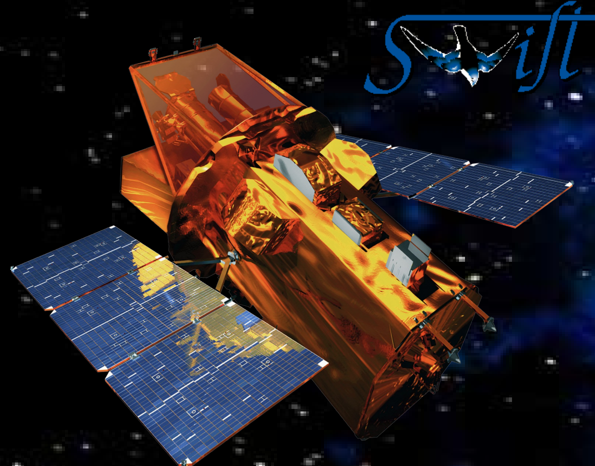
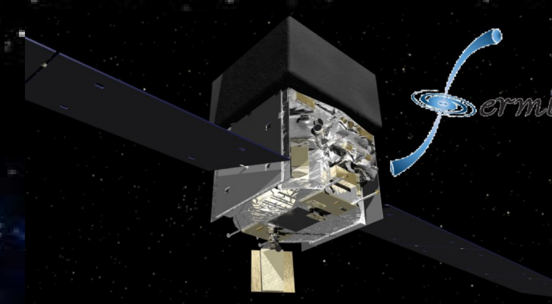
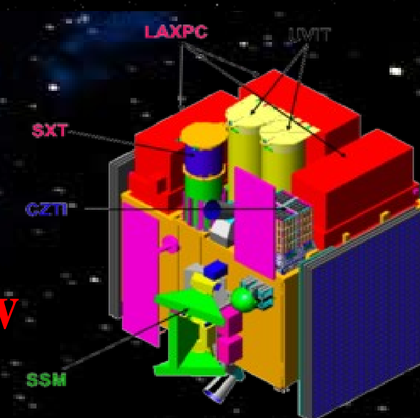
GRB (prompt) spectral evolution

Multi-wavelength and Multi-instrument perspective





Rupal Basak



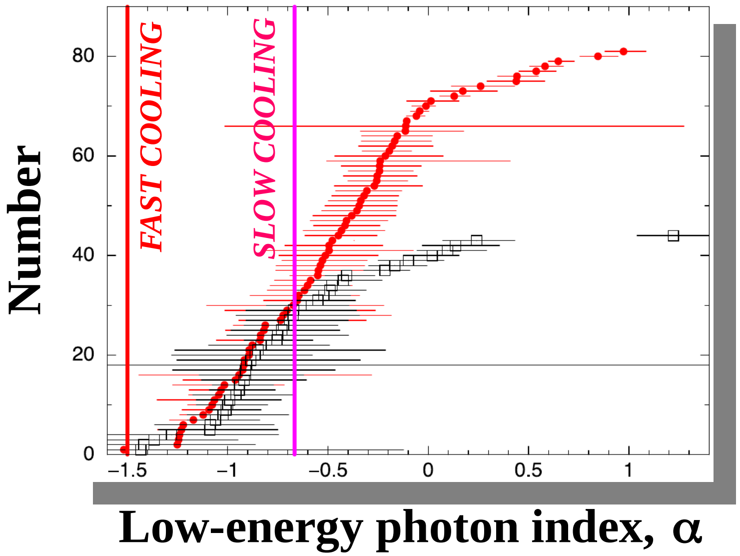
Gamma-ray Bursts : Prompt to Afterglow

NCRA, July 04, 2017

KTH Royal Institute of Technology and Oskar Klein Centre, Stockholm, Sweden

Challenges of the prompt emission study

Basak & Rao 14



- Standard scenario. Synchrotron (Rees & Meszaros 92, 94. Fitted with Band (+93) function.
  1. Shortcomings of synchrotron model (Preece+98).
  2. Wide field of view detectors.
  3. Rapid evolution and Overlapping pulses.

