INTEGRAL observations and Chandra follow up of the X-Ray Flash 040812

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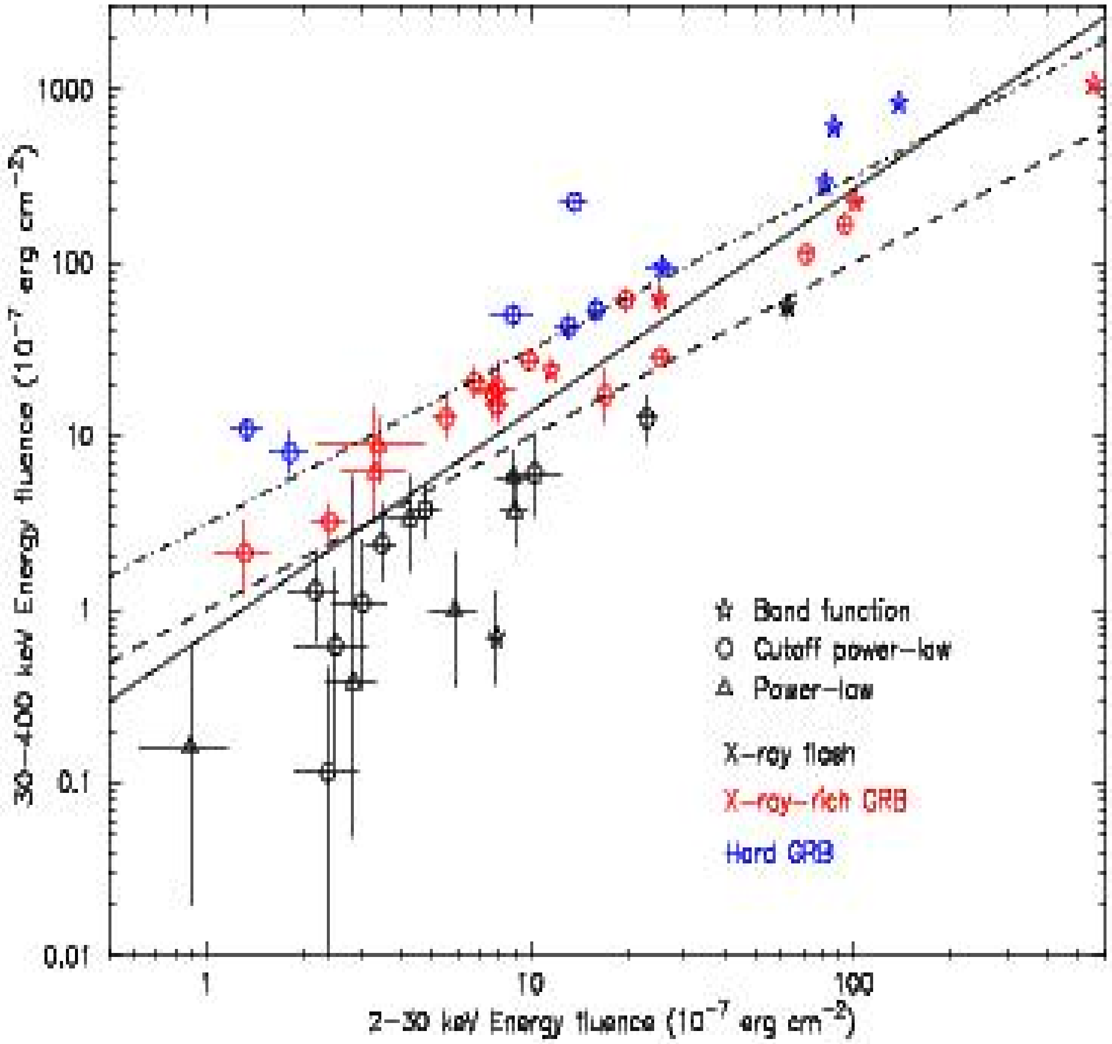
Outline

- ✓ Introduction to some phenomenological aspects of long GRBs & XRFs
- ✓ The INTEGRAL XRF 040812:
  - Prompt emission
  - Afterglow
  - Host galaxy
- ✓ XRF or soft GRB?

GRBs and XRFs



(Lamb et al. 2005, Sakamoto et al. 2005)

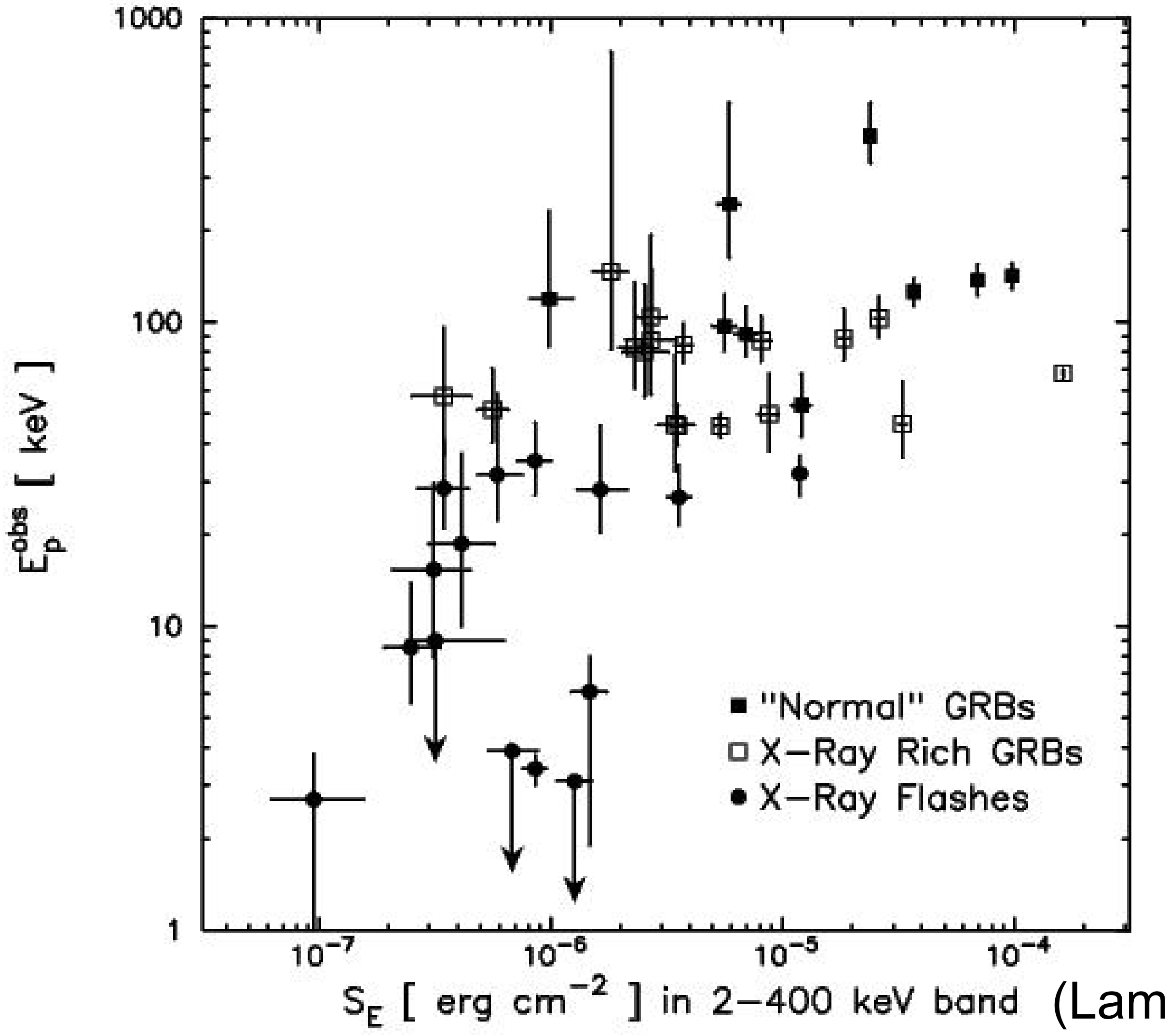
Long GRBs are classified as: 'normal', 'X-rich' and X-ray flash bursts, according to their soft over hard fluence ratio:

