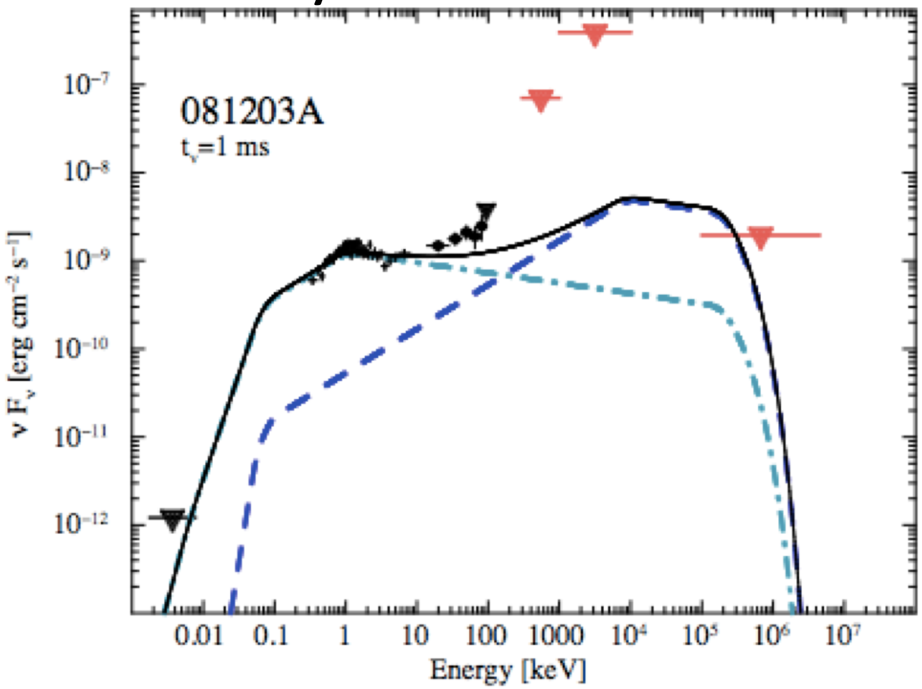


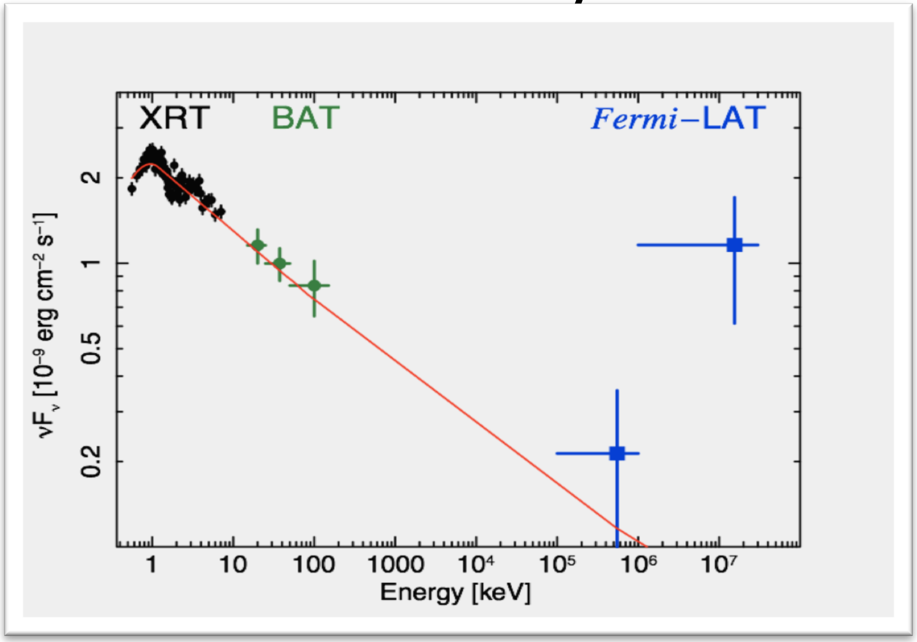
Signature of long duration activity of the central engine

SWIFT: about 40% X-ray afterglows showing X-ray flares on time scales >100 sec (Chincarini et al 2007)

Broad band spectra of X-ray flares

- Sample of SWIFT XRT, BAT and LAT spectra (Troja, LP + Ap.J, 2015)
- Broad bandspectrum consistent with SSC from IS
- Only one LAT detection but consistent with Synchrotron PL