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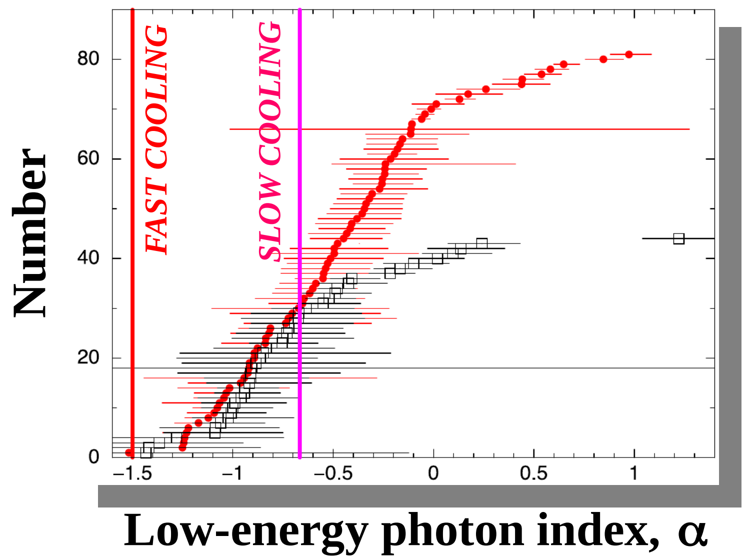
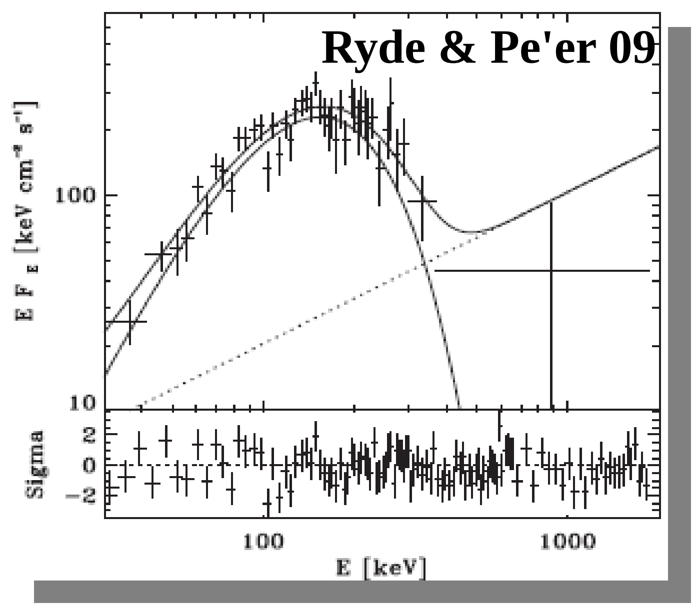
Basak & Rao 14





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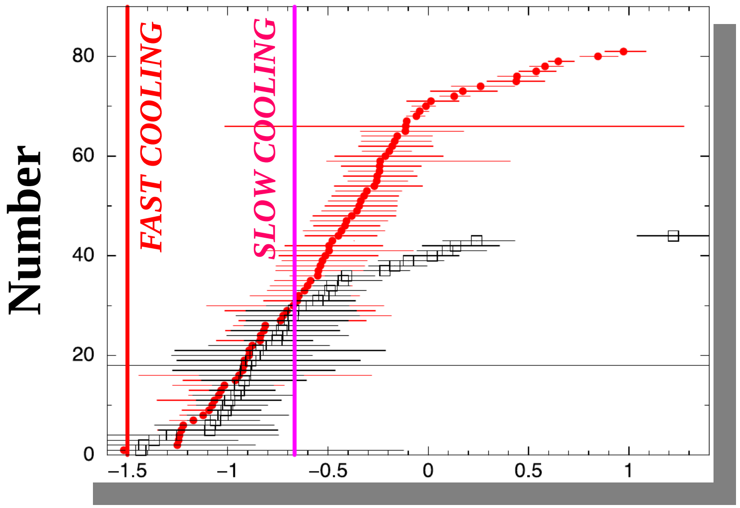
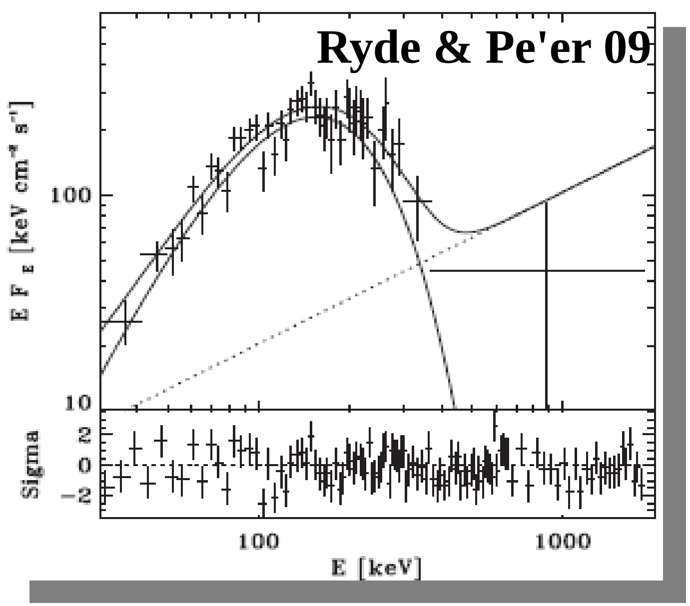