- $\log(S_{2-30}/S_{30-400})<1$ GRB
- $\log(S_{2-30}/S_{30-400})=1$ XRR
- $\log(S_{2-30}/S_{30-400})>1$ XRF

About 1/3 of GRBs are normal, 1/3 are XRR and 1/3 are XRF

GRBs and XRFs

Hardness-intensity relation



(Lamb et al. 2005)

- Softer GRBs (XRFs) are also fainter
- This reflects an intrinsic property of long GRBs: E_{peak}-E_{iso} correlation (Amati et al. 2002)

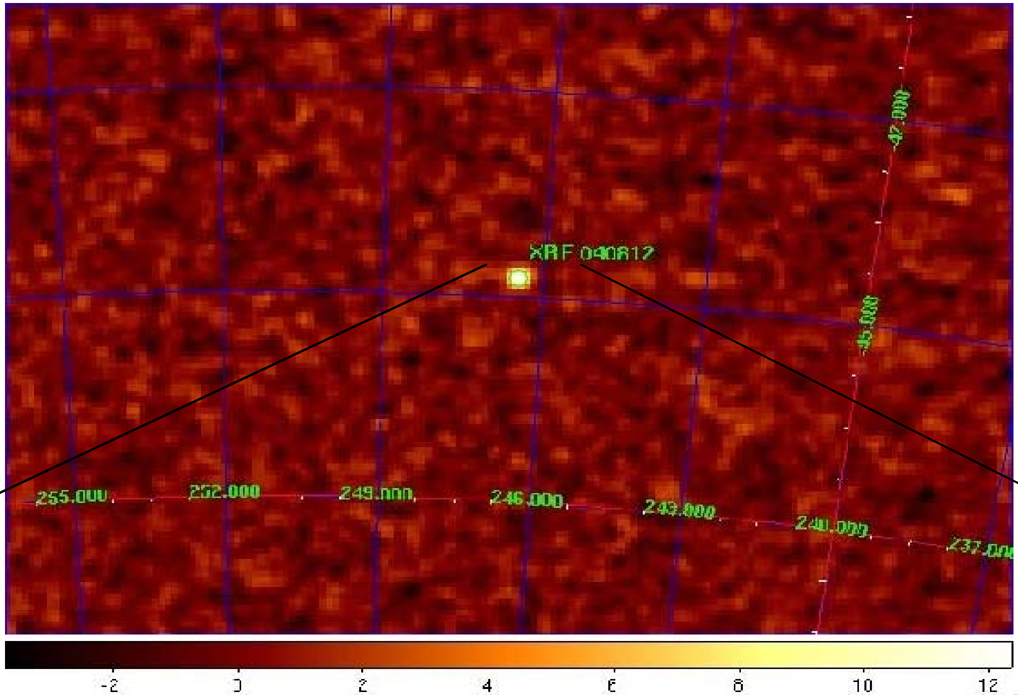
What makes GRBs soft?

- Distant GRBs (Heise et al. 2003)… not for the two intrinsic XRF (060218 and 020903 that are at $z<0.3$)
- GRBs observed off-axis? (Lamb et al. 2005)
- GRBs with low efficiency internal shocks?(Mochkovitch et al. 2004)
- GRBs with mildly relativistic fireball (due for example by high baryon loading)? (Dermer et al. 1999)

