GRB 031203 and a Faint Population of Gamma-Ray Bursts

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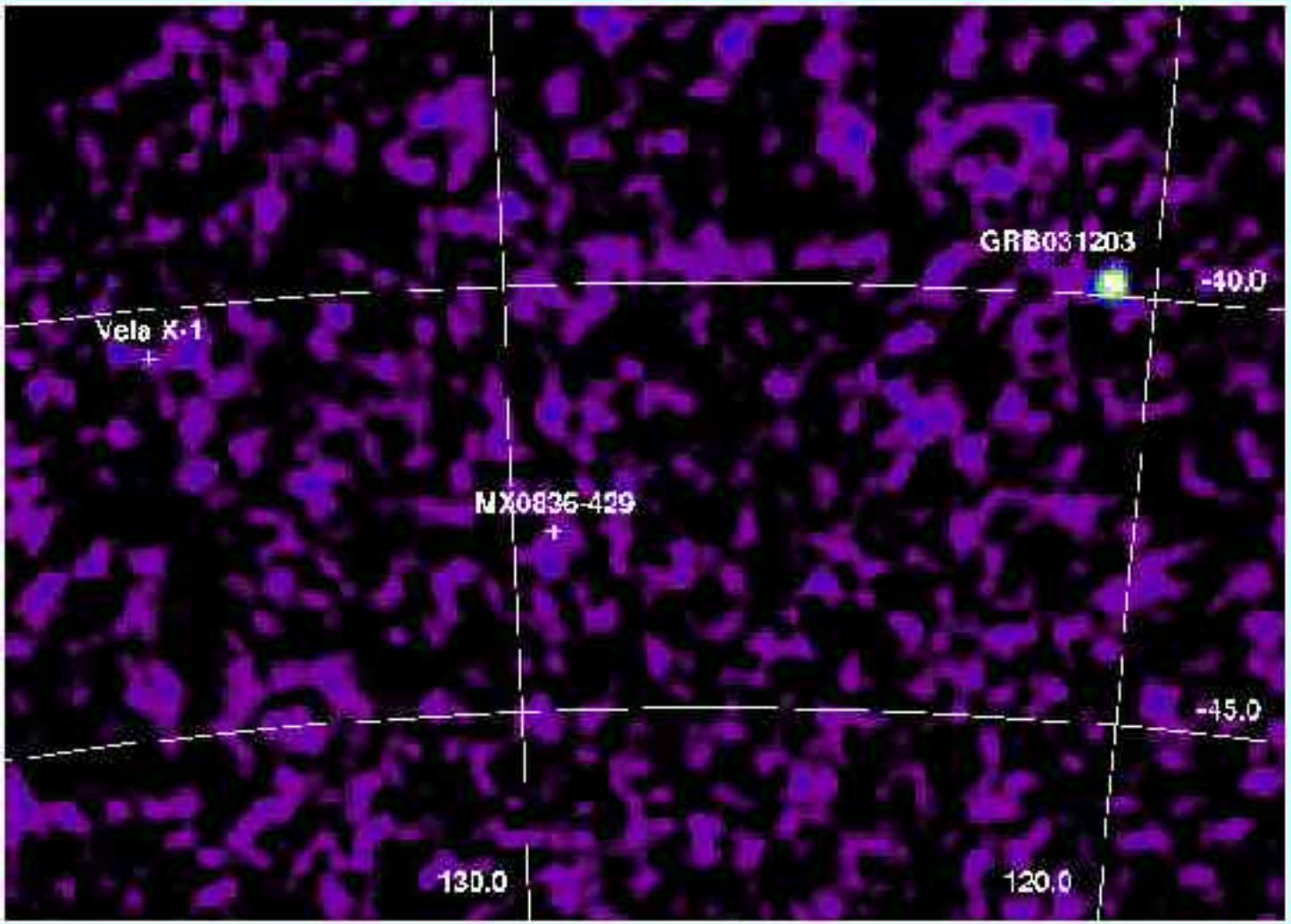
Discovery of GRB 031203 by INTEGRAL



