Gamma-Ray Bursts: open issues and perspectives

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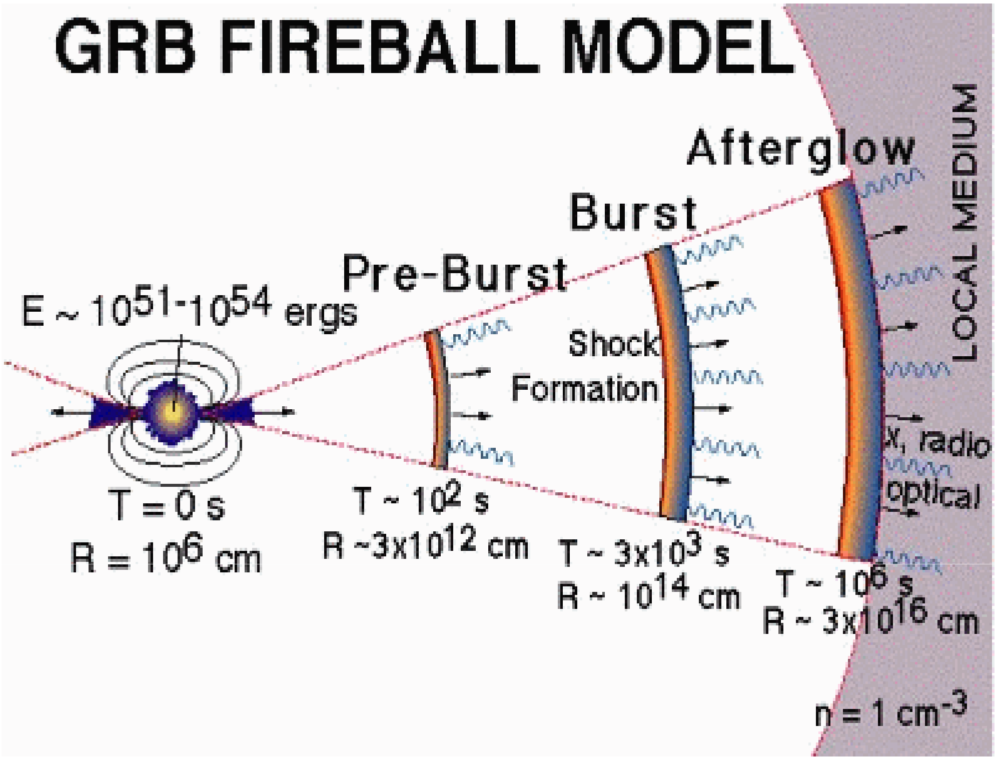
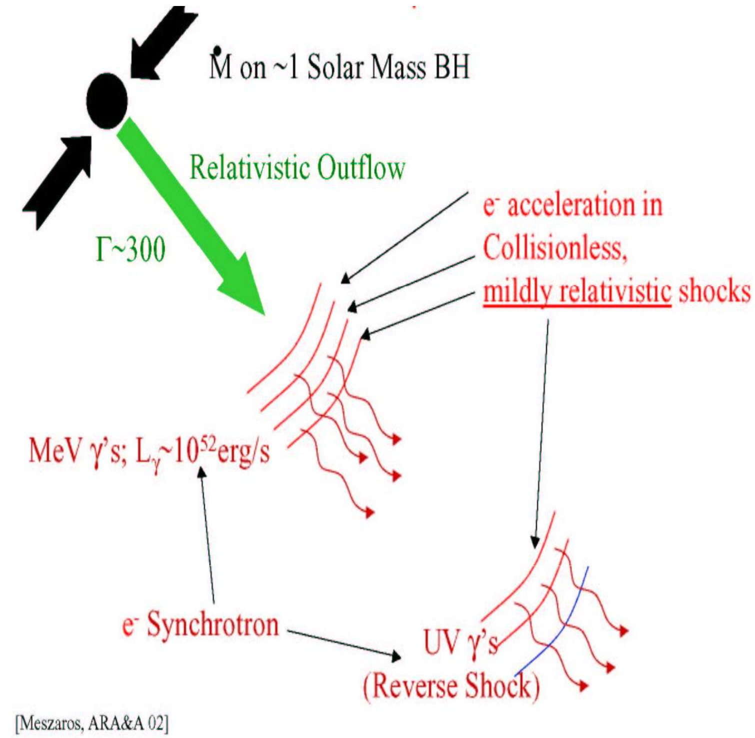
Standard scenarios for GRB phisics

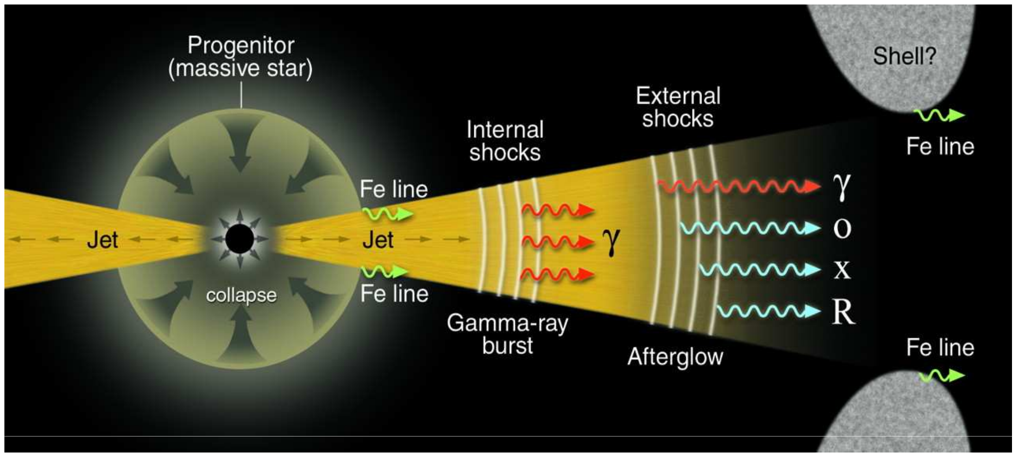




- ms time variability + huge energy + detection of GeV photons -> plasma occurring ultra-relativistic (Γ > 100) expansion (fireball or firejet)
- non thermal spectra -> shocks synchrotron emission (SSM)
- fireball internal shocks -> prompt emission
- fireball external shock with ISM -> afterglow emission

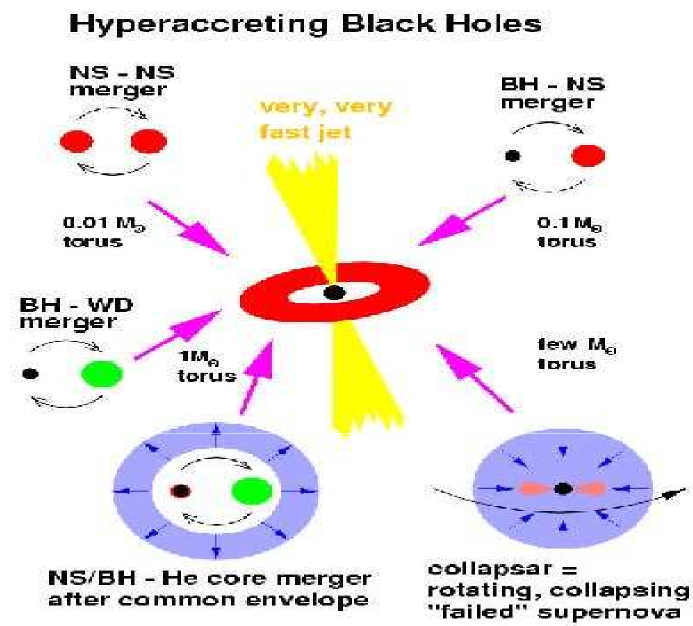
Standard scenarios for GRB progenitors

LONG



- energy budget up to >10^{54} erg
- long duration GRBs
- metal rich (Fe, Ni, Co) circum-burst environment
- GRBs occur in star forming regions
- GRBs are associated with SNe
- likely collimated emission

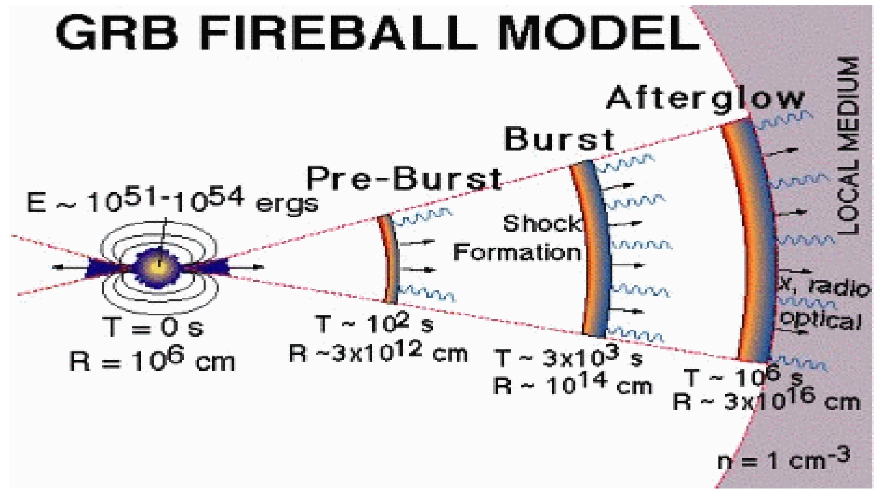
SHORT



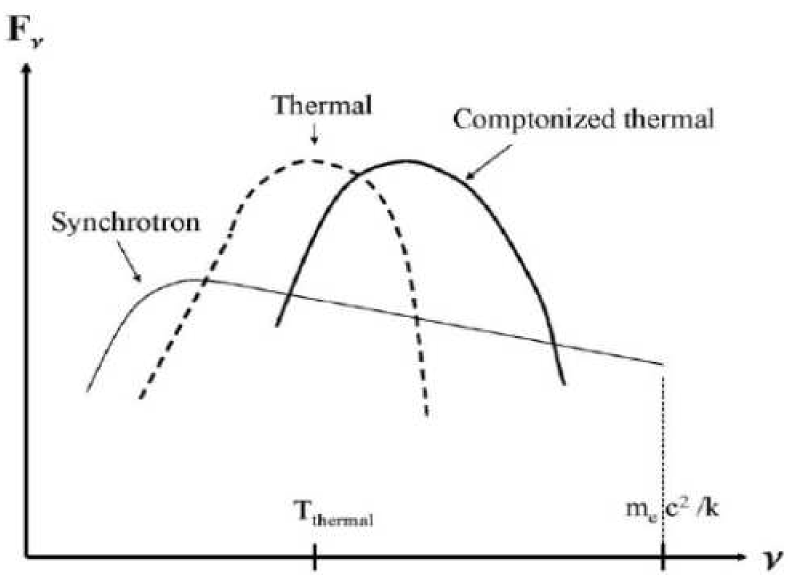
- energy budget up to 10^{51} - 10^{52} erg
- short duration (< 5 s)
- clean circum-burst environment
- old stellar population

Open issues (several, despite obs. progress)

- *GRB prompt emission physics*

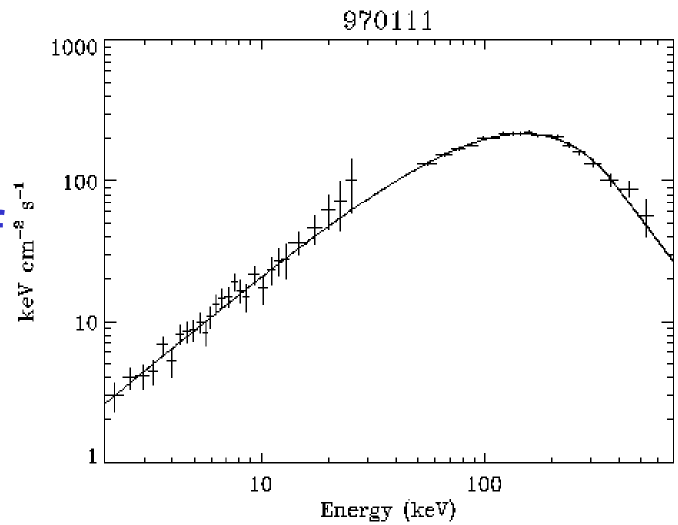


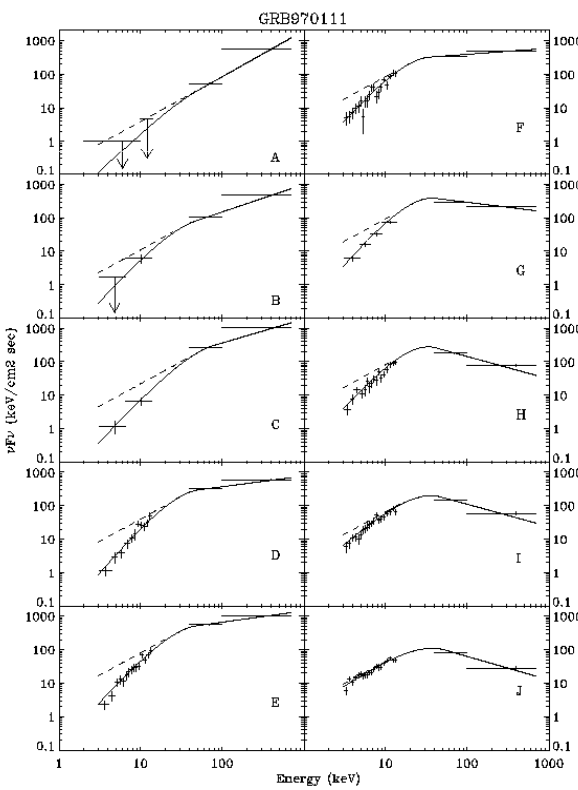
- physics of prompt emission still not settled, various scenarios: SSM internal shocks, IC-dominated internal shocks, external shocks, photospheric emission dominated models, kinetic energy dominated fireball , Poynting flux dominated fireball

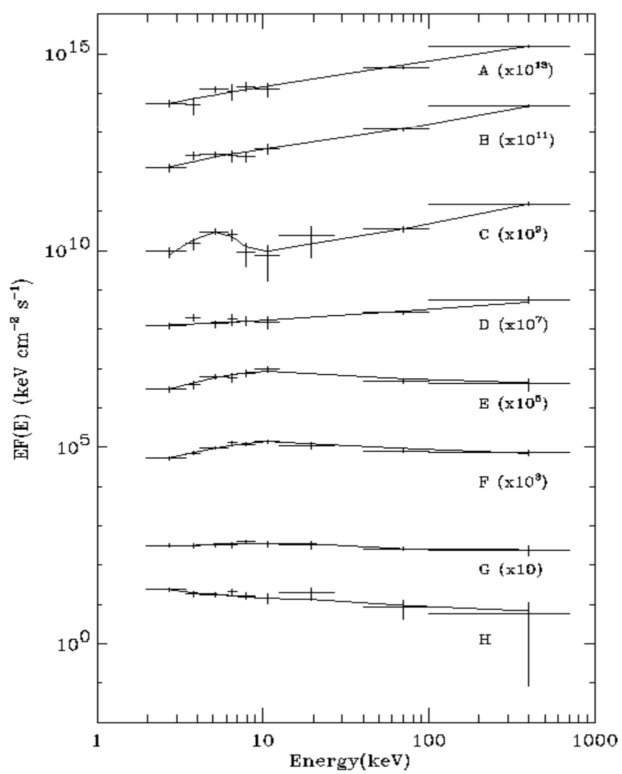


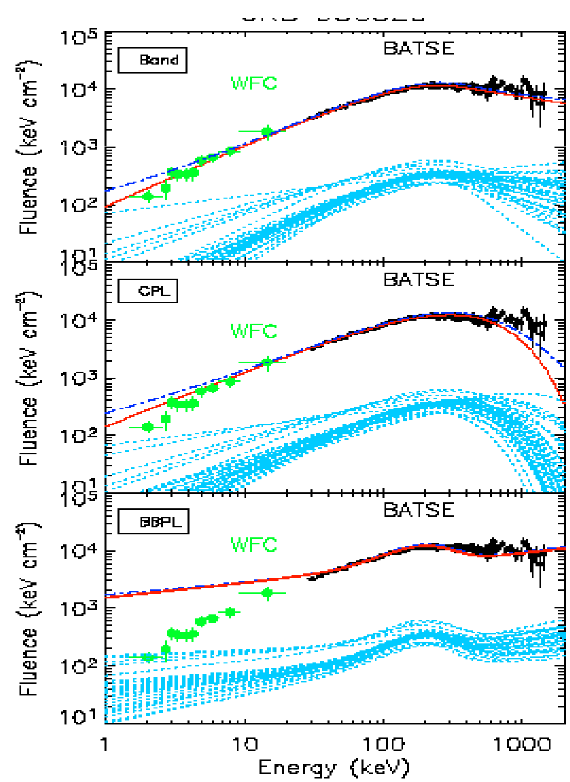
α $N(E)$	$\alpha+1$ $F(E)$	$\alpha+2$ EF_E	model/spectrum
-3/2	-1/2	1/2	Synchrotron emission with cooling
-1	0	1	Quasi–saturated Comptonization
-2/3	1/3	4/3	Instantaneous synchrotron
0	1	2	Small pitch angle/jitter
			inverse Compton by single e^-
1	2	3	Black Body
2	3	4	Wien

- most time averaged spectra of GRBs are well fit by synchrotron shock models
- at early times, some spectra inconsistent with optically thin synchrotron: possible contribution of IC component and/or thermal emission from the fireball photosphere
- thermal models challenged by X-ray spectra



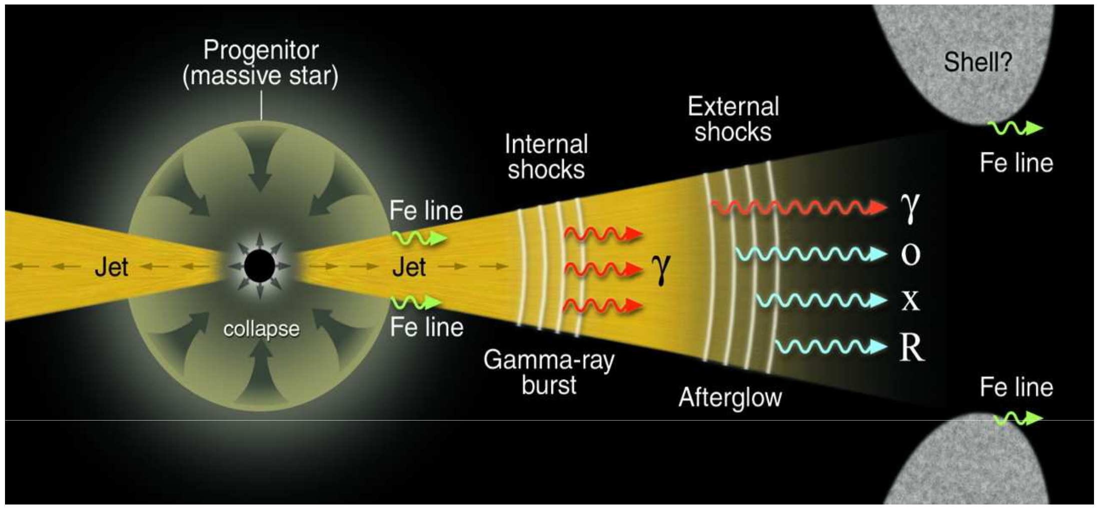


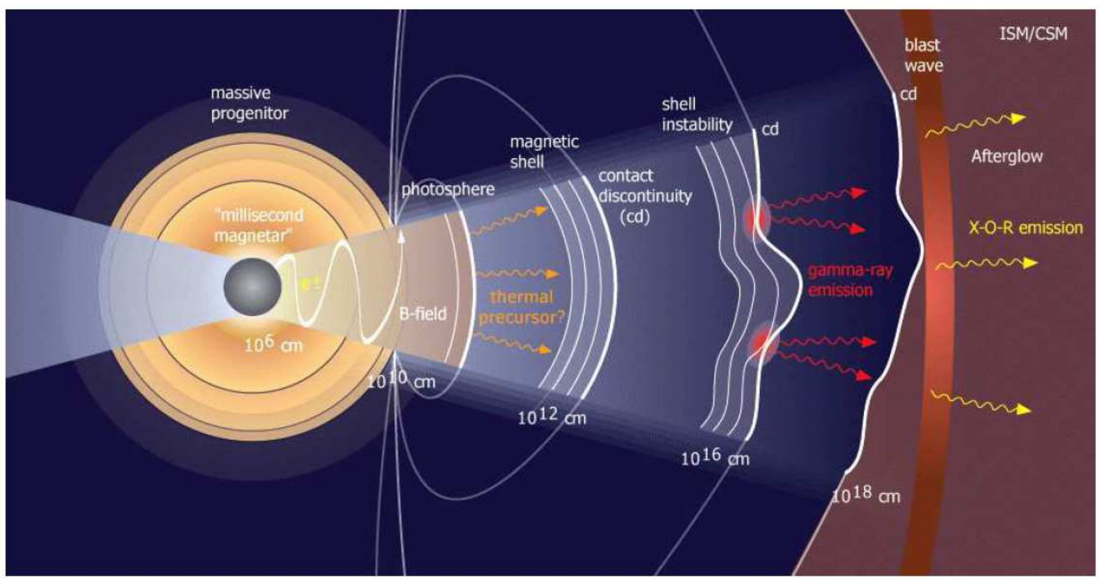




Amati et al. 2001, Frontera et al. 2000, Frontera et al. 2001, Ghirlanda et al. 2007

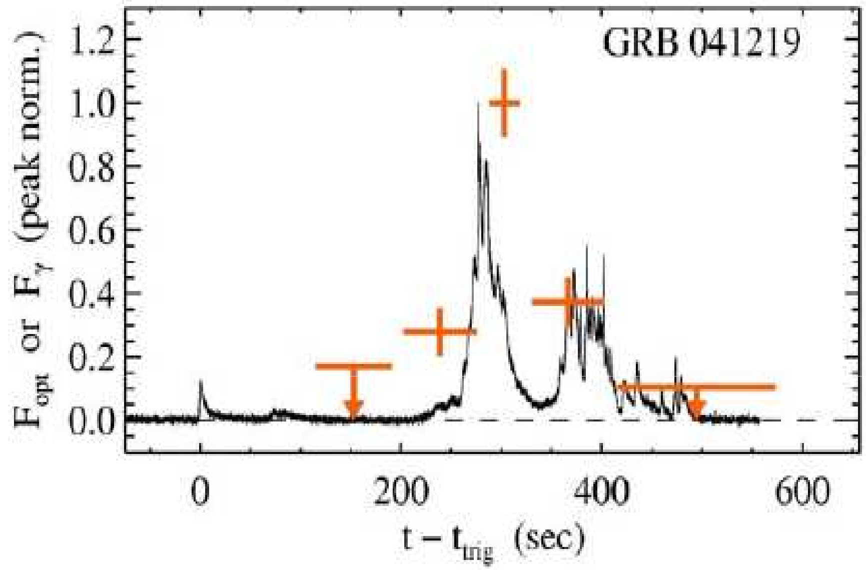
❑ Fireball nature : (baryon kinetic energy or Poynting flux dominated) and bulk Lorentz factor Γ are still to be firmly established

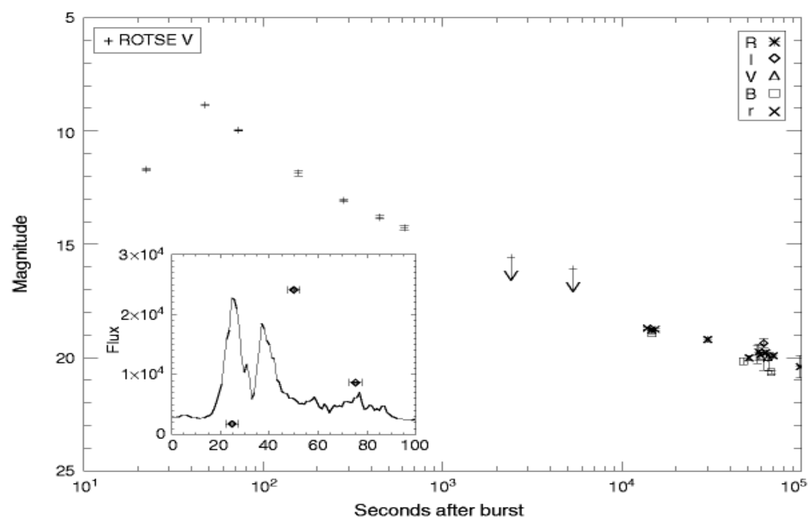


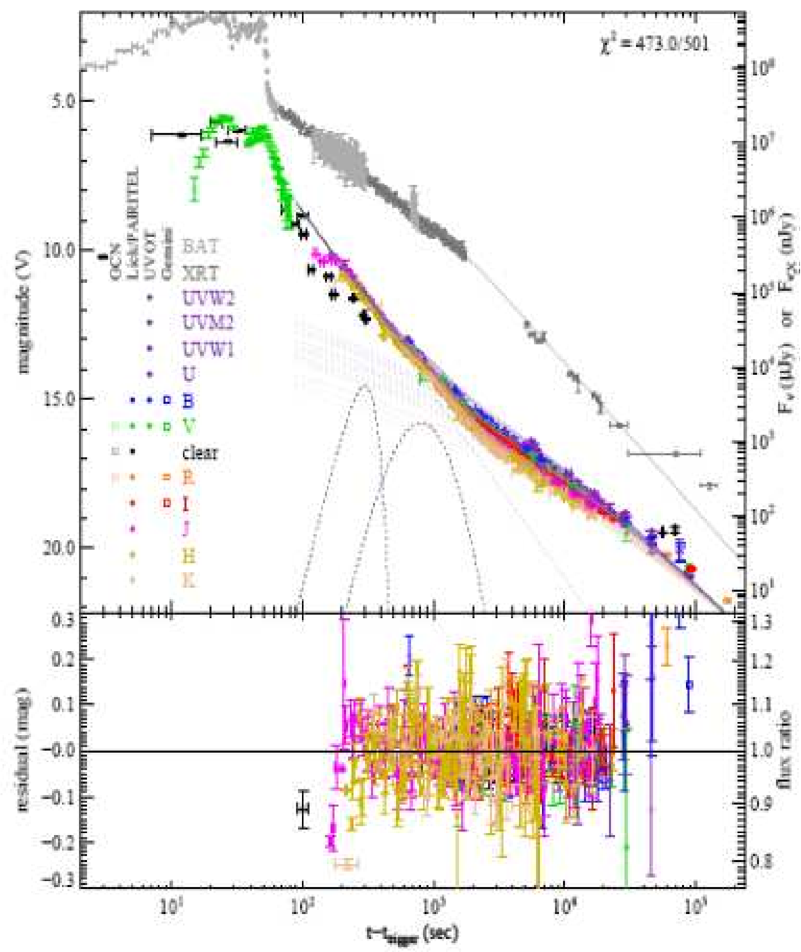


➢ *Prompt optical emission*

❑ prompt x and optical emission: usually significantly different behaviours (optical from reverse shock ? optical from synchrotron and gamma from SSC ?)