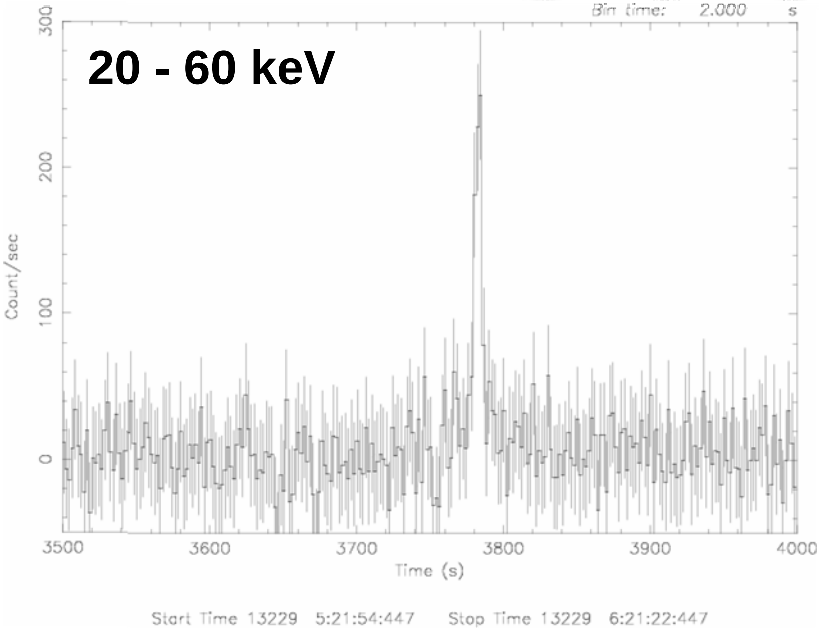
INTEGRAL XRF 040812

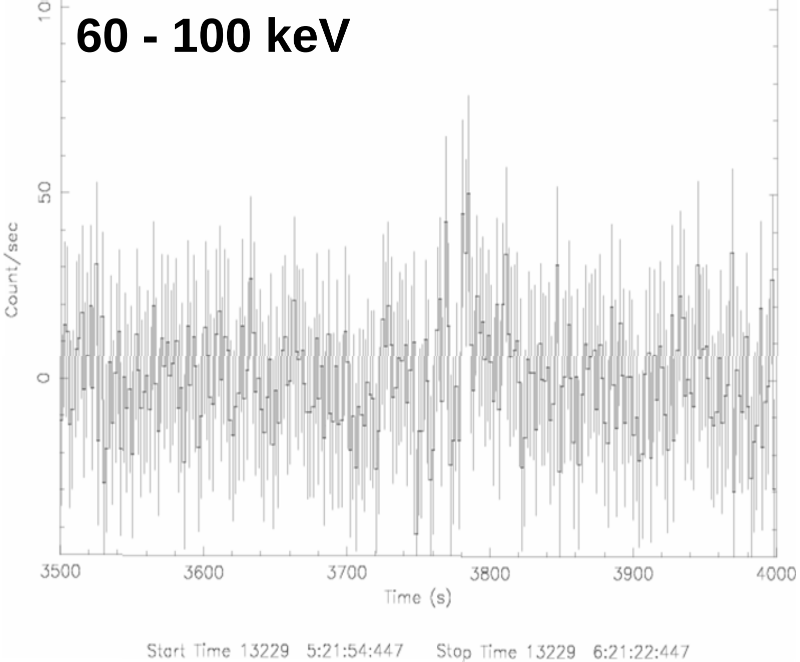
IBAS alert time

2004, Aug 12th
T0=06:01:50 UT



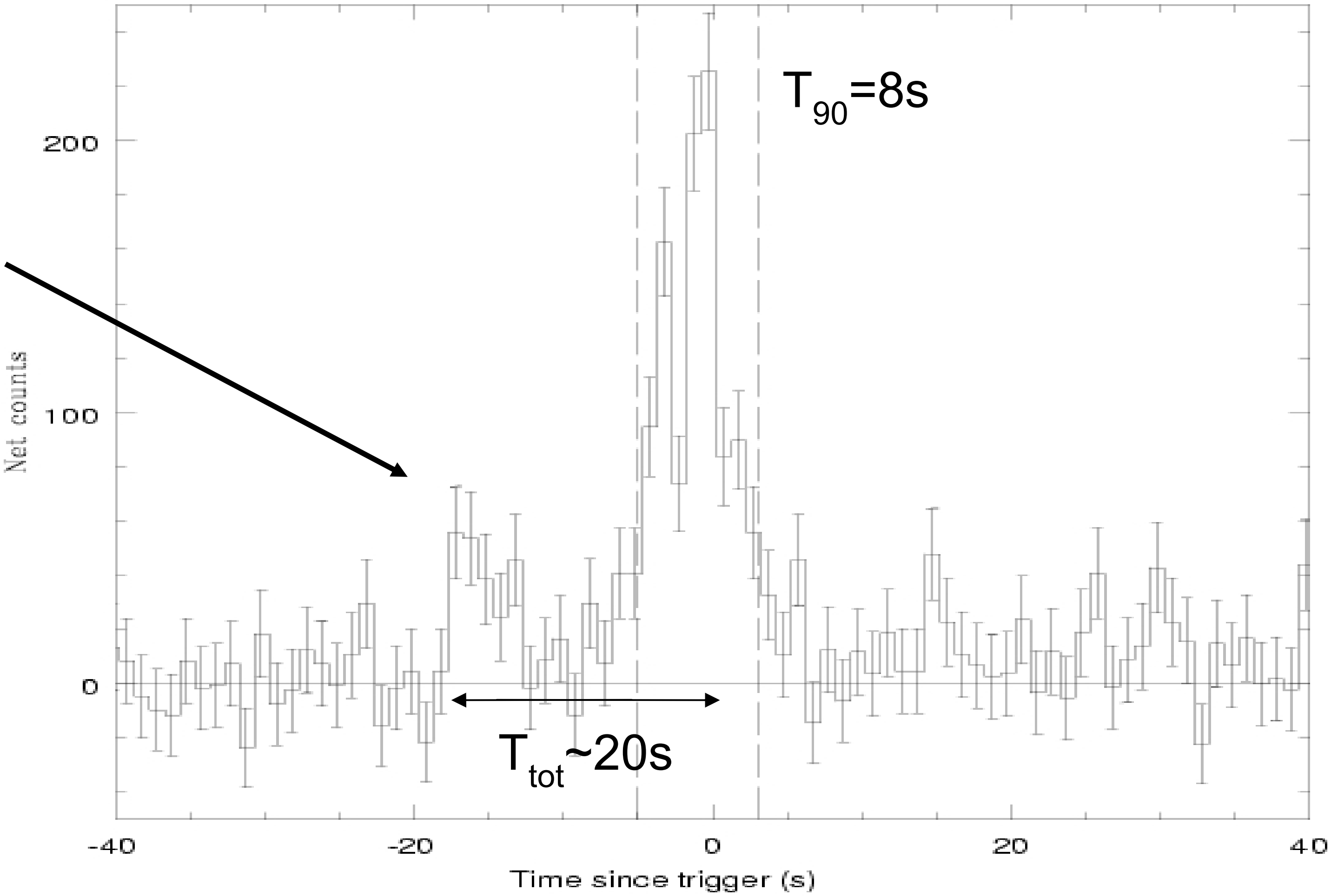
IBIS/ISGRI Significance:
12 σ


20 - 60 keV


60 - 100 keV

The IBIS/ISGRI 20-60 keV burst light curve

...precursor?
T~2s
10% of total counts
Gap of ~3s



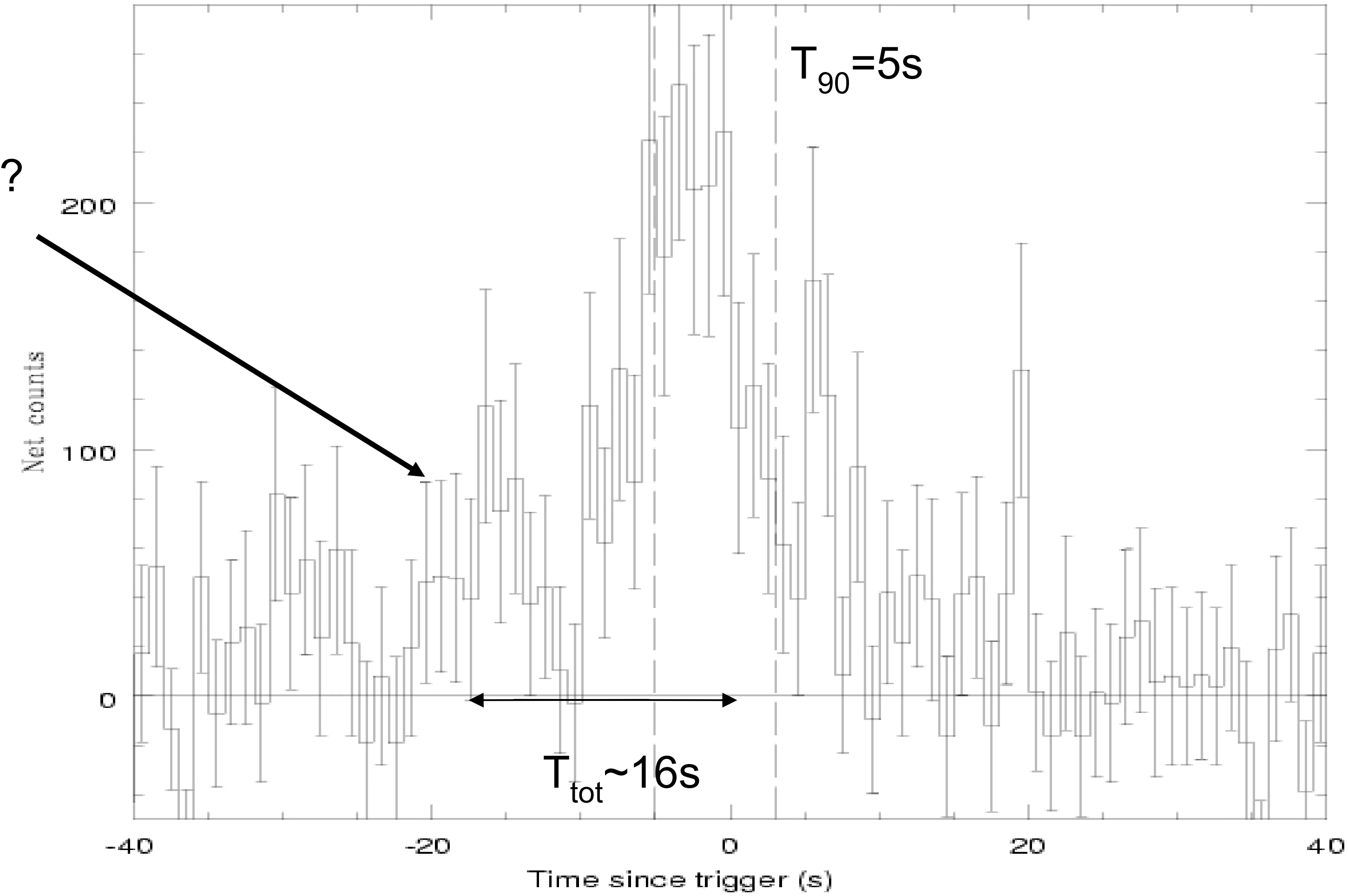
T_{90}=8s

T_{tot}~20s

2004-12-08 06:02:05 UT

The JEM-X 3-35 keV burst light curve