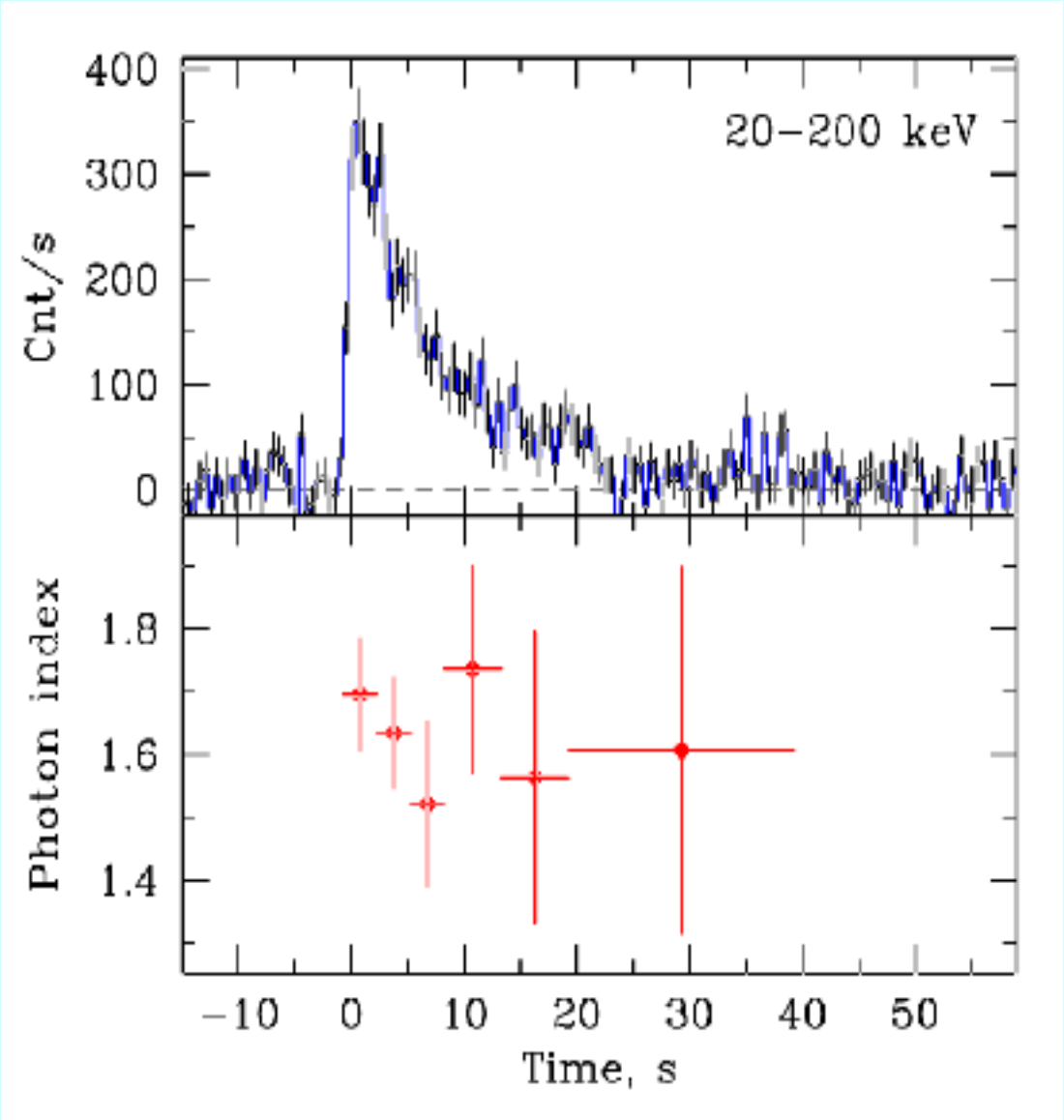
2003 Dec. 3
22:01:28 UTC

Goetz et al.,
GCN 2459;
Mereghetti et al.,
GCN 2460

2' localization
distributed 18s
after trigger

IBIS/ISGRI, 17-50 keV, integration over 20s

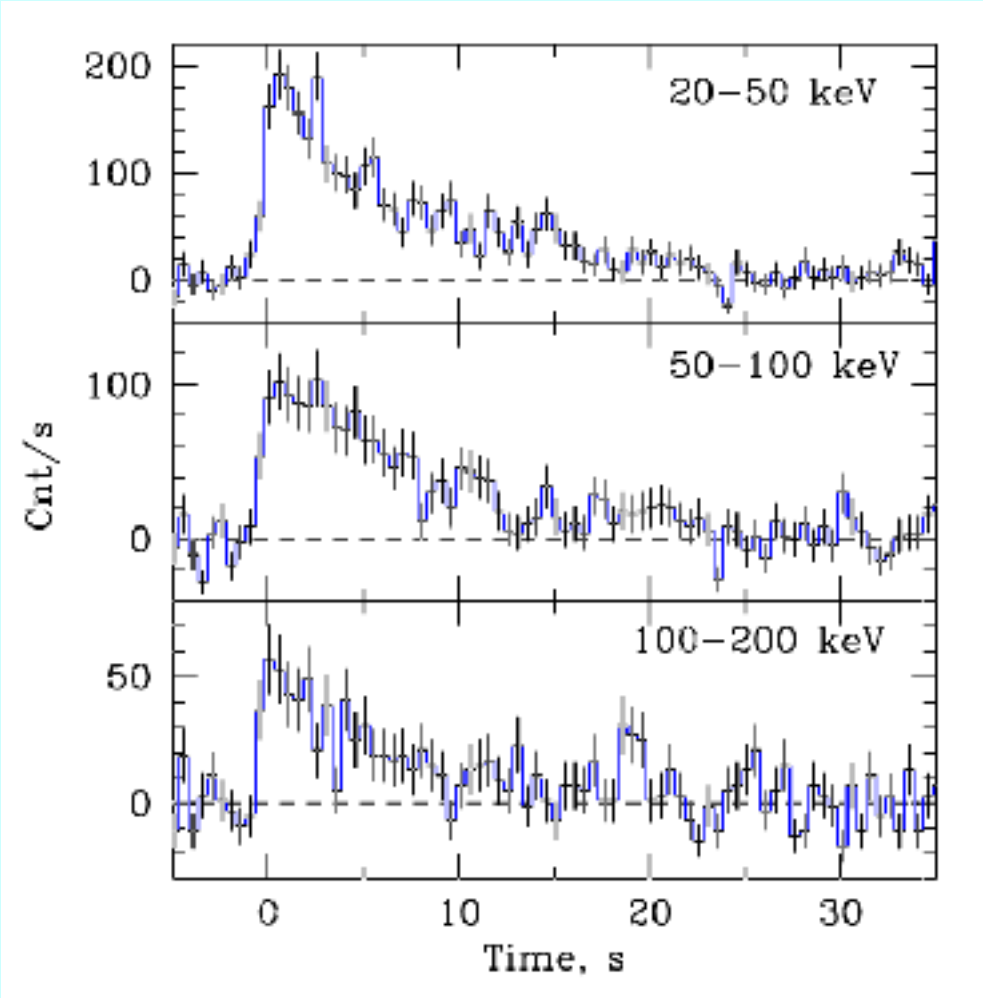
Burst Profile (INTEGRAL/IBIS)

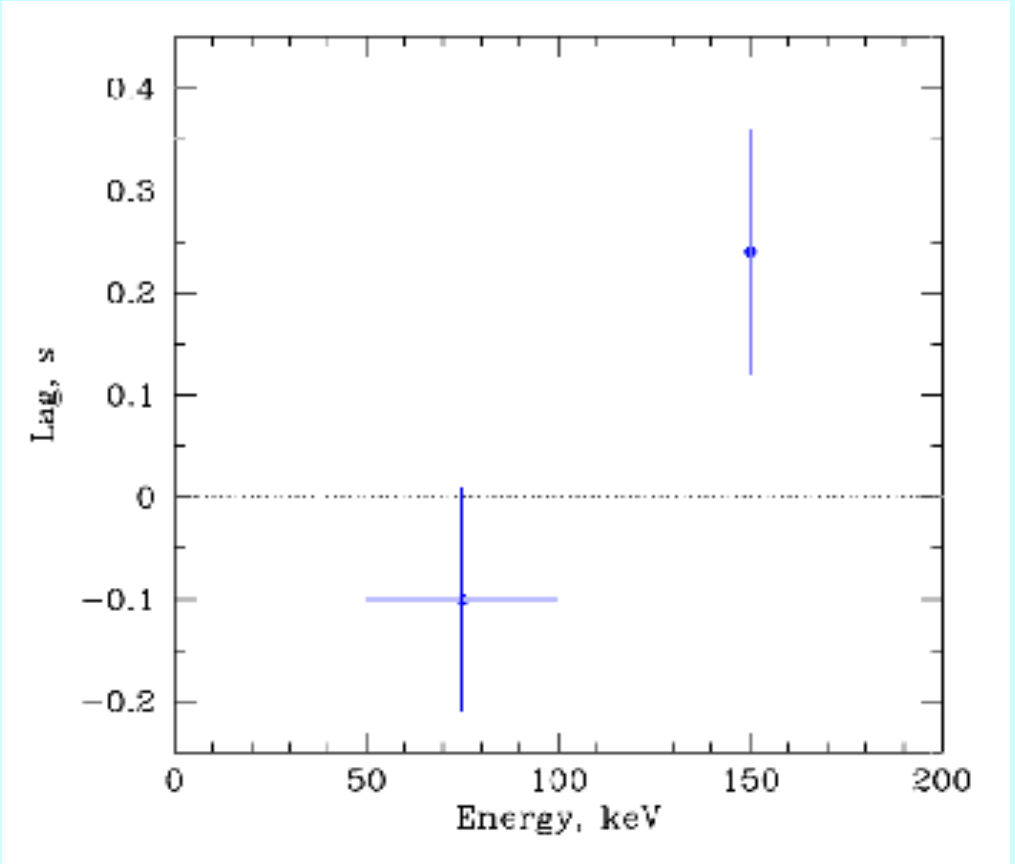


- FRED profile
- Duration ≈ 40s
- Fluence ≈ 2x 10^{-6} erg/cm^2
- Peak flux ≈ 2.4x10^{-7}erg/cm^2
- No spectral evolution

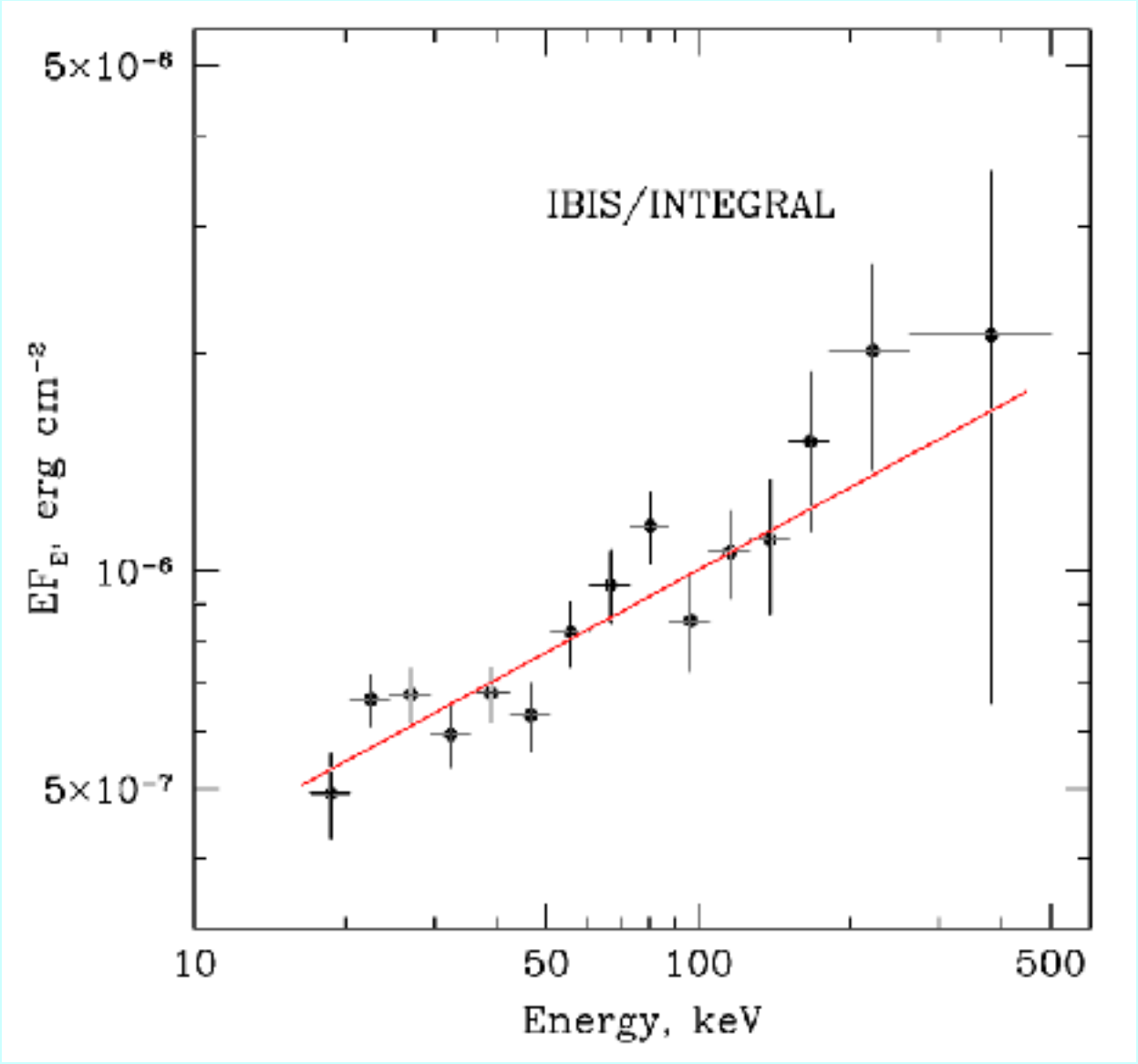
Sazonov, Lutovinov & Sunyaev, 2004 Nature