GRB 100728 Abdo et al., +L.P., Ap.J. 2011

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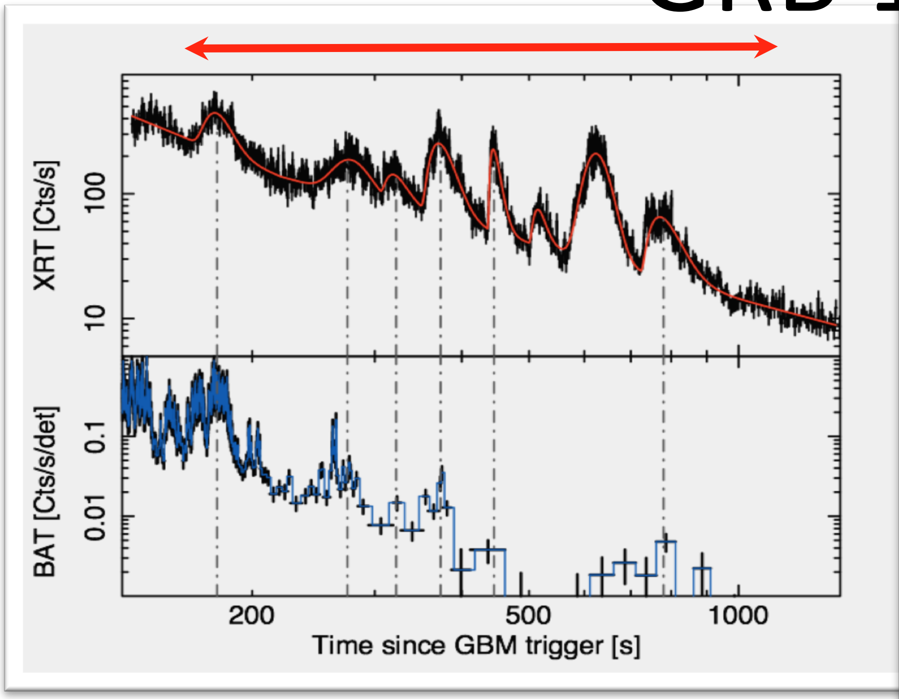
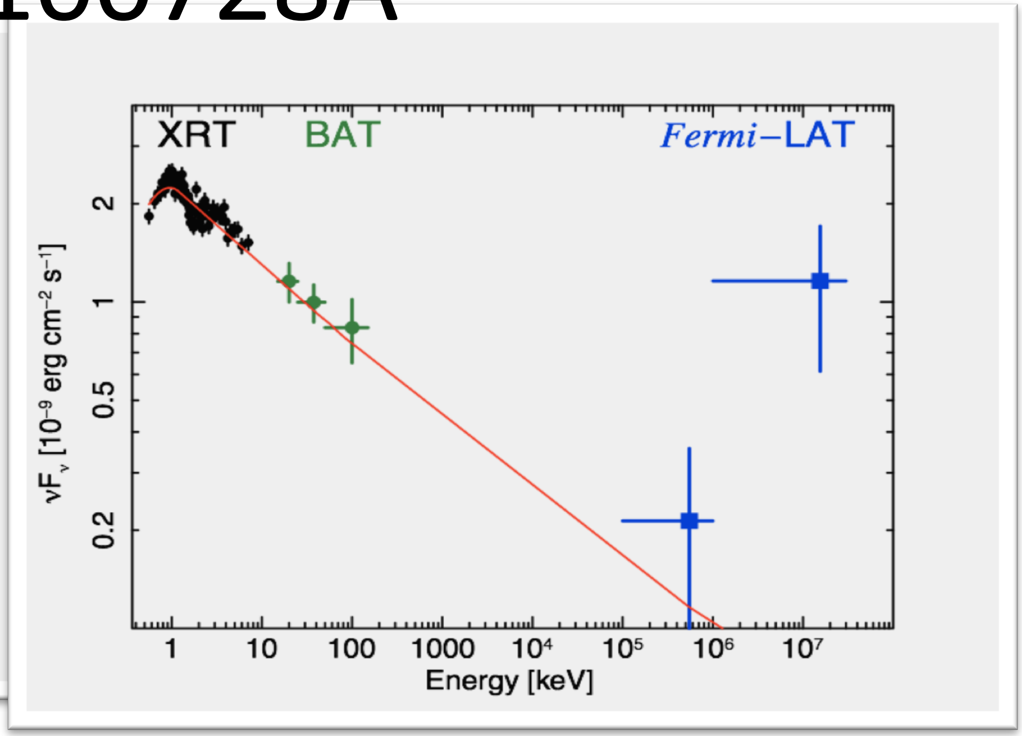
GRB 100728A





8 bright flares in XRT (from ~150 s to ~850 s) with several peaks visible in BAT

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

Simultaneous HE emission detected by Fermi/LAT consistent with the extrapolation of the X-ray flares spectrum