...precursor?
(S/N<3)

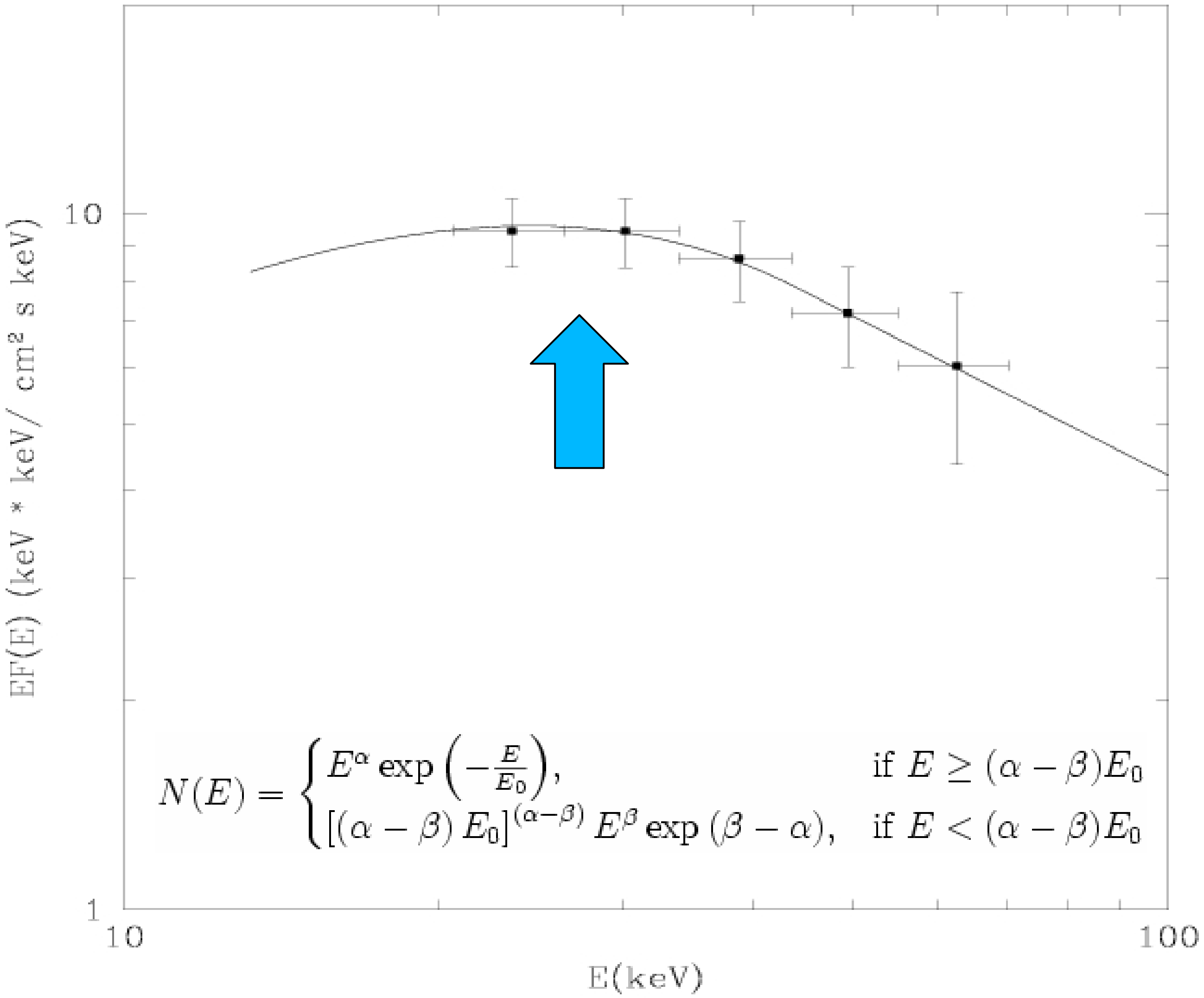


T_{90}=5s

T_{tot}~16s

2004-12-08 06:02:05 UT

Burst spectrum



$$N(E) = \begin{cases} E^{\alpha} \exp\left(-\frac{E}{E_0}\right), & \text{if } E \geq (\alpha - \beta) E_0 \\ \left[(\alpha - \beta) E_0\right]^{(\alpha - \beta)} E^{\beta} \exp(\beta - \alpha), & \text{if } E < (\alpha - \beta) E_0 \end{cases}$$

Assuming a Band model
we found
$\alpha \sim -1$
$\beta \sim -3$
Consistent with typical
XRF values.