20-50 keV marginally lags (0.24±0.12s) behind 100-200 keV





Hard X-ray spectrum



Power law fit:

Γ=-1.63±0.06,

E_{peak}>200 keV (90%)

Follow up observations

- X-ray (XMM-Newton, Chandra) and radio (VLA) afterglow
  Watson et al., Soderberg et al.

- Dust-scattered X-ray echo
  Vaughan et al.

- Host galaxy
  Prochaska et al.

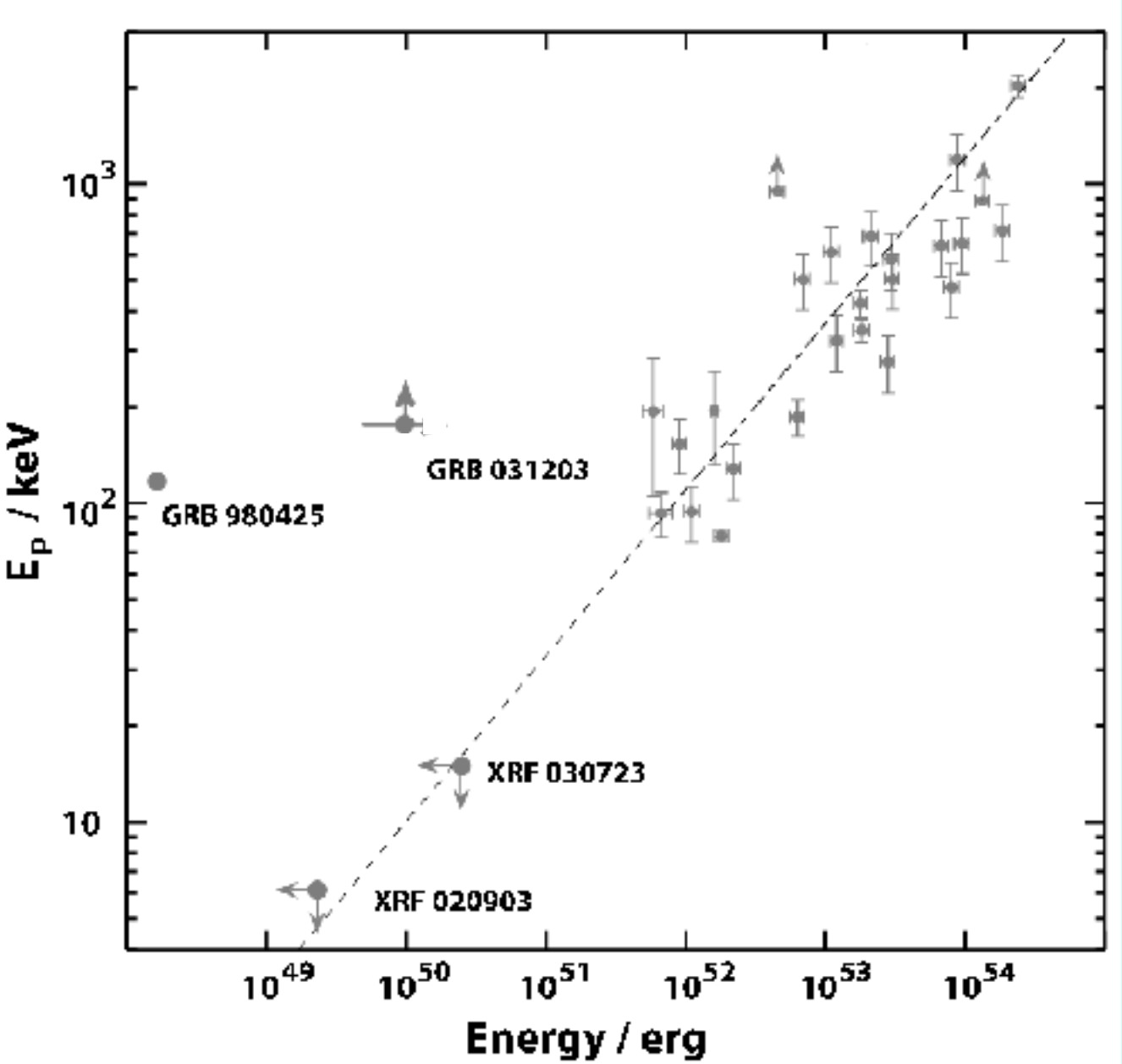
- Supernova
  Thomsen et al., Cobb et al., Gal-Yam et al., Malesani et al.

GRB 031203: an apparently normal GRB with an unusually low luminosity

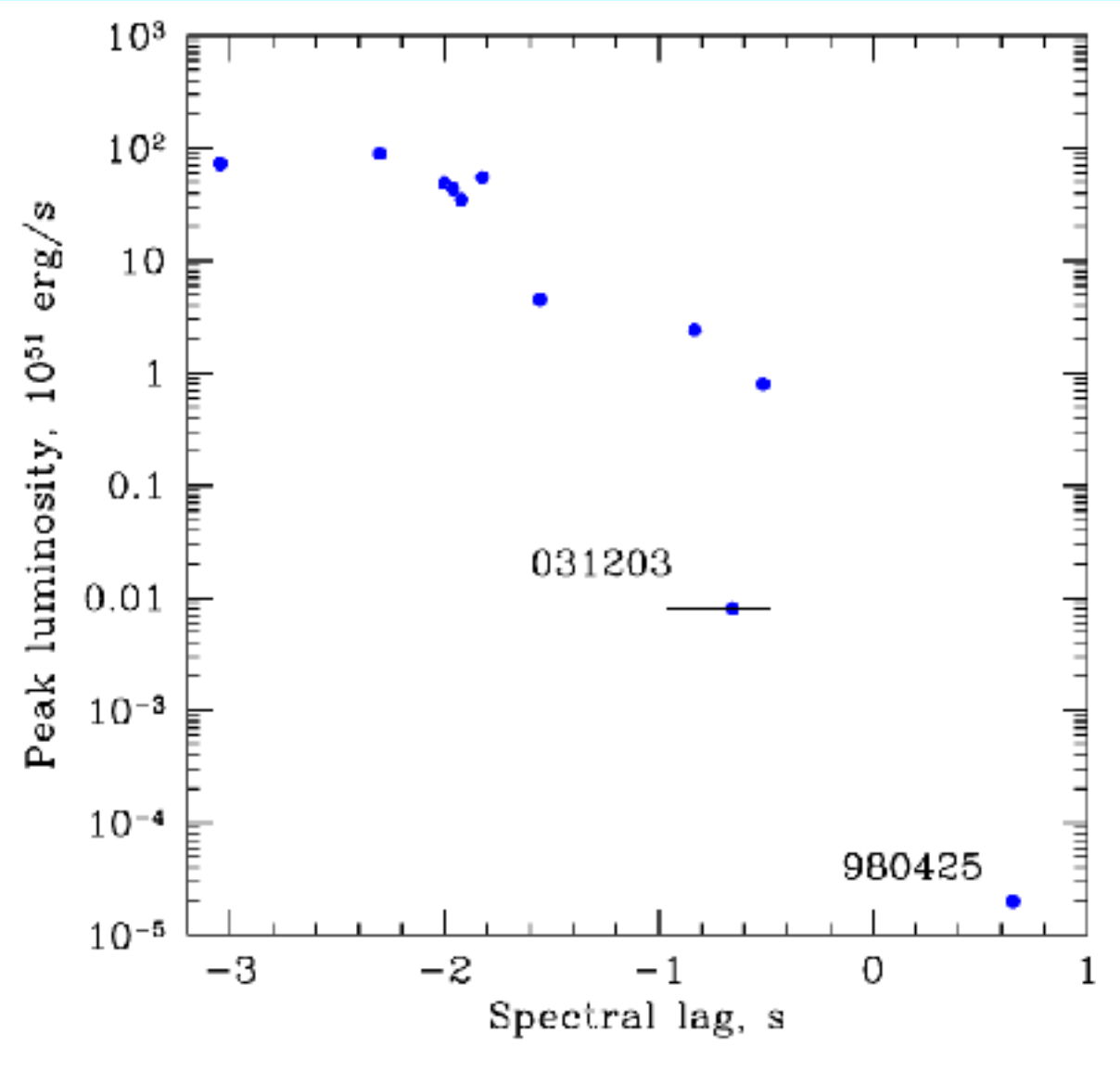
- At z=0.105, the isotropic gamma-ray energy release 6×10^{49} erg < E_{iso} (20-2000 keV) < 1.4×10^{50} erg (depending on E_{peak}>200 keV)

