Spectral and temporal properties of long GRBs detected by INTEGRAL from 3 keV to 8 MeV

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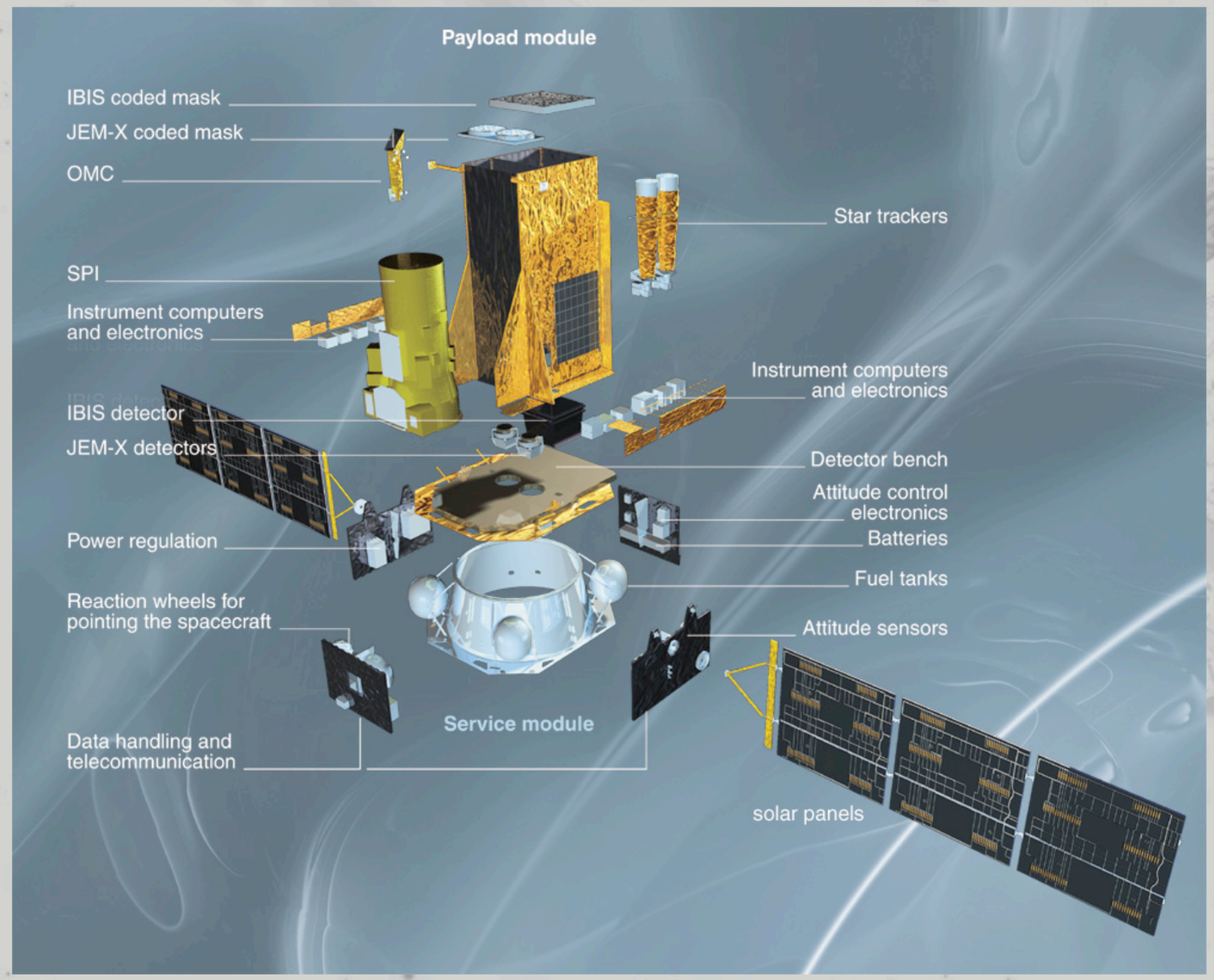
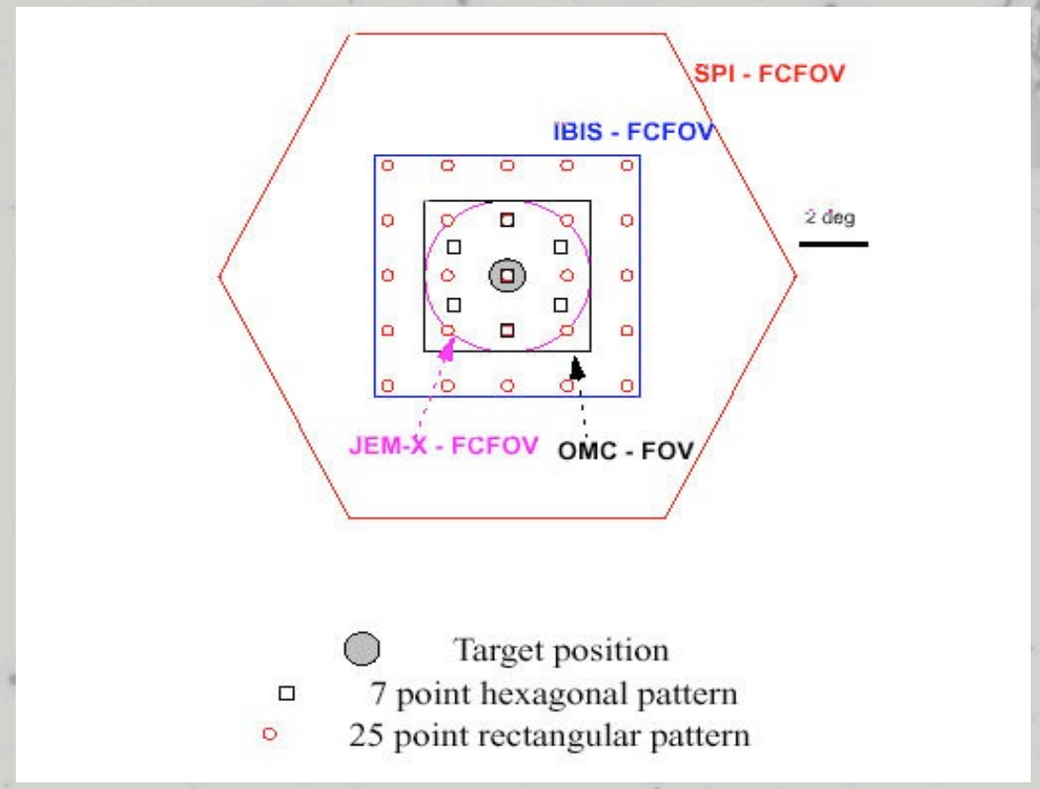
INTEGRAL