The E(F(E)) peak energy
is at

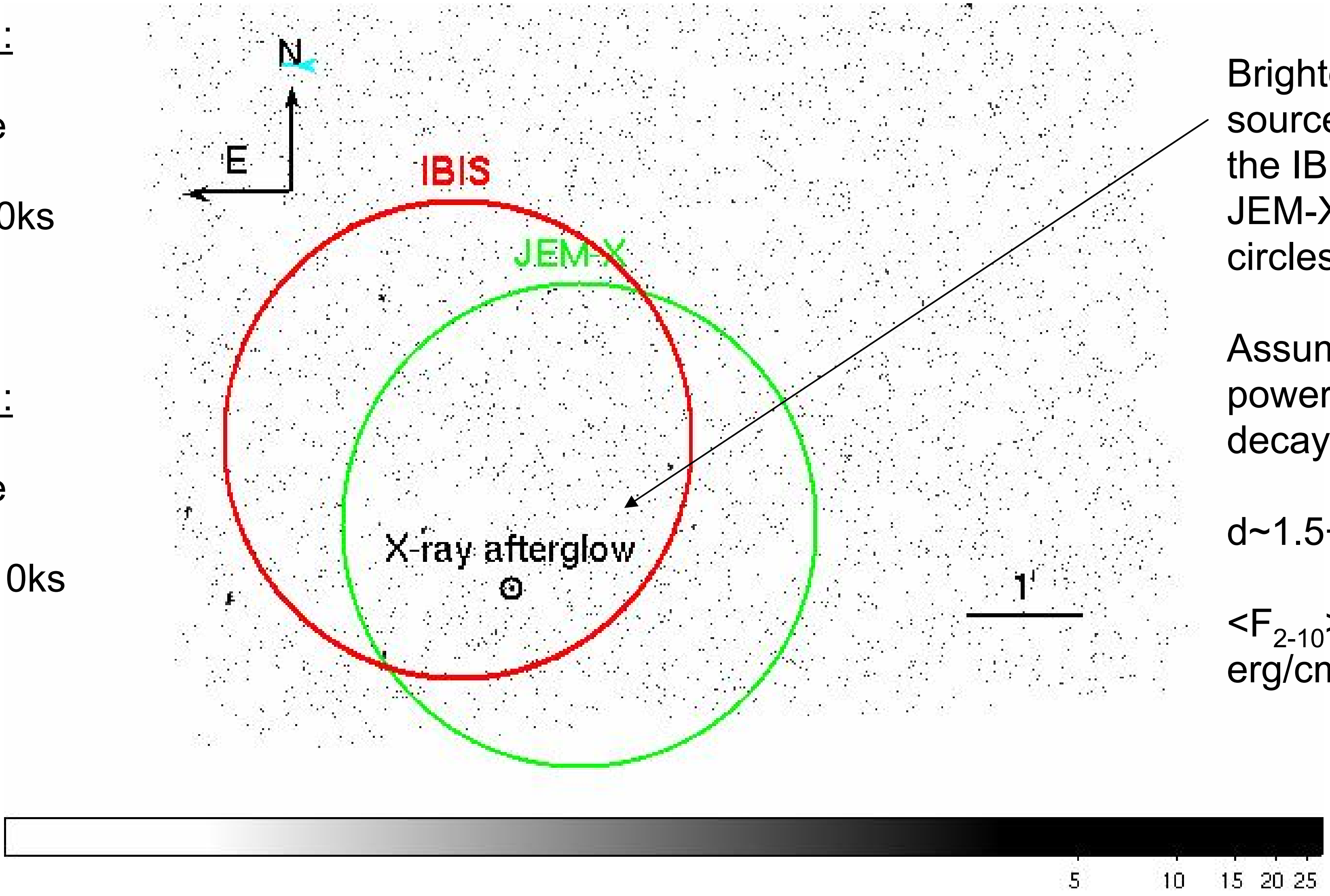
E_{peak}=25+/-5 keV

F_{20-200}=2.2x10^{-8} erg/cm^{2}s

Chandra: X-ray afterglow discovery

<u>1 epoch:</u>
5 days
after the
burst
Texp=10ks

<u>2 epoch:</u>
10 days
after the
burst
Texp=10ks



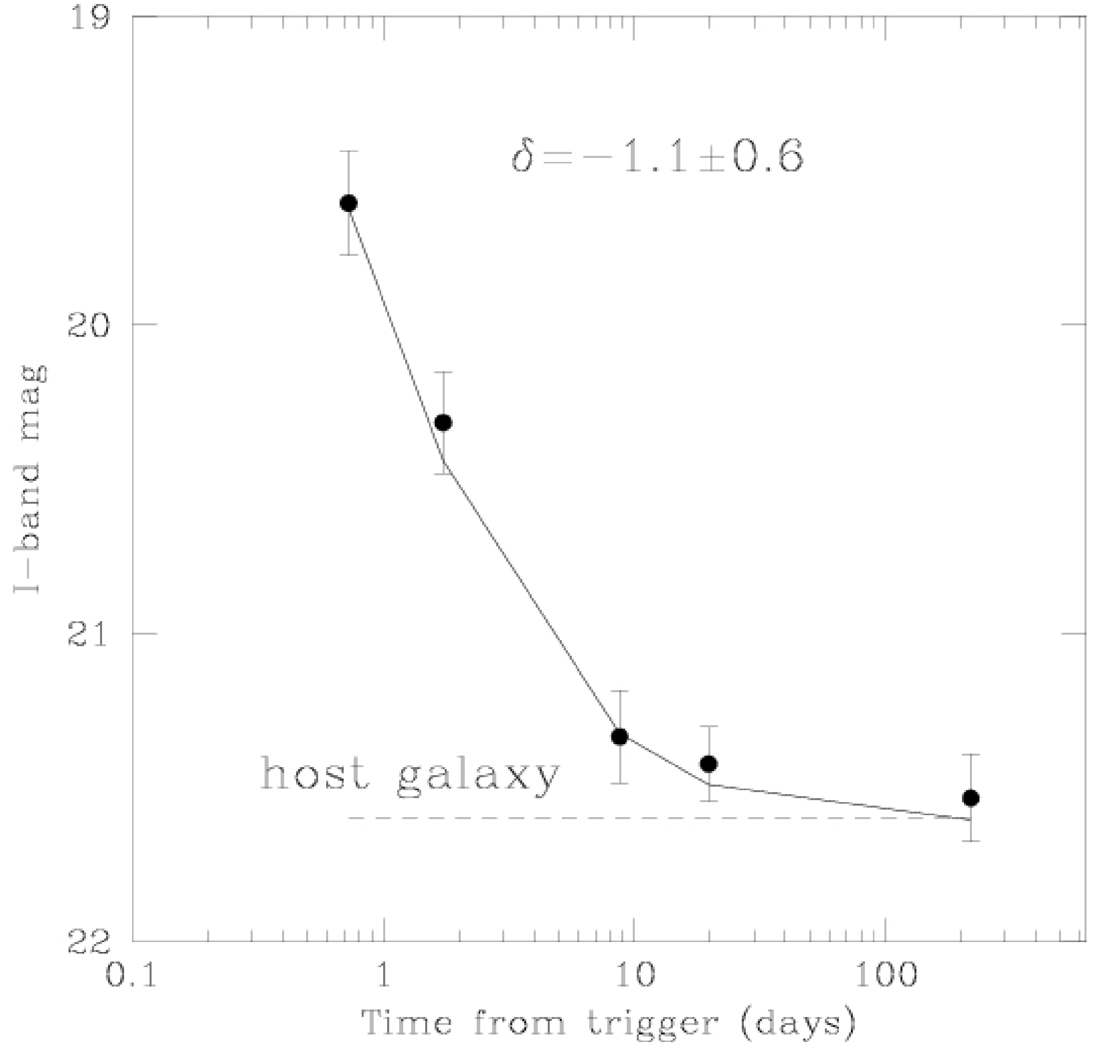
Brightest source within the IBIS & JEM-X error circles

Assuming a power law decay:

d~1.5+/-1.0

$\langle F_{2-10} \rangle \sim 10^{-13}$ erg/cm^{2}s