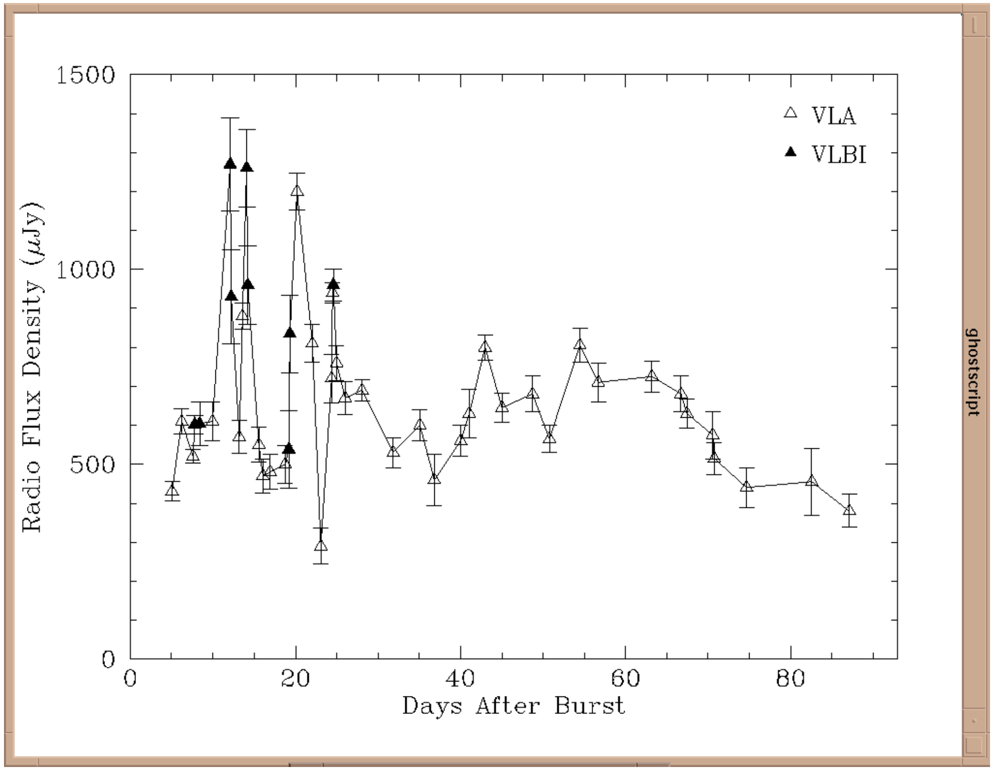
Hard spectrum: 1.4 +/- 0.2 (1 σ)