- ~1000 times less than cosmological bursts but ~100 times more than GRB 980425

GRB 031203 violates the E_{iso}-E_{peak} relation

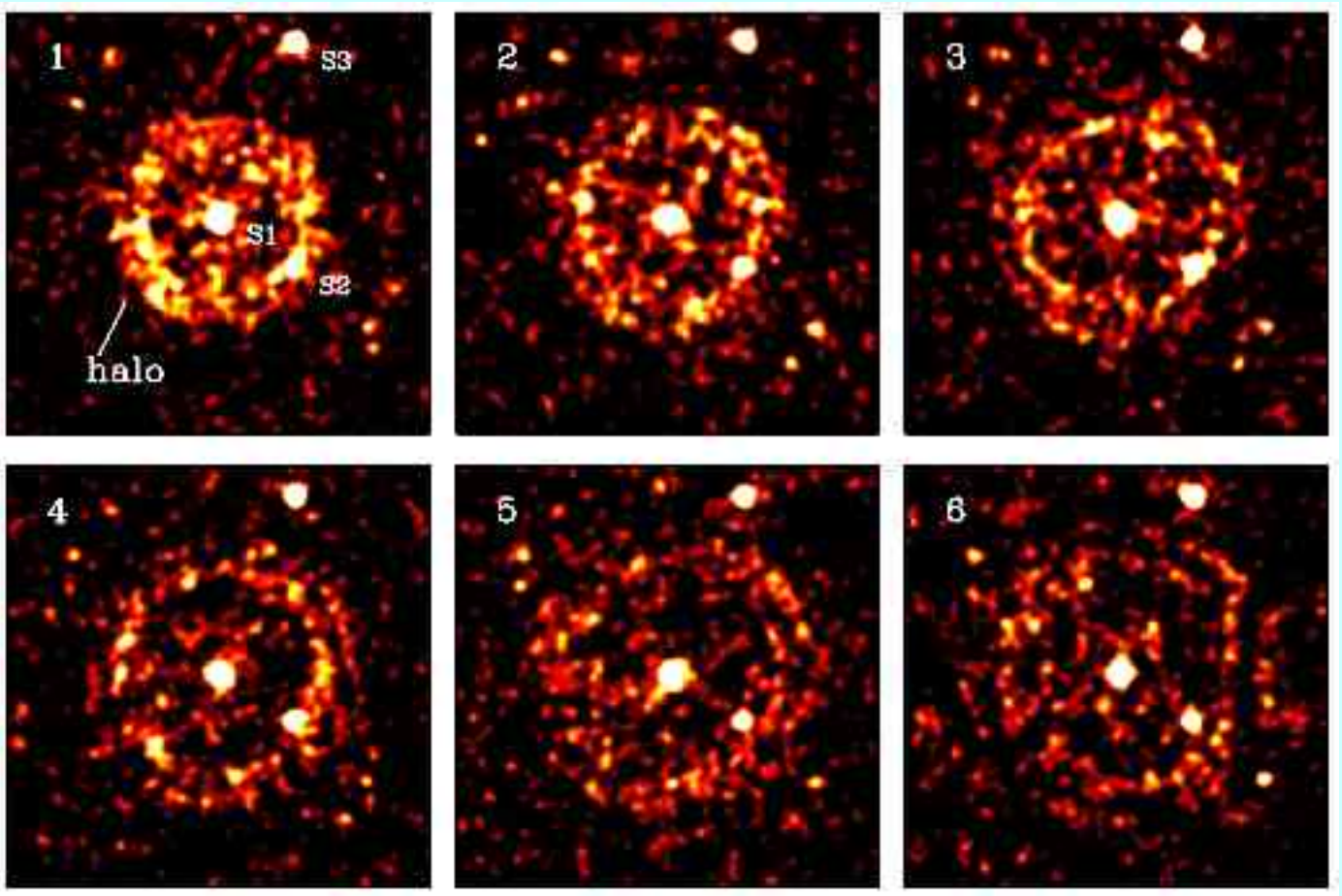


... and the lag-luminosity relation



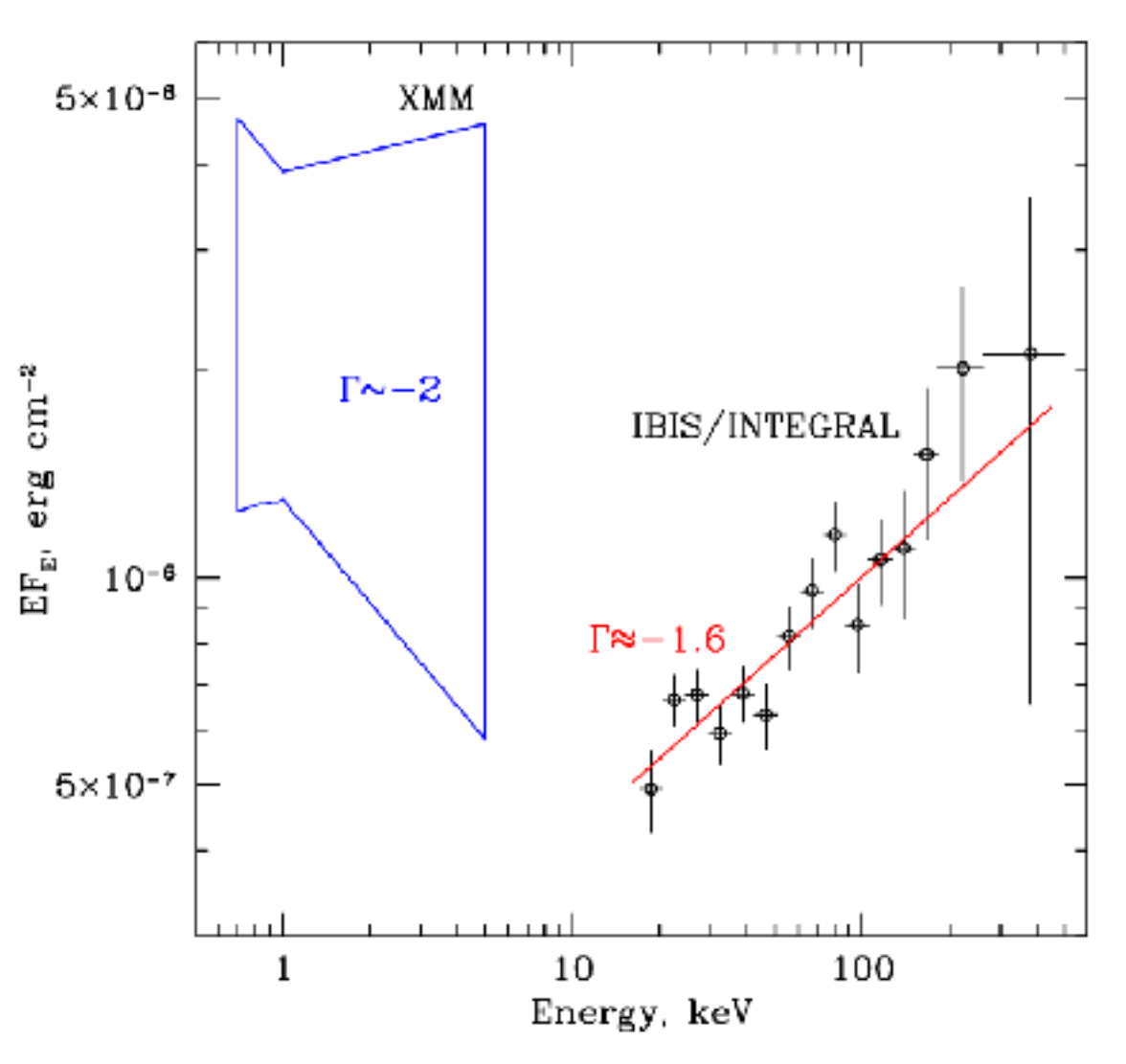
Schaefer 2003

Evolving dust-scattered X-ray halo



XMM-Newton (6 hours, 7.6 hours, 9.2 hours... after the burst)