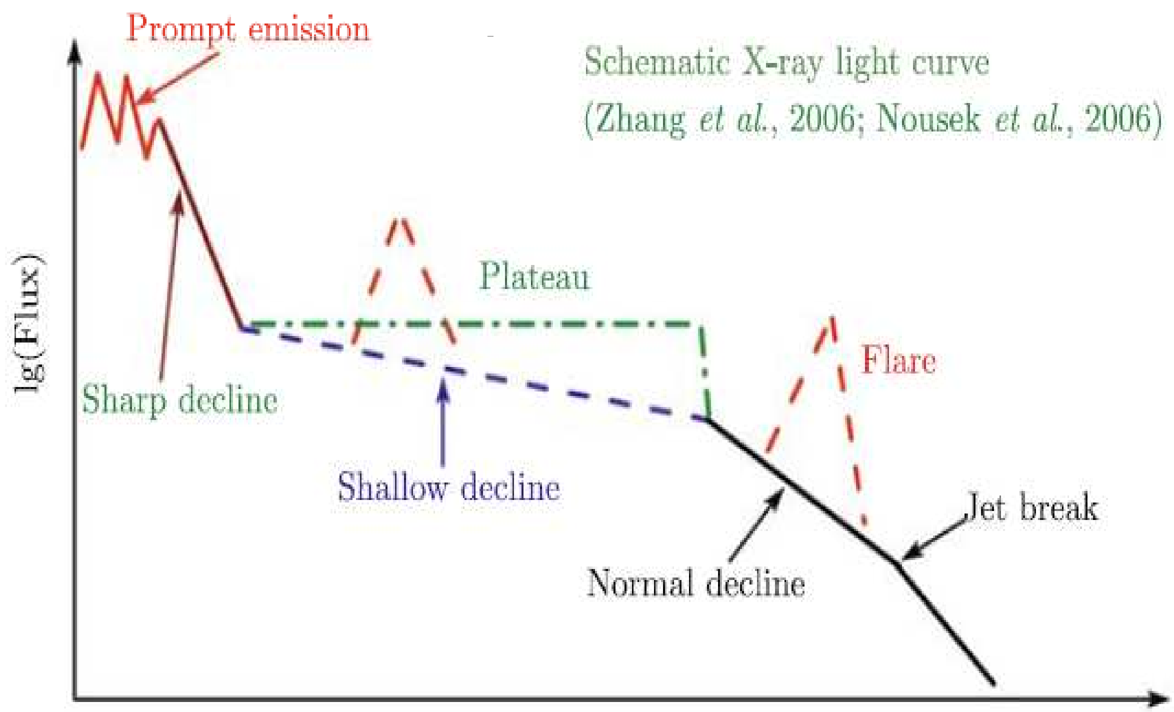






➢ *Early X-ray afterglow*

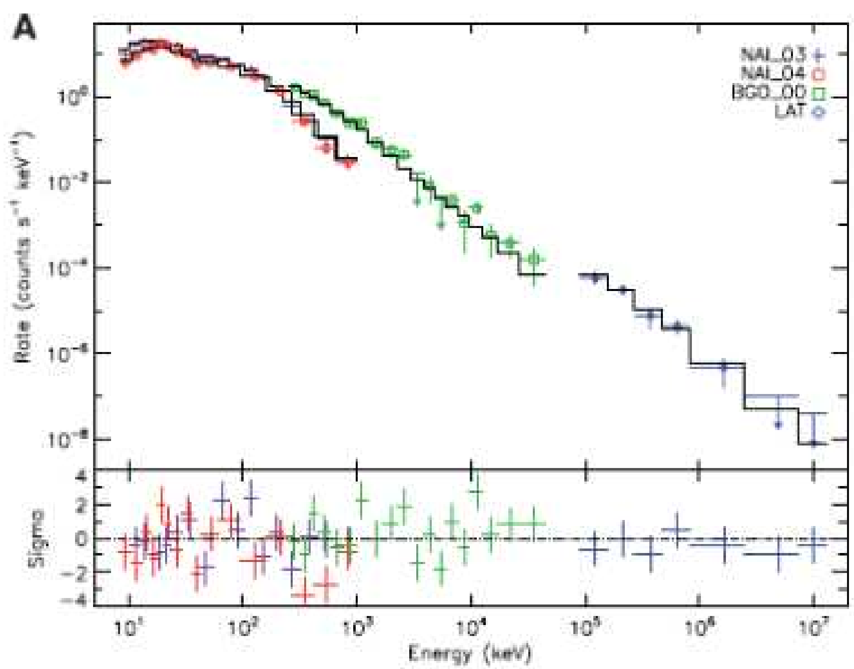
- ❑ new features seen by Swift in X-ray early afterglow light curves (initial very steep decay, early breaks, flares) mostly unpredicted and unexplained
- ❑ initial steep decay: continuation of prompt emission, mini break due to patchy shell, IC up-scatter of the reverse shock sinchrotron emission ?
- ❑ flat decay: probably “refreshed shocks” (due either to long duration ejection or short ejection but with wide range of Γ) ?
- ❑ flares: could be due to: refreshed shocks, IC from reverse shock, external density bumps, continued central engine activity, late internal shocks…

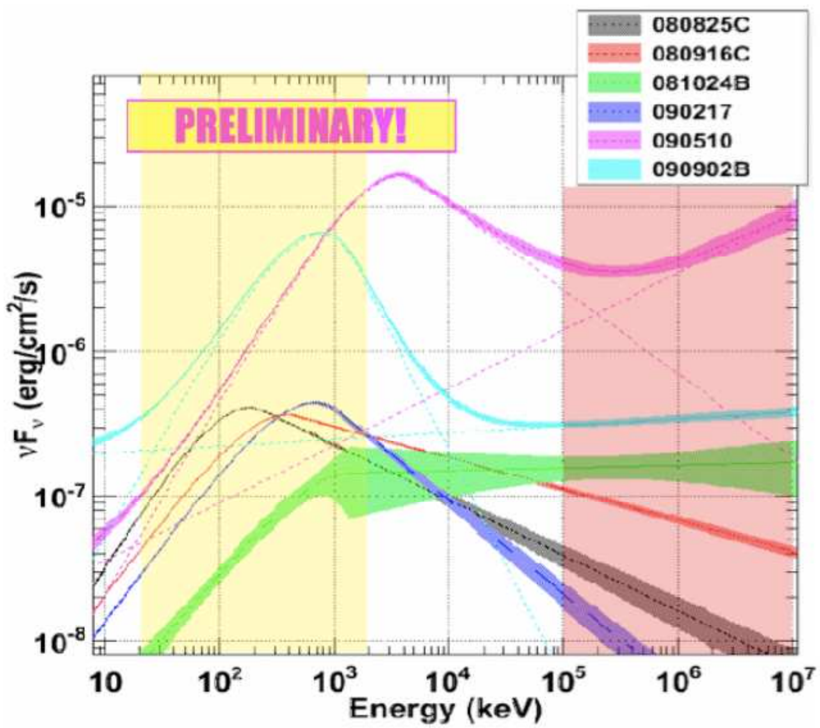


➢ *VHE (> 100 MeV) properties of GRBs by Fermi and AGILE*

❑ the huge radiated energy, the spectrum extending up to VHE without any excess or cut-off and time-delayed GeV photons of GRB 080916C measured by Fermi are challenging evidences for GRB prompt emission models

❑ nevertheless, an excess at E > 100 MeV, modeled with an additional power-law component, is detected in some GRBs (e.g., GRB 090902B, GRB090510): SSC of lower energy sinchrotron emission, IC of photospheric emission, hadronic processes



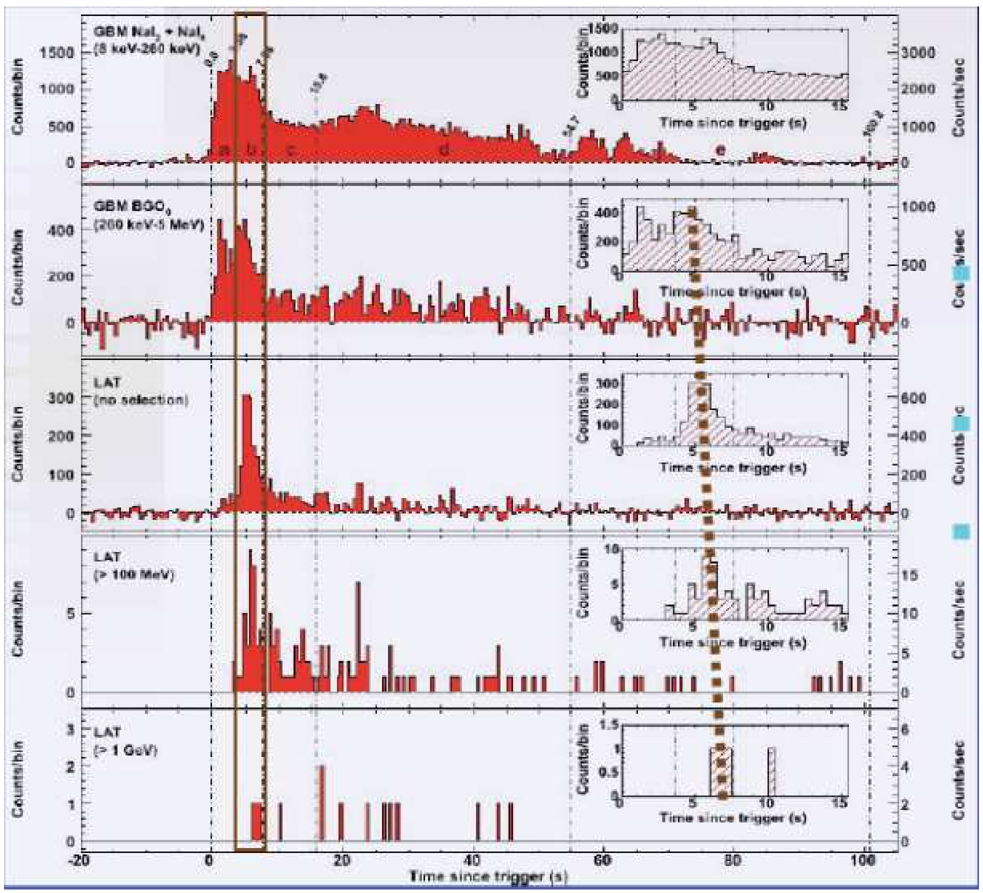


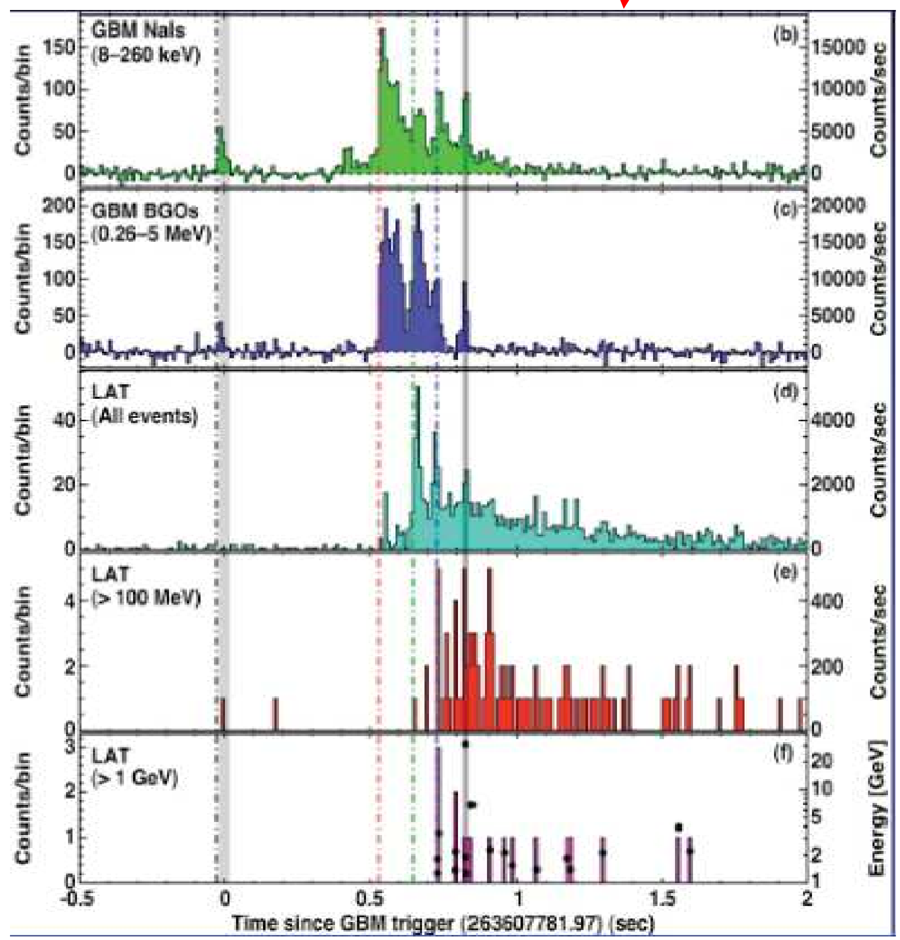
Abdo et al. 2009

- ❑ significant evidence (at least for the brightest GRBs) of a delayed onset of HE emission with respect to soft gamma rays;

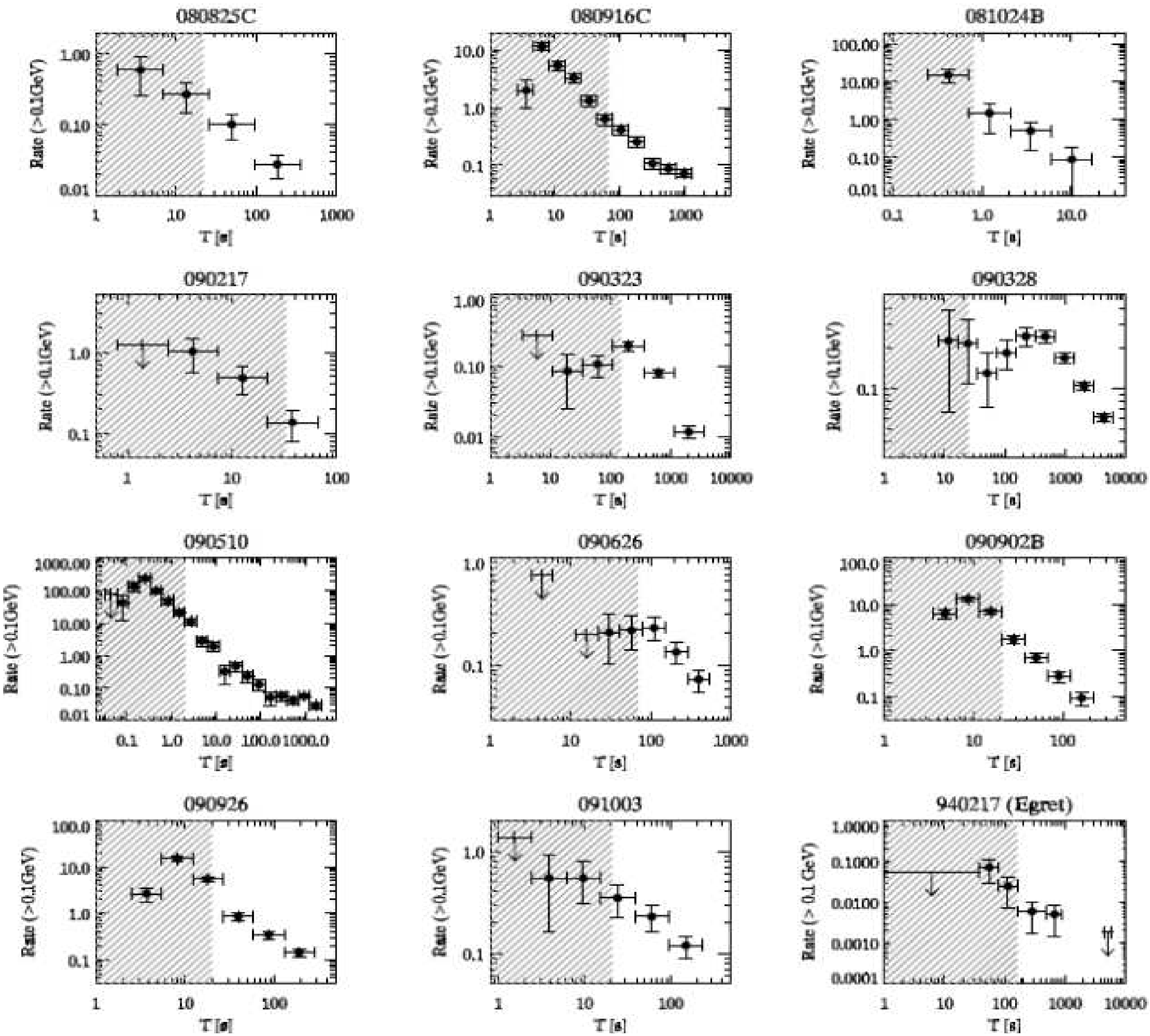
- ❑ the time delay appears to scale with the duration of the GRB (several seconds in the long GRBs 080916C and 090902B, while 0.1 − 0.2 s in the short GRBs 090510 and 081024B)

- ❑ again, challenging for models (hadronic: e.g., proton acceleration time ?)





❑ prolonged HE emission: afterglow ? (e.g., Ghisellini et al. 2010)



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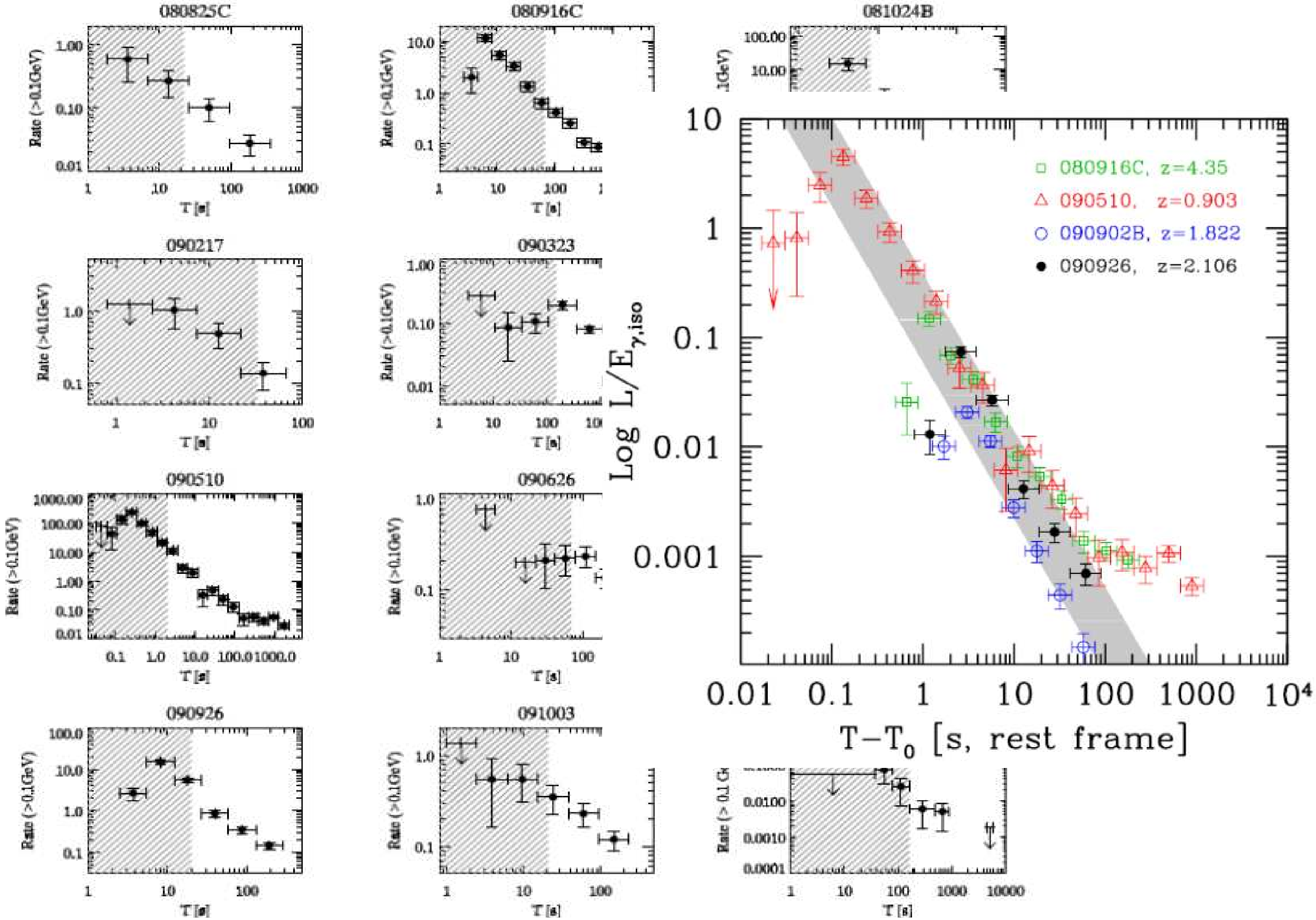
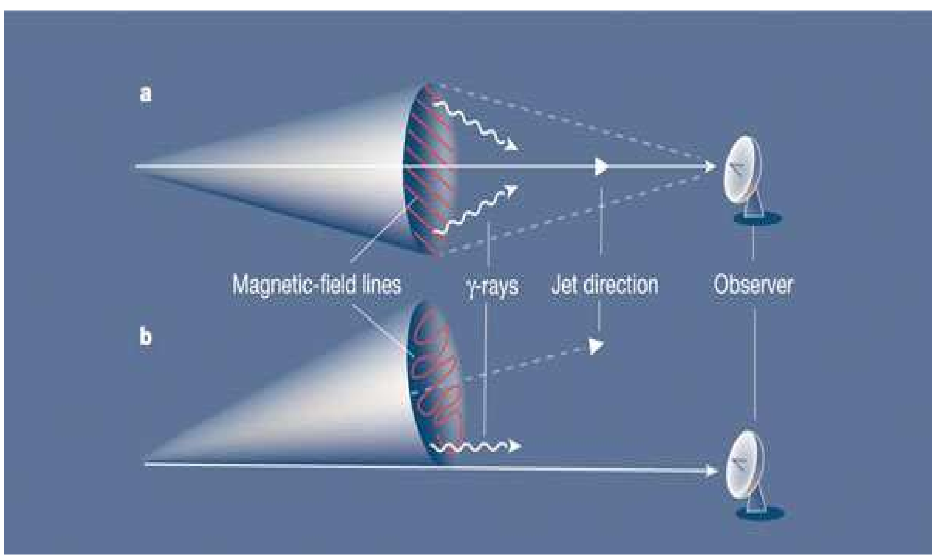
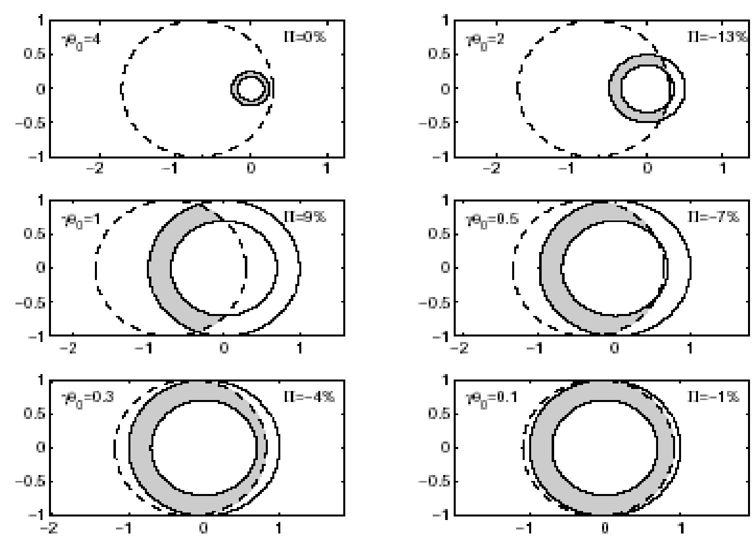


➢ *Polarization*

- until 2010, no secure detection of polarization of prompt emission (some information from INTEGRAL?), very recently measurements of 10-30% by GAP for few GRBs;
- polarization of a few % measured for some optical / radio afterglows
- radiation from synchrotron and IC is polarized, but a high degree of polarization can be detected only if magnetic field is uniform and perpendicular to line of sight
- small degree of polarization detectable if magnetic field is random, emission is collimated (jet) and we are observing only a (particular) portion of the jet or its edge