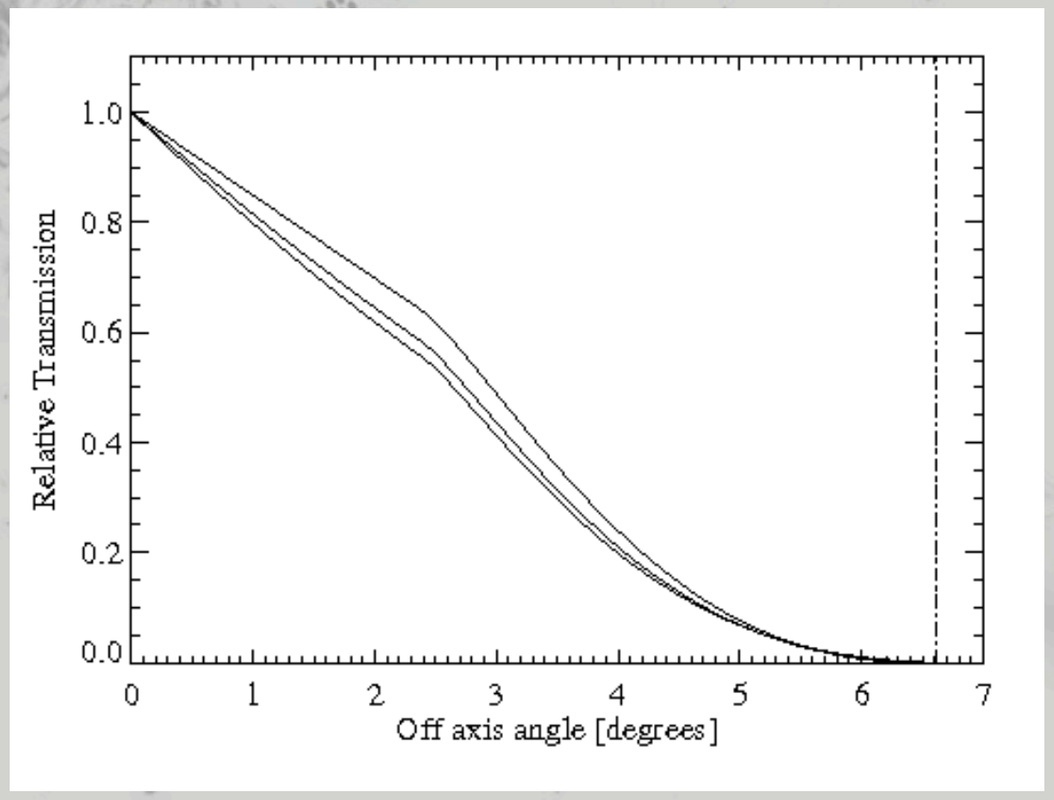


- Launched in October 2002
- Highly eccentric orbit
  - Apogee ~ 150,000 km
  - Perigee ~ 10,000 km
- 72 hour orbit (80% observing time)
- 4 main instruments:
  - Spectrometer SPI
  - Imager IBIS
  - X-ray Monitor JEM-X
  - Optical Monitoring camera OMC

INTEGRAL Detectors

	JEM-X	IBIS/ISGRI	SPI
Energy range	3-35 keV	20 keV- 1 MeV	20 keV- 8 MeV
Fully Coded FOV	5°	8°	16°
Half response FOV	7.5°	19°	35°
Normalisation factor	0.95	1	1.19



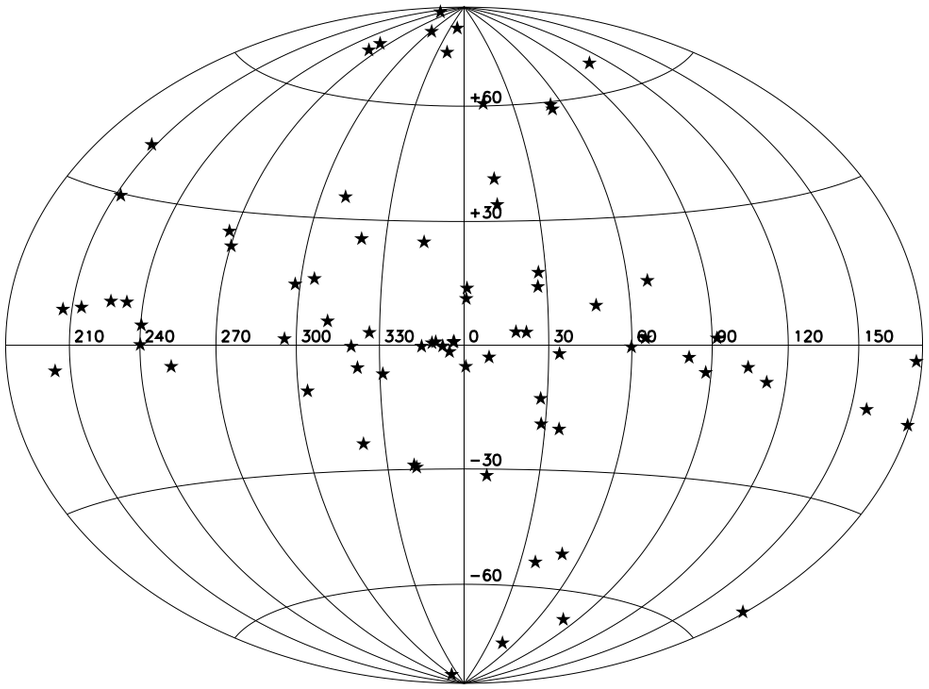


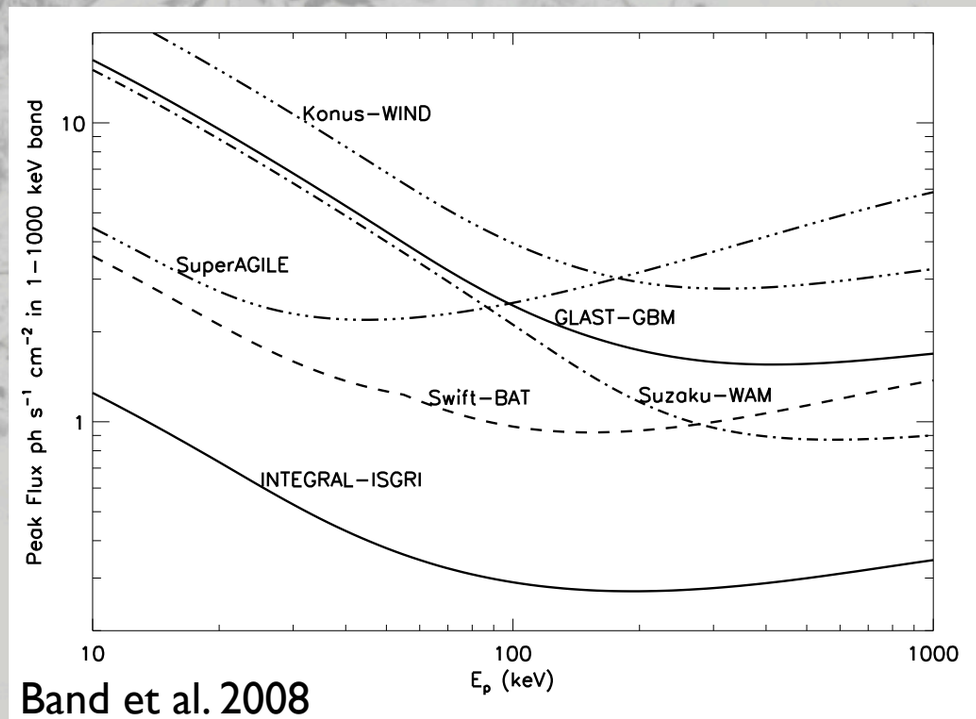
INTEGRAL view of GRBs

• Since its launch INTEGRAL has triggered 78 GRBs within the IBIS/ISGRI field of view (20-200 keV) at a rate of ~0.8 GRBs/month.

• Most of the GRB detected are located in the direction of the Galactic Plane.