$$\nu_m \propto \epsilon_e^{3/2} \epsilon_B^{1/2} L^{1/2} \Gamma^{-2} t_v^{-1}$$

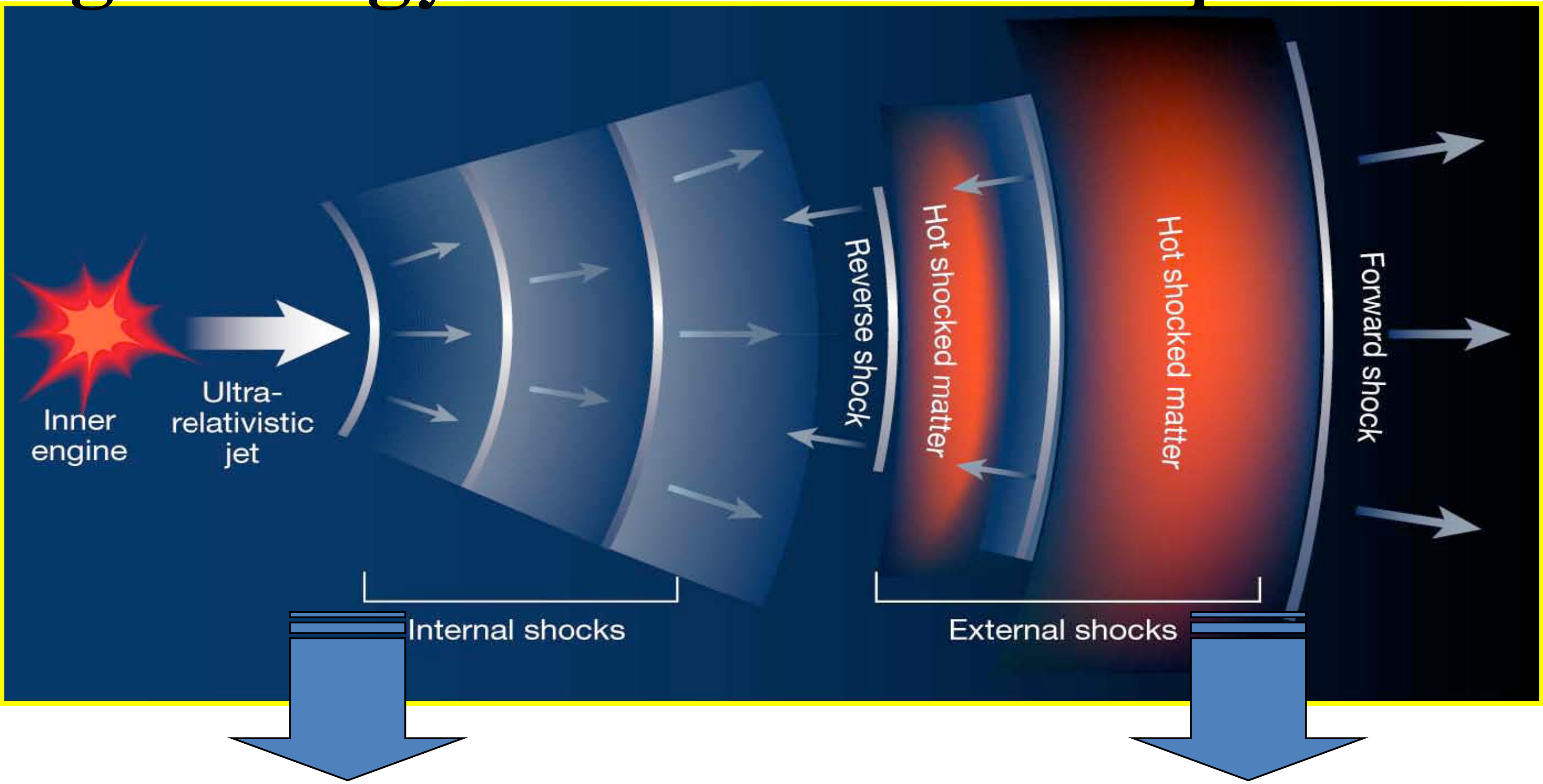
Aabdo et al., +L.P., Ap.J. 2011

GRB970508: evidence of relativistic expansion by shock-driven Synchotron emission

- Radio light curves showing scintillation(dumping after a few weeks => relativistic expansion (Frail +97)



High Energy emission in GRBs: predictions



- SSC in internal shocks, 1 MeV-10 GeV (Meszaros et al., Galli & Guetta 2007)
- p-γ interaction, MeV – TeV (Gupta & Zhang 2007)

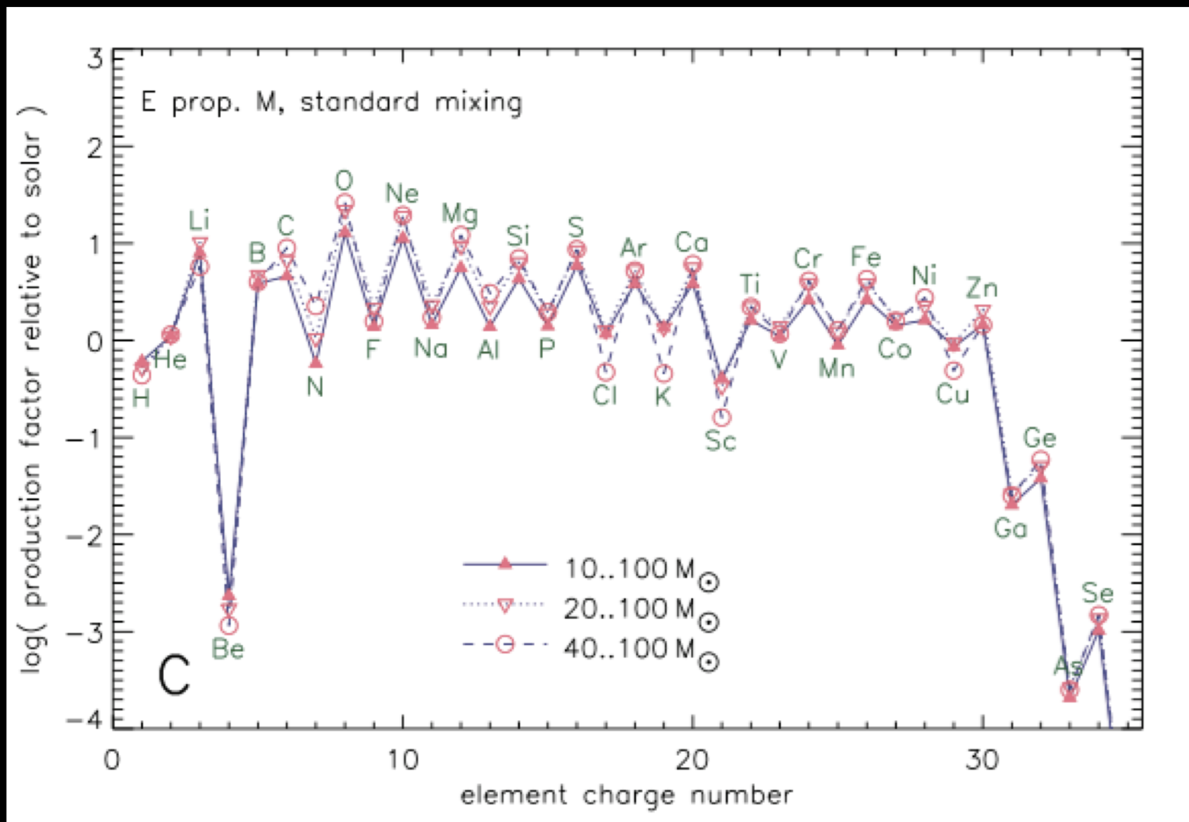
- SSC in RS, keV-GeV (Kobayashi et al. 2007
- SSC in FS, MeV-TeV (Galli & Piro 2007)
- p-γ interaction in FS, GeV – TeV (Boettcher & Dermer 2003)