Powerful X-ray event happened 2000±2000 s after the burst (Vaughan et al. 2004)

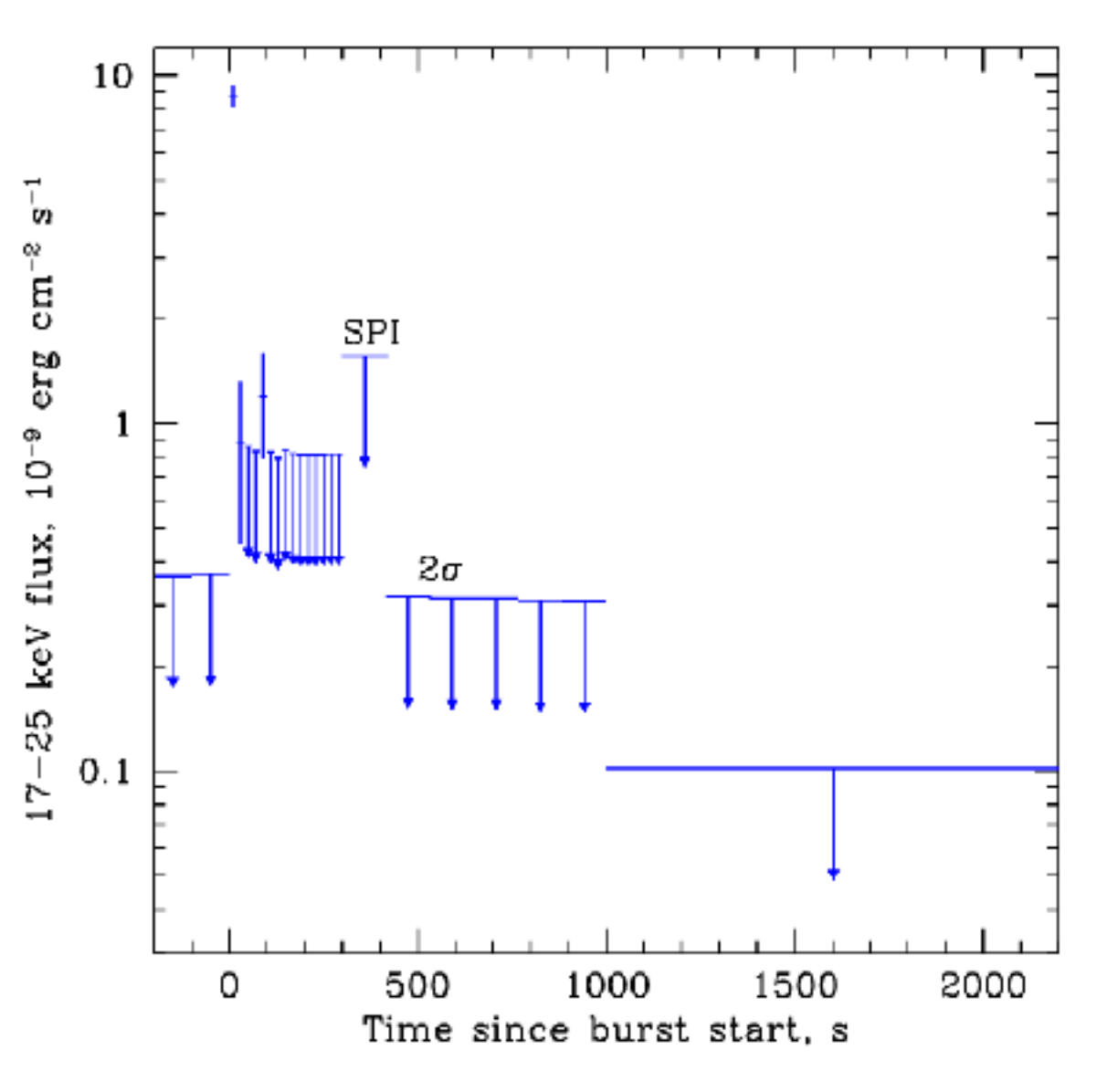


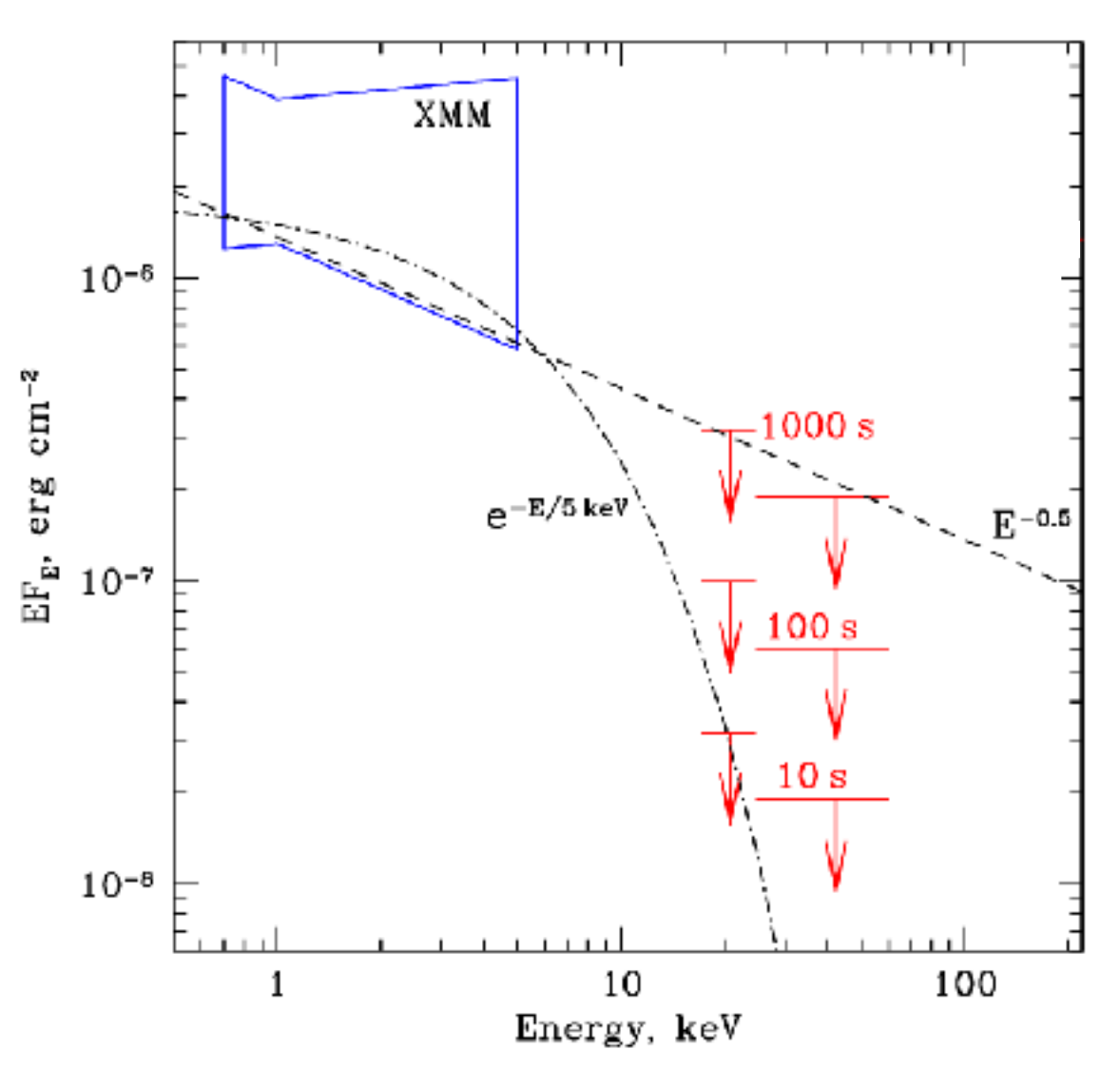
XMM spectrum is inconsistent with IBIS spectrum