• IBIS/ISGRI great sensitivity has made INTEGRAL one of the best observatories for the detection of faint GRBs (peak flux ~ 0.1 ph cm^{-2} s^{-1})



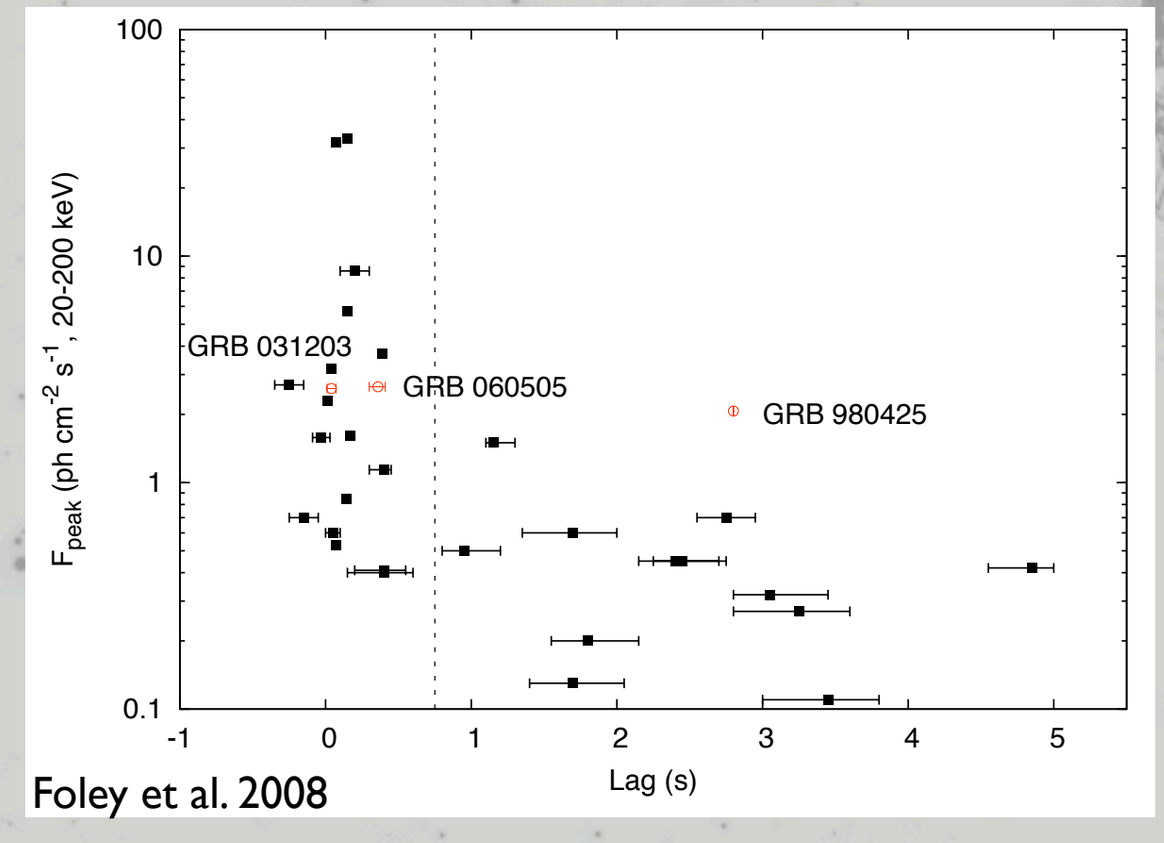


Band et al. 2008

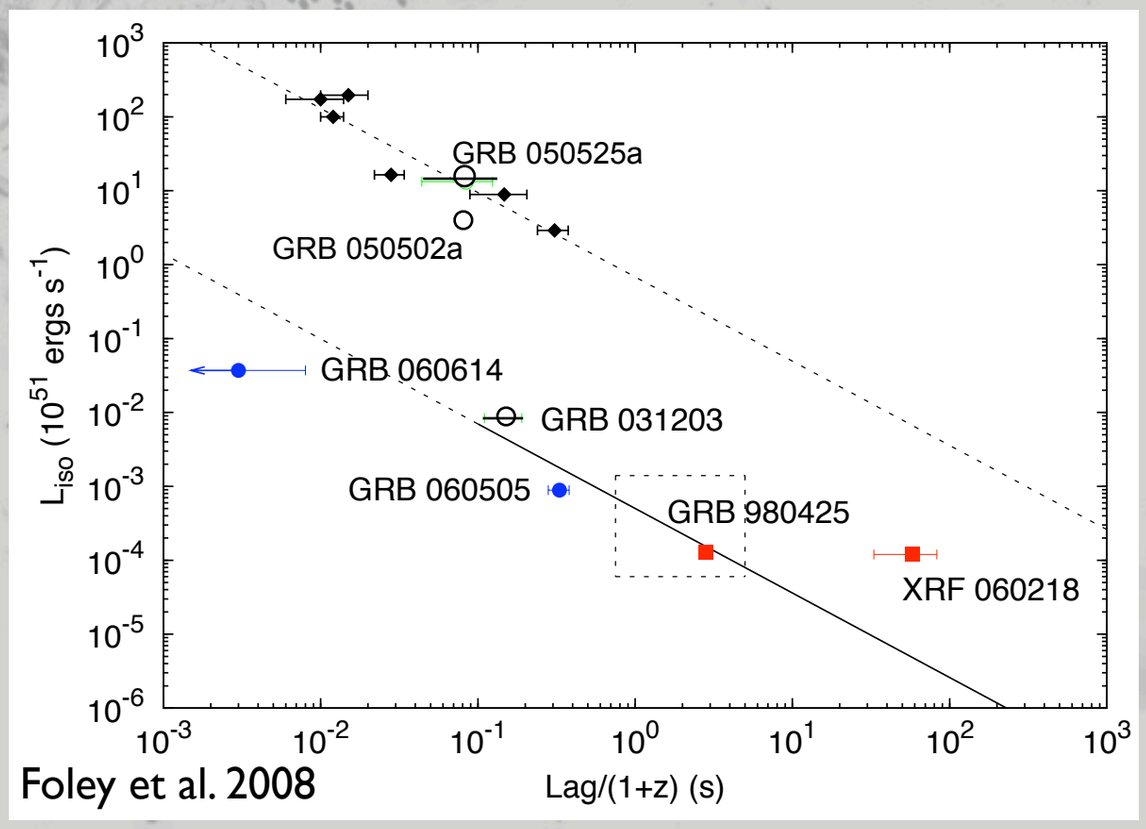
INTEGRAL view of GRBs

- Long lag GRBs tend to have low peak fluxes (Foley et al. 2008).
- These GRBs seem to dominate the local GRB population (result found at 2.5σ by Foley et al. 2008 and later confirmed by Vianello et al. 2009 at 3σ).

- Polarisation studies of GRB 041219A:
  - Polarisation of first pulse using SPI: (60±30)% (McGlynn et al. 2007)
  - Significant polarisation, with variation in amplitude and polarisation angle during the burst, was found in IBIS data for this GRB (Götz et al. 2009).