The origin of the GeV emission

- Contemporaneus detection of LAT emission with prominent X-ray flare activity calls for a connection of the two emission components
- X-ray flares are usually associated to Internal Shock from a long duration central engine. The 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 Γ>400. In this context there are two solutions:
    - Synchrotron is consistent
    - Inverse Compton: the flat spectral shape (preliminary) exhibited in the LAT range can be accounted by a IC but requires a very large $\gamma_m = 1800\ \varepsilon_e$
  - External IC component onto the electrons of the forward shock

PopIII enrichment chemical abundance

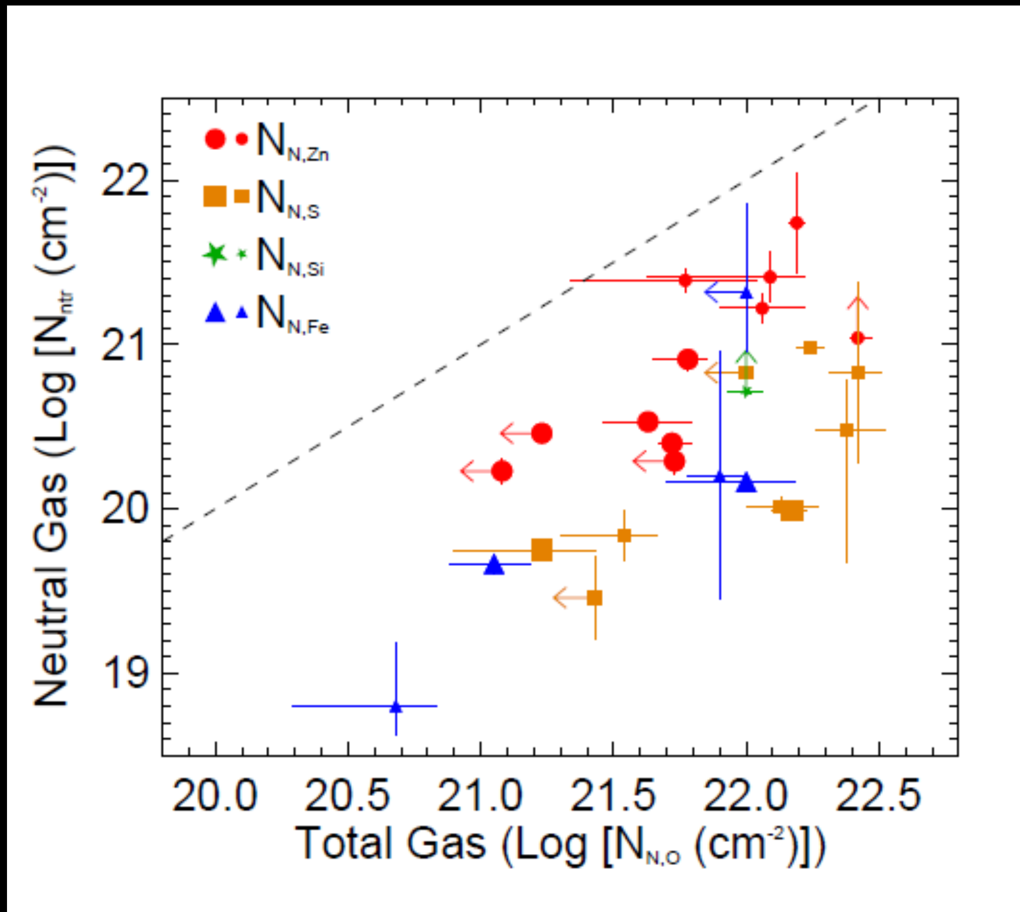
Chemical enrichment from popIII explosions is roughly solar with a strong odd/even effect