Possible solution (Prochaska et al. 2004):

The line-of-sight dust column is higher then adopted, which would lower the XMM flux

INTEGRAL data permit to constrain hard X-ray flux at any moment from 0.5 hour before up to 1day after the burst



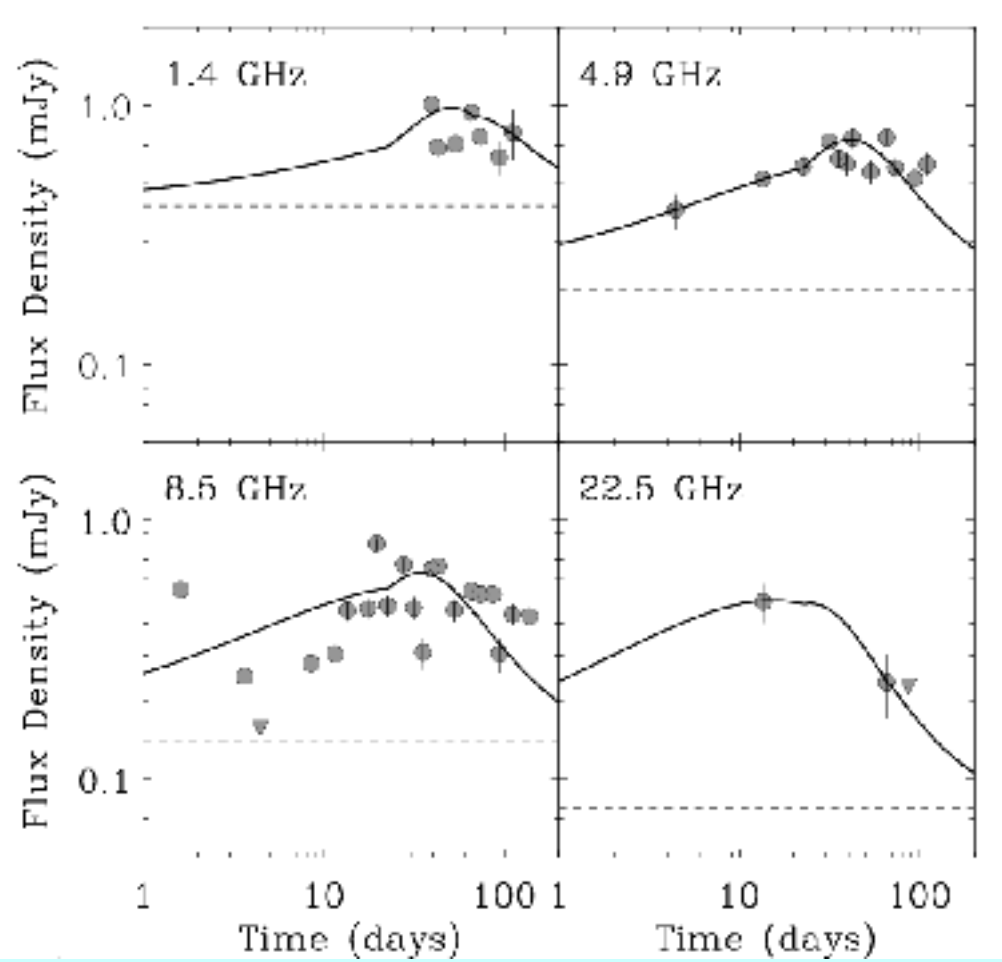


A short event requires an abrupt spectral cut off between 5 and 17 keV

Data prefer an event lasting ≥100 s

A long secondary peak or early afterglow?

VLA Observations of GRB 031203

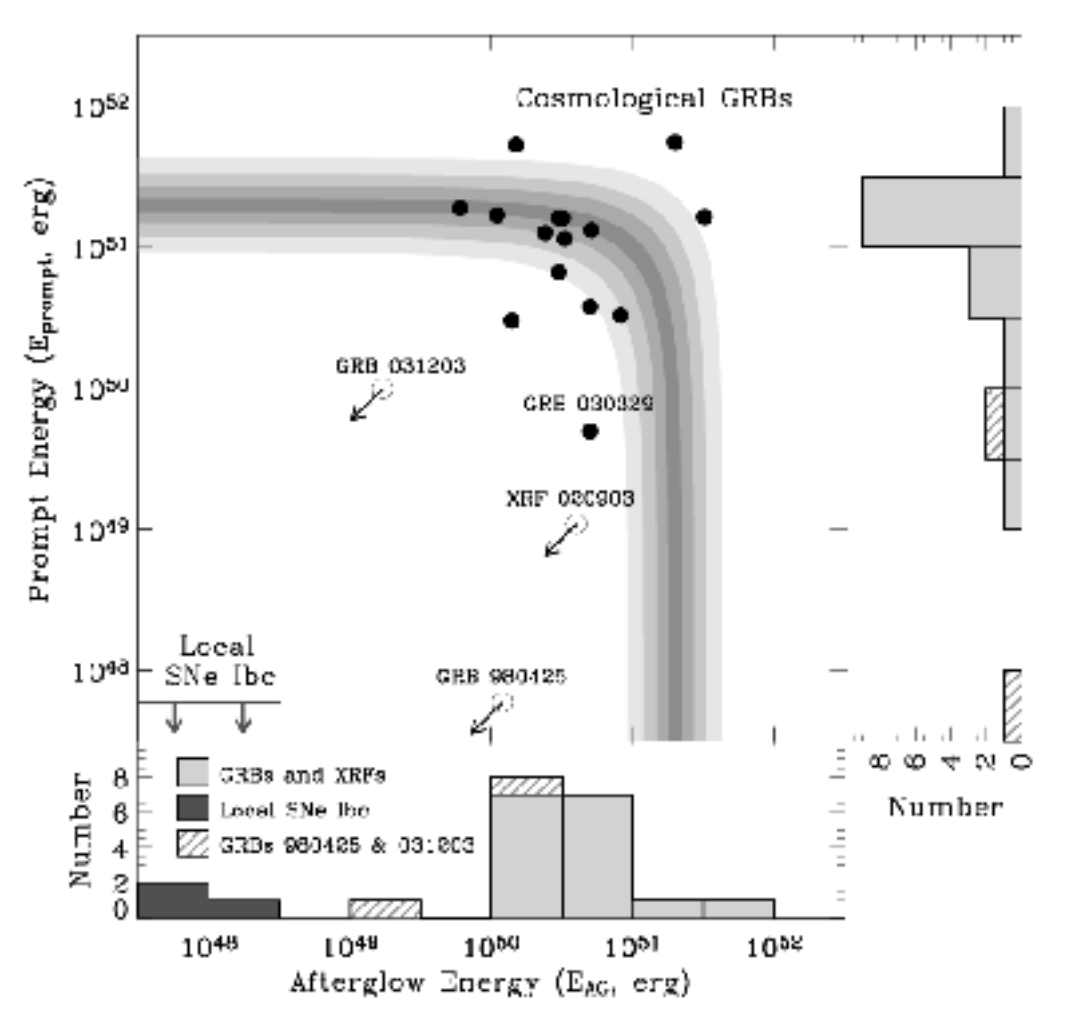


Model: quasi-spherical mildly relativistic ejecta expanding into a uniform circumburst medium

- No collimation of ejecta
- Energy ~2 x 10^{49} erg
- CSM density ~1 $cm^{-3}s$
- No rebrightening t<0.5 yr