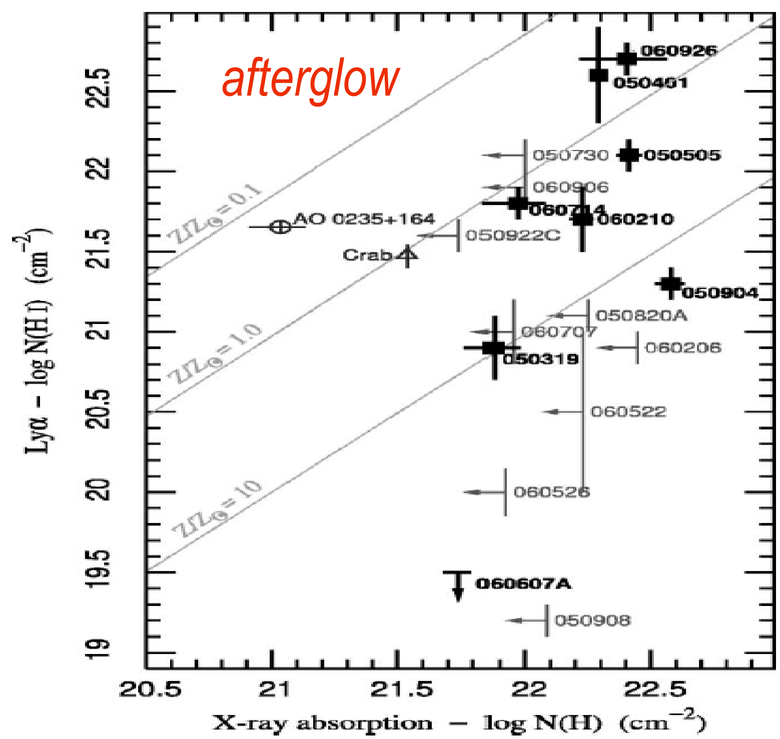


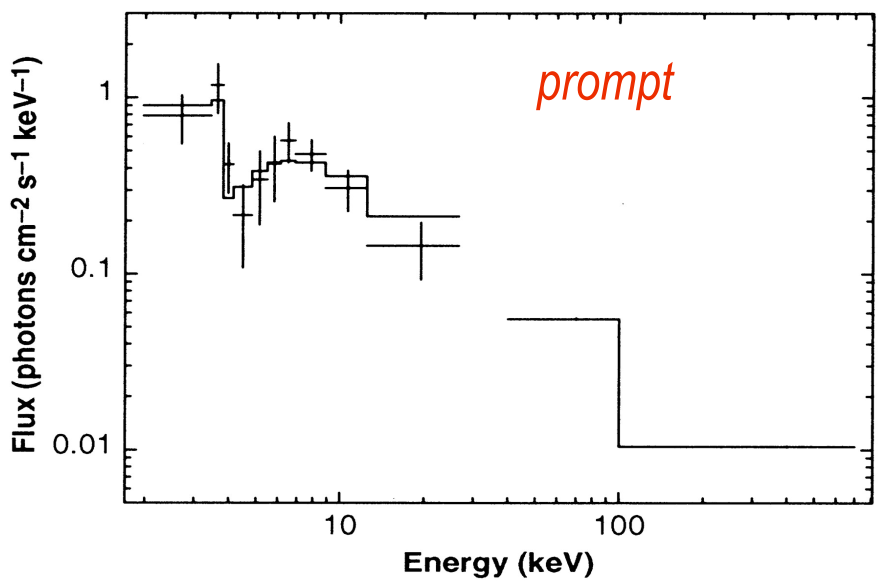
➢ *Circum-burst environment*

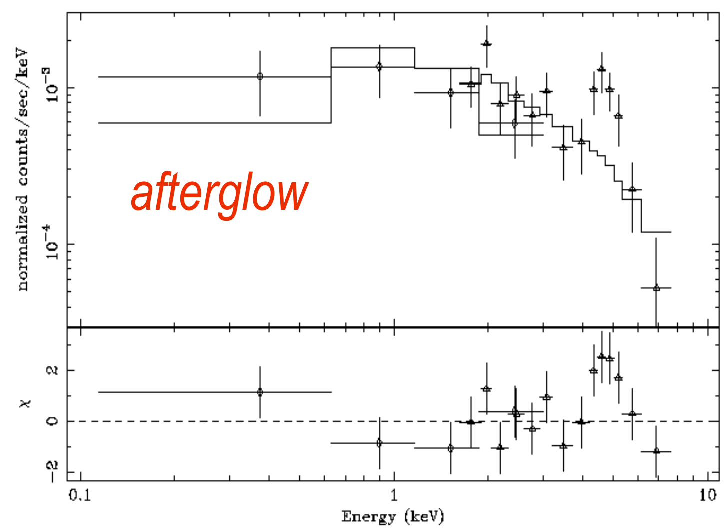
- ❑ evidence of overdense and metal enriched circum-burst environment from absorption and emission features

- ❑ emission lines in afterglow spectrum detected by BeppoSAX but not by Swift

- ❑ Swift detects intrinsic NH for many GRB afterglows, often inconsistent with NH from optical (Lyα)

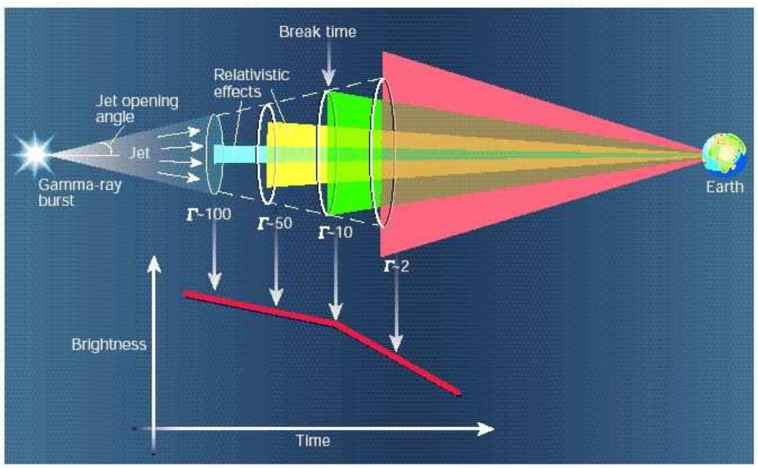


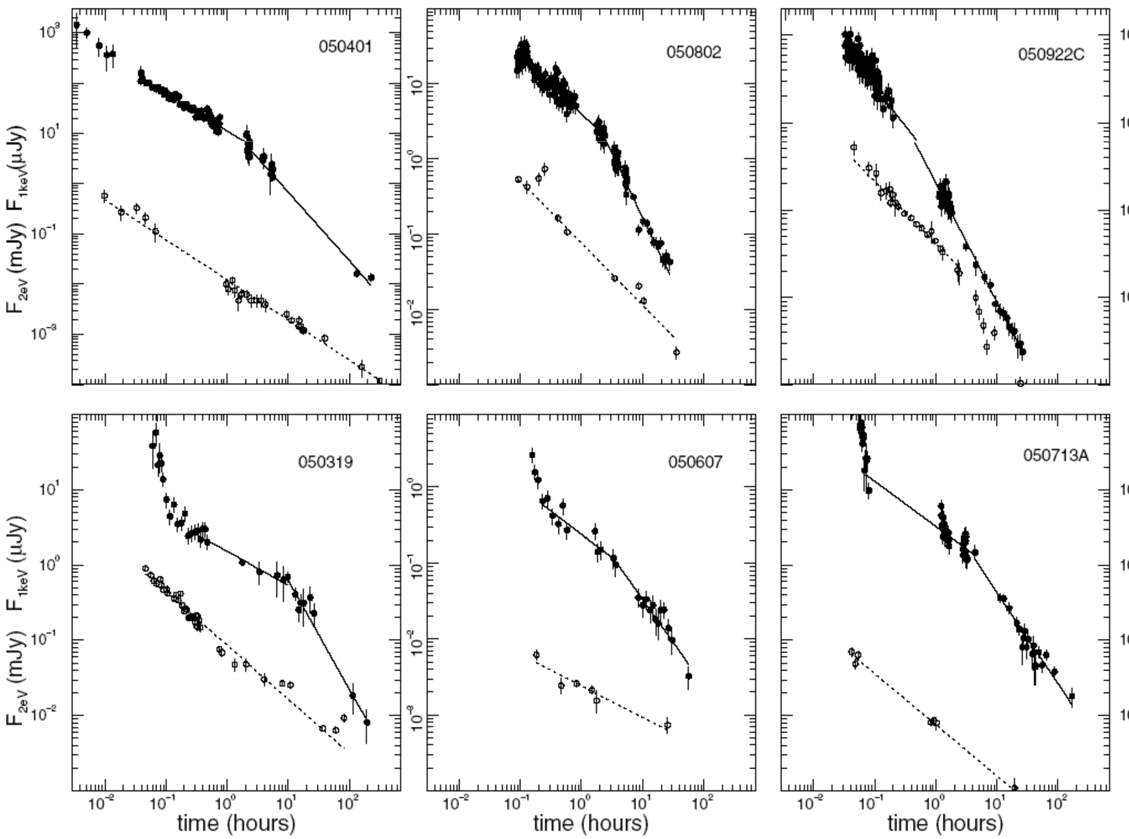




Amati et al. 2000, Watson et al. 2007, Antonelli et al. 2000

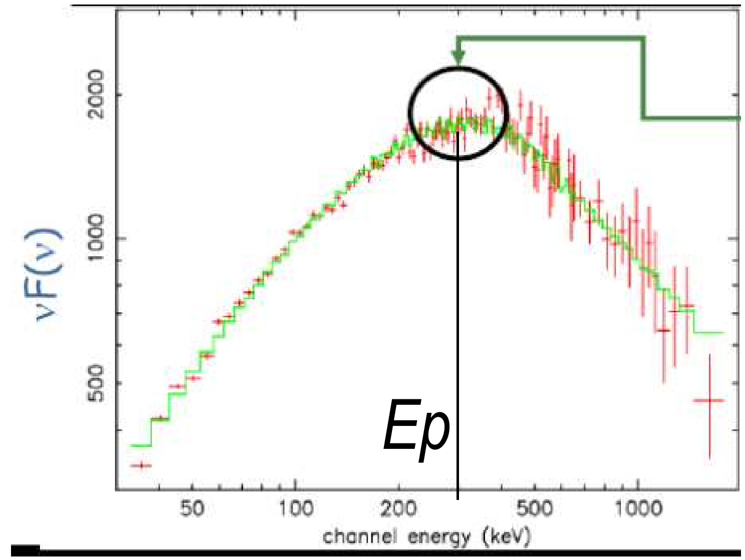
- *Collimated or isotropic ? The problem of missing breaks*
- lack of jet breaks in several Swift X-ray afterglow light curves, in some cases, evidence of achromatic break
- challenging evidences for Jet interpretation of break in afterglow light curves or due to present inadequate sampling of optical light curves w/r to X-ray ones and to lack of satisfactory modeling of jets ?

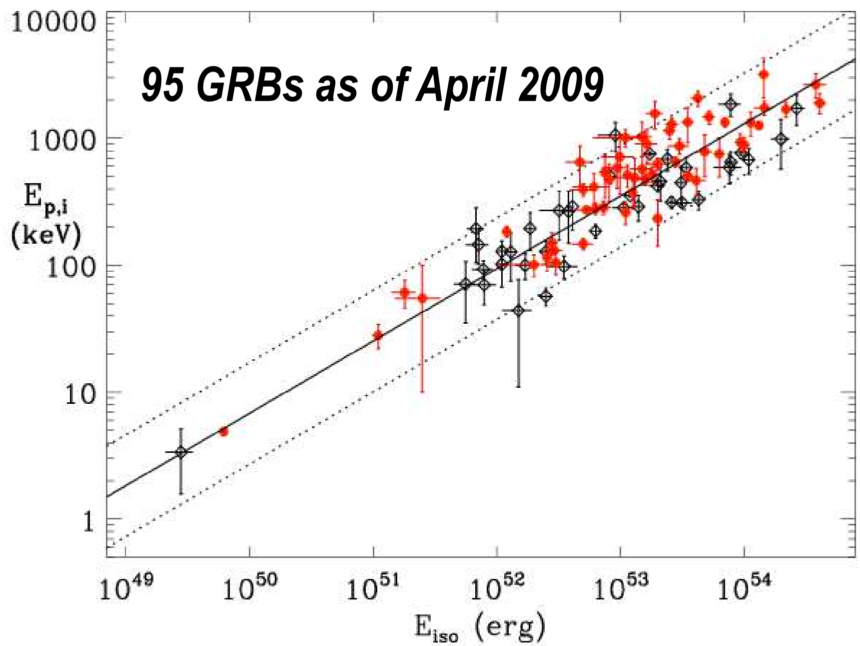




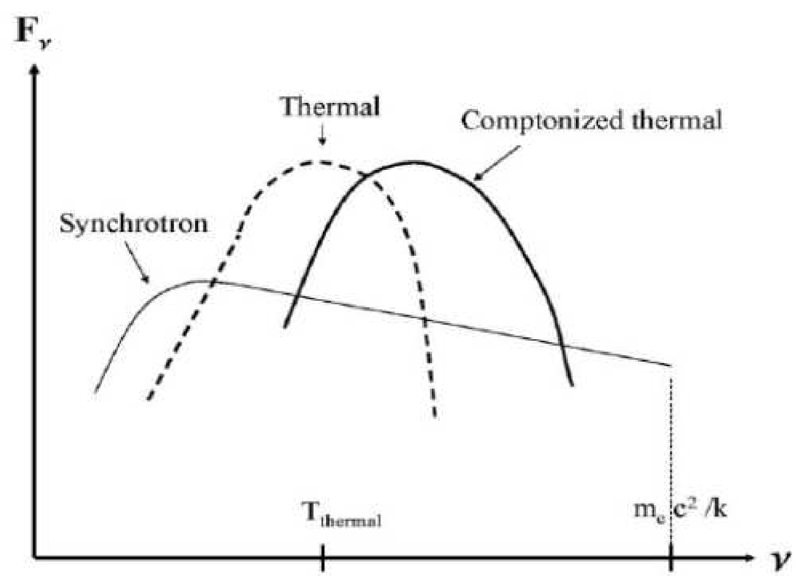
➢ *Spectrum-energy correlations: GRB physics, short/long, debates*

- Strong correlation between Ep,i and Eiso for long GRBs: test for prompt emission models (physics, geometry, GRB/XRF unification models), identification and understanding of sub-classes of events, GRB cosmology
- debate on the impact of detectors thresholds

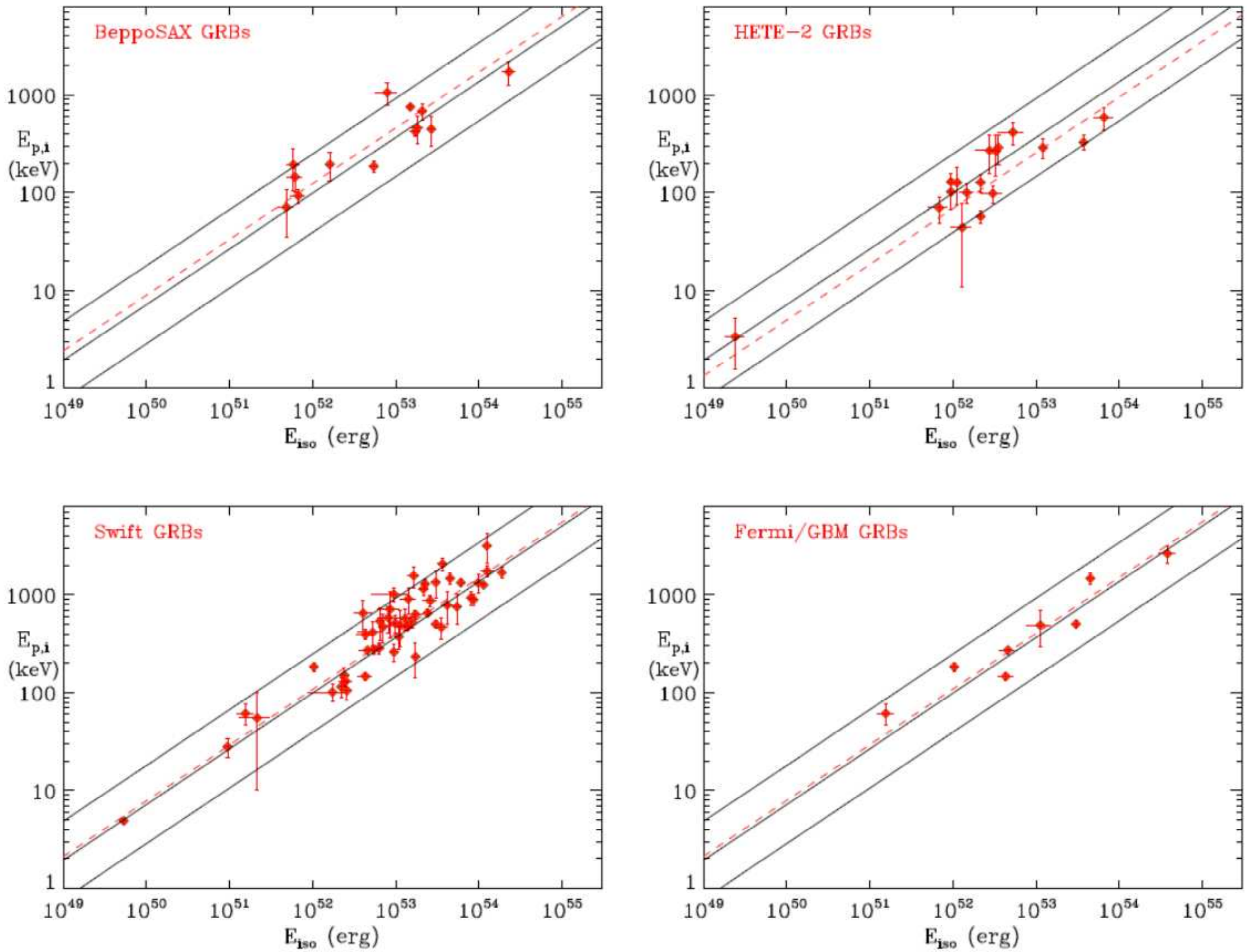




Amati et al. 2002 - 2009

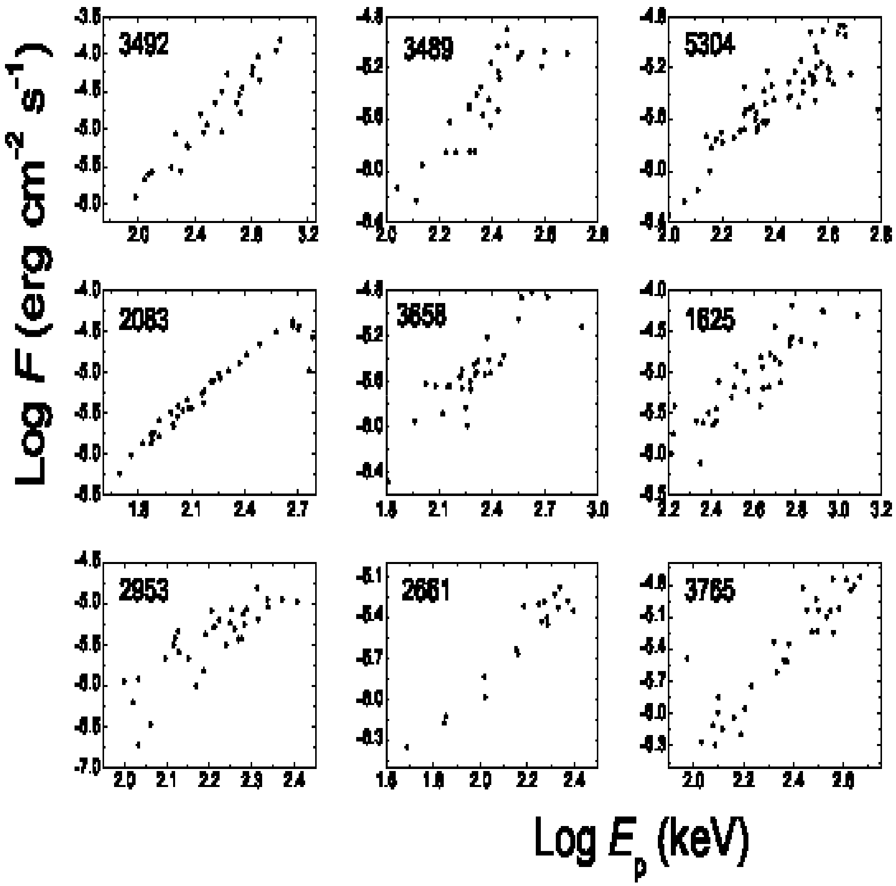


❑ the normalization of the correlation varies only marginally using GRBs measured by individual instruments with different sensitivities and energy bands

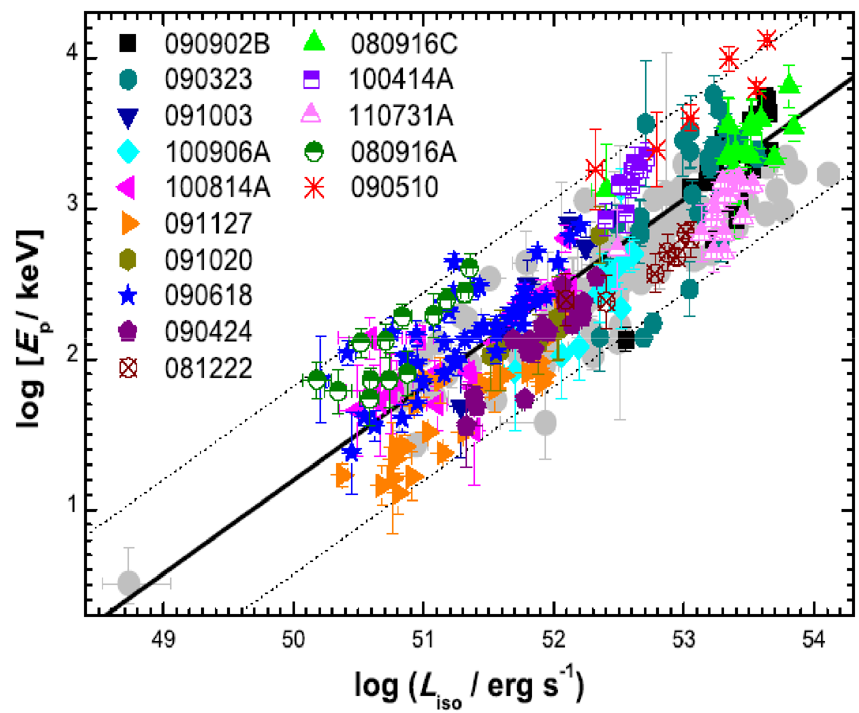


Amati , Frontera & Guidorzi 2009

➢ the Ep,i– Liso correlation holds also within a good fraction of GRBs (Liang et al.2004, Firmani et al. 2008, Frontera et al. 2012, Ghirlanda et al. 2009): **robust evidence for a physical origin and clues to explanation**



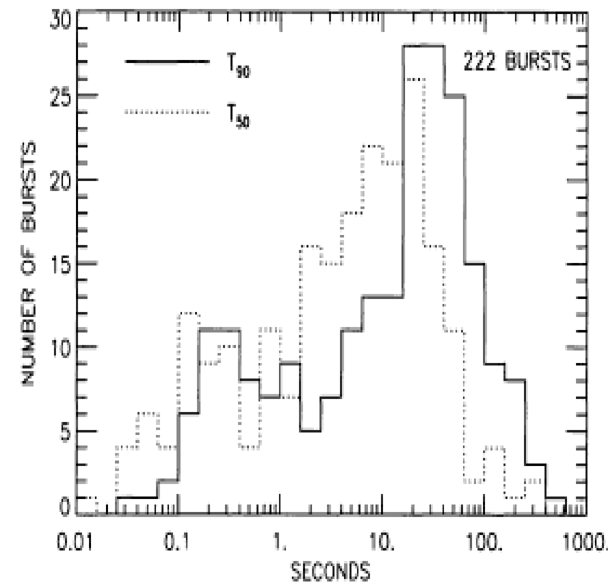
BATSE (Liang et al., ApJ, 2004)

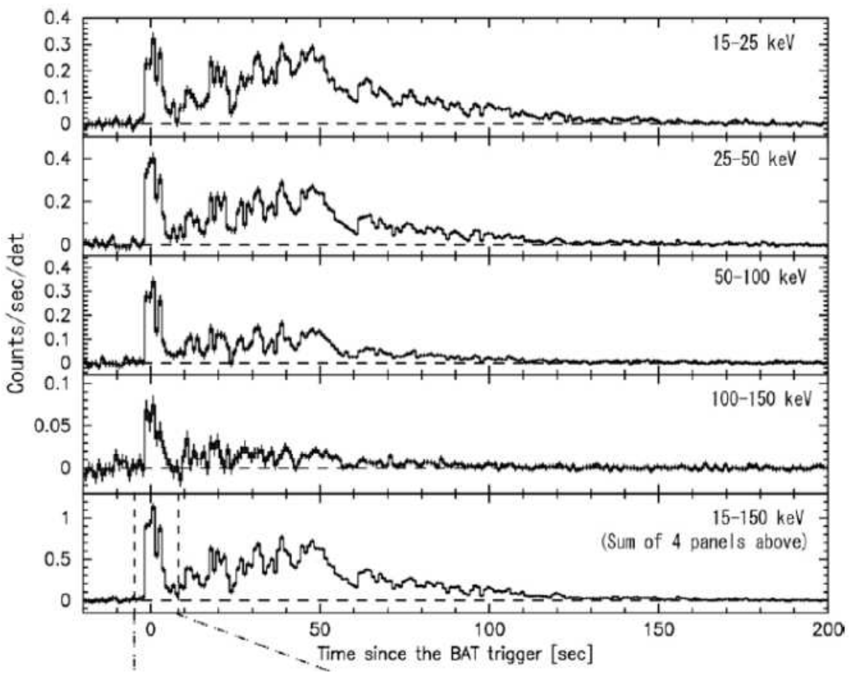


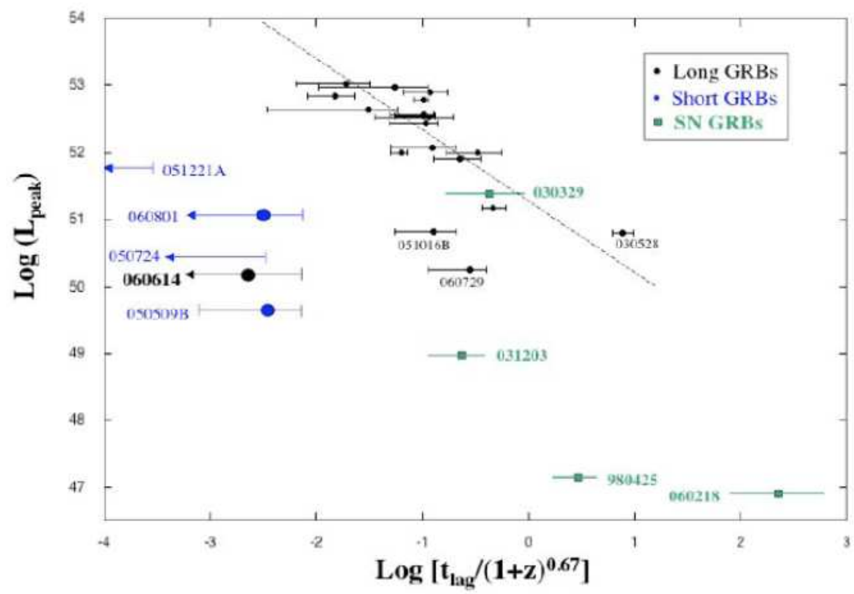
Fermi (e.g., Li et al. , ApJ, 2012)

➤ *Short / long classification and physics*

- ❑ Swift GRB 060614: a long GRB with a very high lower limit to the magnitude of an associated SN -> association with a bright GRB/SN is excluded
- ❑ high lower limit to SN also for GRB 060505 (and, less stringently, XRF 040701)
- ❑ In the spectral lag – peak luminosity plane, GRB06061 lies in the short GRBs region -> need for a new GRB classification scheme ?