Heger&Woosley 2008

X-rays probe the close ionized environment

Opt-IR

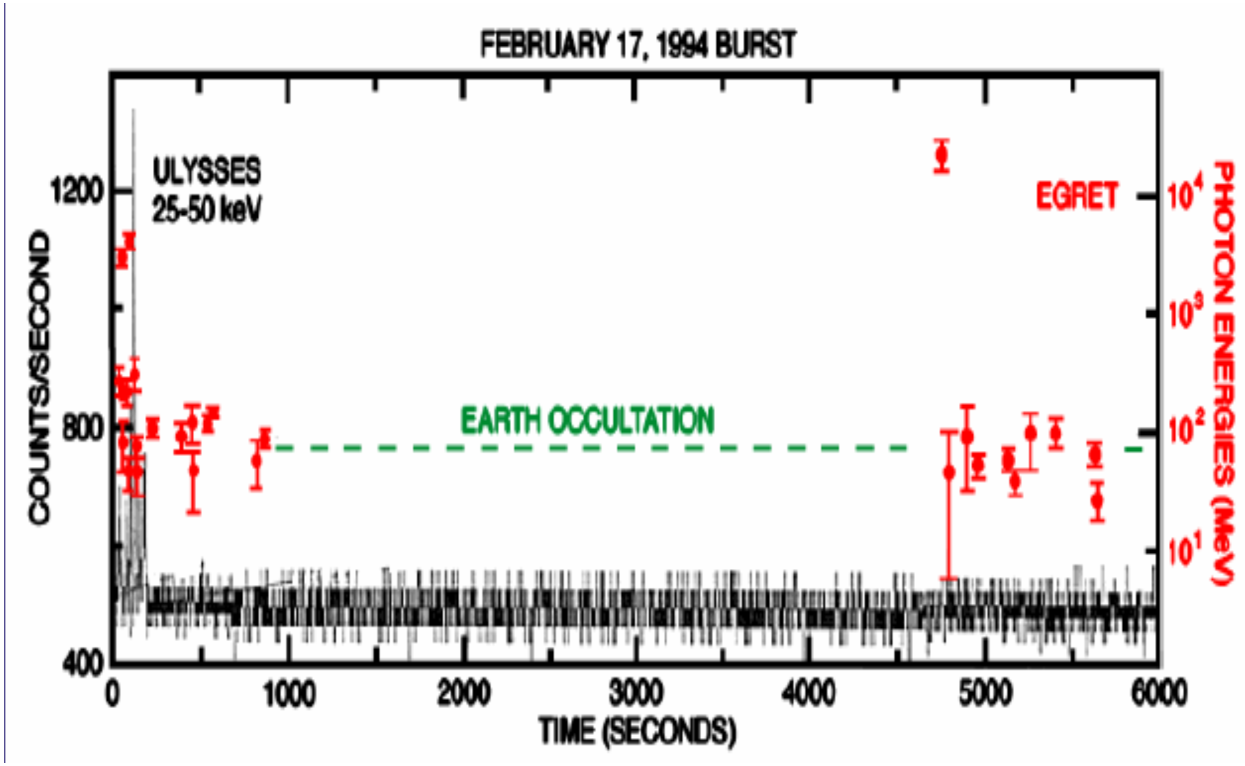


X-Ray

Schady et al 2010

Observations: the first GeV delayed emission

• **GRB 940217 (Hurley et al. 1994): detected by EGRET presents VHE emission at hundreds-thousands of s after GRB onset, including a 18 GeV photon;**



Basic predictions of Internal vs External Shock

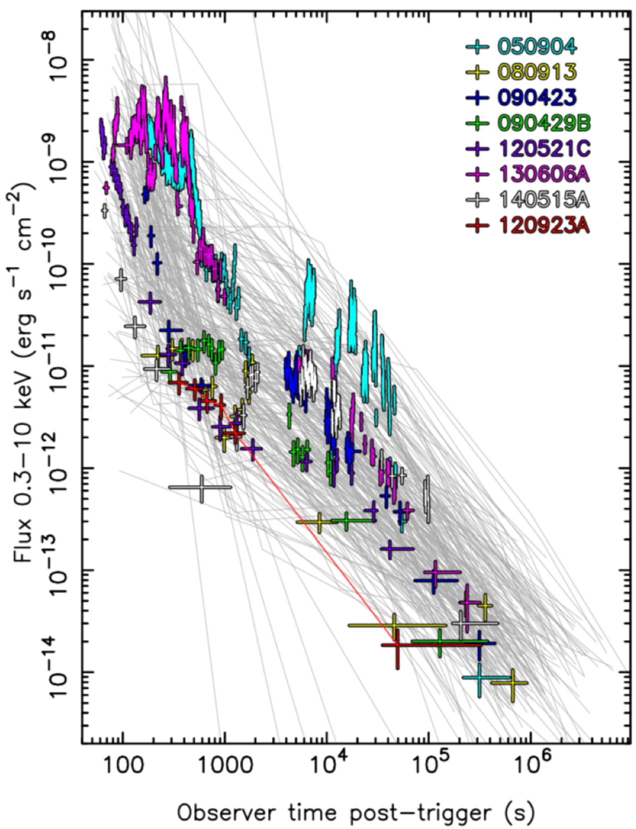
•

•**In the IS the source is more compact, with opacity due to e+e- becoming substantial above the GeV**