Foley et al. 2008



Foley et al. 2008

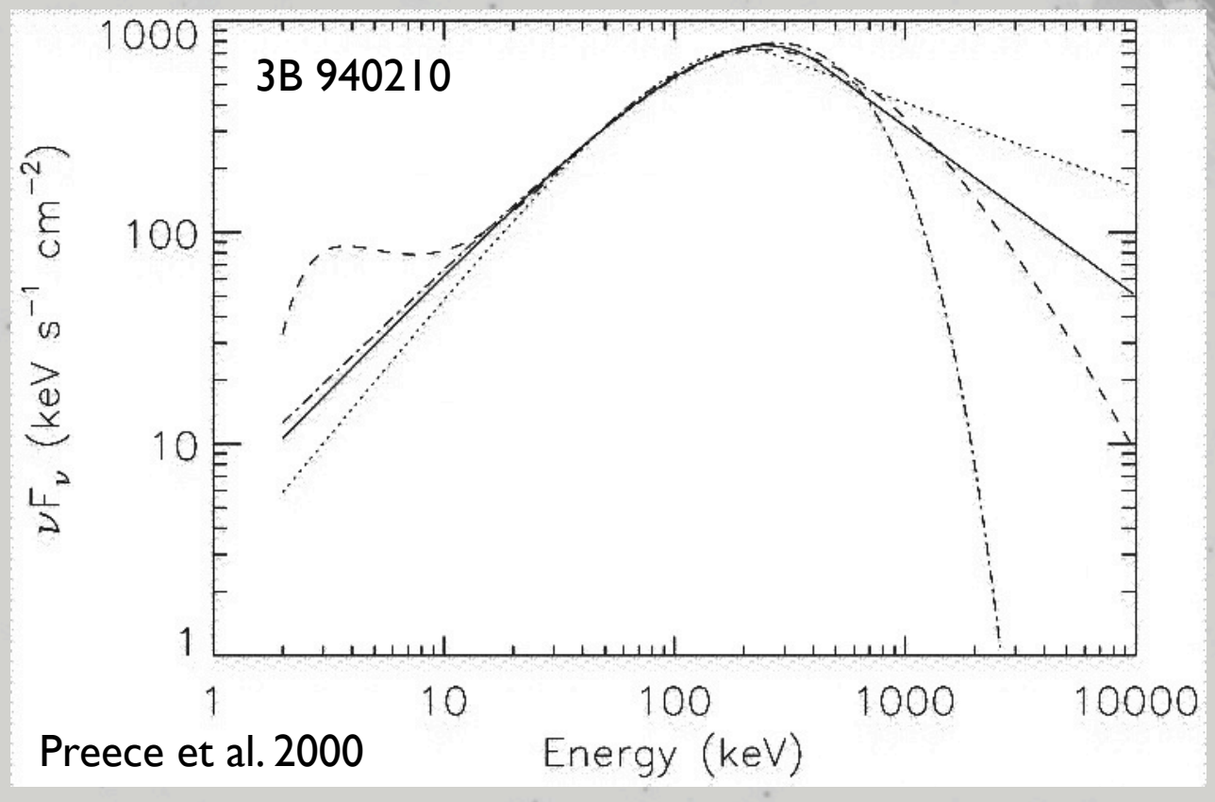
Introduction

• Around 14% of the GRBs detected with BATSE presented an excess with respect to the expected rising power-law index at energies below 20 keV, indicating an additional component to the synchrotron model (Preece et al. 1996, 2000).

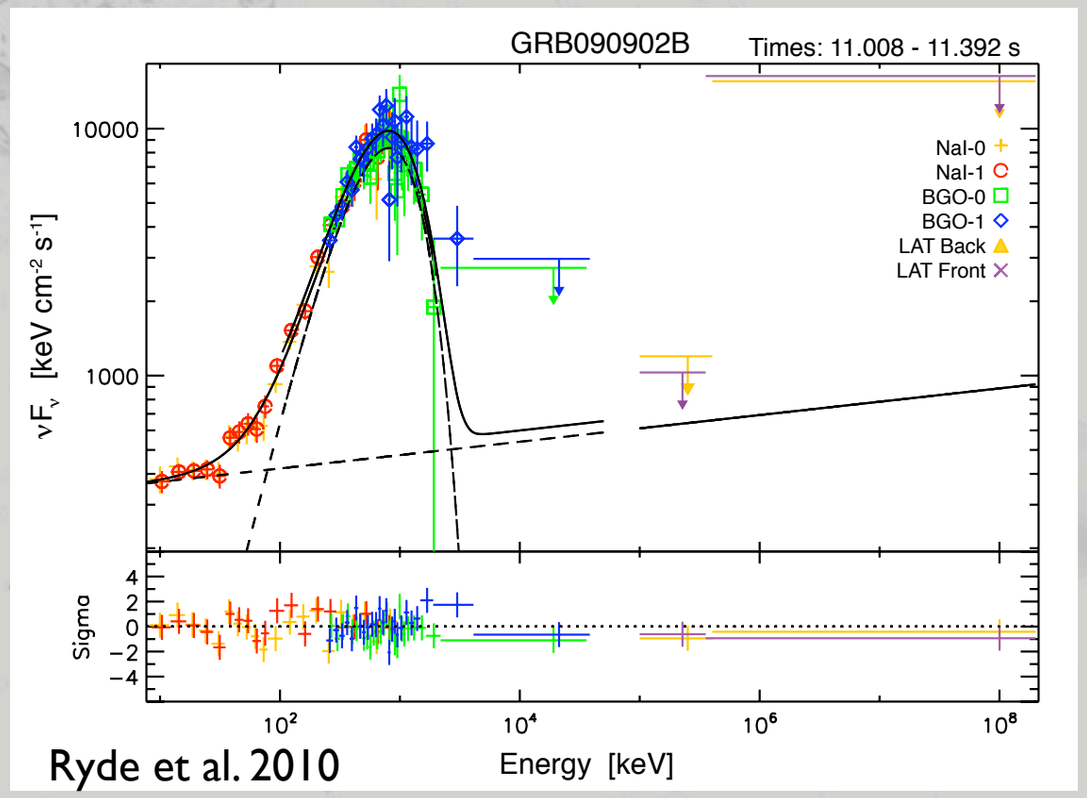
• Ryde et al. 2010 proposed thermal emission to explain the prompt emission spectra from the Fermi GRB 090902B where a blackbody plus power-law provided the best spectral fit

• INTEGRAL is the only mission capable of detecting GRB prompt emission below 8 keV with high performance with its JEM-X detector.

• Combining the 3 high energy instruments onboard INTEGRAL we are able to study the prompt emission of GRBs from 3 keV up to 8 MeV.



Preece et al. 2000



Ryde et al. 2010

Data Sample

• 21 out of the 78 GRBs triggered by IBIS/ISGRI were also detected within the JEM-X field of view (3-35 keV)

• Most of these burst are faint (peak flux < 0.7 ph cm^{-2} s^{-1} in the 20-200 keV energy range).

• A fluence limit of > 2.5 x 10^{-7} erg cm^{-2} in the 3-35 keV energy range was imposed for this study.

• 7 GRBs out of the initial 21 detected by JEM-X satisfy this criterion. These bursts cover all three classes of GRBs based on their fluence ratio i.e. classical GRBs, X-ray rich and X-ray flashes.

• From a sample of 49 GRBs out of the 78 GRBs triggered by INTEGRAL/IBIS, 8% were classified as XRFs, 51% as XRRs and 41% as GRBs