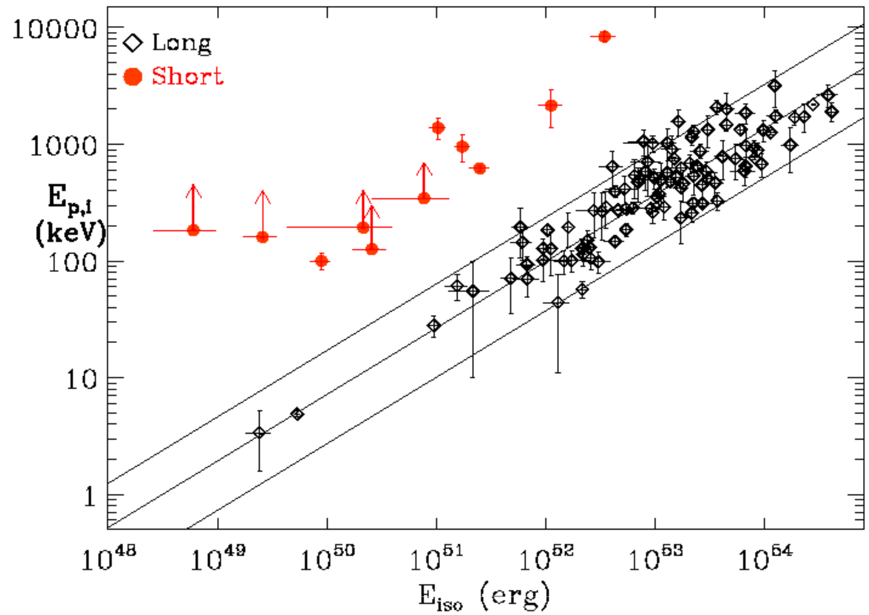


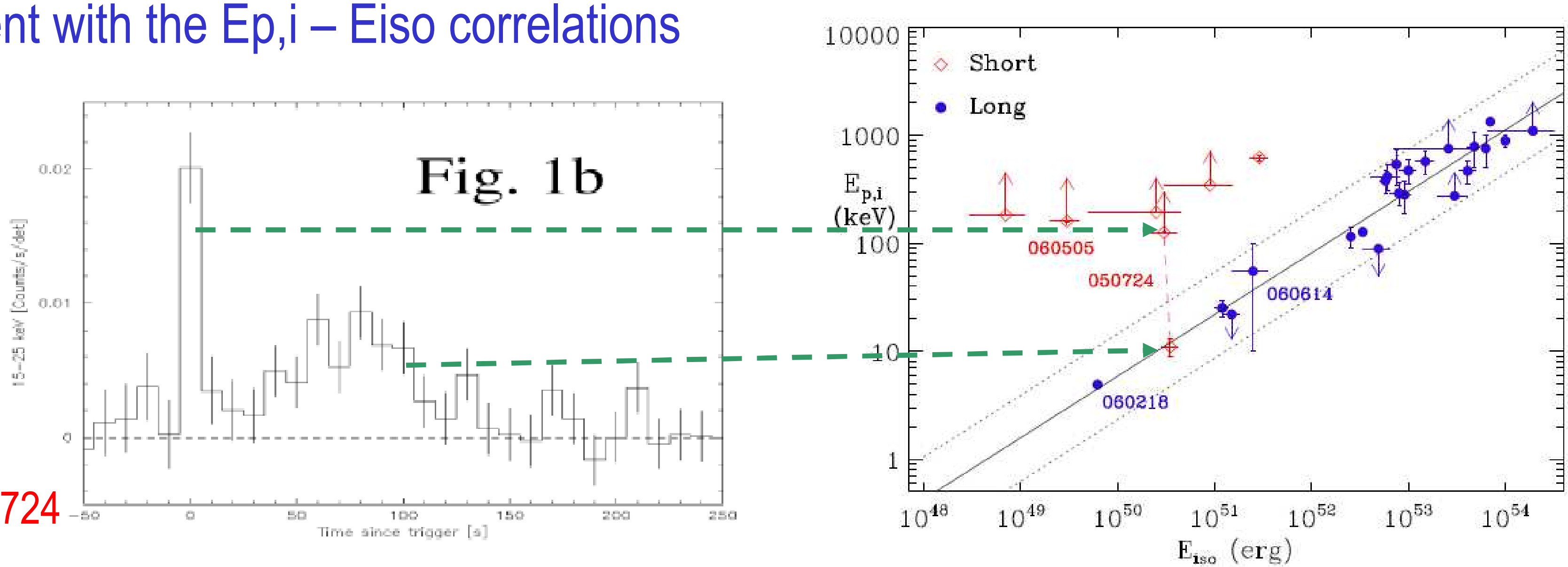




Gehrels et al., 2006

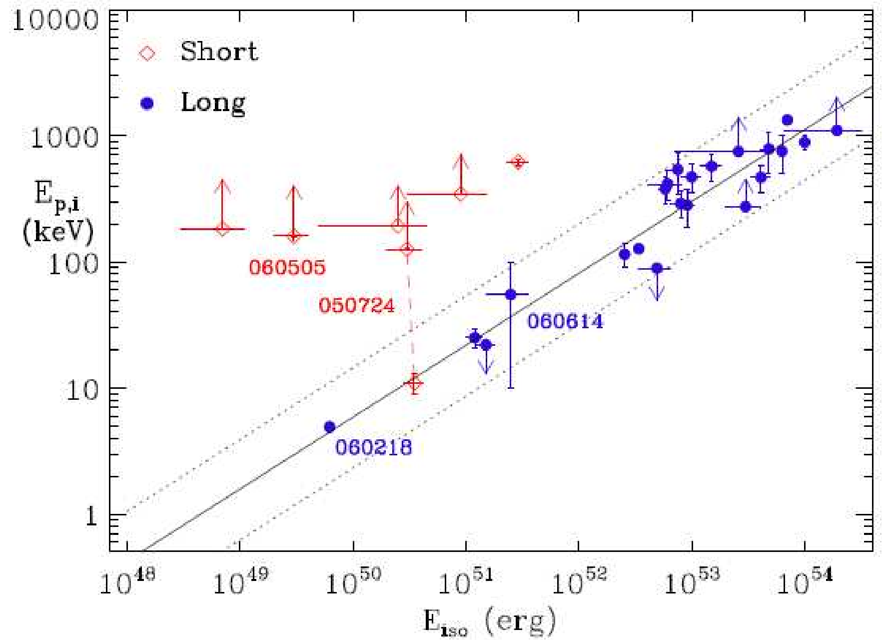
- only very recently, redshift estimates for short GRBs
- estimates and limits on Ep,i and Eiso are inconsistent with Ep,i-Eiso correlation holding for long GRBs
- low Eiso values and high lower limits to Ep,i indicate inconsistency also for the other short GRBs
- long weak soft emission in some cases, consistent with the Ep,i – Eiso correlations

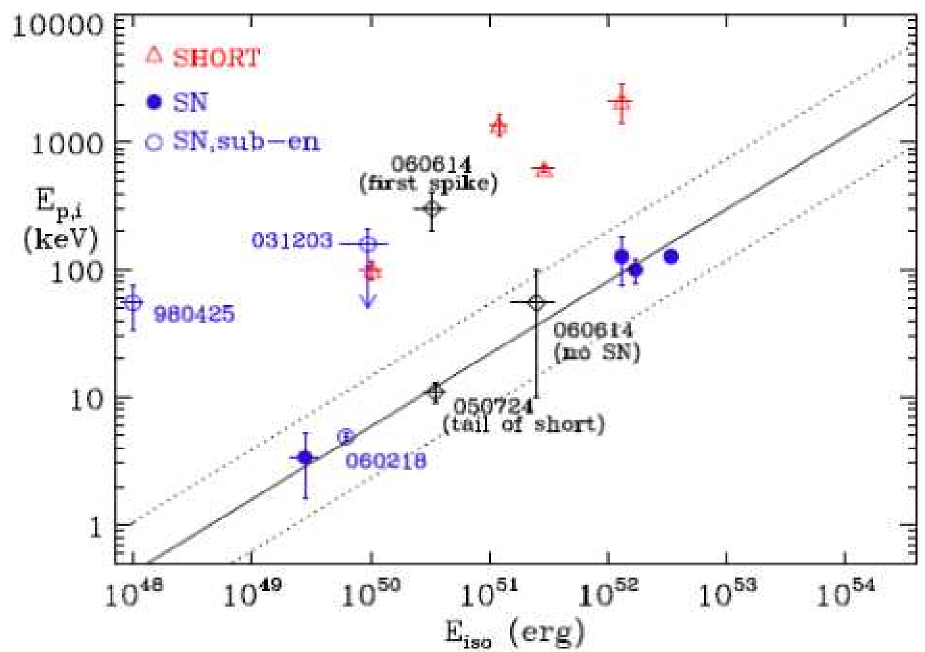




GRB0050724

- ❑ only very recently, redshift estimates for short GRBs
- ❑ all SHORT Swift GRBs with known redshift and lower limits to Ep.i are inconsistent with the Ep,i-Eiso correlation
- ❑ intriguingly, the soft tail of GRB050724 is consistent with the correlation
- ❑ GRB 060614: no SN, first pulse inconsistent with correlation, soft/long tail consistent: evidence that two different emission mechanisms are at work in both short and long GRB, with different relative efficiency in the two classes (-> "intermediate" GRB)



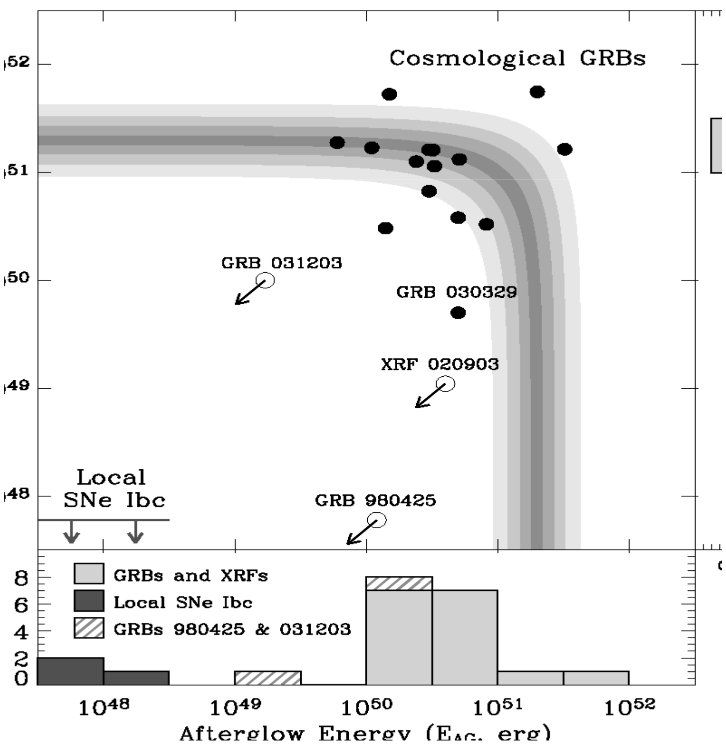


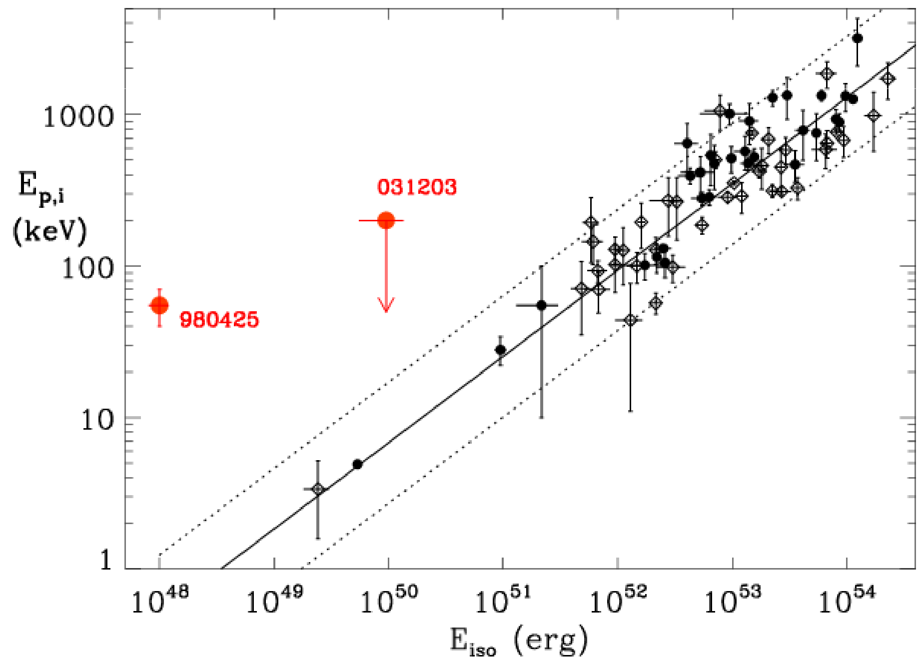
Amati 2006, Amati+ 2007

➢ *Sub-energetic GRBs*

- ❑ GRB980425 not only prototype event of GRB/SN connection but closest GRB (z = 0.0085) and sub-energetic event (Eiso ~ 10^{48} erg, Ek,aft ~ 10^{50} erg)

- ❑ GRB031203: the most similar case to GRB980425/SN1998bw: very close (z = 0.105), SN2003lw, sub-energetic

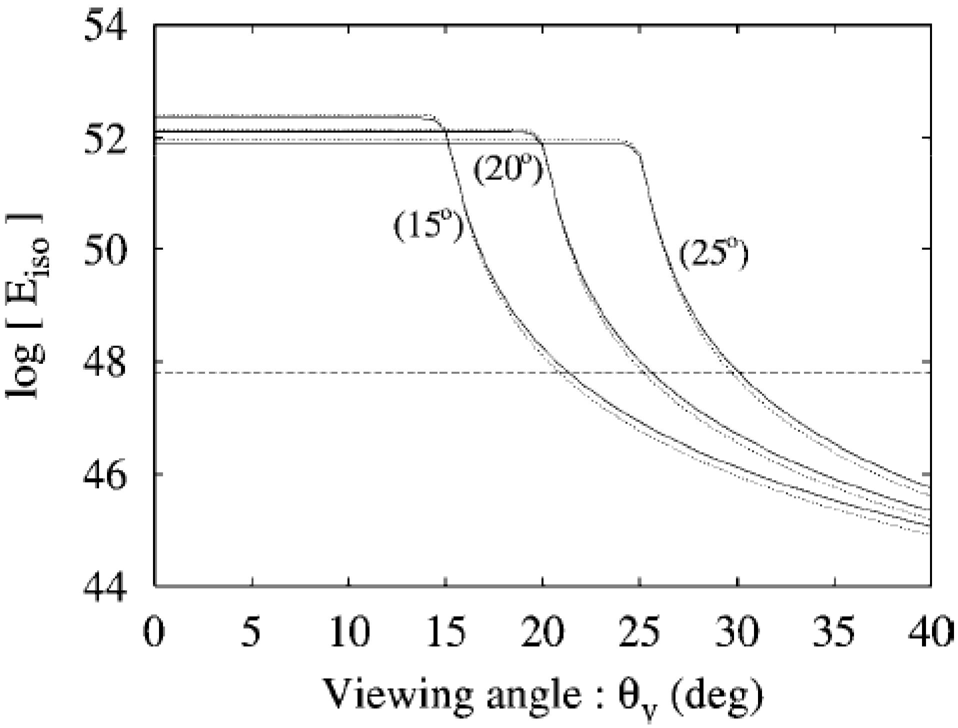


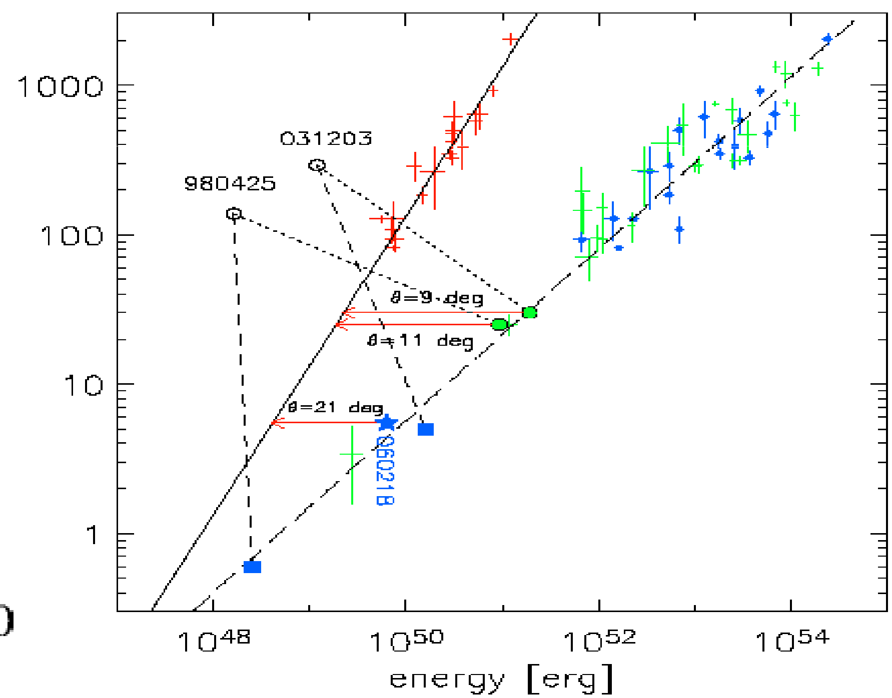


Soderberg et al. 2006

- the most common explanations for the (apparent ?) sub-energetic nature of GRB980425 and GRB031203 and their violation of the Ep,i – Eiso correlation assume that they are NORMAL events seen very off-axis (e.g. Yamazaki et al. 2003, Ramirez-Ruiz et al. 2005)
- $\delta=[\gamma(1 - \beta\cos(\theta v - \Delta\theta))]^{-1}$, $\Delta Ep \propto \delta$, $\Delta Eiso \propto \delta^{(1+\alpha)}$

  $\alpha=1\div2.3$ -> $\Delta Eiso \propto \delta^{(2 \div 3.3)}$



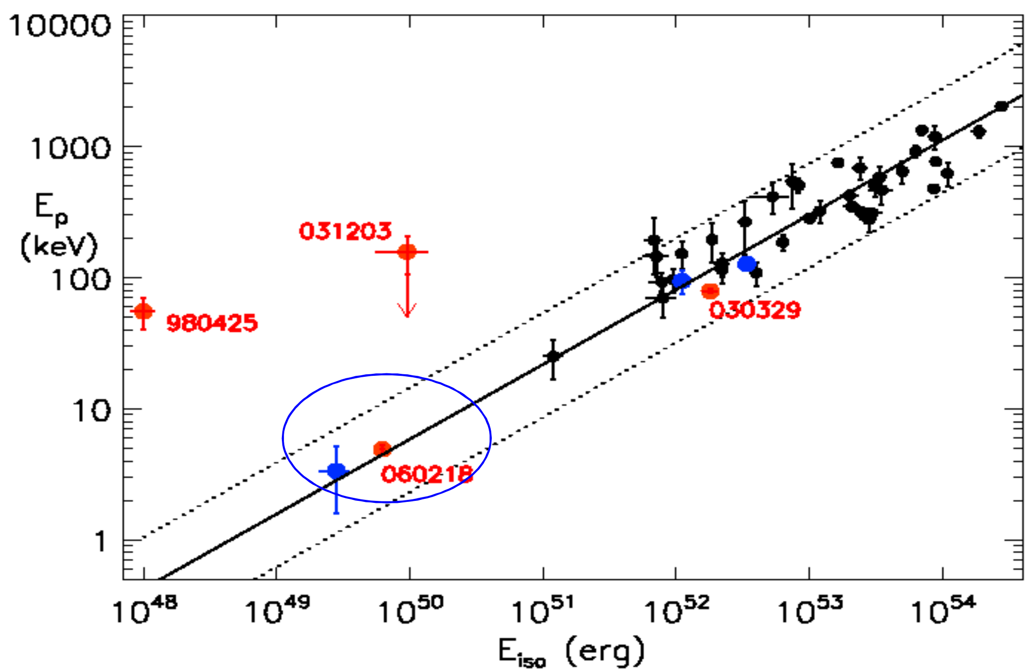


Yamazaki et al., ApJ, 2003

- GRB 060218, a very close (z = 0.033, second only to GRB9809425), with a prominent association with SN2006aj, and very low Eiso (6 x 10^{49} erg) and Ek,aft -> very similar to GRB980425 and GRB031203

- but, contrary to GRB980425 and (possibly) GRB031203, GRB060218 is consistent with the Ep,i-Eiso correlation -> evidence that it is a truly sub-energetic GRB -> likely existence of a population of under-luminous GRB detectable in the local universe

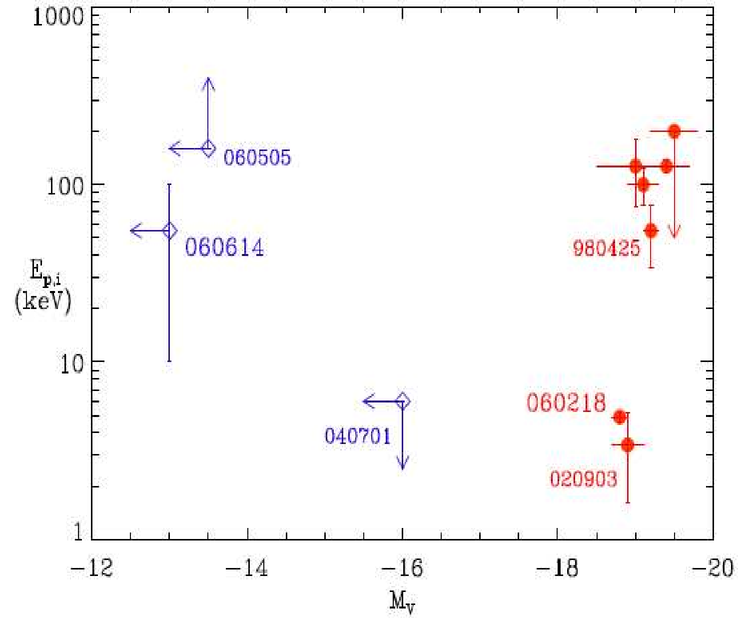
- also XRF 020903 is very weak and soft (sub-energetic GRB prompt emission) and is consistent with the Ep-Eiso correlation



Amati et al., 2007

➤ *GRB/SN connection*

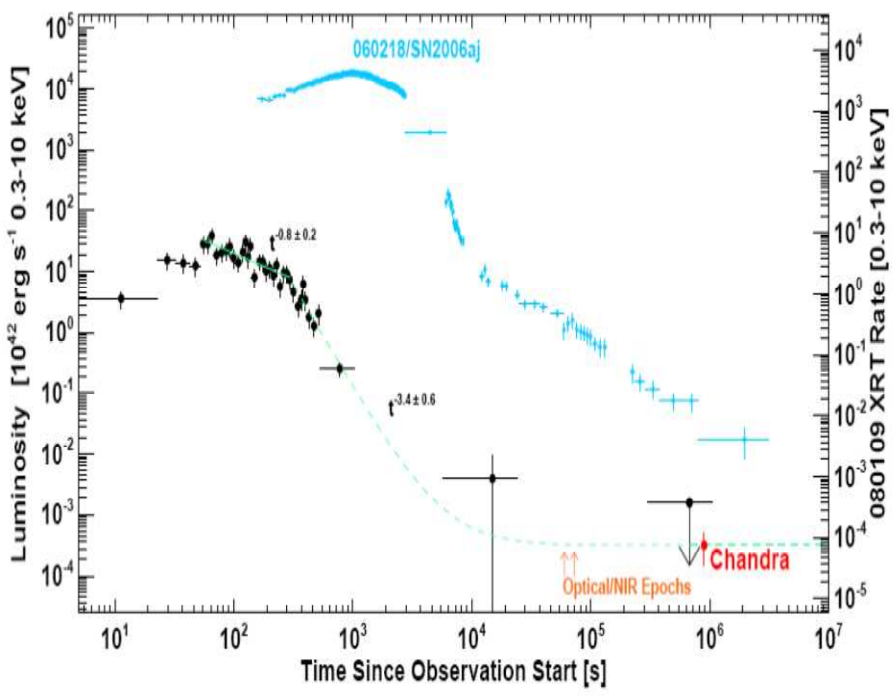
- are all long GRB produced by a type Ibc SN progenitor ?
- which fraction of type Ibc SN produces a GRB, and what are their peculiarities ?
- are the properties (e.g., energetics) of the GRB linked to those of the SN ?
- long GRBs with no (or very faint) associated SNe



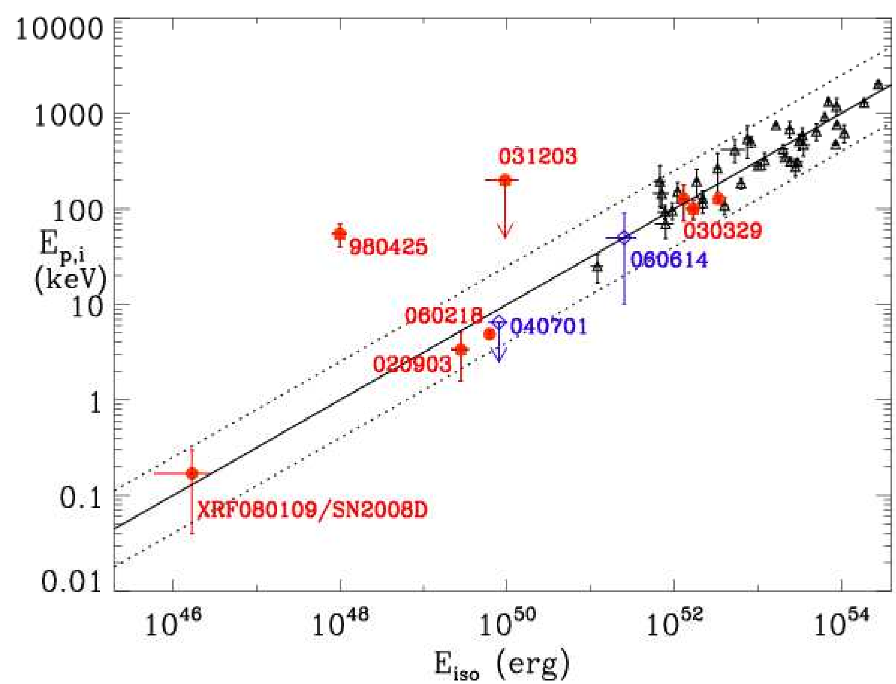
GRB/SN	z	$E_{p,i}$ (keV)	E^{iso}_{prompt} (10^{50} erg)	θ_{jet} (deg)	E^{jet}_{prompt} (10^{50} erg)	SN $E^{iso(a)}_{K}$ (10^{50} erg)	SN peak mag
980425/SN 1998bw	0.0085	55±21	0.01±0.002	-	<0.012	200-500	M_V=−19.2±0.1
060218/SN 2006aj	0.033	4.9±0.3	0.62±0.03	>57	0.05–0.65	20–40	M_V=−18.8±0.1
031203/SN 2003lw	0.105	<200	1.0±0.4	–	<1.4	500-700	M_V=−19.5±0.3
030329/SN 2003dh	0.17	100±23	170±30	5.7±0.5	0.80±0.16	~400	M_V=−19.1 ± 0.2
020903/BL-SNIb/c	0.25	3.4±1.8	0.28±0.07	–	<0.35	–	$M_V \sim -18.9$
050525A/SN 2005nc	0.606	127±10	339±17	4.0±0.8	0.57±0.23	–.	$M_B=-18.9^{+0.1}_{-0.5}$
021211/SN 2002lt	1.01	127±52	130±15	8.8±1.3	1.07±0.13	–	$M_U \sim -18.9$
060505	0.089	>160	0.3±0.1	–	–	–	$M_R > -13.5$
060614	0.125	10–100	25±10	~12	0.45±0.20	–	$M_V >\sim -13$
040701	0.215	<6.	0.8±0.2	–	–	–	$M_V > -16$

Amati et al. 2007

- Recent Swift detection of an X-ray transient associated with SN 2008D at z = 0.0064, showing a light curve and duration similar to GRB 060218
- Debate: very soft/weak XRF or SN shock break-out ?
- Peak energy limits and energetics consistent with a very-low energy extension of the Ep,i-Eiso correlation (Li 2008, based on XRT and UVOT data)
- Evidence that this transient may be a very soft and weak GRB (XRF 080109), thus confirming the existence of a population of sub-energetic GRB ?