VLT I-band afterglow detection

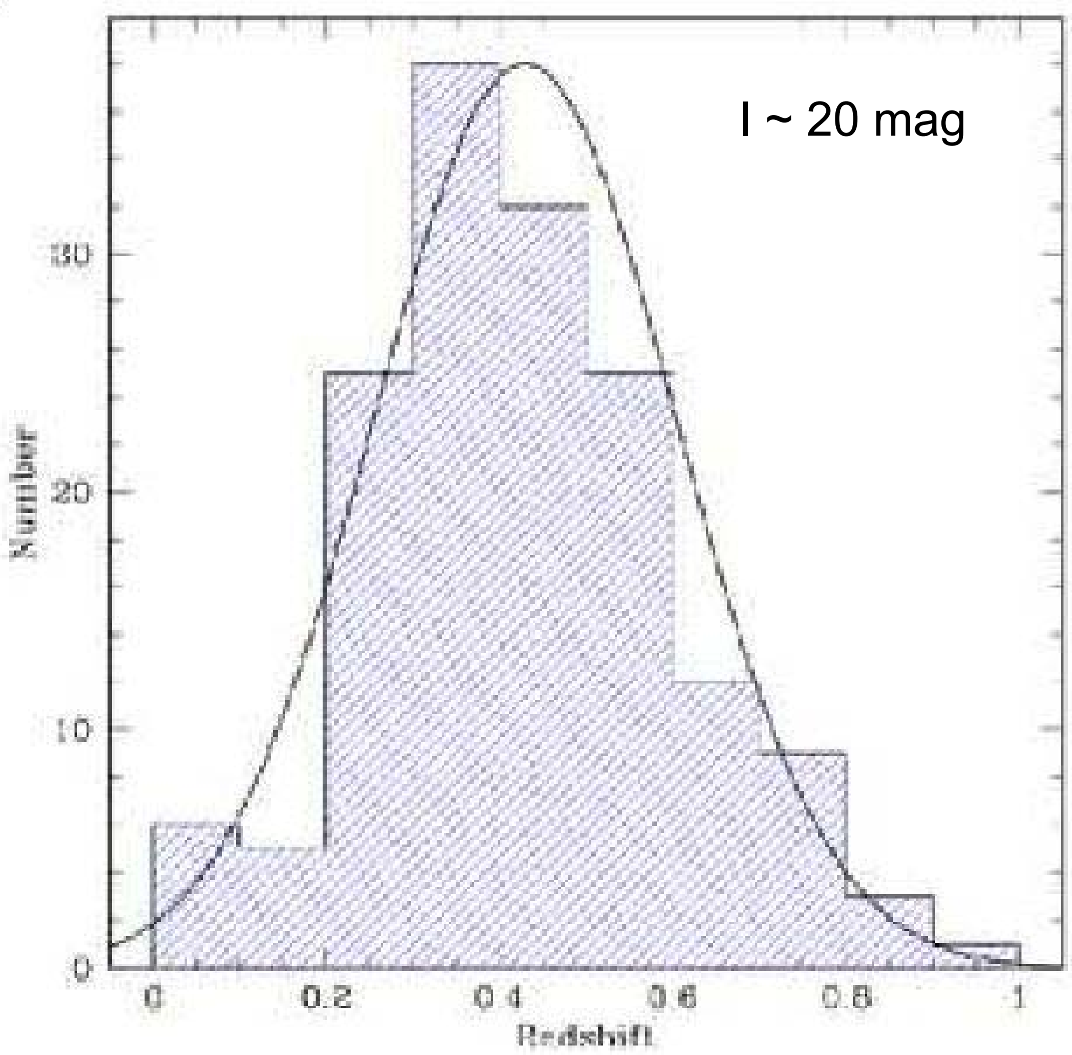


D'Avanzo et al. 2004

- Chandra localization enabled to detect the optical counterpart in the very crowded region localized with IBIS
- D'Avanzo et al. 2004 published VLT observations of the optical afterglow of XRF 040812
- They found a power law flux decay superimposed to a constant emission from the host galaxy at I~20 mag (corrected for our galaxy extinction)