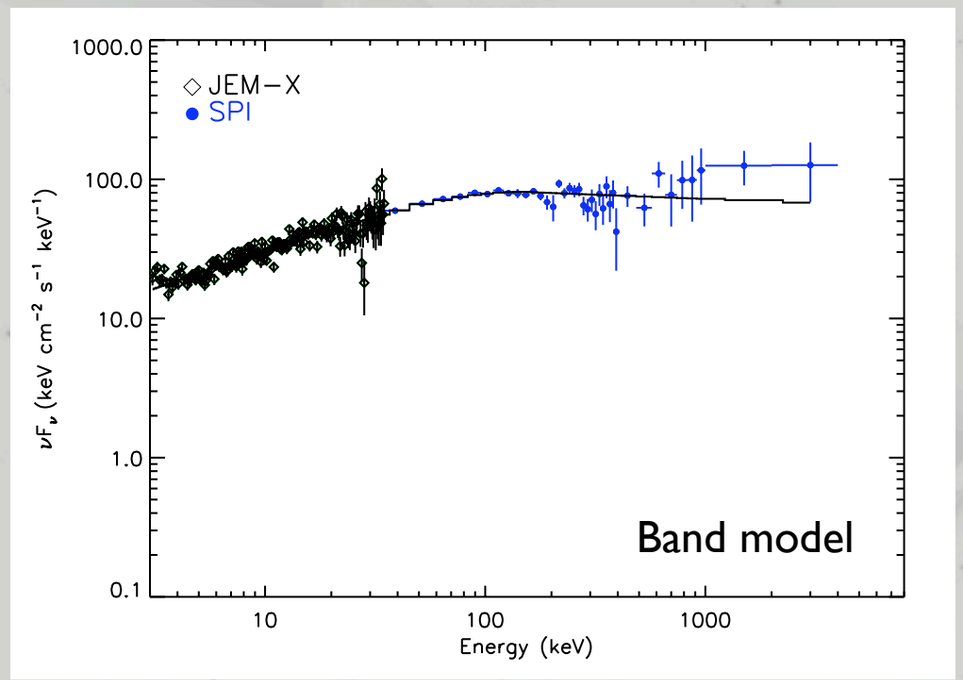
Summary of Results

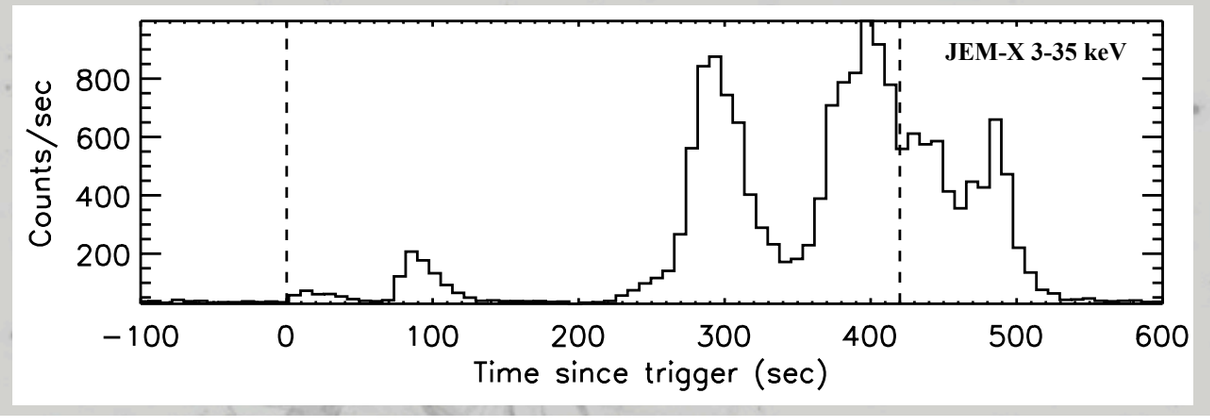
• All the results correspond to the best fit of the joint spectrum of JEM-X, IBIS and SPI in the T90 .

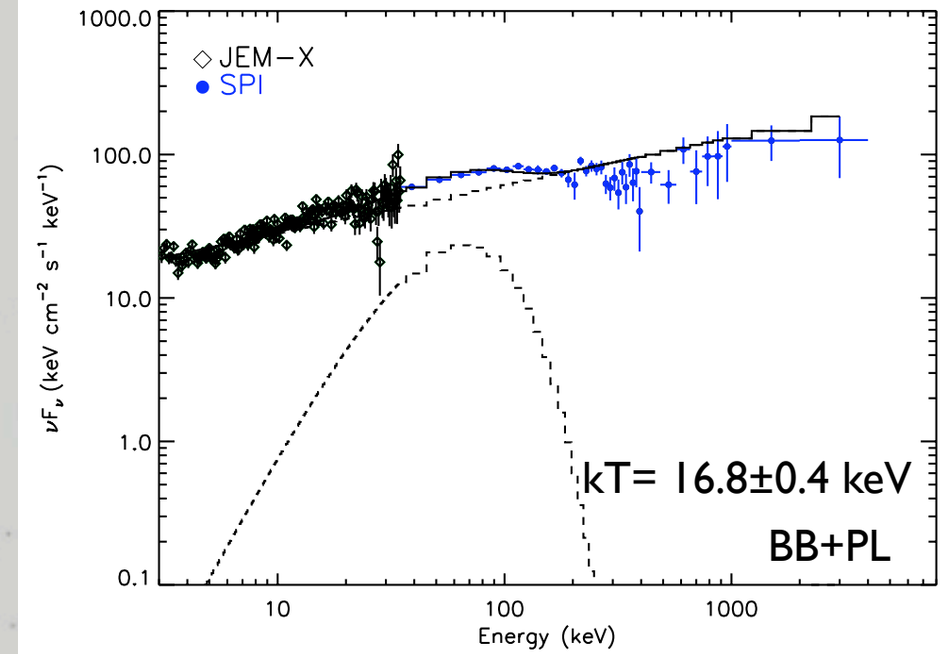
• In all cases a simple power-law (PL), a Band model (Band), a blackbody + power-law (BB+PL) and a power-law with exponential decay were considered.

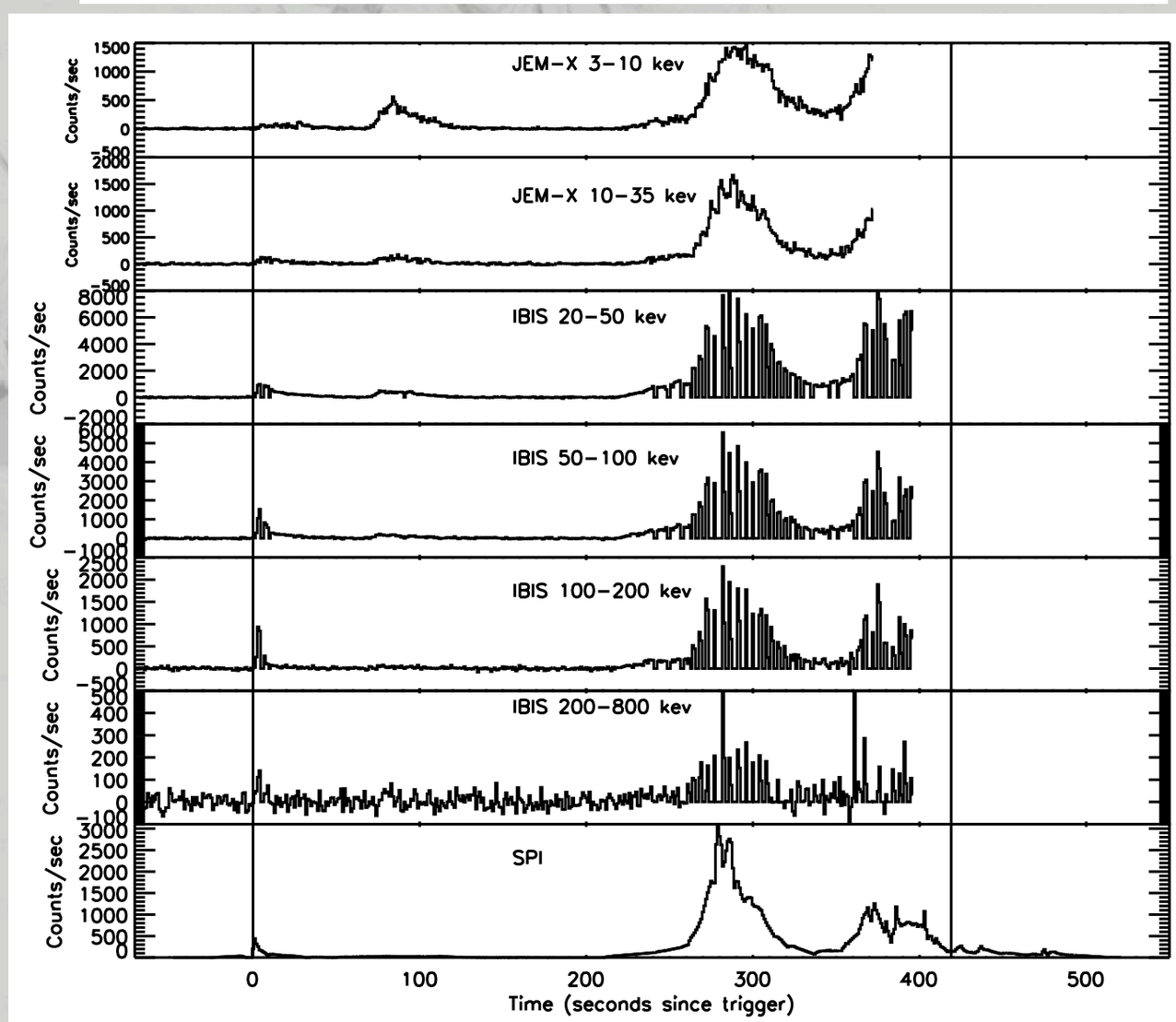
GRB	Class	T_{90} (sec)	Peak Flux (20-200) (ph cm^{-2} s^{-1})	Best Fit	α	β	E_o/kT (keV)	E_{peak}	red. χ^2/dof
040812	XRF	22	0.7	PL	---	-2.33±0.85	---	---	0.6/66
041219A	GRB	420	33	Band	-1.44±0.01	-2.06±0.05	---	146±11	1.54/212
050520	GRB	52	0.53	BB+PL	-1.49±0.09	---	22±4	---	0.68/76
051105B	XRR	13	0.31	PL	-1.91±0.06	---	---	---	0.63/49
080613	GRB	20	1.3	PL	-1.23±0.06	---	---	---	0.34/37
081003A	XRR	22	0.3	BB+PL	-1.66±0.11	---	6.4±0.8	---	0.77/44
081016	GRB	27	3.3	BB+PL	-1.66±0.09	---	18.6±1.7	---	0.88/56