Modjaz et al., ApJ, 2008



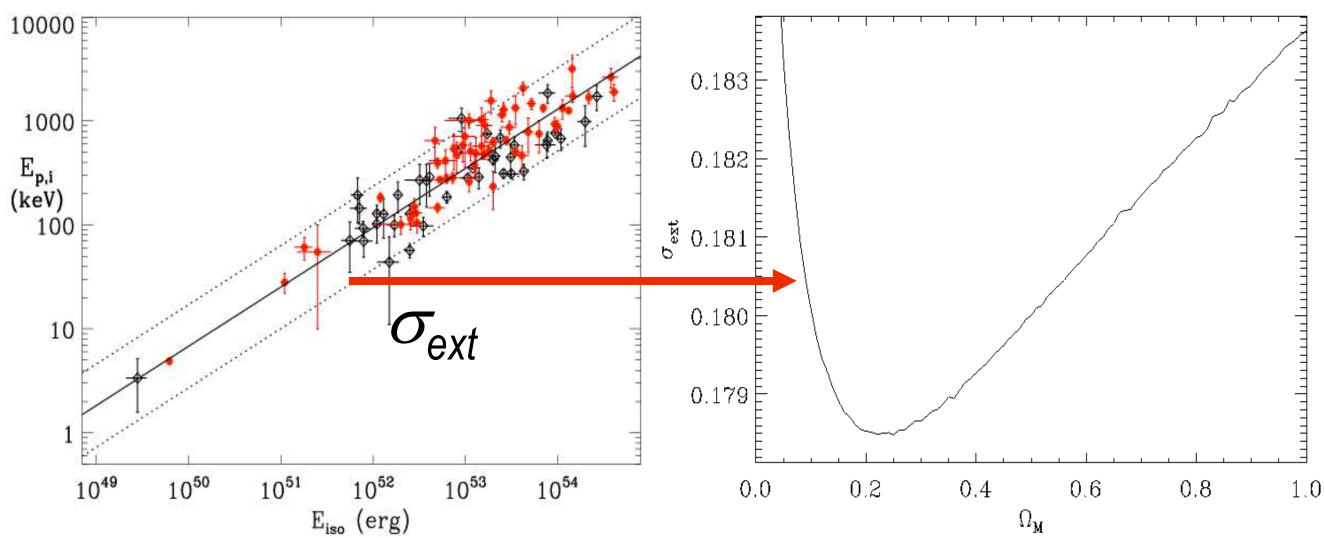
Amati, 2008, this workshop

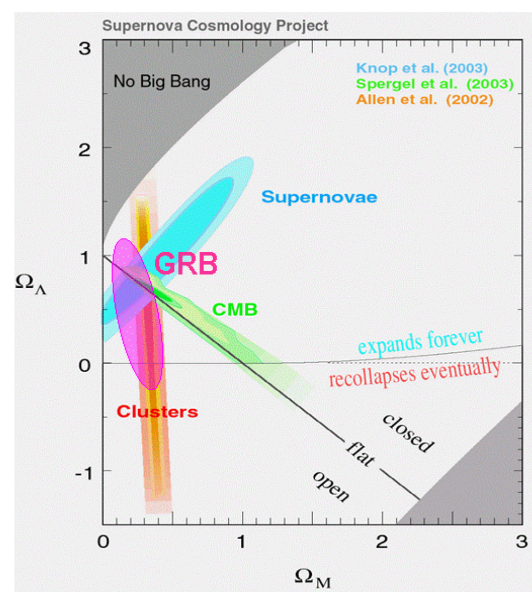
➢ *GRB cosmology ?*

- GRB have huge luminosities and a redshift distribution extending far beyond SN Ia and even beyond that of AGNs
- high energy emission -> no extinction problems
- **potentially powerful cosmological sources**
- estimate of cosmological parameters through spectrum-energy correlations ?

$$E_{p,i} = E_{p,obs} \times (1 + z)$$

$$E_{\gamma,iso} = \frac{4\pi D_l^2}{(1+z)} \int_{1/1+z}^{10^4/1+z} E\,N(E)\,dE \quad \mathrm{erg} \;\rightarrow\; D_l = D_l(z, H_0, \Omega_M, \Omega_\Lambda, \ldots)$$





Amati et al. 2008, 2012

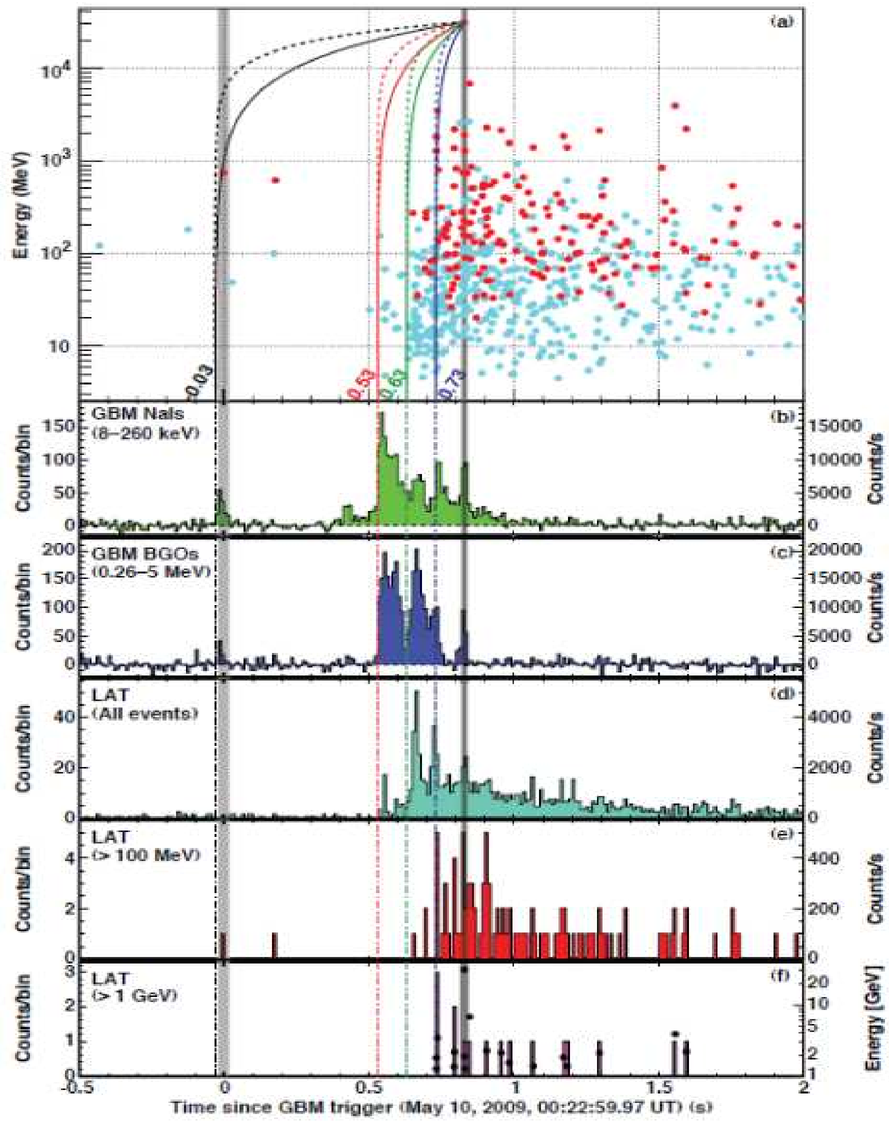
❑ Using time delay between low and high energy photons to put Limits on Lorentz Invariance Violation (allowed by unprecedent Fermi GBM + LAT broad energy band)

$$v_{\rm ph} = \frac{\partial E_{\rm ph}}{\partial p_{\rm ph}} \approx c\left[1 - s_n \frac{n+1}{2}\left(\frac{E_{\rm ph}}{M_{{\rm QG},n}c^2}\right)^n\right]$$

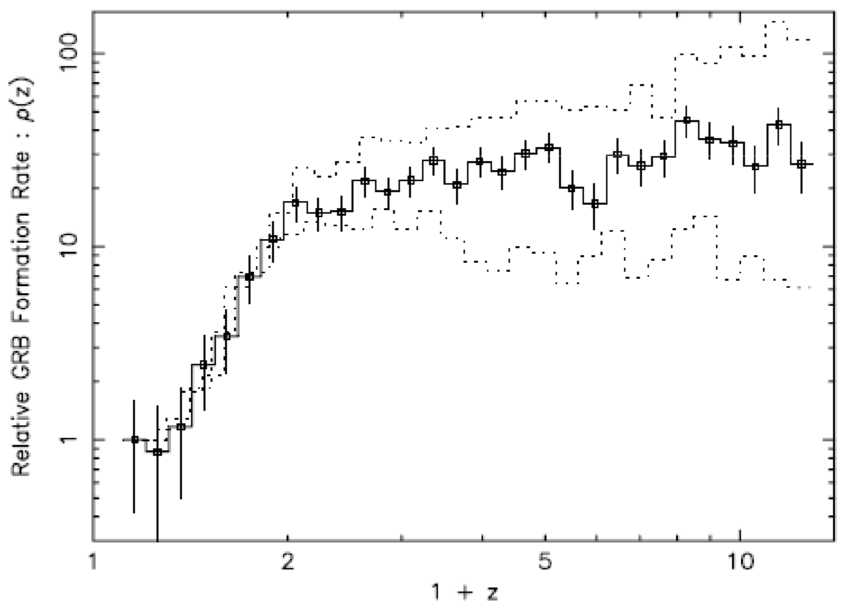
$$\Delta t = s_n \frac{(1+n)}{2H_0}\frac{(E_h^n - E_l^n)}{(M_{{\rm QG},n}c^2)^n}\int_0^z \frac{(1+z')^n}{\sqrt{\Omega_m(1+z')^3+\Omega_\Lambda}}\,dz'$$

GRB 990510 $E_h = 30.53^{+5.79}_{-2.56}$ GeV

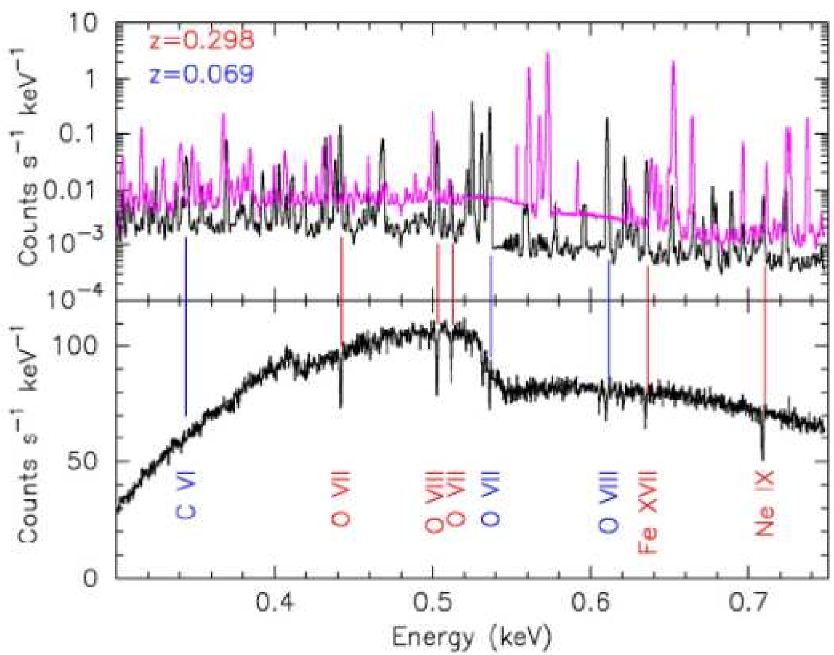
$t_{\rm start}$ (ms)	limit on $\lvert\Delta t\rvert$ (ms)	Reason for choice of $t_{\rm start}$ or limit on Δt	E_l (MeV)	valid for s_n	lower limit on $M_{\rm QG,1}/M_{\rm Planck}$
−30	< 859	start of any observed emission	0.1	1	> 1.19
530	< 299	start of main < 1 MeV emission	0.1	1	> 3.42
630	< 199	start of > 100 MeV emission	100	1	> 5.12
730	< 99	start of > 1 GeV emission	1000	1	> 10.0
—	< 10	association with < 1 MeV spike	0.1	± 1	> 102
—	< 19	if 0.75 GeV γ is from 1st spike	0.1	± 1	> 1.33
$\left\lvert\frac{\Delta t}{\Delta E}\right\rvert < 30\ \frac{\rm ms}{\rm GeV}$		lag analysis of all LAT events	—	± 1	> 1.22



- use of GRBs as tracers of star formation up to the dark ages of the universe
- evidence that GRBs are biased SFR tracers if not accounting for metallicity evolution
- use of GRBs as cosmological beacons for the study of the ISM and the IGM (e.g., WHIM) evolution up to very high z

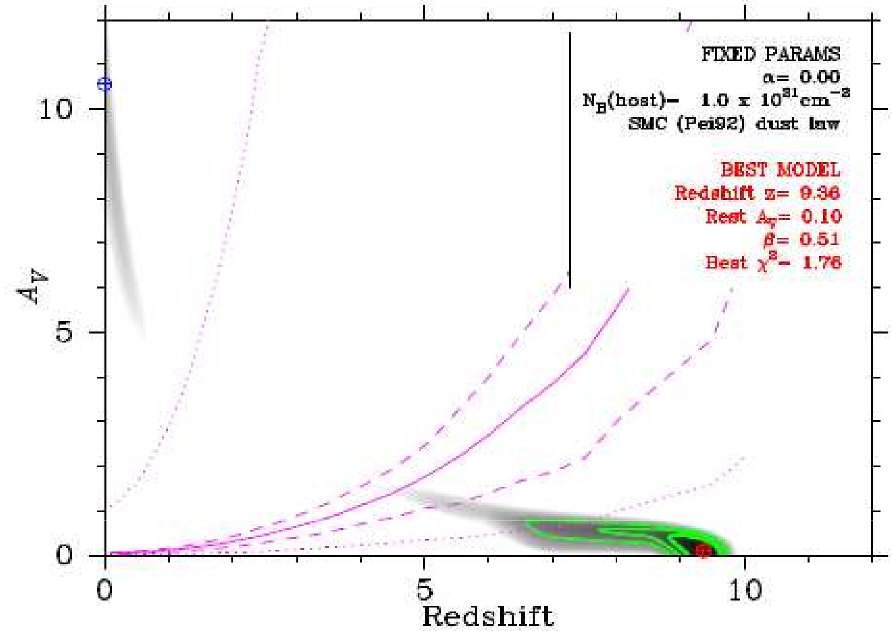


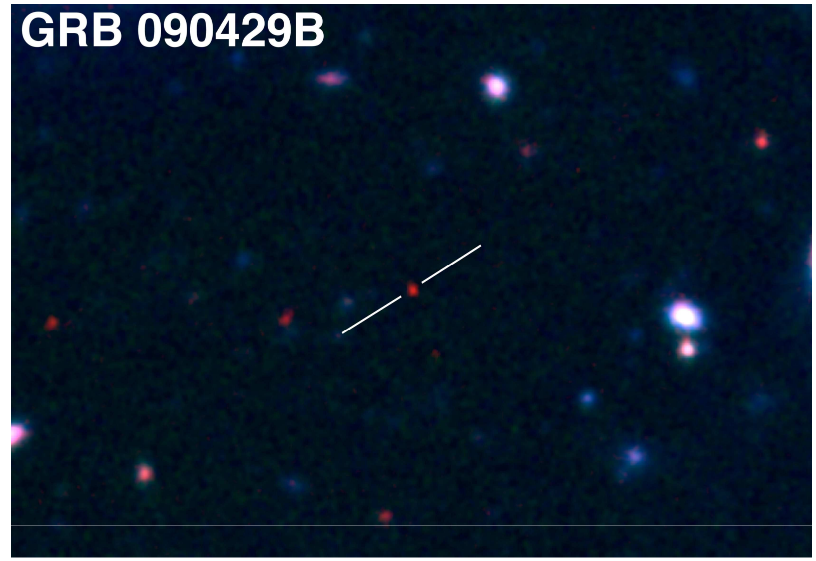
Yonetoku et al. 2004

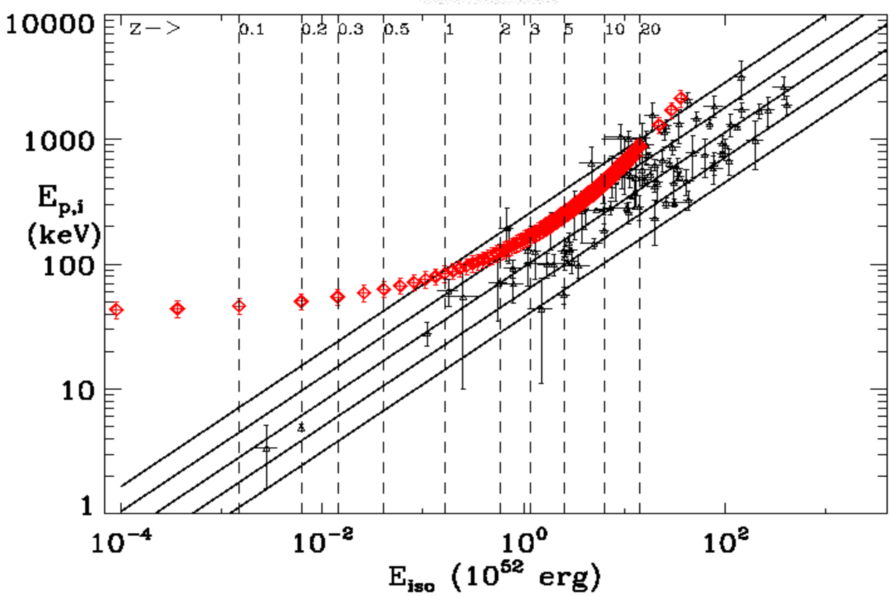


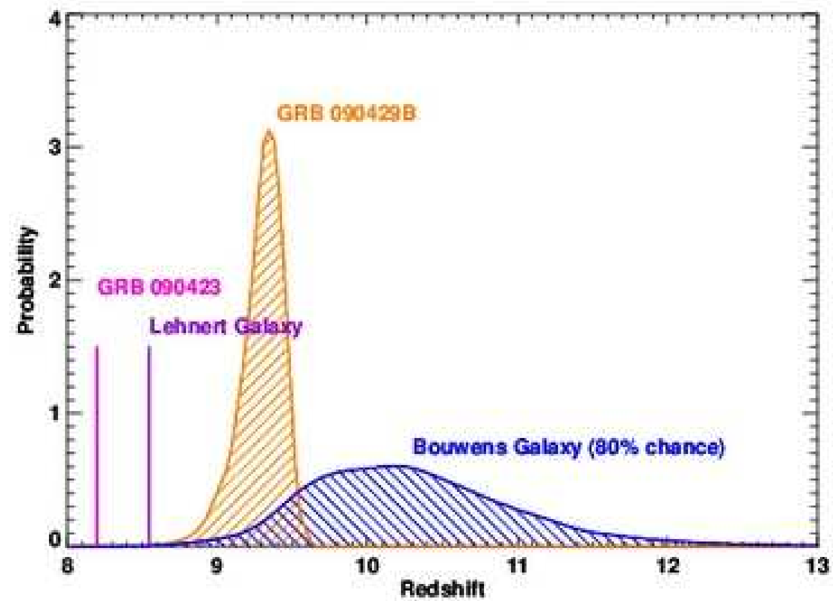
Branchini et al. 2009, ORIGIN team

❑ The case of GRB 090429B at a photometric redshift of ~9.4 ! (Cucchiara et al. 2011): a (pop III ?) star exploded at only 500 millions years since big-bang



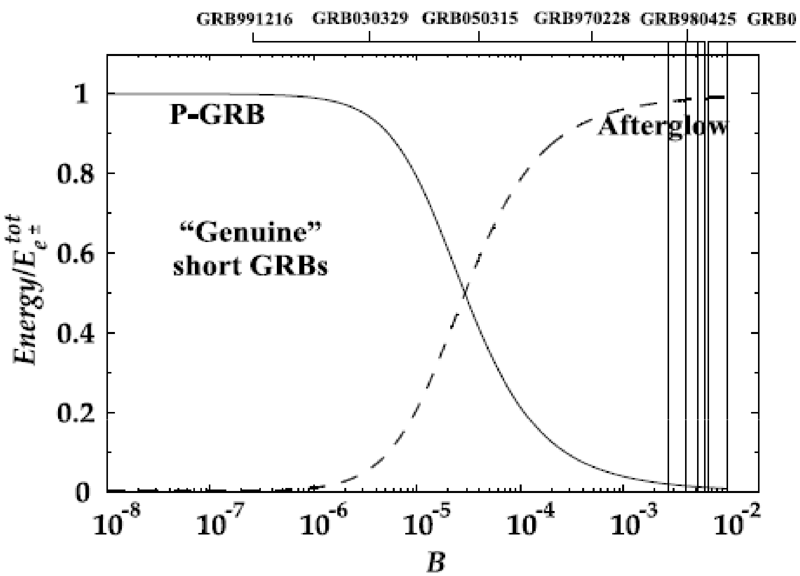


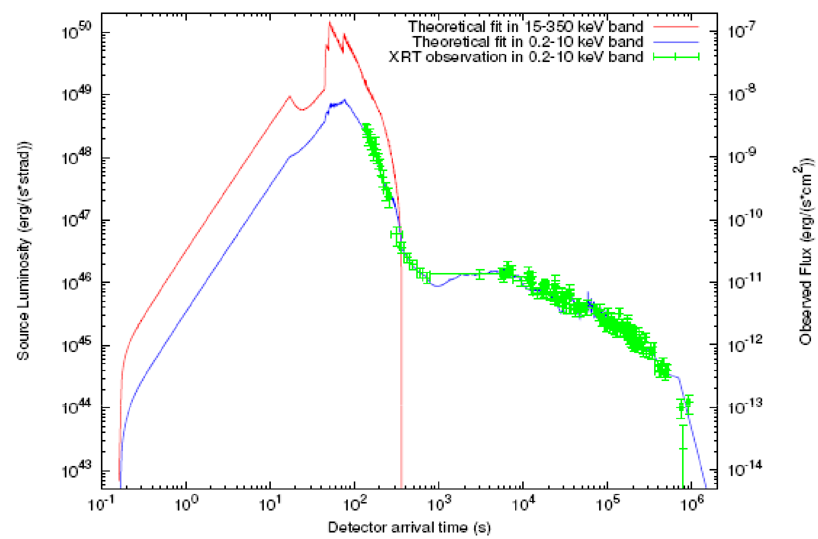




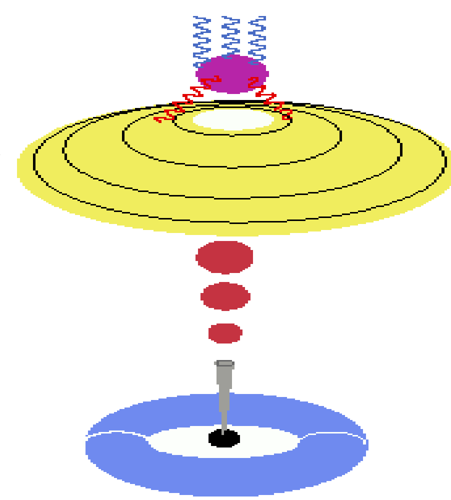
➢ *Alternative scenarios*

❑ EMBH / fireshell model (Ruffini et al.)