Soderberg, Kulkarni, Berger et al. 2004 Nature

Prompt emission energy vs. afterglow kinetic energy

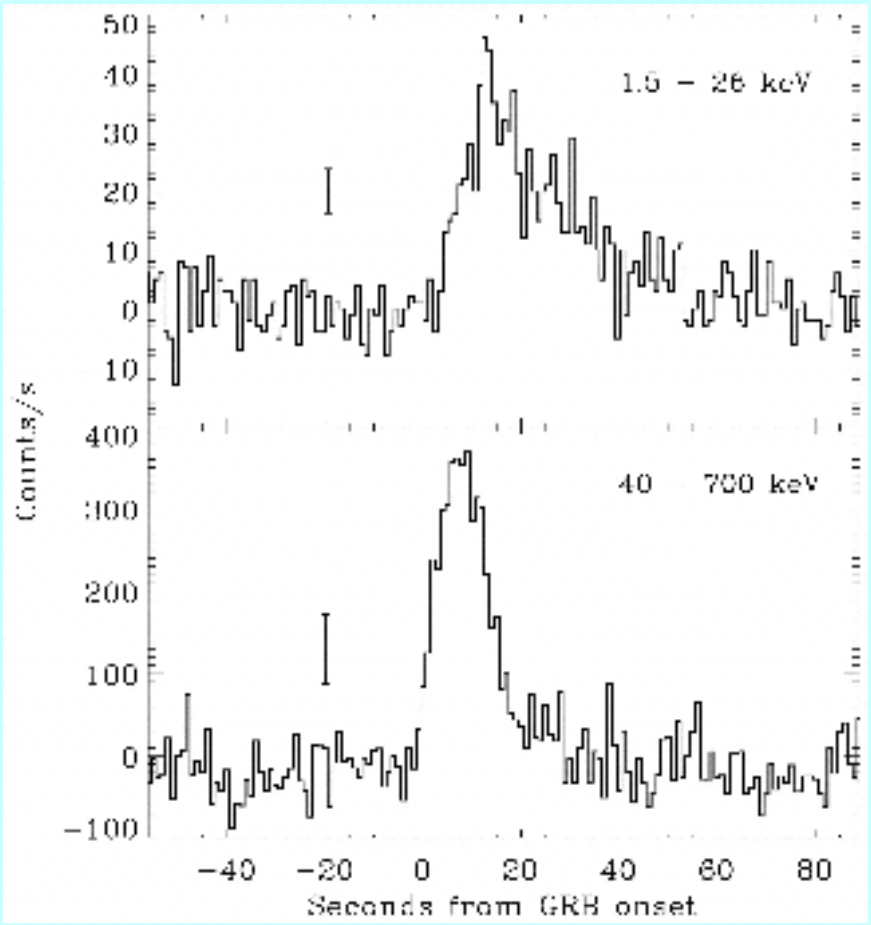


E_{prompt} and E_{AG} have been corrected for beaming, except for GRB 980425, XFR 020903 and GRB 031203

Most bursts cluster around $E_{prompt} + E_{AG} = 2 \times 10^{51}$ erg, while GRBs 031203 and 980425 are sub-energetic

Soderberg et al. 2004

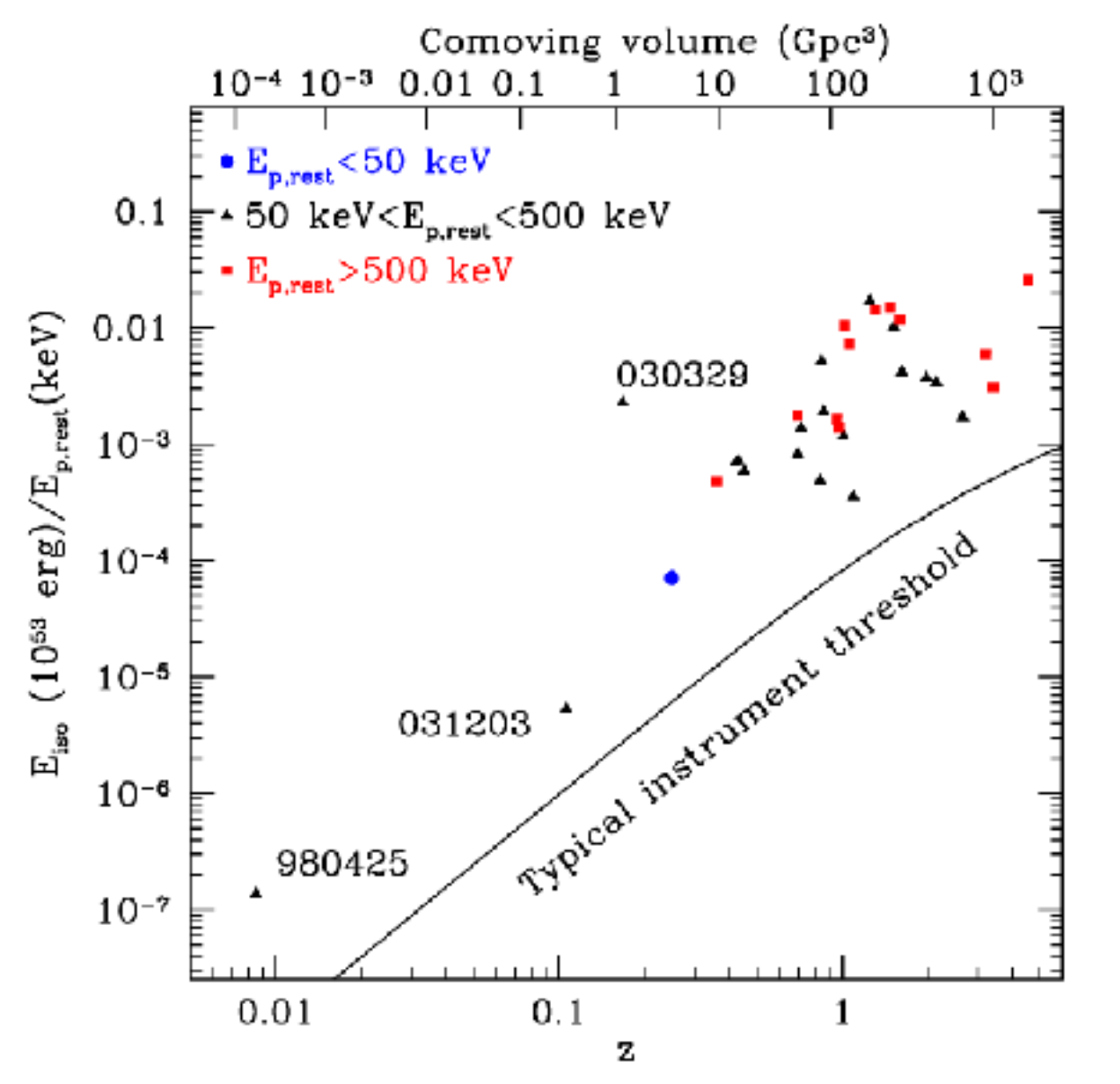
GRB 031203/SN 2003lw appears similar to GRB 980425/SN 1998bw



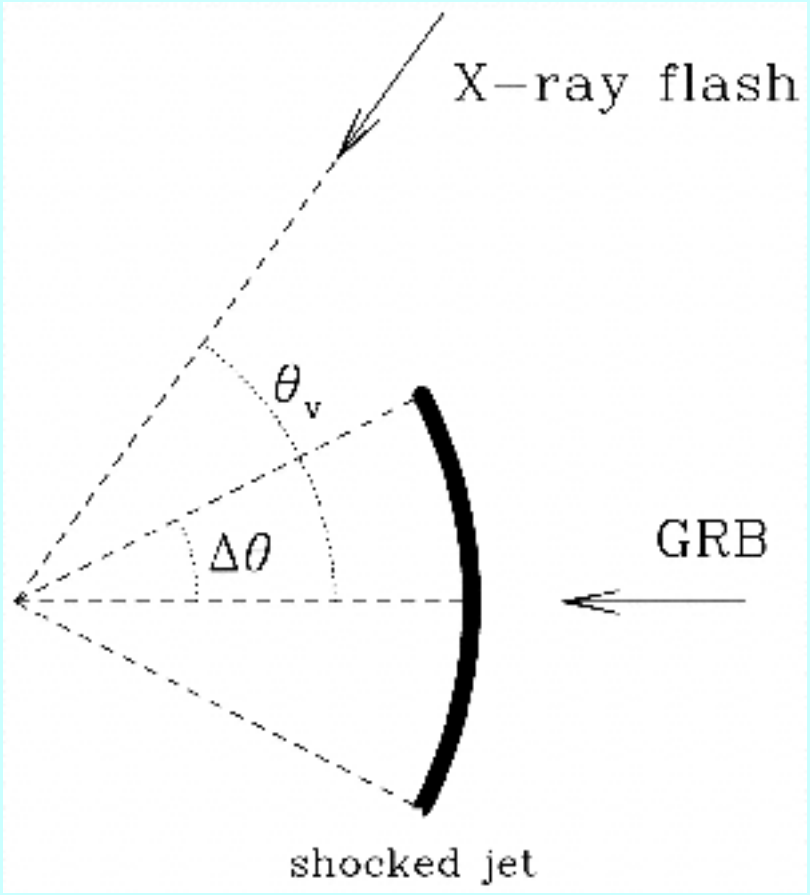
Pian et al. 2000

- Simple temporal profile
- Outliers to the E_{iso}-E_{peak} and luminosity-lag relations
- Faint (or undetected) optical/X-ray afterglow

GRBs 980425 and 031203 – tip of the iceberg?