VLT I-band afterglow detection

D'Avanzo et al. 2004



- Host galaxy spectrum unfortunately shows no lines within 4500Ả 8600Ả
- Host brightness I ~ 20 mag
- A sample of SDSS galaxies with $I \sim I_{XRF040812}$ at known z, they inferred a redshift of $0.3<z<0.7$ (D'Avanzo et al. 2004)
- This is in agreement with the lack of typical Hα and OIII emission lines

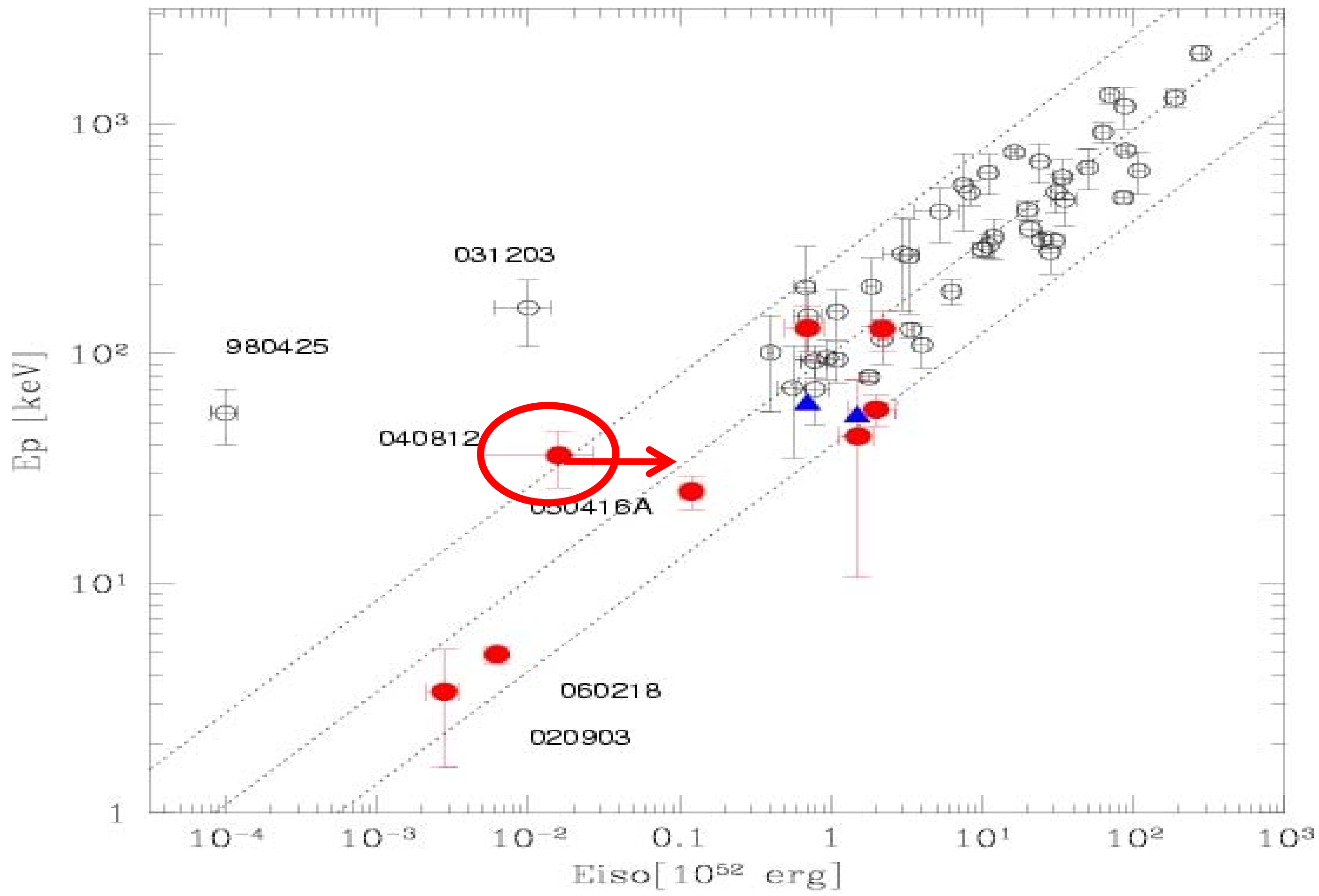
Results

- From the burst spectral properties:
  - $\text{Fluence}_{20\text{-}200\ \text{keV}} \sim 2\times10^{-7}$ erg cm^{-2}
  - $E_{peak} \sim 25$ keV
- From the host galaxy: $0.3<z<0.7$

=> $E_{iso} = (4\pi D^2 \times \text{Fluence})/(1+z) \sim (1.6+/-1.1)10^{50}$ erg

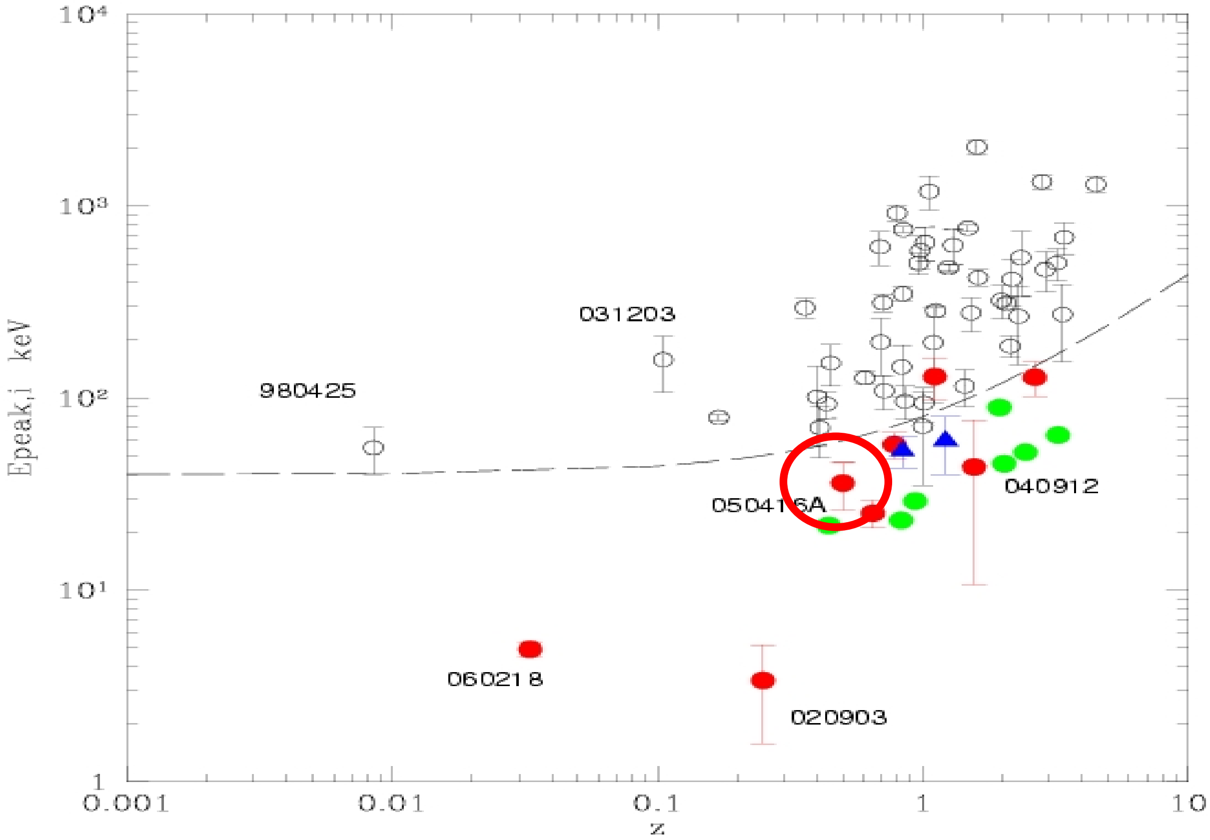
=> $E_{peak} = E_{p,obs}(1+z) \sim (37+/-10)$ keV