❑ CannonBall (CB) (Dar et al.)



❑ Precessing jet (Fargion et al.), stochastic wakefield plasma acceleration (Barbiellini et al.), ns-quark star transition, …

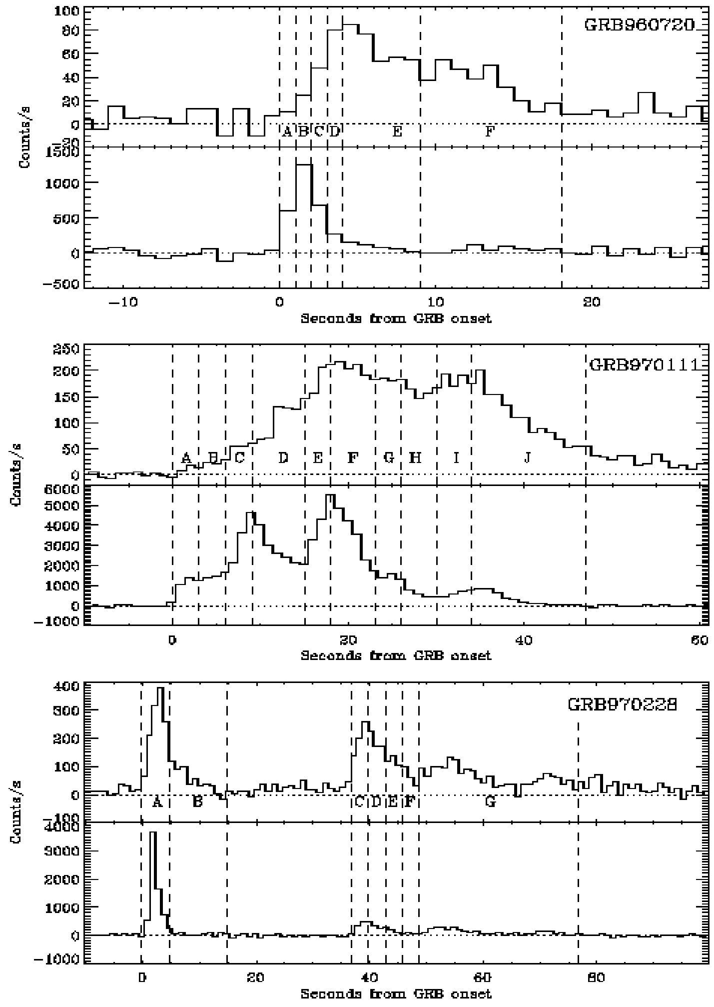
❑ Short GRB as SGR giant outbursts

GAME: GRB And All-sky Monitor Experiment

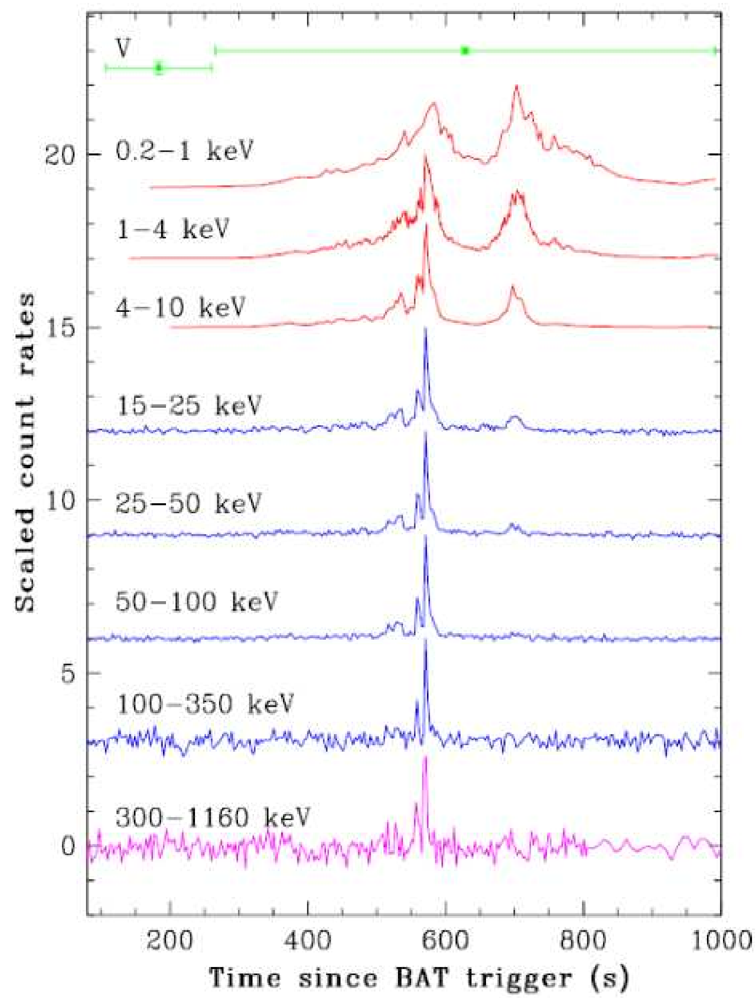
Our scientific motivation for GRB studies: broad band spectroscopy (down to 1 keV) of the prompt emission

- **Physics of the GRB continuum prompt emission:**
  - Broad spectrum from 10 MeV down to 1 keV
  - Transient spectral components (e.g. BB);
- **Establishing the GRB progenitors and their distance from the properties of circumburst environment:**
  - Column density NH and its time behaviour;
  - Absorption edges;
- **X-Ray Flashes: origin, population size, link with GRB**
- **Increasing the detection rate of high-z GRB with low energy threshold: SFR up to dark ages, pop III stars, etc**
- **Physical origin of spectral-energy correlations and their exploitation for cosmology.**

❑ Relevance of GRB prompt low energy (<10 keV) X-ray emission

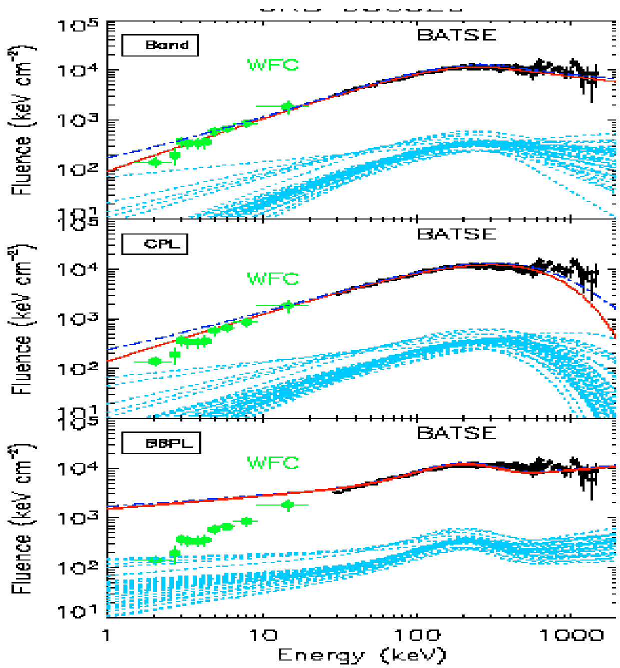


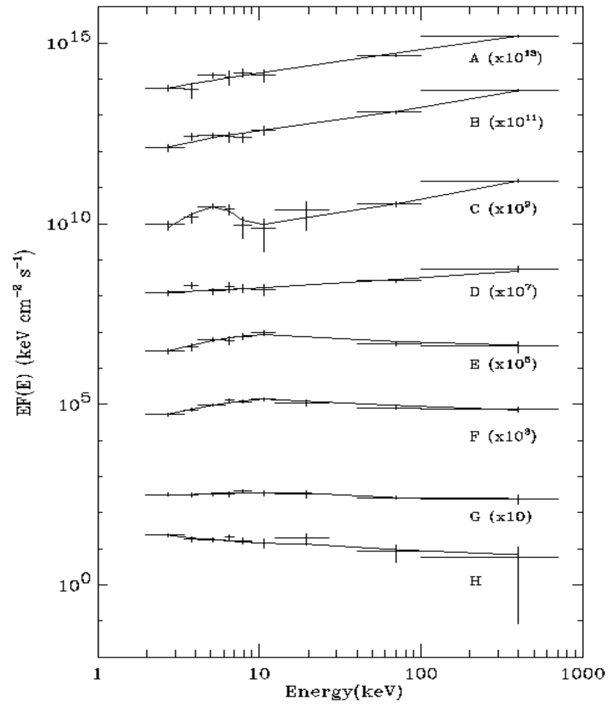
BeppoSAX (top: 2-28 keV, bottom: 40-700 keV)

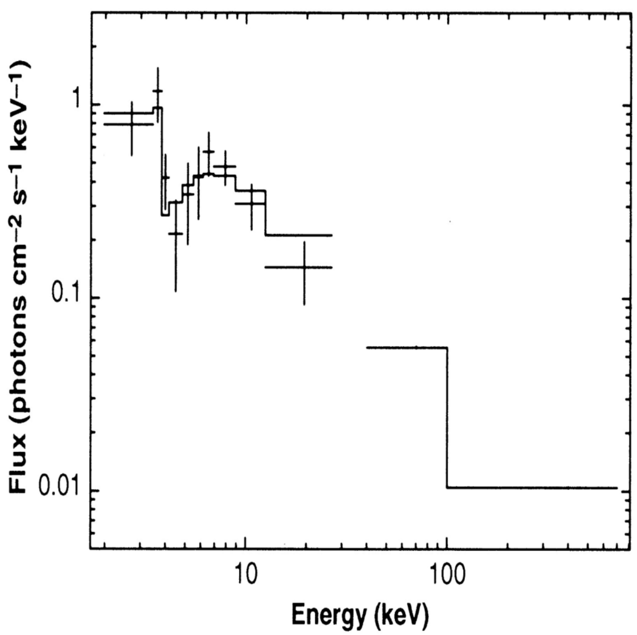


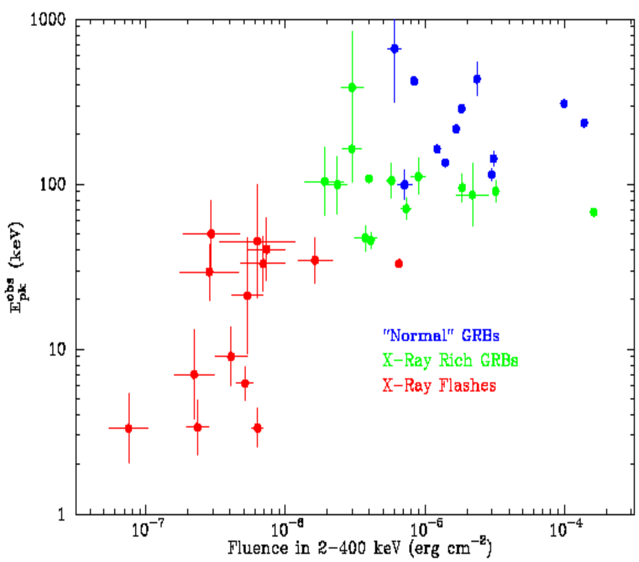
Swift XRT (rare / unique case) + Swift/BAT + konus/WIND

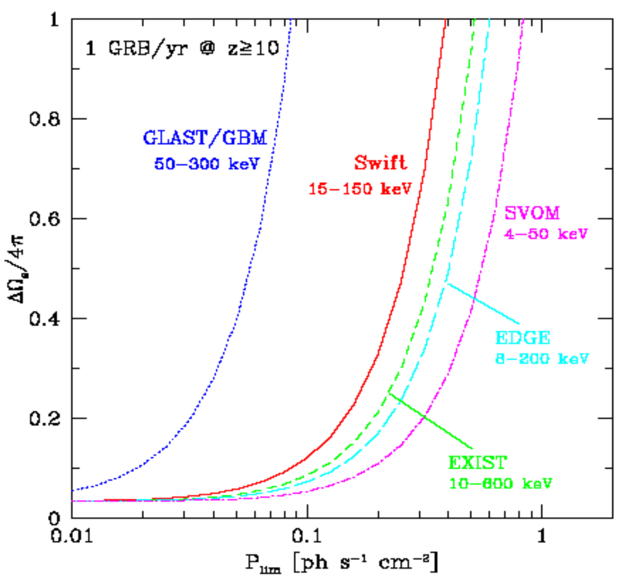
- emission models and thermal components;
- absorption features (CBM, redshift)
- X-Ray Flashes and
- high redhsift GRBs
- Ep-intensity correlations
- GRB vs SN shock breakout











The proposed payload for GAME

Science Drivers:

1. Wide-band spectroscopy of the prompt emission of GRBs down to 1 keV (and up to a few MeVs) + accurate (1-2 arcmin) determination and prompt dissemination of
2. All-sky monitoring of Galactic and Extragalactic X-ray sources in 1-50 keV with a 1-2 arcmin location accuracy and high sensitivity (a few mCrab)

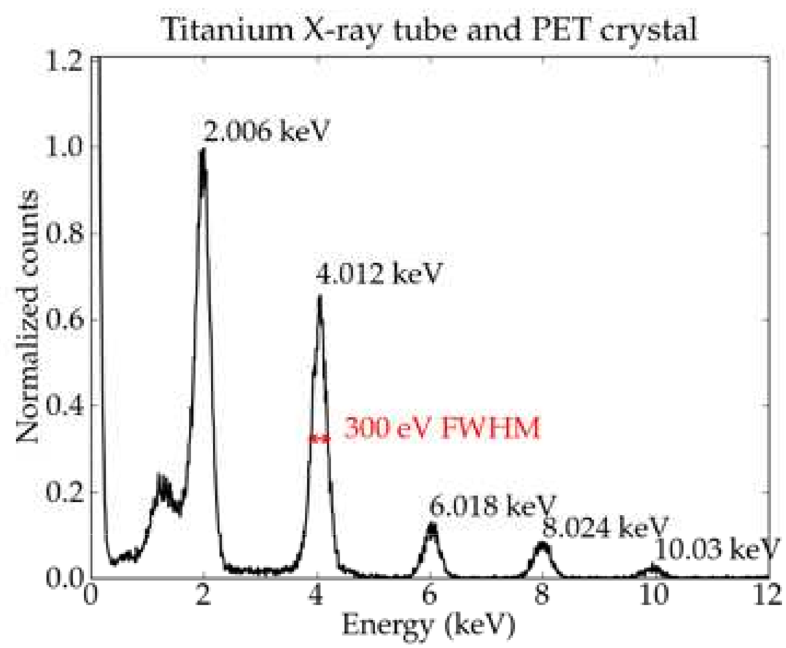
Proposed instrumentation:

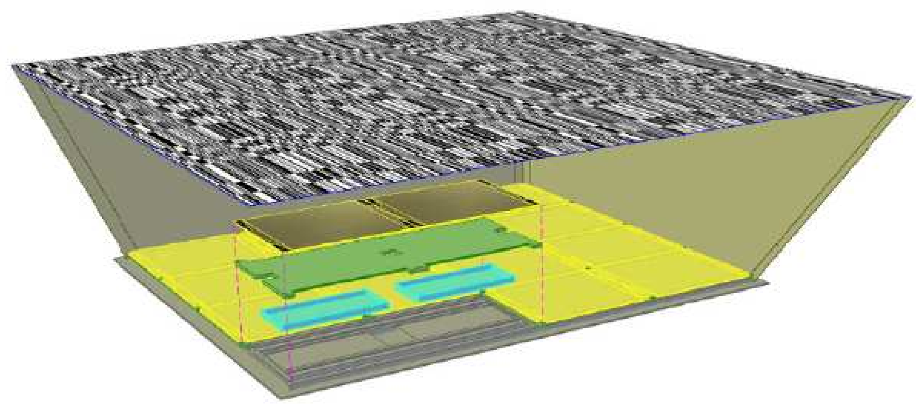
- X-ray Monitor (XRM): 1-50 keV, 6 units, Imaging, Silicon Drift Detectors with Coded Mask, large FOV (3 sr FC)
- Xard X-rays Imager (HXI): 10-200 keV, Imaging, CZT detectors, wide FOV (20°x20° FWHM)
- Soft Gamma-ray Spectrometer (SGS):
  15 keV – 10 MeV NaI(Tl)/CsI(Na) phoswich detector, 8 units

The X-Ray Monitor

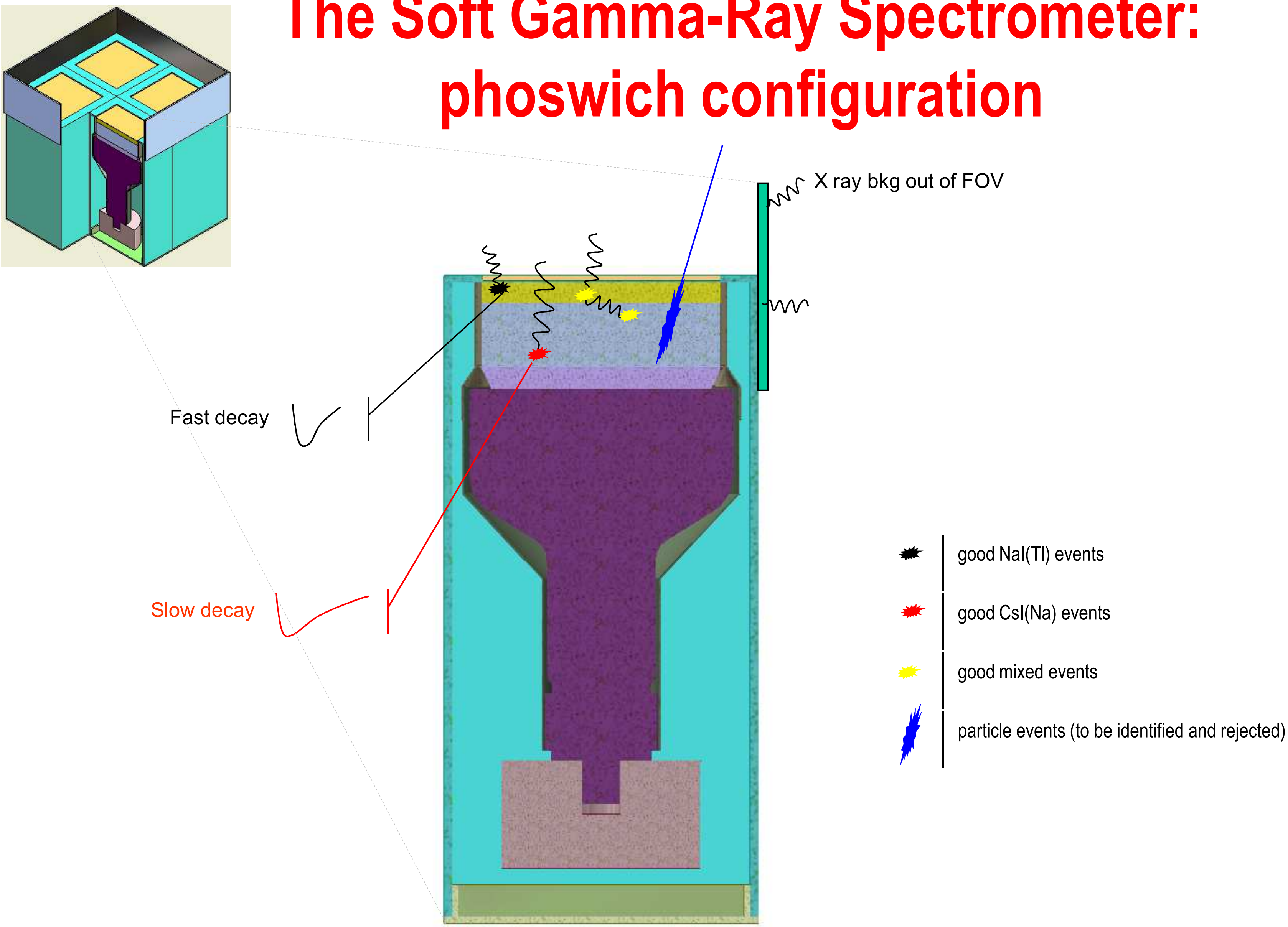
- ❑ Use of Silicon Drift Detectors (SDC) heritage of the LHC/Alice experiment at CERN with excellent performances (energy resolution 200-300 eV, low energy threshold < 2 keV, time res. < 10μs) can be used to build large area detectors)

- ❑ The SDC detector has asymmetric position resolution: ≤100μm in one direction and ~2-3 mm in the orthogonal direction.
  - ⇒ Asymmetric 2D coded mask
  - ⇒ 2 orthogonal units always looking at the same FoV to guarantee arcmin prompt localization of Gamma Ray Bursts





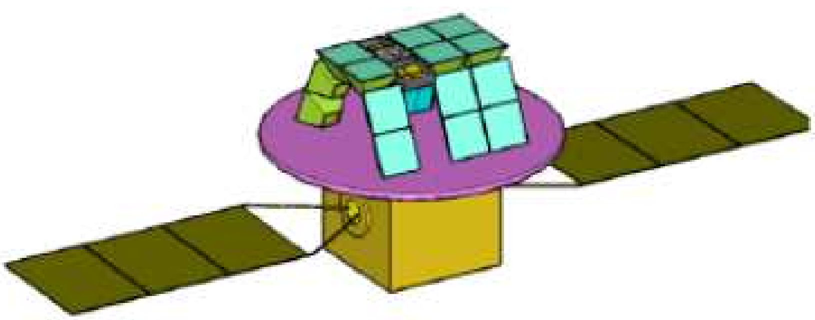
The Soft Gamma-Ray Spectrometer: phoswich configuration



Mission profile and Payload configuration

***Table 1**: Main characteristics of the whole satellite.*

Parameter	Value
Mass	~500 kg (PMM total), ~250 kg (GAME payload)
Power	~240 W (total), ~150 W (GAME payload)
Telemetry budget	~4.8 Gb/orbit
Telemetry Downlink	X-band, ~4.0 Mbps for 15 passes/day/station (10 min transmission/pass)
Ground Stations	Alcantara, Malindi



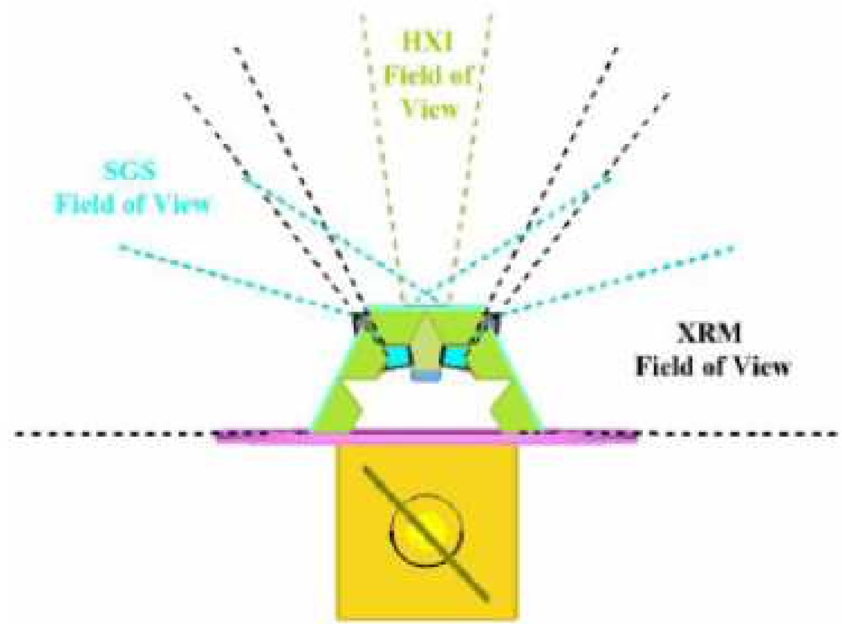


***Figure 5.** An hypothesis of allocation of XRM, HXI and SGS. The dimensions of the bus are ~1 m^3.*

***Table 2**: Main characteristics and resources of the GAME instruments*

	XRM	HXI	SGS
Energy Range [keV]	1-50	10-200	20-20000
Energy Resolution FWHM	250 [eV]	5 keV@60 keV	15% @60 keV
Time Resolution [μs]	~10	~10	~1
Effective Area [cm^2]	>550 in FCFoV (through mask)	~170	~1500 @ 300keV
Angular Resolution	5 arcmin	~1.5°	-
Point Source Location Accuracy	<1 arcmin	~30 arcmin	-
Field of View	~3.0 sr FCFoV ~5.4 sr PCFoV	20° x 20°FWHM	~2.5 sr (FWHM)
Sensitivity (5-σ)	300 mCrab or ~2.5 ph/cm^2/s in 1s, FCFOV ~ 2 mCrab (50 ks) (FCFOV)	~ 10 mCrab (1 day)	~ 1 Crab in 1s
Mass plus 20% contingency [kg]	140	30	80
Volume [mm^3]	1307 x 1316 x 700 (whole)	375x375x550	283 x 283 x 320 (1 unit)
Power plus 20% contingency [w]	100	20	30
Data rate (orbit average) kbit/s	~750	3.2	~40

GAME collaboration / funding scheme

Table 4- *Proposed distribution of contributions*

	Respons.	Note
Mission Architect	ESA	
Spacecraft Launch	ESA	VEGA
Spacecraft Architect	ESA	Industry (including spacecraft AIV)
Spacecraft Platform	Brazil Slovenia	PMM: Brazil (eventual X-band transponder SLO)
Science Payload	Italy Brazil Germany Czech Rep.	XRM: Italy ASI-INAF + Czech Rep. HXI: Brazil SGS: Italy ASI-INAF DH: Germany Tübingen Mech. Structure: Czech Rep. ?
Mission Operations	ESA Italy Brazil	MOC: ESA Ground station Malindi ASI Ground station Alcantara INPE
Science Operations	Italy	GAME SDC: ASI