GRB 041219A

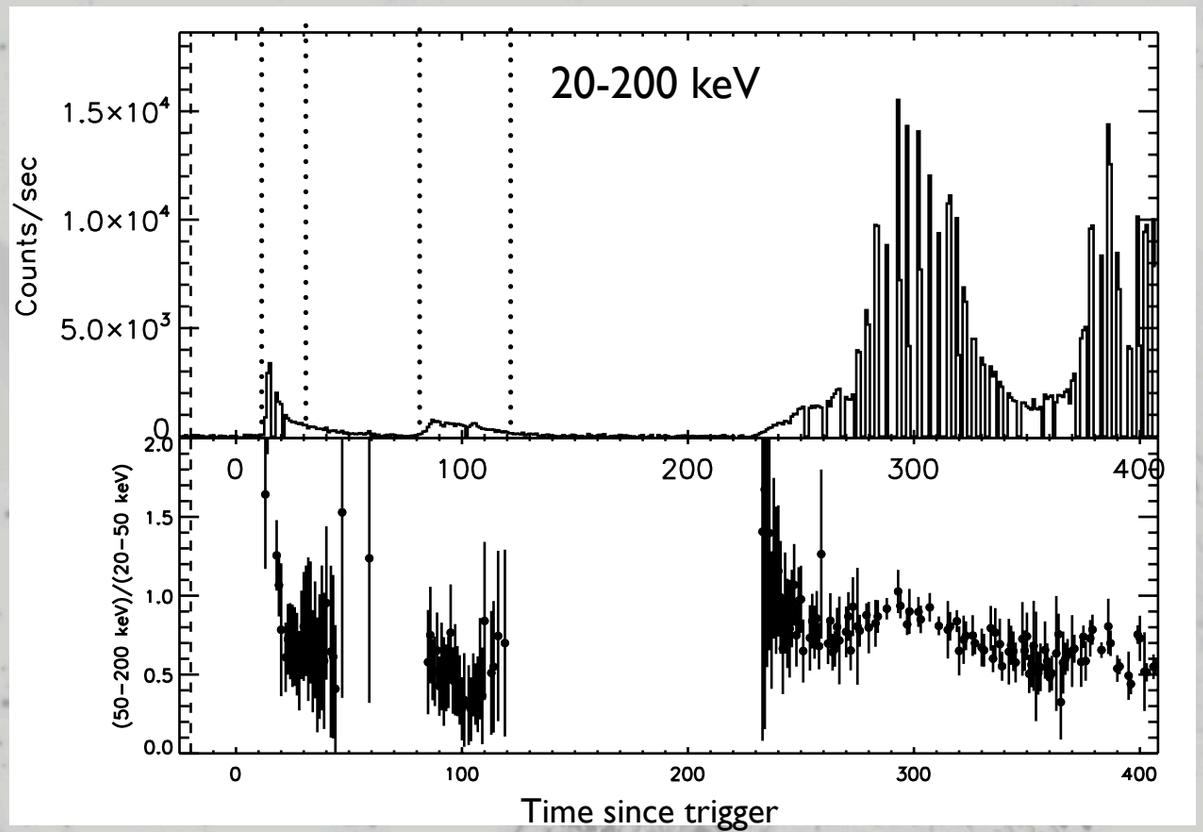

◇ JEM−X
● SPI
Band model
νF_ν (keV cm^{-2} s^{-1} keV^{-1})
Energy (keV)

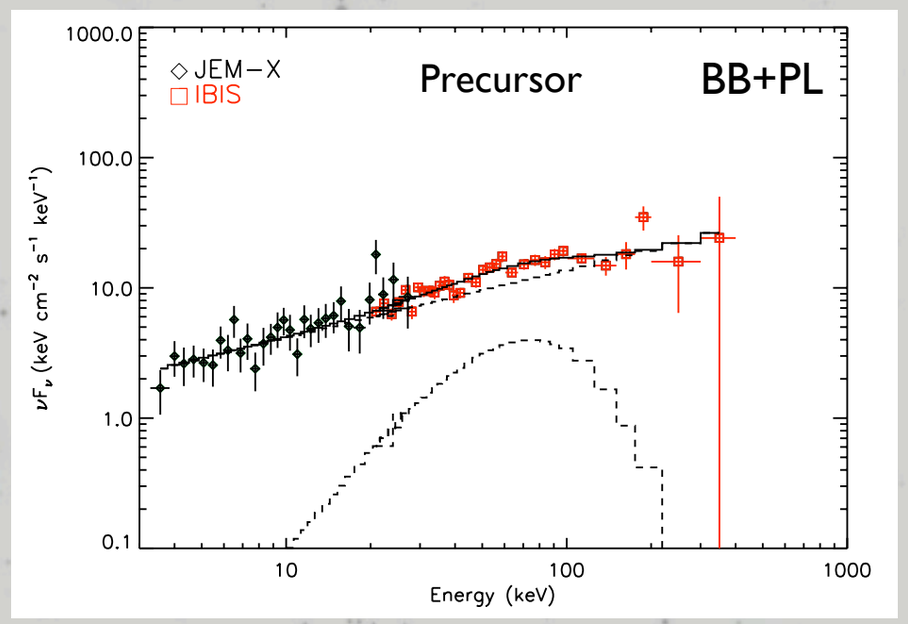

JEM-X 3-35 keV
Counts/sec
Time since trigger (sec)


◇ JEM−X
● SPI
kT= 16.8±0.4 keV
BB+PL
νF_ν (keV cm^{-2} s^{-1} keV^{-1})
Energy (keV)

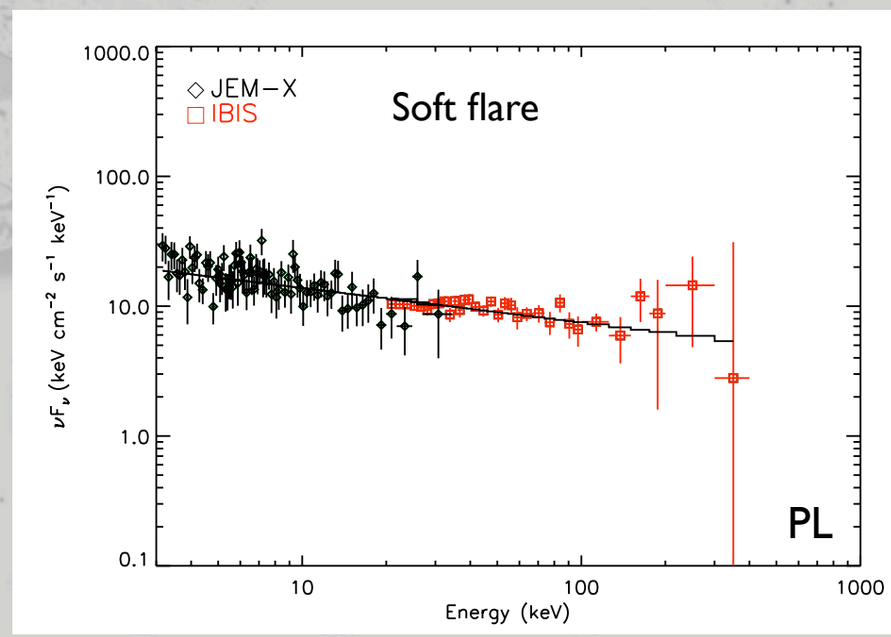

JEM−X 3−10 kev
JEM−X 10−35 kev
IBIS 20−50 kev
IBIS 50−100 kev
IBIS 100−200 kev
IBIS 200−800 kev
SPI
Counts/sec
Time (seconds since trigger)