•The radius of the source

- Internal Shock $R \sim 2\Gamma^2 c t_v \sim 10^{13}$ cm
- External shock Rdec~ 10^{17} cm

X-ray properties



Tanvir+19

Conclusions I

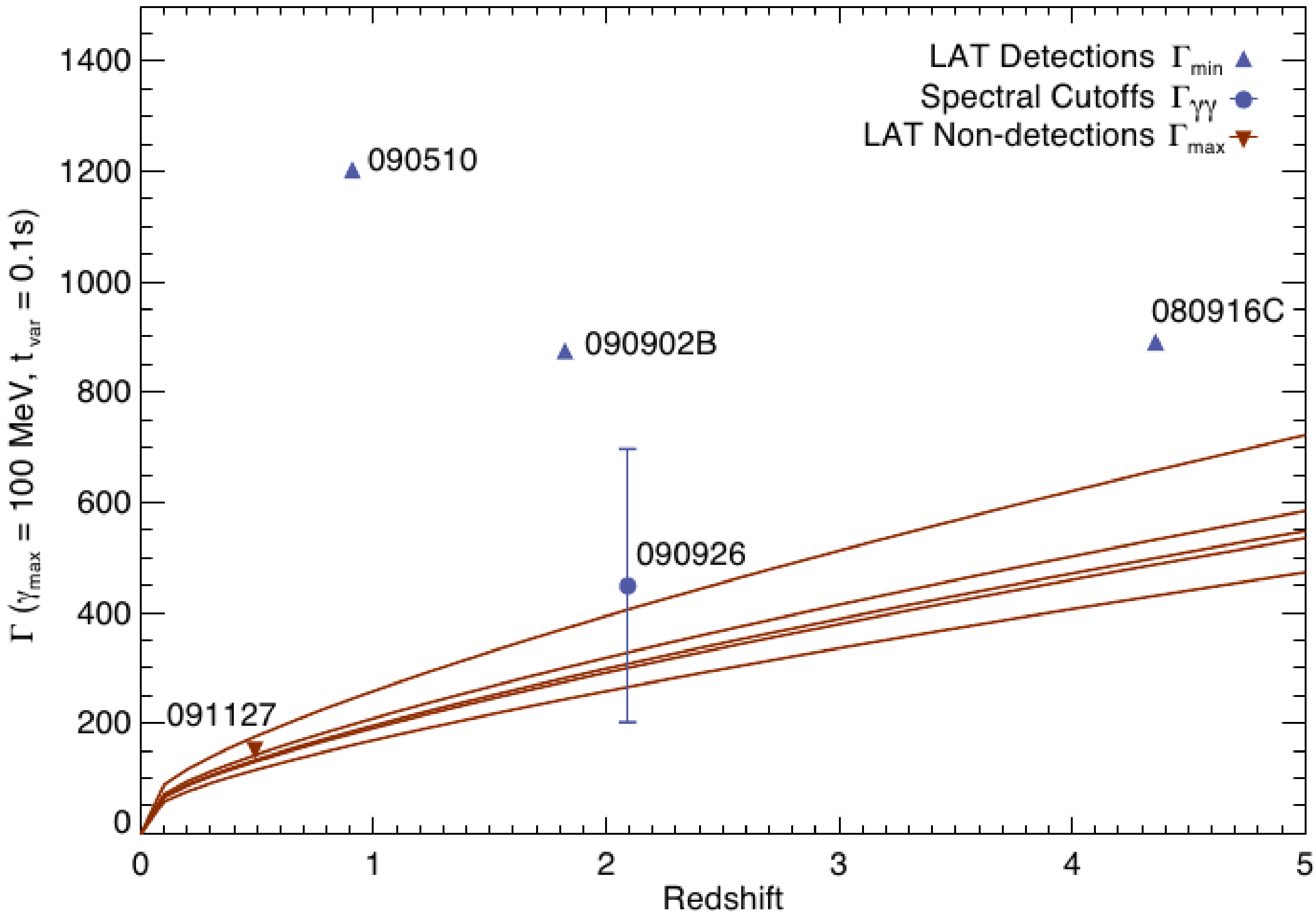
- Prompt phase characterized by paucity of GeV photons => break or opacity (consistent with IS). Lack of IC component: magnetic dominated flow?
- Bright Delayed emission in few bright GRBs: high Lorentz factor. Consistent with Synch. Ext. Shock
- GeV counterparts to X-ray flares fainter than expected, yet consistent with Inverse Compton from Internal Shock