- The collaboration includes scientist from INAF, INFN, Italian Universities, Sweden, Czech Republic, Poland, Germany, Slovenia, USA, Brazil

Expected performances

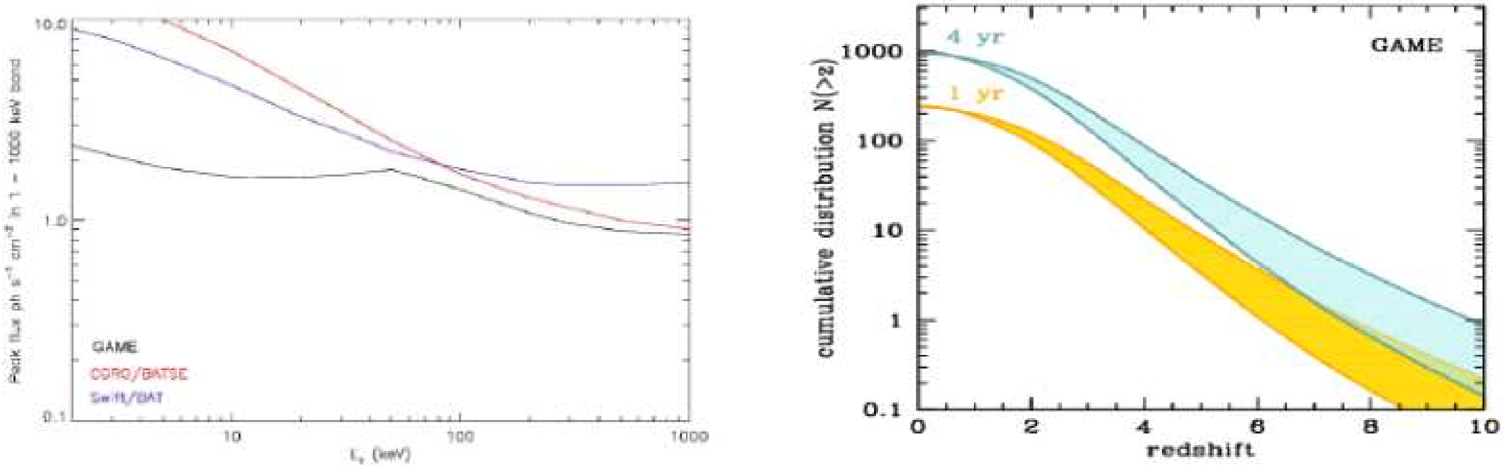


Figure 8. Left panel *(adapted from a figure by Band 2003): expected GAME flux sensitivity as a function of GRB spectral peak energy (Ep) compared with that of BATSE and Swift/BAT.* ***Right panel****: cumulative redshift distribution of long GRBs predicted for GAME. Shaded regions take into account the error on the evolution parameters: orange (cyan) shaded region refers to 1yr (4yr) of mission.*

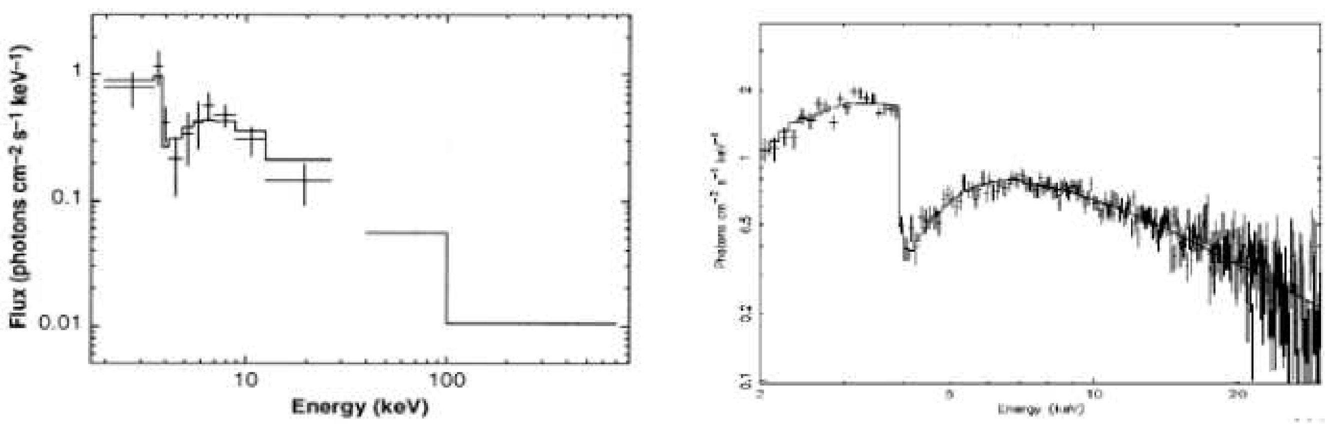
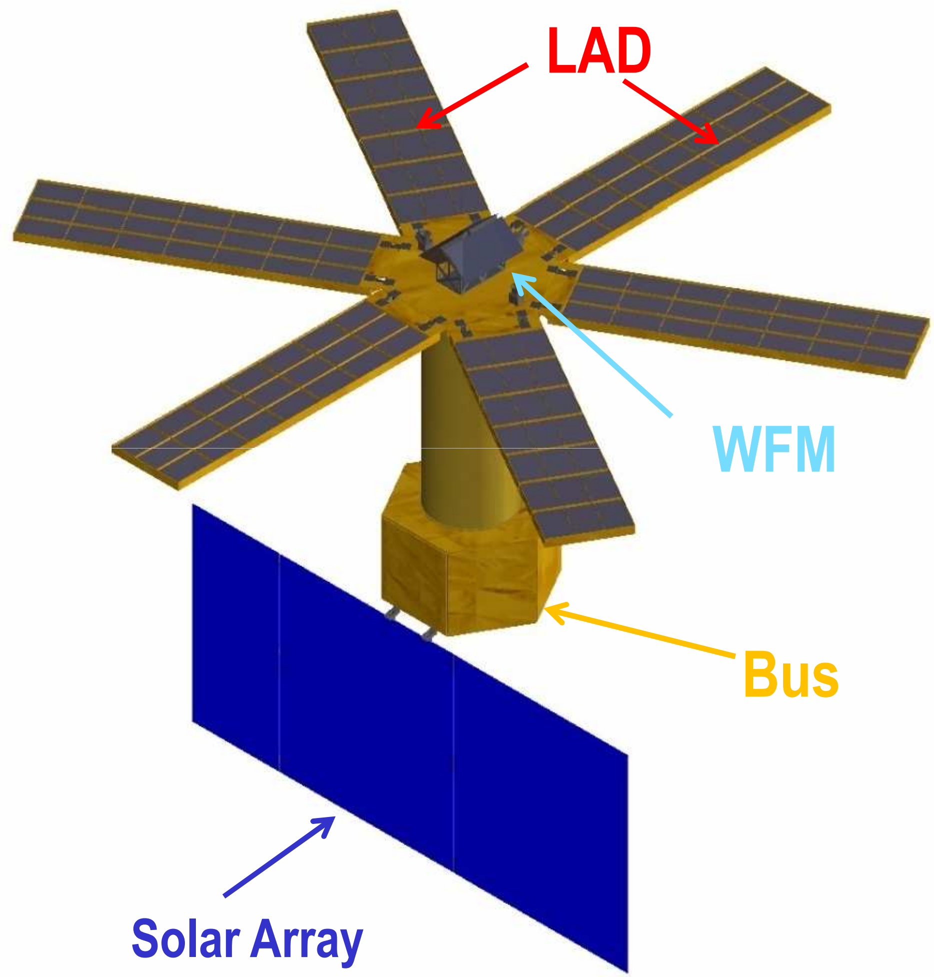


Figure 9. *Comparison between the X-ray transient absorption feature observed with BeppoSAX/WFC in the first 13 s of GRB 990705 (left) (Amati et al., 2000) that expected with GAME. The edge would be detected with a significance of more than 40 sigma.*

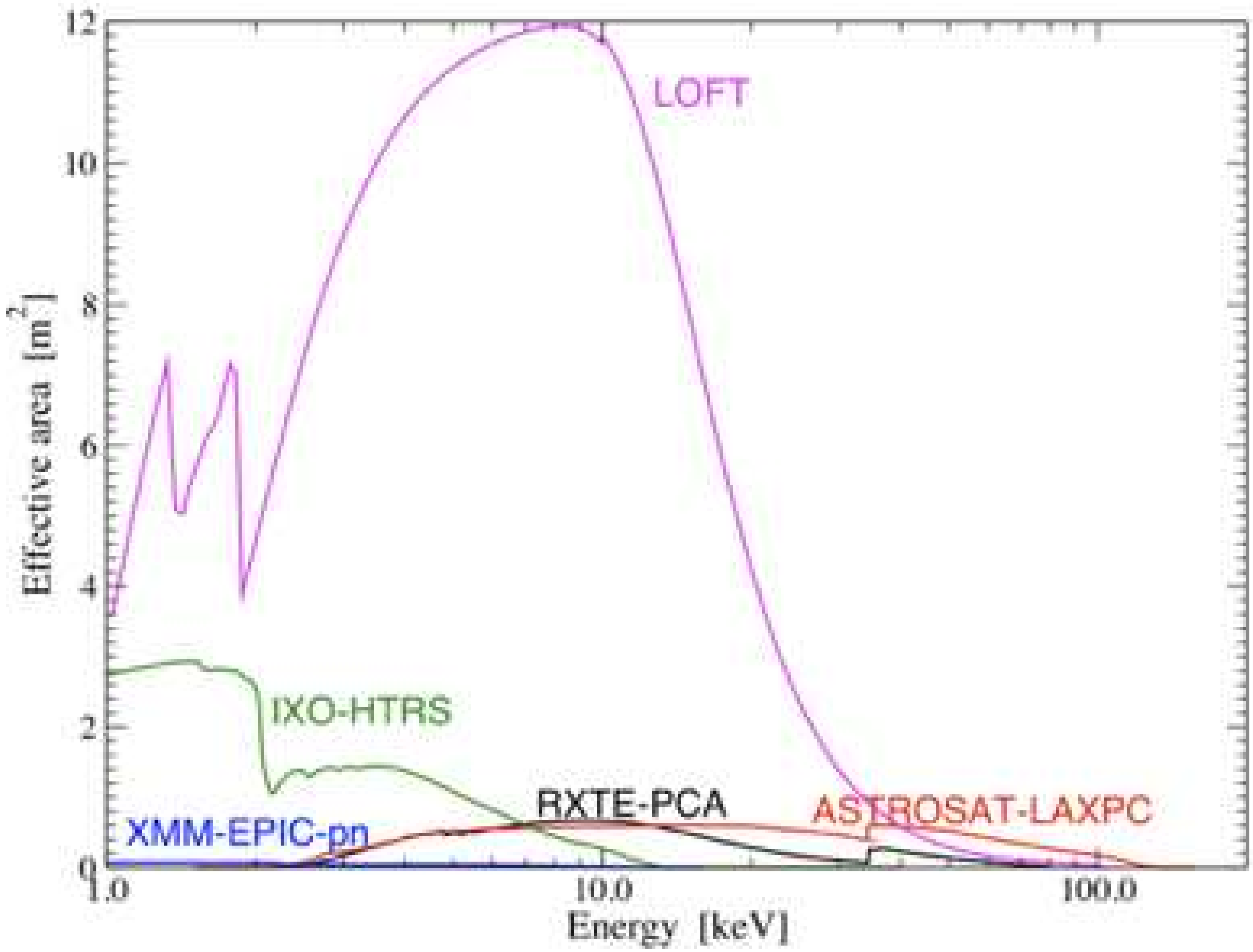
GRB Science with LOFT

- ❑ Mission profile: Large Area Detector (LAD) and Wide FIeld Monitor (WFM)

- ❑ Based on Silicon Drift Detectors (SDC) heritage of the LHC/Alice experiment at CERN with excellent performances (energy resolution 200-300 eV, low energy threshold < 2 keV, time res. < 10μs) can be used to build large area detectors)



LOFT in one plot

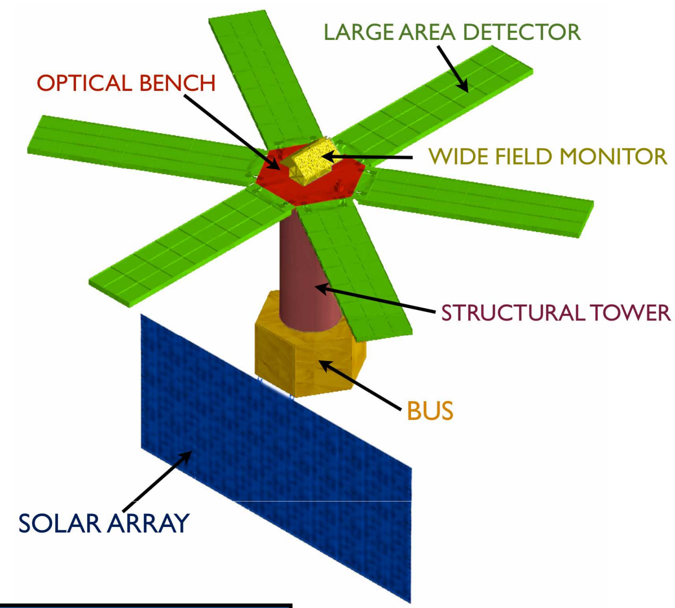


What can do LOFT for GRBs ?

❑ LOFT, possibly in combination with other GRB experiments flying at the same epoch, can give us useful clues to some of the still open issues through:

1) **Measurements of the prompt emission down to ~1 keV with the WFM**

2) Measurements of the early afterglow with the LAD



Parameter	Single Unit	Overall WFM
Energy Range	2-50 keV	2-50 keV
Geometric Area	400 cm^2	1600 cm^2
Energy Resolution FWHM	< 350 eV	< 350 eV
Field of View Fully Coded Partially Coded Zero Response	0.40 sr 2.90 sr 118°	0.80 sr 3.95 sr 154°
Angular Resolution	5' x 2°	5' x 5'
Point Source Location Accuracy (10σ, 1D)	<1' x 20'	< 1'x1'
On-axis sensitivity at 5σ in 1 s	610 mCrab	430 mCrab
On-axis sensitivity at 5σ in 50 ks	2.7 mCrab	1.9 mCrab

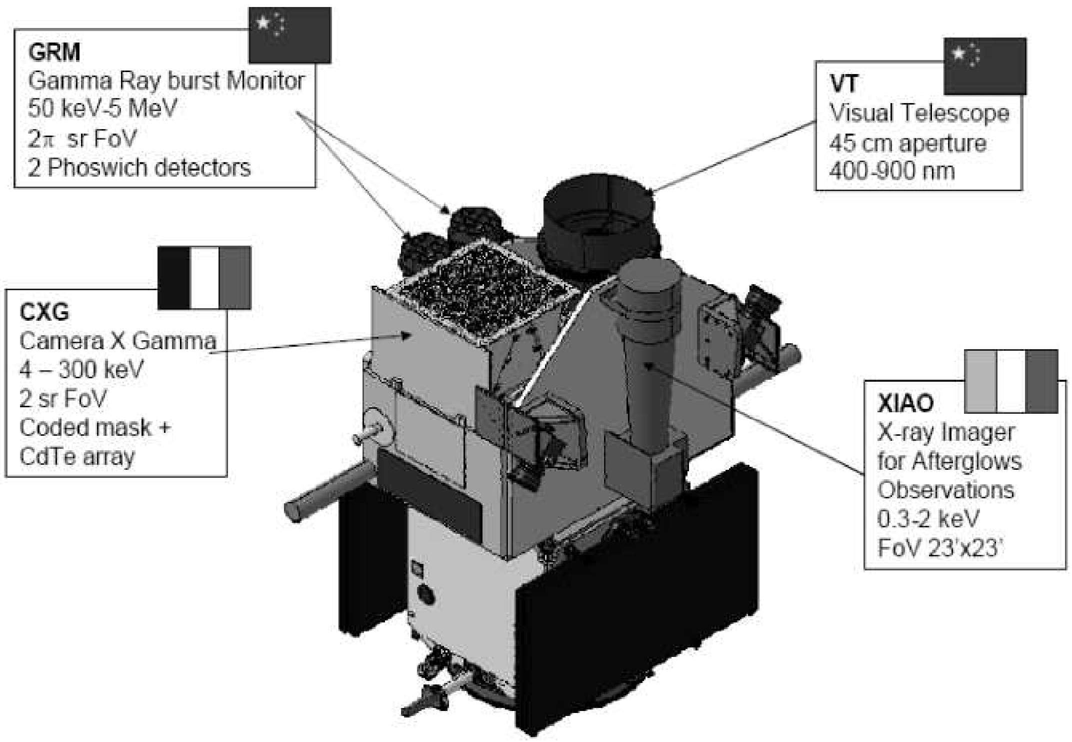
❑ In the > 2017 time frame SVOM ?

➢ spectral study of prompt emission in 5-5000 keV -> accurate estimates of Ep and reduction of systematics (through optimal continuum shape determination and measurement of the spectral evolution down to X-rays)

➢ fast and accurate localization of optical counterpart and prompt dissemination to optical telescopes -> increase in number of z estimates and reduction of selection effects

➢ optimized for detection of XRFs, short GRB, sub-energetic GRB, high-z GRB

➢ substantial increase of the number of GRB with known z and Ep -> test of correlations and calibration for their cosmological use



Conclusions

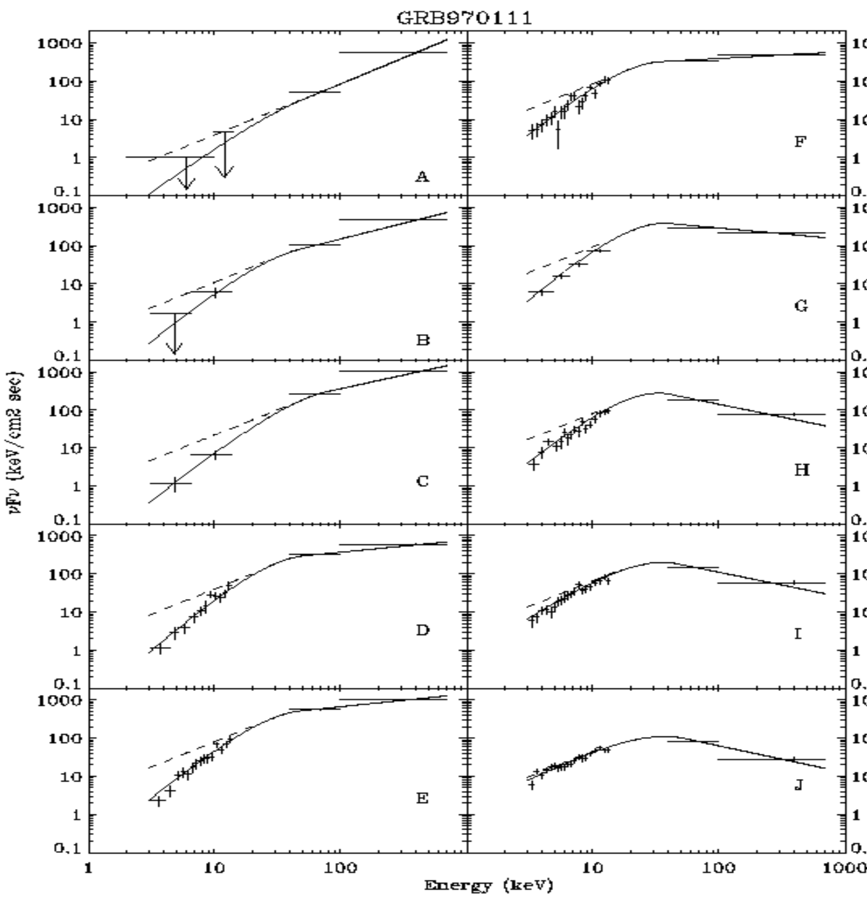
- GRBs are one of the most interesting phenomena for modern astrophysics and science in general, with relevant implications, e.g., for the physics of matter in extreme condition, shock physics, late stages of stellar evolution, core-collapse SNe, black-hole physics, SFR and ISM evolution up to early Universe, cosmology;

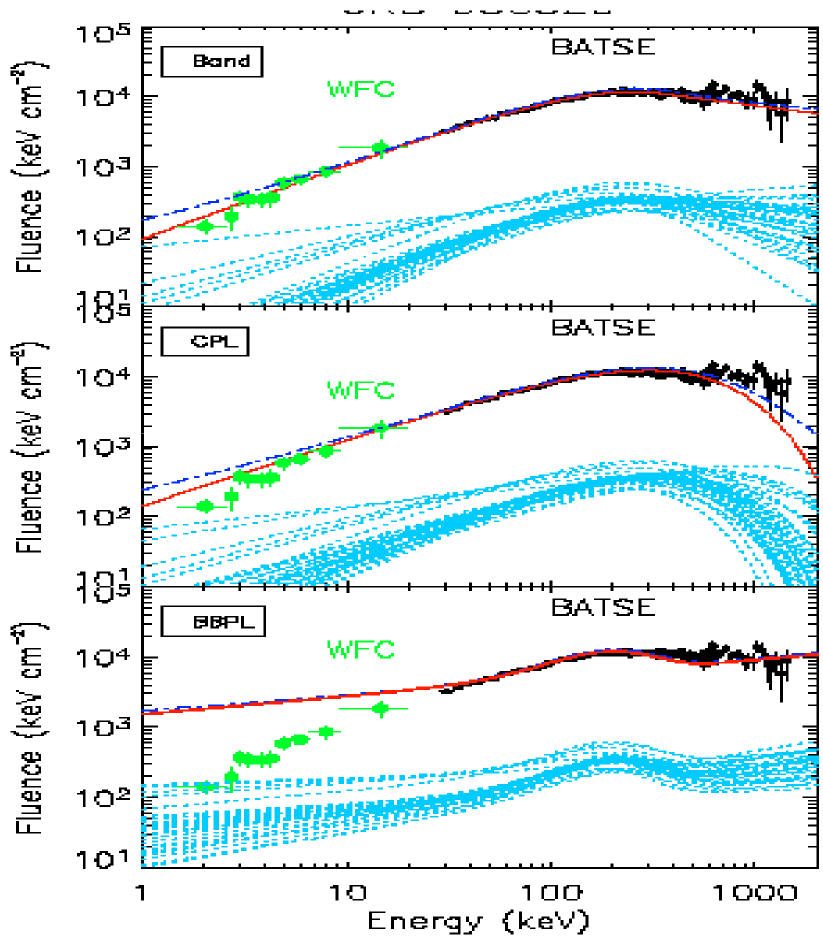
- Despite the huge observational progress in the last 15 years, several open issues still affect our knowledge of the GRB phenomenon, e.g.: prompt emission physics, absorption / emission features from the CBM, early X-ray afterglow and prompt optical phenomenology, properties of VHE emission, collimation and jet structure, GRB/SN connection, short/long dicotomy and intermediate GRBs, nature and true rate of XRFs and under-luminous local GRB/SN events, reliability and accuracy of Ep-intensity correlations, link betwween high-z GRBs and pop III stars;

- Several of these can be addressed by means of sensitive broad-band measurements of the prompt emission down to 1 keV, which is the main goal of the proposed GAME mission and could be partially done by LOFT (ESA/M3, under assessment study) and the possible future Chinese-French mission SVOM.