GRB 041219A



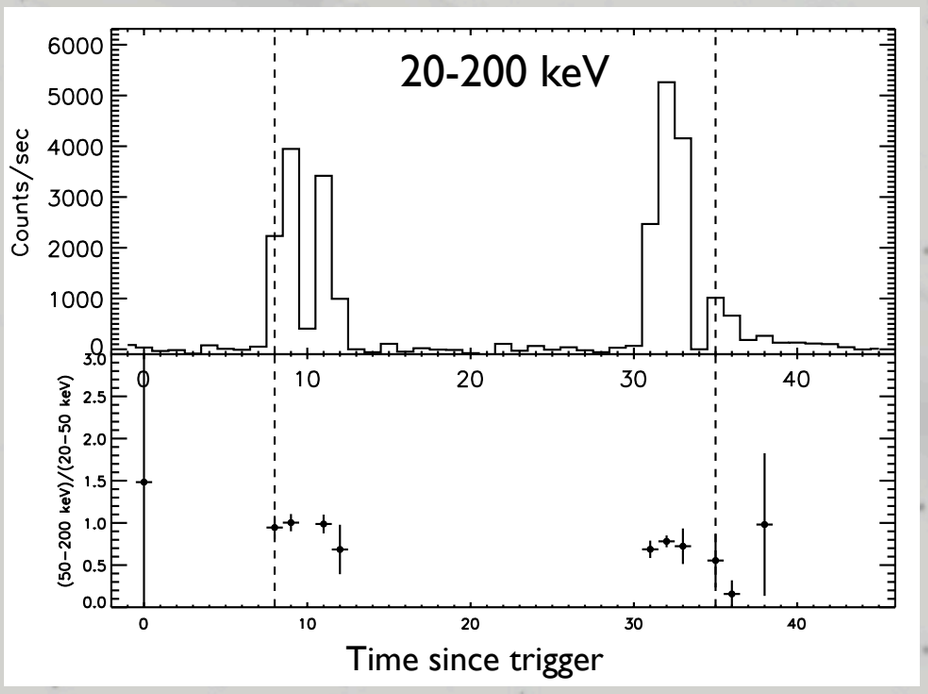


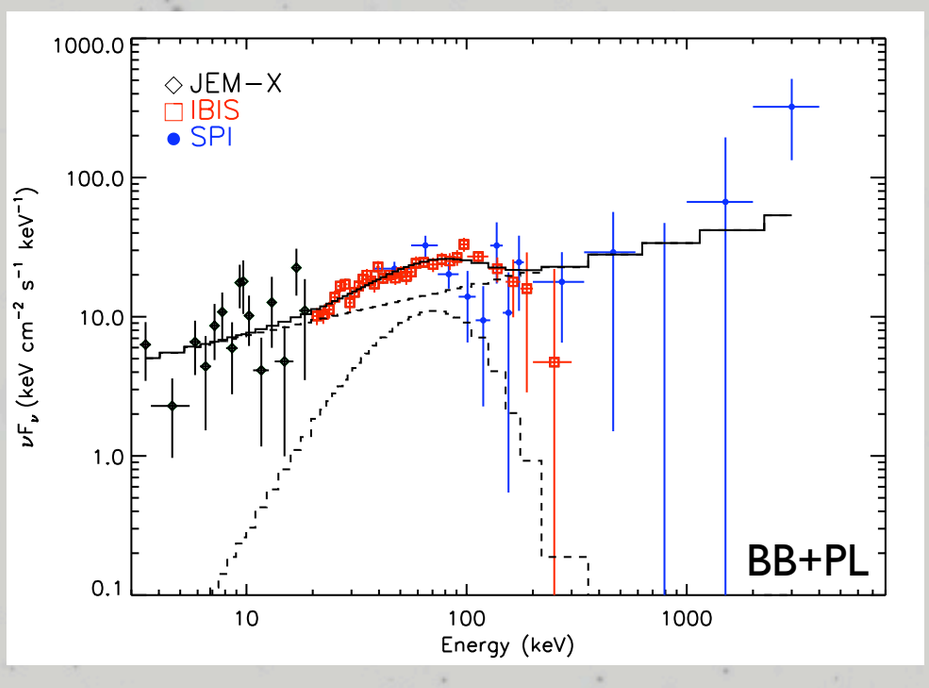
- Precursor:
  - α= 1.28±0.05
  - kT= 21±2 keV

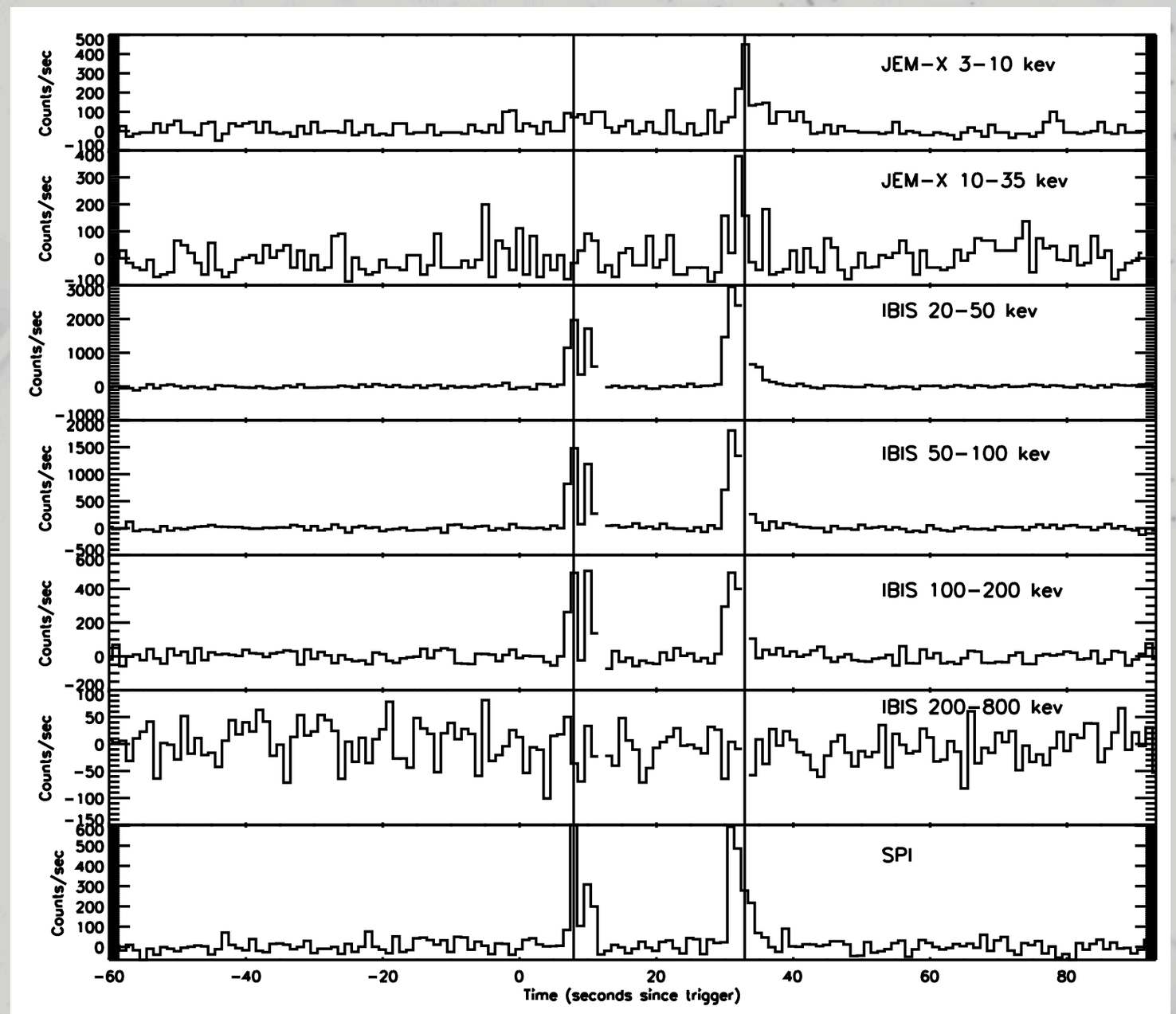


- Soft flare: α= 2.26±0.02

GRB 081016A


20-200 keV
Counts/sec
(50–200 keV)/(20–50 keV)
Time since trigger


JEM–X
IBIS
SPI
BB+PL
Energy (keV)