E_{peak}-E_{iso} correlation



- XRF040812 satifies the correlation (within the large uncertainties)
- 040812 ranks among XRR rather than intrinsic XRF

E_{peak} vs redshift



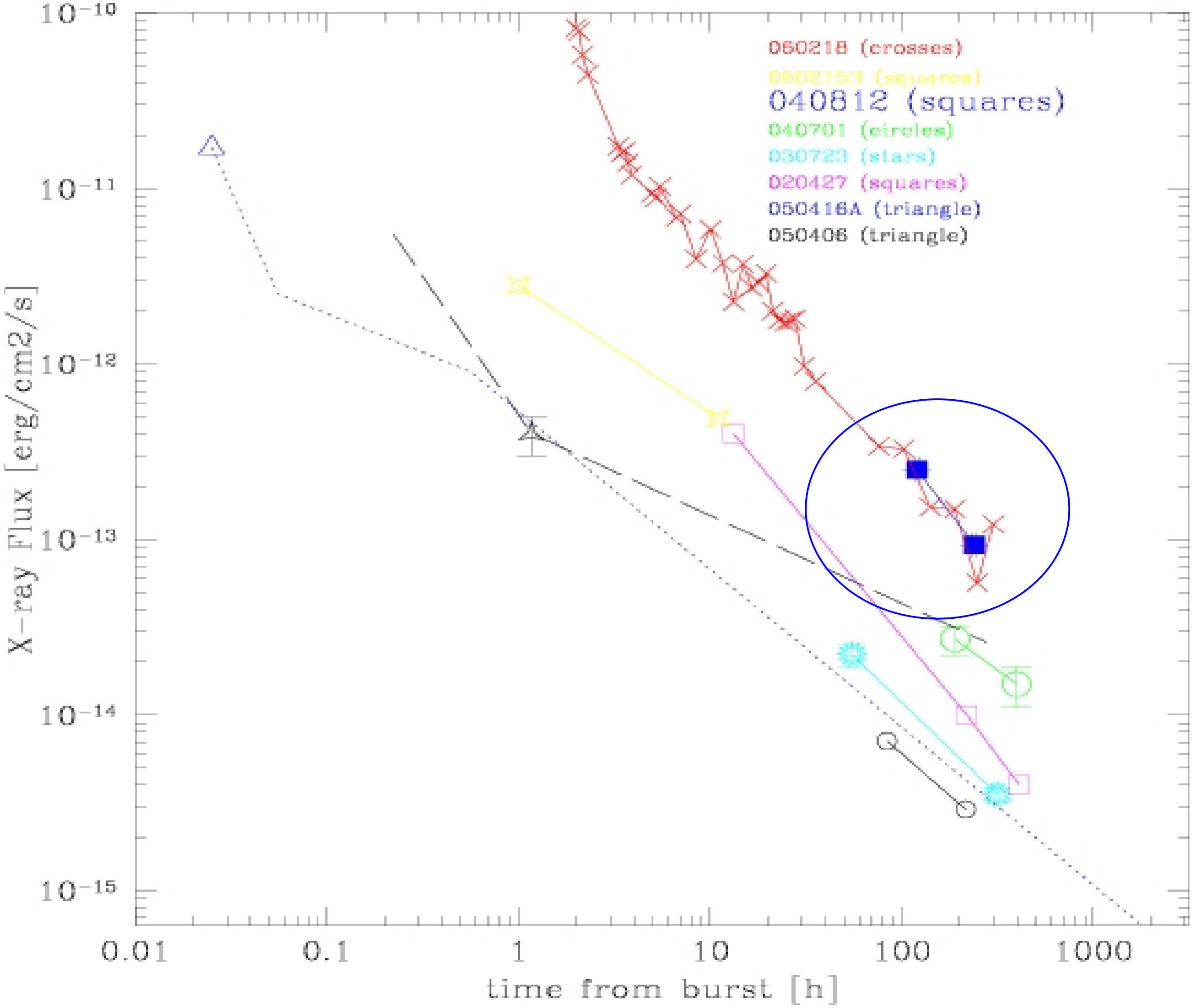
Stratta et al. 2007

- XRF 040812 confirm that most of XRFs are 'soft GRBs' and only 2 (so far) are intrinsic XRF
- The Epeak vs z distribution possibly evidence a different origin for intrinsic XRF

Summary

- We analyzed the burst 040812 observed with IBIS+JEM-X
- The burst light curve and spectrum are consistent with other XRFs
- We analyzed Chandra data taken in two epochs (5 and 10 days after the burst) and we confirm the presence of the afterglow.
- The 1” X-ray afterglow localization enabled to discover the host galaxy of this XRF at $0.3<z<0.7$ (D'Avanzo et al. 2004). We found that taking into account for cosmological redshift:
  - it matches the E_{peak}-E_{iso} correlation
  - XRF 040812 is more an X-ray rich GRB rather than an intrinsic XRF
  - This confirm the results that basically all XRFs discovered so far are more soft GRBs at intermediate redshift ($z\sim1$) rather than intrinsic XRF. Only 2 bursts are 'Intrinsic' X-ray Flashes, namely: 060218 and 020903

Chandra: X-ray afterglow discovery



Stratta et al. 2007

XRF 040812 X-ray afterglow decay rate is consistent with other XRFs afterglows observed at similar epochs that, in turn, are consistent with GRBs X-ray afterglow.

$F_\nu \sim k(t/t0)^{-d}$

with d~1.5+/-1.0