Backup slides

❑ Importance of the low energy X-rays (specially time resolved) for testing GRB prompt emission physics

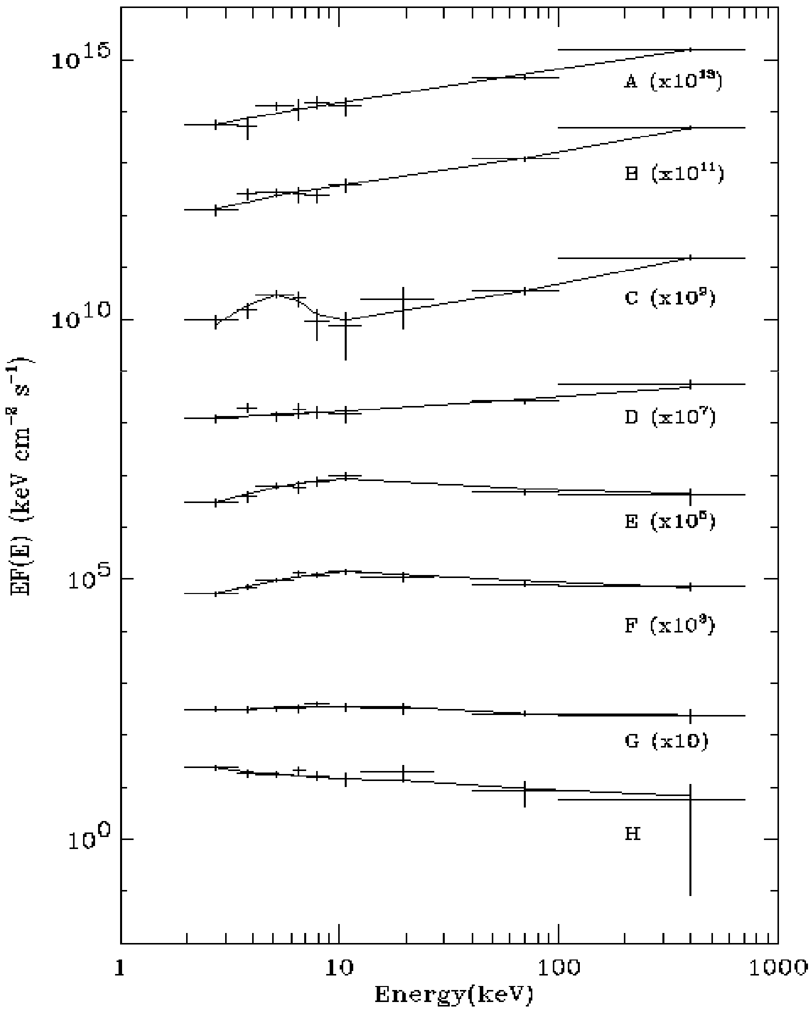




Amati et al. 2001, Frontera et al. 2000, Ghirlanda et al. 2007

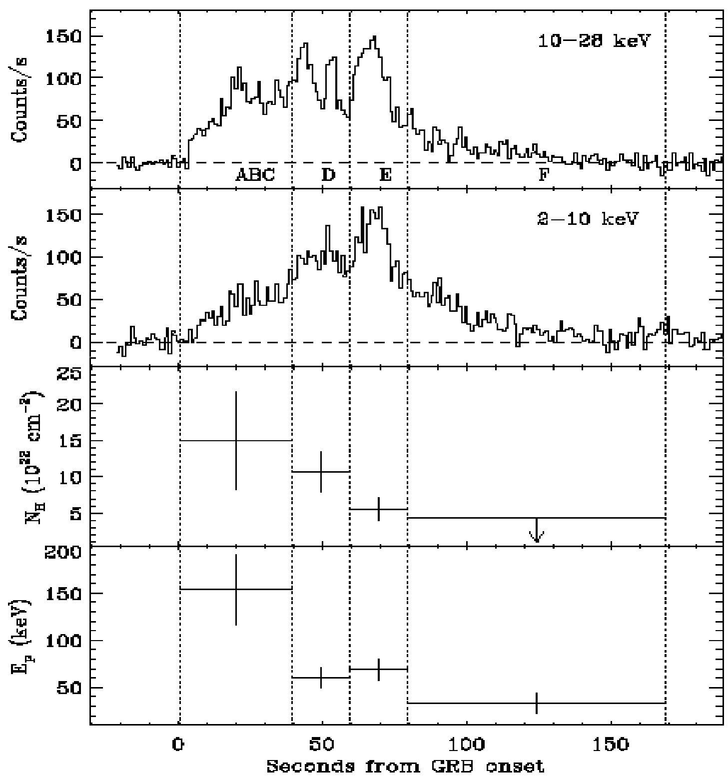
❑ **Tansient bump, consistent with a 2 keV blackbody, observed in the low energy band with BeppoSAX WFC**

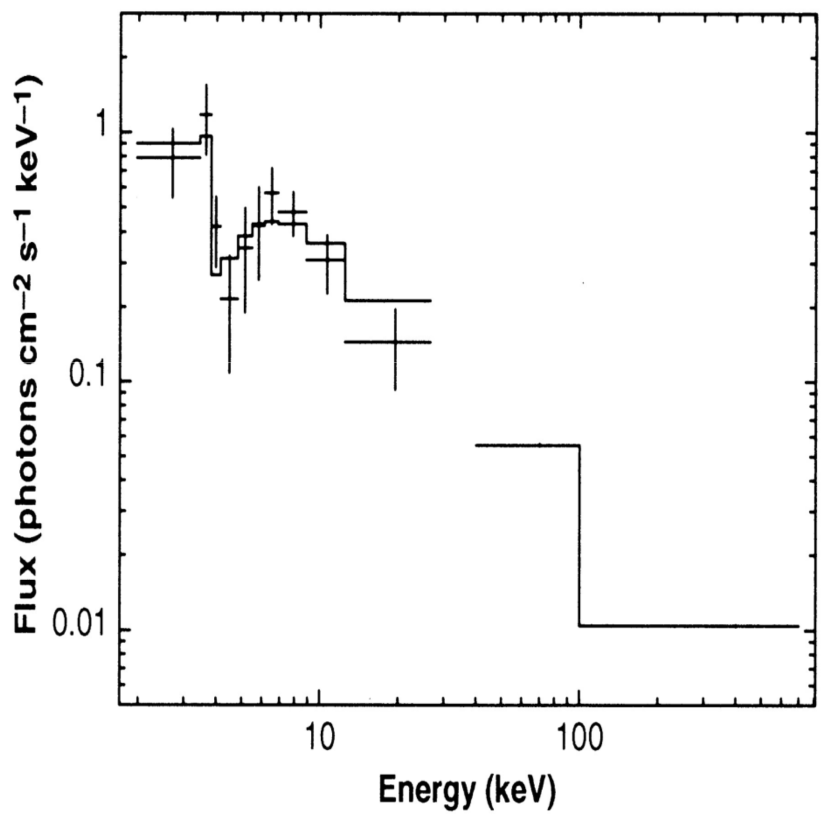
GRB 990712



Frontera et al. 2001

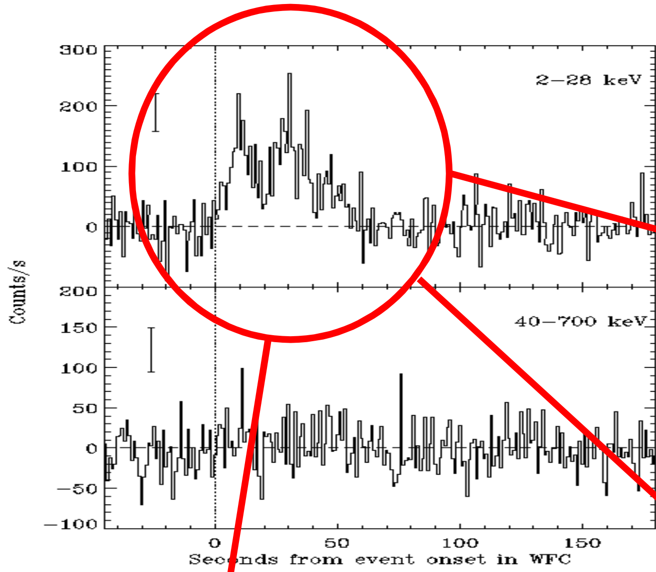
❑ X-ray features: properties (density profile, composition) of circum-burst environment (progenitors, X-ray redshift)

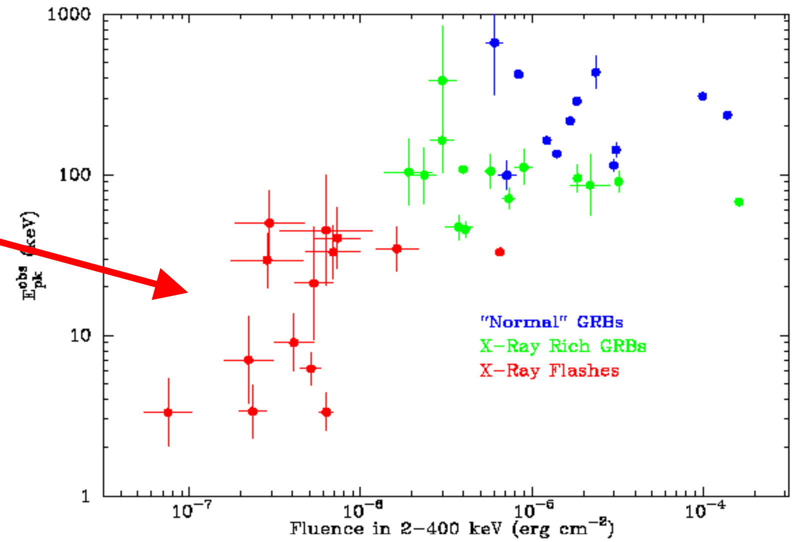




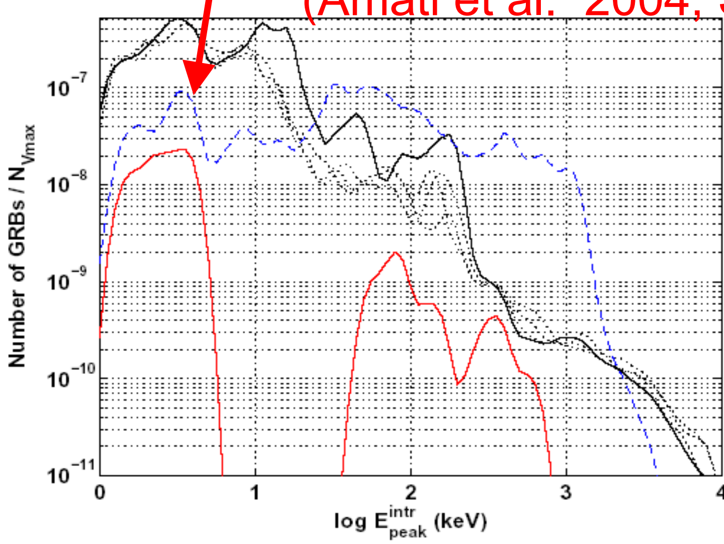
(Frontera et al., ApJ, 2004, Amati et al, Science, 2000)

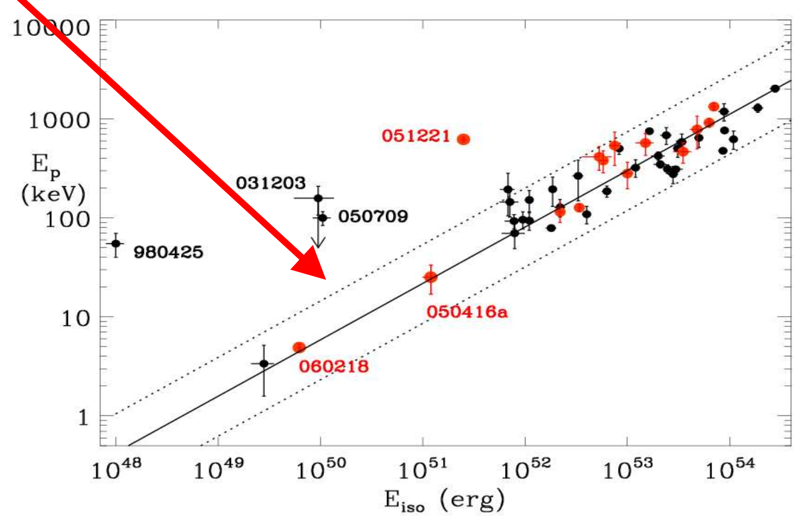
❑ X-Ray Flashes: origin, population size, link with GRB





(Amati et al. 2004, Sakamoto et al. 2005

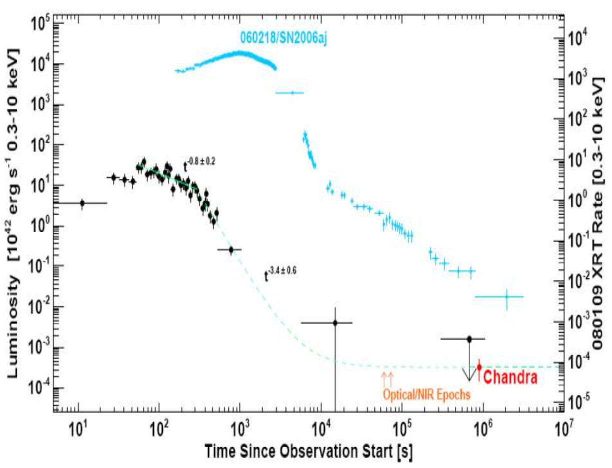


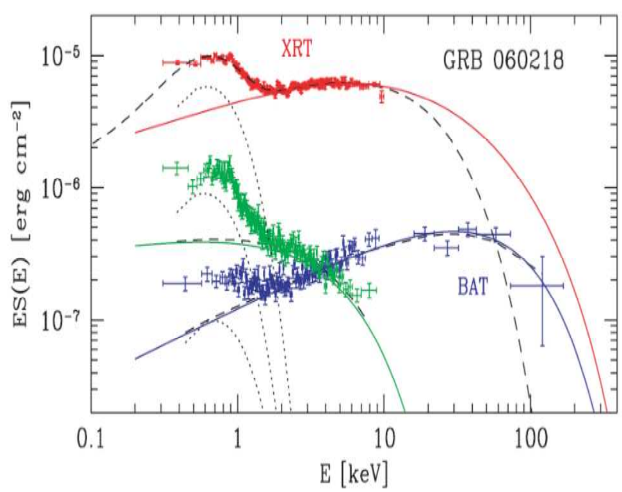


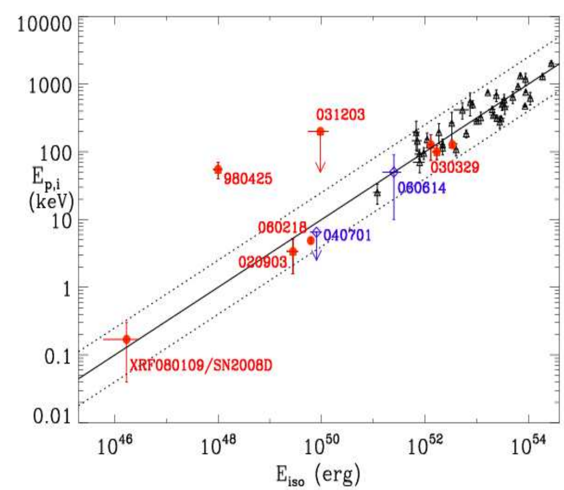
(Amati 2008, Pelangeon et al. 2008

❑ Soft/long X-ray transients GRB 060218 and XRF 080109 associated with SN 2006aj (at z = 0.038) and SN 2008D at z = 0.0064

- ➢ Debate: very soft/weak XRF or SN shock break-out ?
- ➢ Peak energy limits and energetics consistent with a very-low energy extension of the Ep,i-Eiso correlation holding for normal GRBs and XRFs: Evidence that these transients may be very soft and weak GRBs, thus confirming the existence of a population of sub-energetic GRB ?



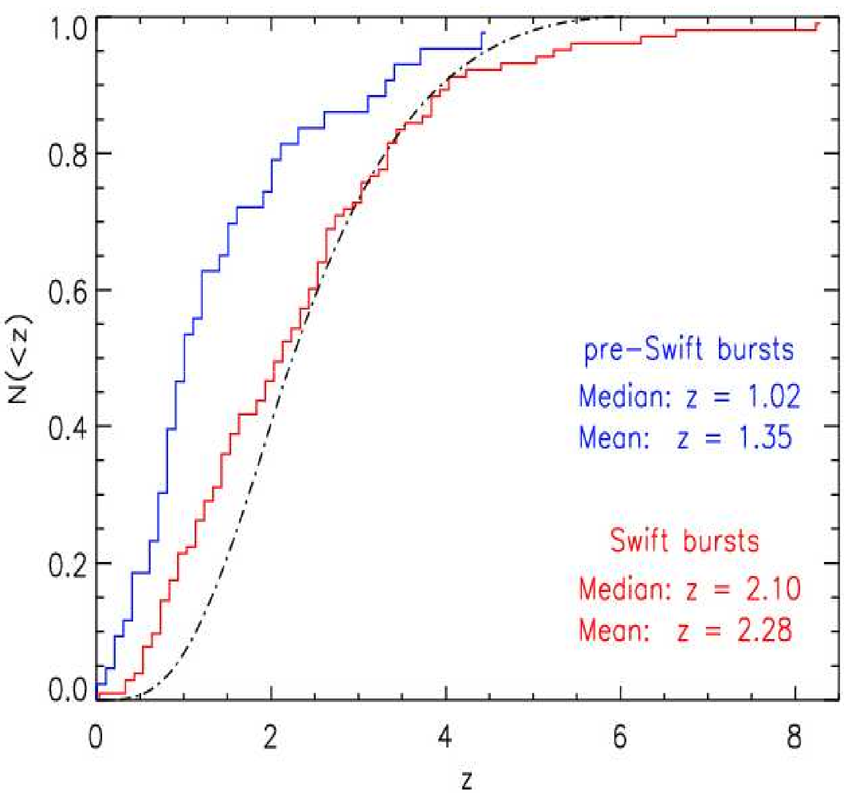




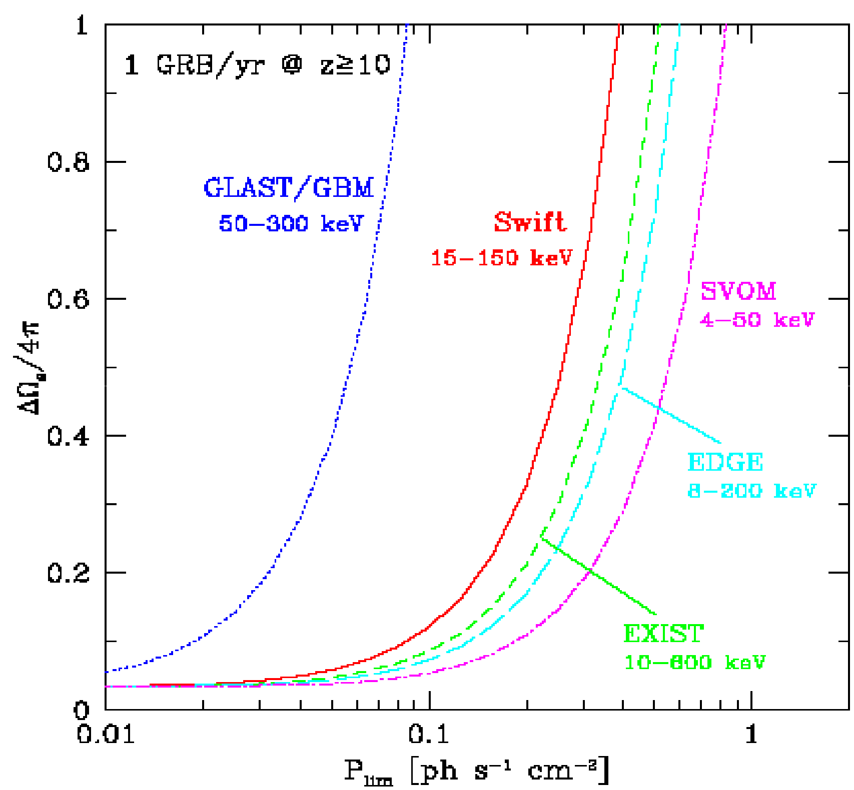
Modjaz et al., ApJ, 2008

Amati et al., 2009

❑ Increasing the detection rate of high-z GRB with low energy threshold: SFR up to dark ages, pop III stars, …

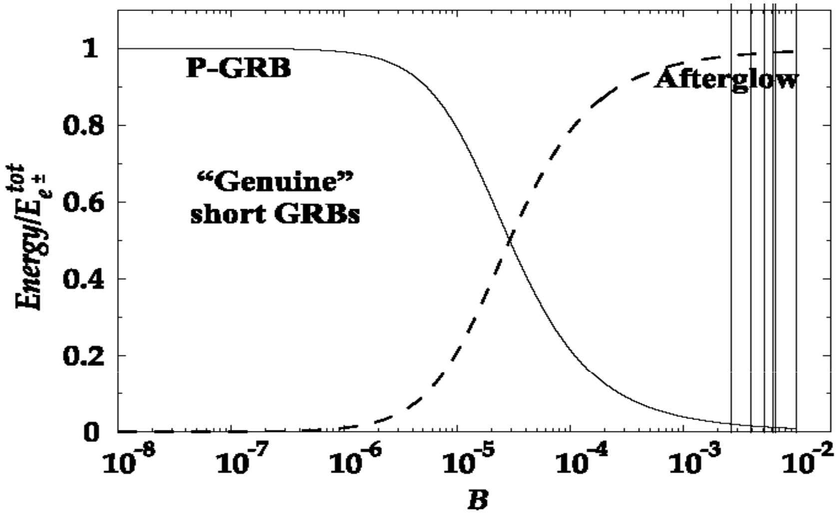


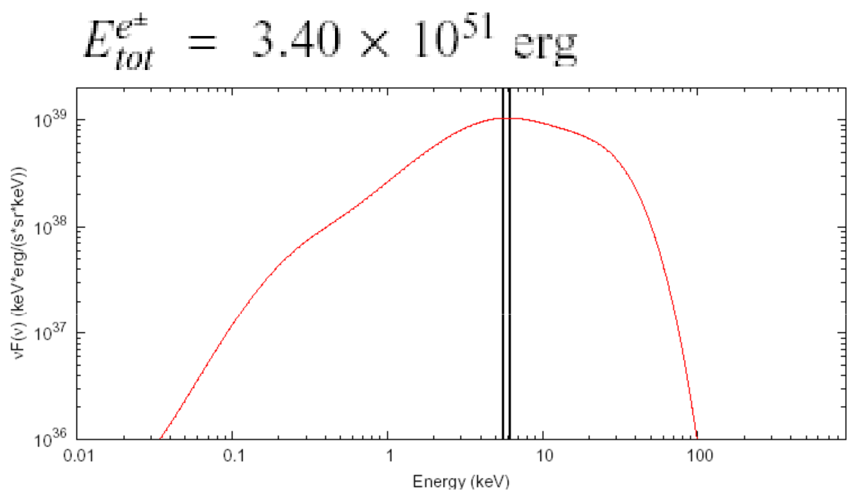
(Stanek et al. 2010)

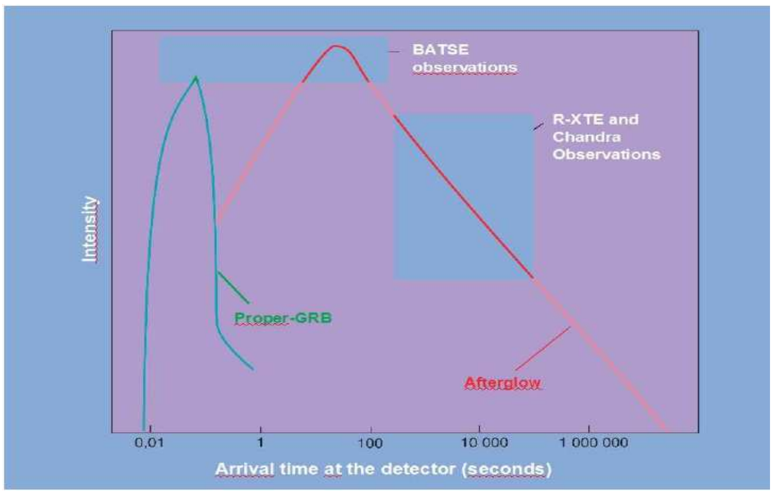


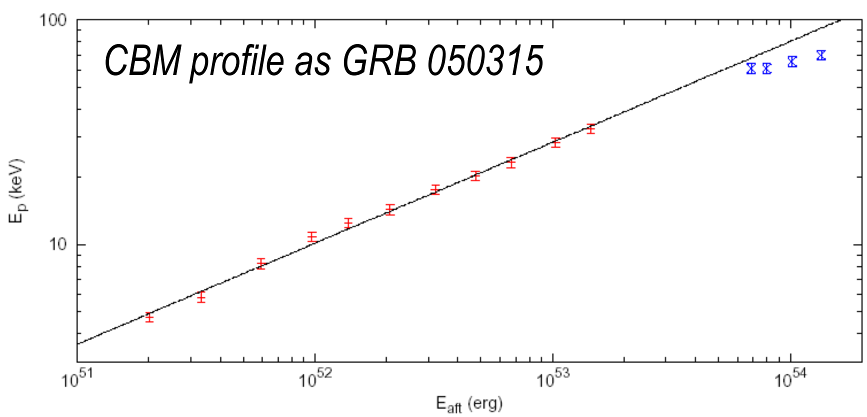
(Salvaterra et al. 2007)

- Ep,i – Eiso correlation in alternative scenarios, e.g. the **"fireshell model"** by Ruffini et al.: by assuming CBM profile from a real GRB and varying Etot, the correlation is obtained, with a slope of 0.45+/+0.01 (consistent with obs.) (Guida et al. 2008)



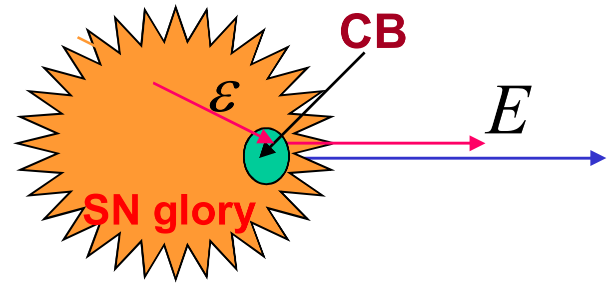






- Ep,i – Eiso correlation also predicted in the "**cannon-ball model**" by Dar et al. with a specific functional shape

$$E \approx \gamma\delta\varepsilon(1+\cos\vartheta_i)/(1+z)$$



$$e+\gamma \rightarrow e'+\gamma'$$

$$\delta \approx 2\gamma/(1+\gamma^2\vartheta^2)$$

$$(1+z)E_p \propto \gamma\delta$$

$$E_{iso}^{\gamma} \propto \delta^3$$

$$\mathrm{L_p} \propto \delta^4/(1+z)$$

For a single CB :

$$\Rightarrow (1+z)L_p \propto \mathrm{E_{iso}^{4/3}}$$

$$\theta^2 \approx 1/\gamma^2 \Rightarrow \delta \approx \gamma \Rightarrow (1+z)E_p \sim (E_{iso}^{\gamma})^{2/3}$$

$$\vartheta^2 >> 1/\gamma^2 \Rightarrow \delta << \gamma \Rightarrow (1+z)E_p \sim (E_{iso}^{\gamma})^{1/3}$$

$$\Rightarrow (1+z)\cdot \mathrm{Ep} \approx \overline{\mathrm{Ep}}\cdot[(\mathrm{Eiso/Eo})^{1/3} + (\mathrm{Eiso/Eo})^{2/3}]$$

Background and context

- **2002-2004:** we participated to the ESA phase A study of LOBSTER-ISS with the goal of extending the energy band of the lobster-eye (MCP based) wide field telescope from 0.1 – 5 keV up to at last 1 MeV in order to allow deteciton and study of GRBs soft X-ray emission

- **2005**: LOBSTER-ISS phase A study successfully concluded, mission approved to phase B, but ESA program suspended following shuttle Columbia accident

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The gamma-ray burst monitor for Lobster-ISS

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- **2006-2009:** Within an ASI-INAF contract for AAE studies, science goals and instrument requirements defined for:

  a) broad band spectroscopy (1 keV – 10 MeV) of the GRB prompt emission;

  b) X- ray Sky Monitoring in 1 – 50 keV

- In parallel, R&D activities performed at INAF/IASF institutes in Rome and Bologna (supported by ASI and PRIN INAF) and in collaboration with INFN (Trieste, Bologna, Rome)

- **June 2010:** Invited to join by MIRAX PI, science case and a payload proposal presented and discussed at INPE (Brazil)

- **July 2010:** Brazilian Space Agency (AEB) invites ASI to discuss the possible Italian contribution to MIRAX, based also on AEB-ASI cooperation agreements.

- **April 2011:** ASI solicited INAF to perform an evaluation (currently in progress) of the scientific merit of our proposed payload for MIRAX

- Spring 2012: **proposal revisited, re-named GAME (Grb and All-sky Monitor Experiment) and submitted (last Friday !) to ESA in response to the "Call for a Small mission opportunity for a launch in 2017"**