Limits on bulk Lorentz factors

Lower limits: LAT detections

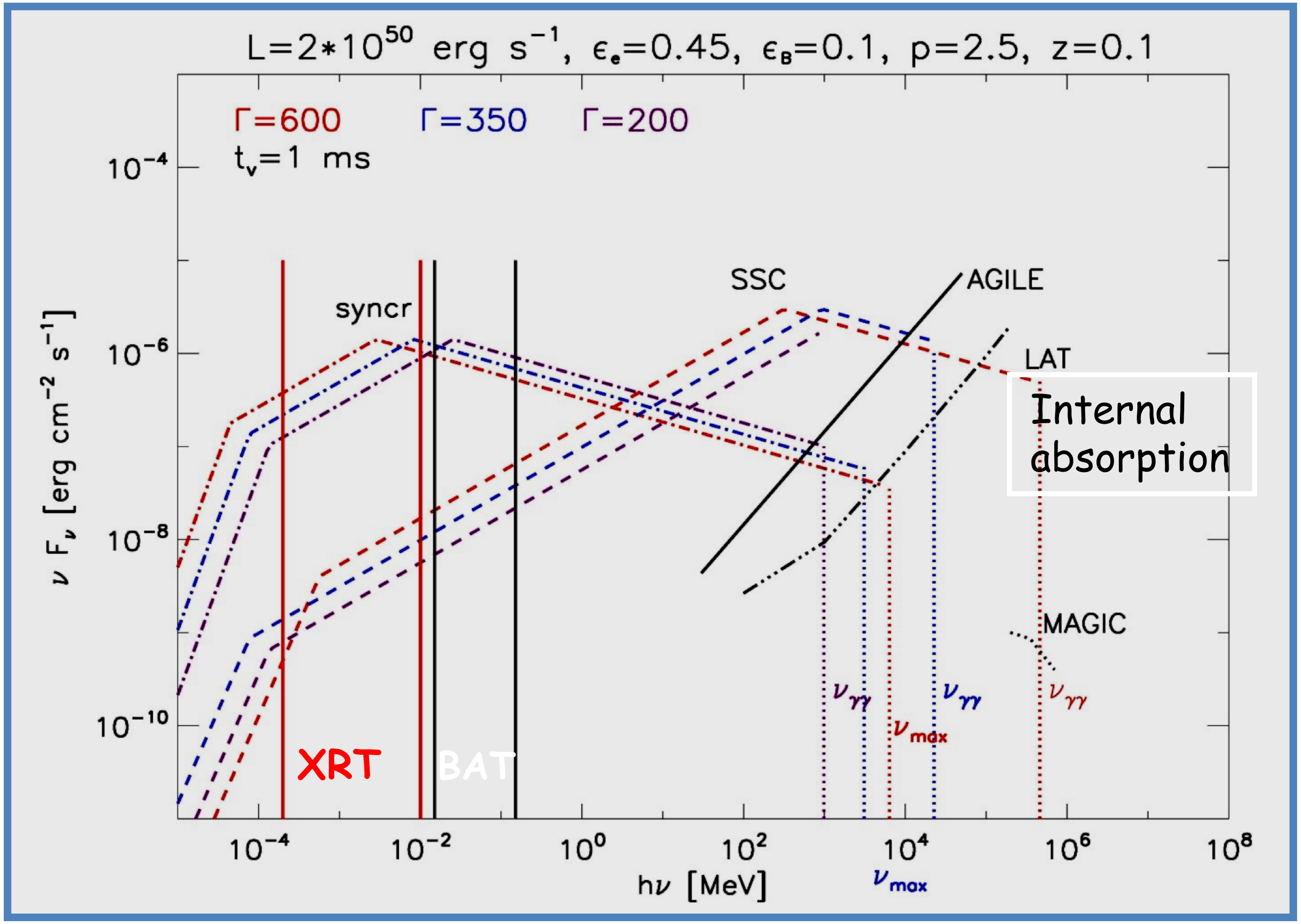
Upper limits: LAT NON-detections

Caveat: assume prompt tv, and γγ abs



Ackermann+ 2012

Predictions for the prompt phase: IS



- GeV-Tev emission suppressed by internal gg absorption, depending on Gamma

Galli&Guetta(2007)

Forward Ext. shock: the first application to GRB940217