JEM–X 3–10 kev
JEM–X 10–35 kev
IBIS 20–50 kev
IBIS 50–100 kev
IBIS 100–200 kev
IBIS 200–800 kev
SPI
Counts/sec
Time (seconds since trigger)

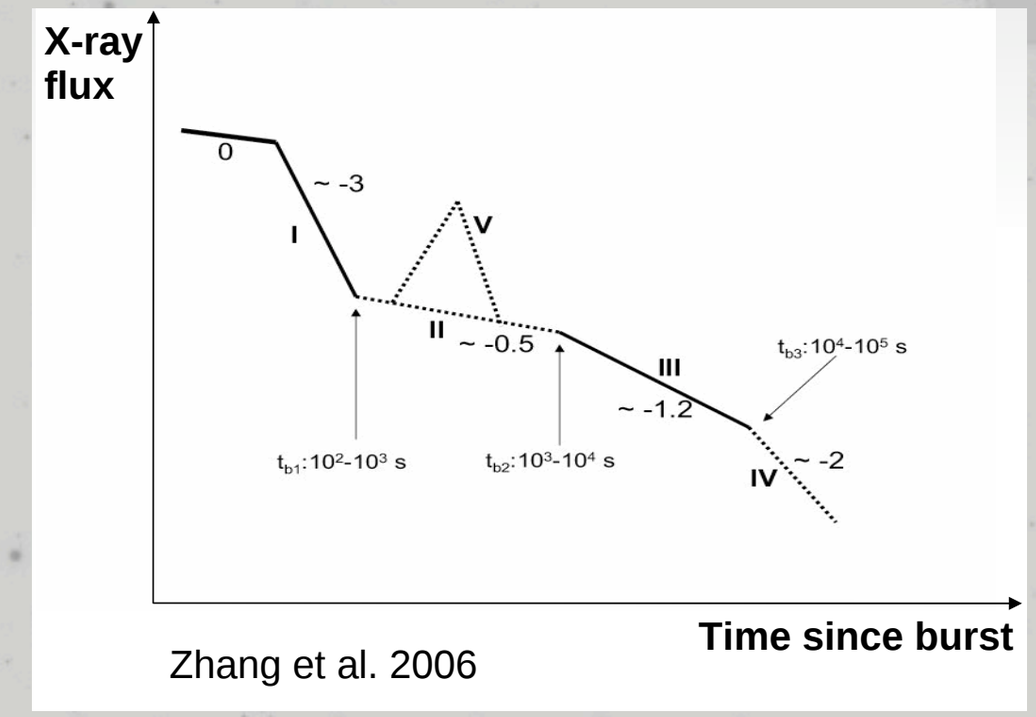
Post Burst X-ray Emission

• A search for post burst X-ray emission between 3-35 keV has been done for several of the 21 GRBs detected by JEM-X.

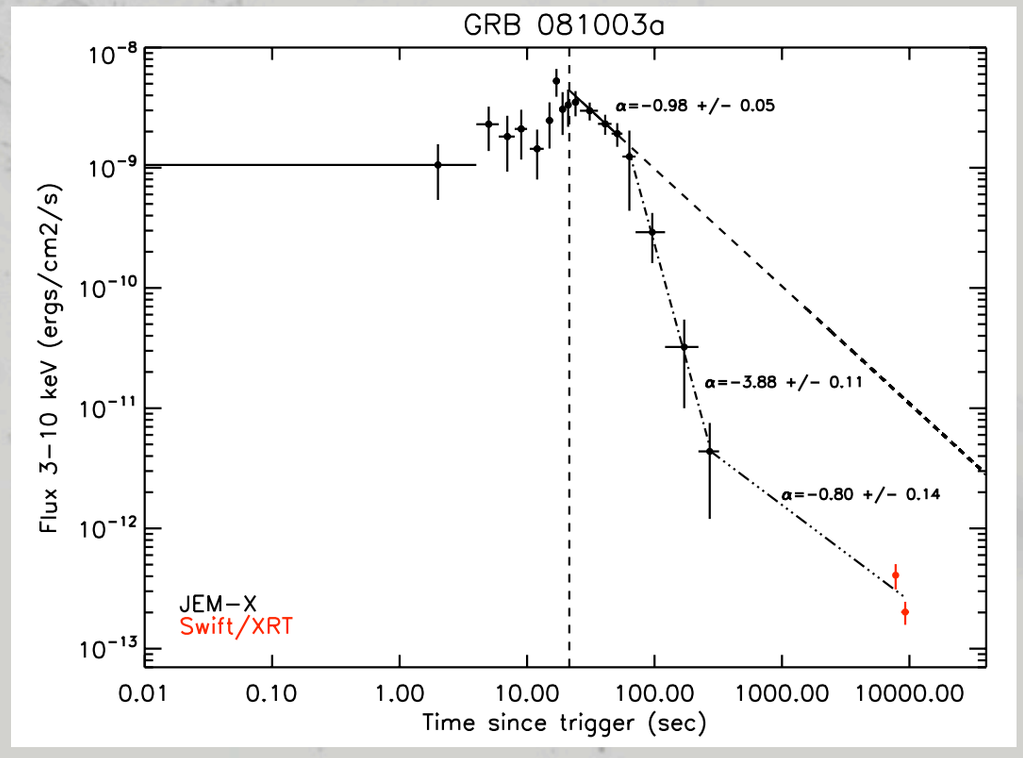
• A 3.5σ detection has been found for GRB 041219A 609 seconds after trigger in the 3-35 keV energy range (20% of the emission occurs in the 10-35 keV energy range) integrating over a time interval of 250 seconds. A power-law was fit to the spectrum with $\alpha = 2.2 \pm 0.7$ and a flux of 2.9×10^{-10} ergs cm^{-2} s^{-1} in the 3-35 keV energy range.

• Post GRB X-ray emission has been also detected for GRB 081003a. A break in the X-ray light curve was observed at 57 seconds after the GRB trigger.

• There are marginal detections (below 3σ) for GRB 050520, GRB 080613, GRB 081016 at early times after the prompt emission.



Zhang et al. 2006



Conclusions

• From the 78 GRBs triggered by IBIS/ISGRI so far, 21 have also been detected by JEM-X in the 3-35 keV energy range.

• A set of 7 GRBs, including 4 GRBs, 2 XRRs and 1 XRFs has been studied spectrally and temporally from 3 keV up to 8 MeV using JEM-X, IBIS/ISGRI and SPI.

• The BB+PL has been found to be the best fit in 3 cases, suggesting possible thermal emission.

• In the only case where the Band model was the best fit, the BB+PL was statistically equally valid.

• A link between the precursor of GRB 041219A and the soft flare coming after it has been found, confirming that the soft flare should be considered more like an “echo” of the precursor rather than an independent flare part of the GRB.

• Post X-ray emission has been found for at least two GRBs. A break is observed in the X-ray light curve of GRB 081003a at 57 seconds after the burst trigger.