Off-axis events?



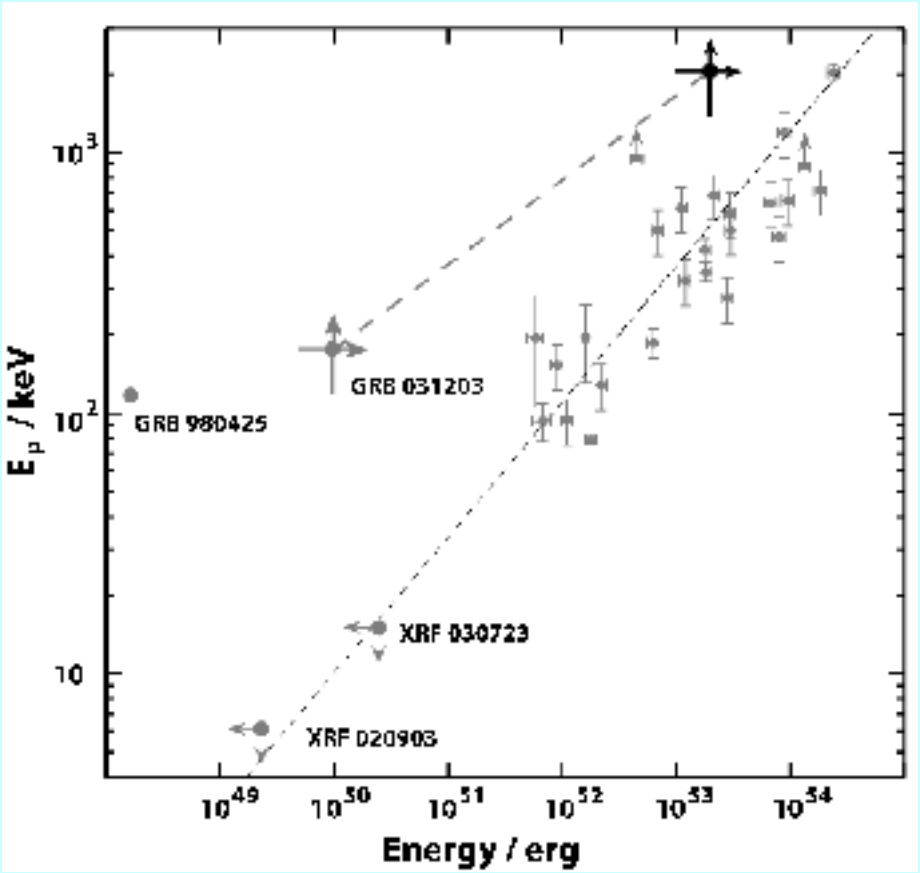
$$E_{iso,off}/E_{iso,on} \sim [\Gamma(\Theta_v - \Delta\Theta)]^{-6}$$
$$E_{p,off}/E_{p,on} \sim [\Gamma(\Theta_v - \Delta\Theta)]^{-2}$$

If we want GRB 031203 ($E_{iso,off} \sim 10^{50}$ erg) to have $E_{iso,on} \sim 10^{53}$ erg, then $(\Theta_v - \Delta\Theta) \sim 1/\Gamma \sim$ a few deg and $E_{p,on} > 2$ MeV

GRBs 980425 and 031203 would be among the hardest bursts ever observed if viewed on axis

Off-axis events?

E_{iso}-E_p relation still not obeyed



Ramirez-Ruiz et al., astro-ph/0412145

<u>More serious problem:</u>
Solid angle subtended by such slightly off-axis events is similar to that subtended by their on-axis counterparts,

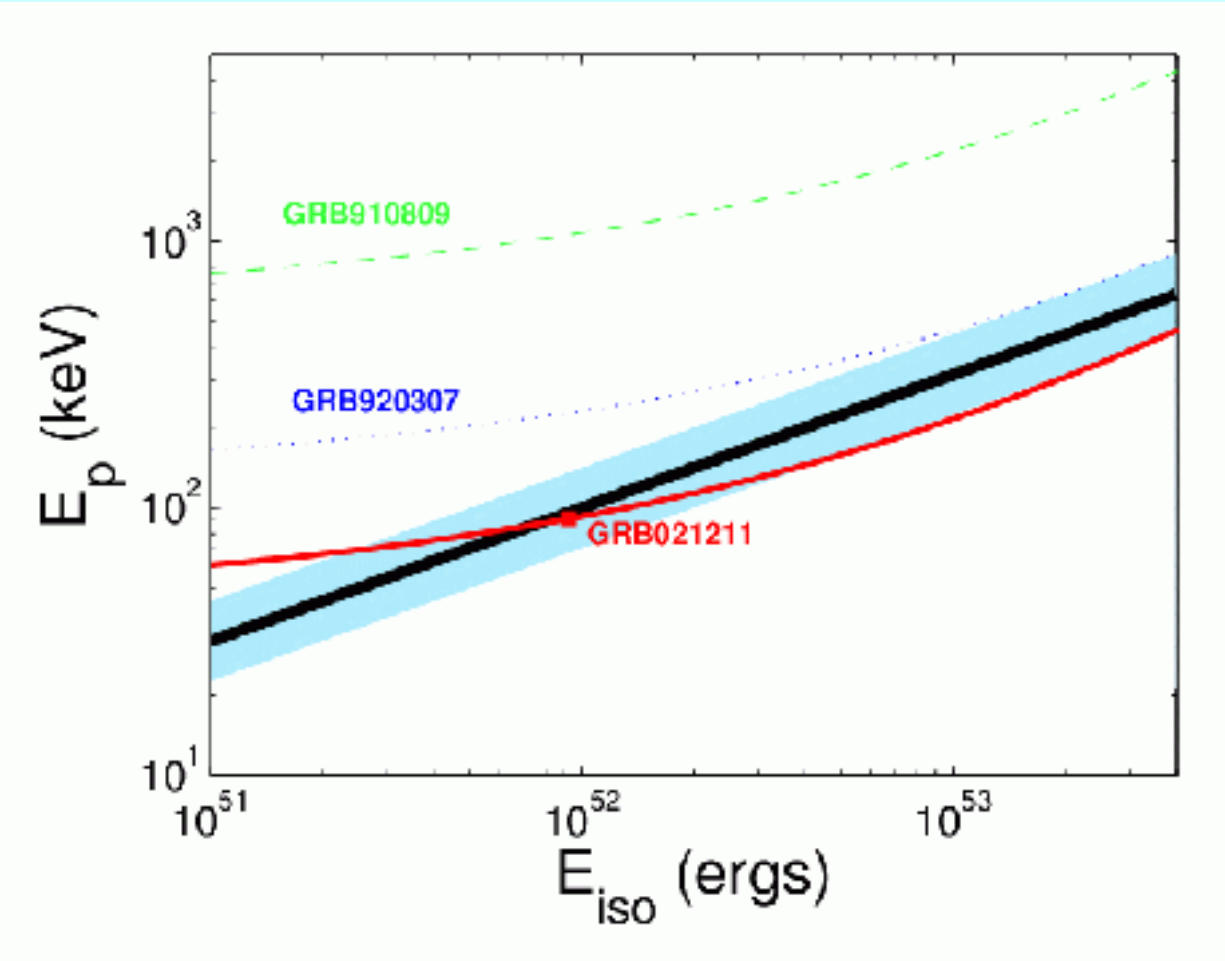
but the latter are ~1000 times brighter, so why are there no bright (fluence~10^{-3} erg/cm^2) local (z~0.1) GRBs???

Conclusions

- GRBs 980425 and 031203 are likely truly sub-energetic events
- Such intrinsically weak cosmic explosions can be more numerous than "standard" ones
- This implies a diversity of energy release - seems OK for collapsar theory (MacFadyen, Woosley & Heger 2001)
- The Amati relation is probably not universal
- A larger sample of GRBs with known distances in needed!

SWIFT is in orbit!

40 per cent of BATSE GRBs do not obey the E_{iso}-E_p relation regardless of their (unknown) redshift!



Nakar & Piran, astro-ph/0412232