Low-energy photon index, α



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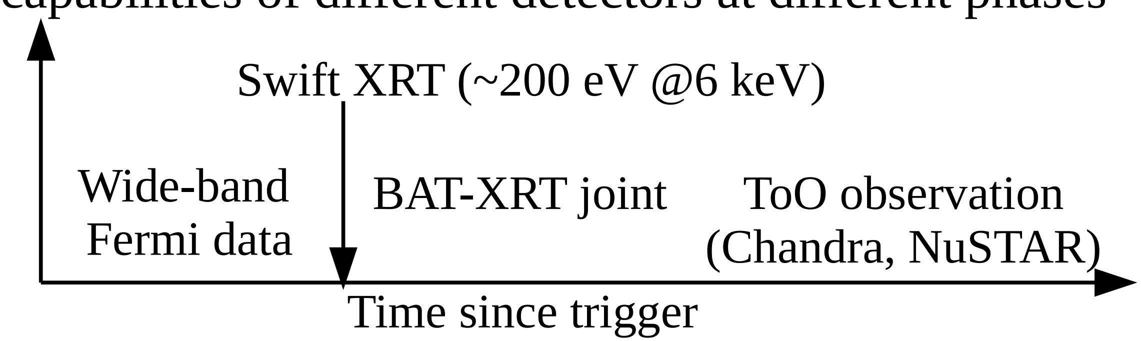
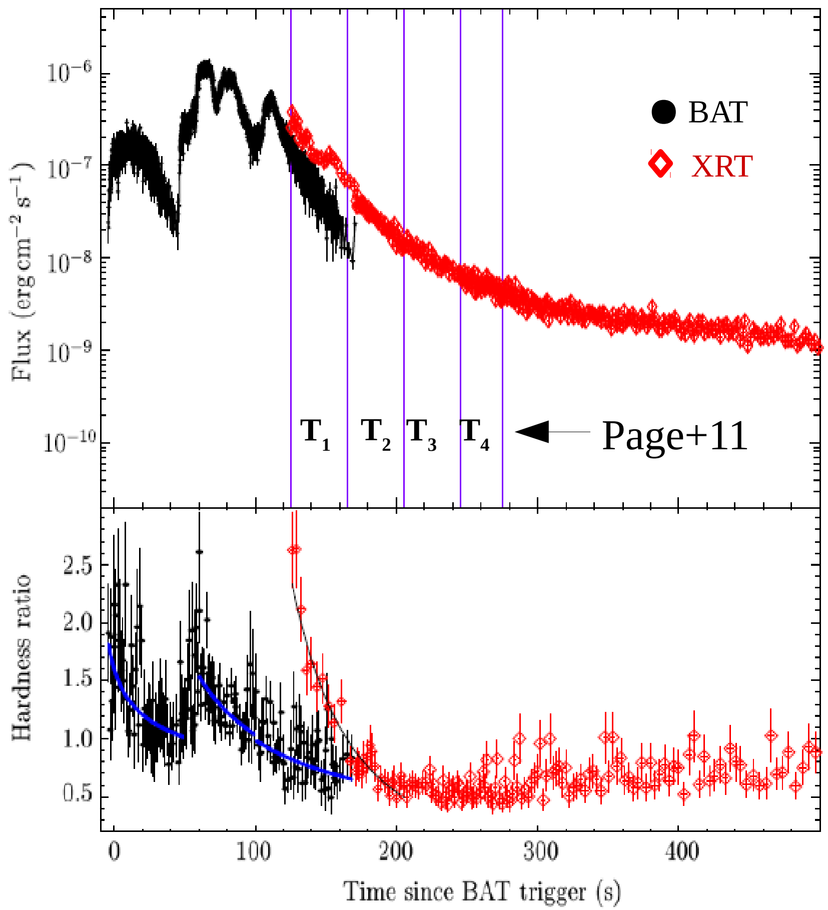
- **Single pulse:** Crider+97; Ghirlanda+03; Ryde 04, Ryde & Pe'er 09: Thermal emission.

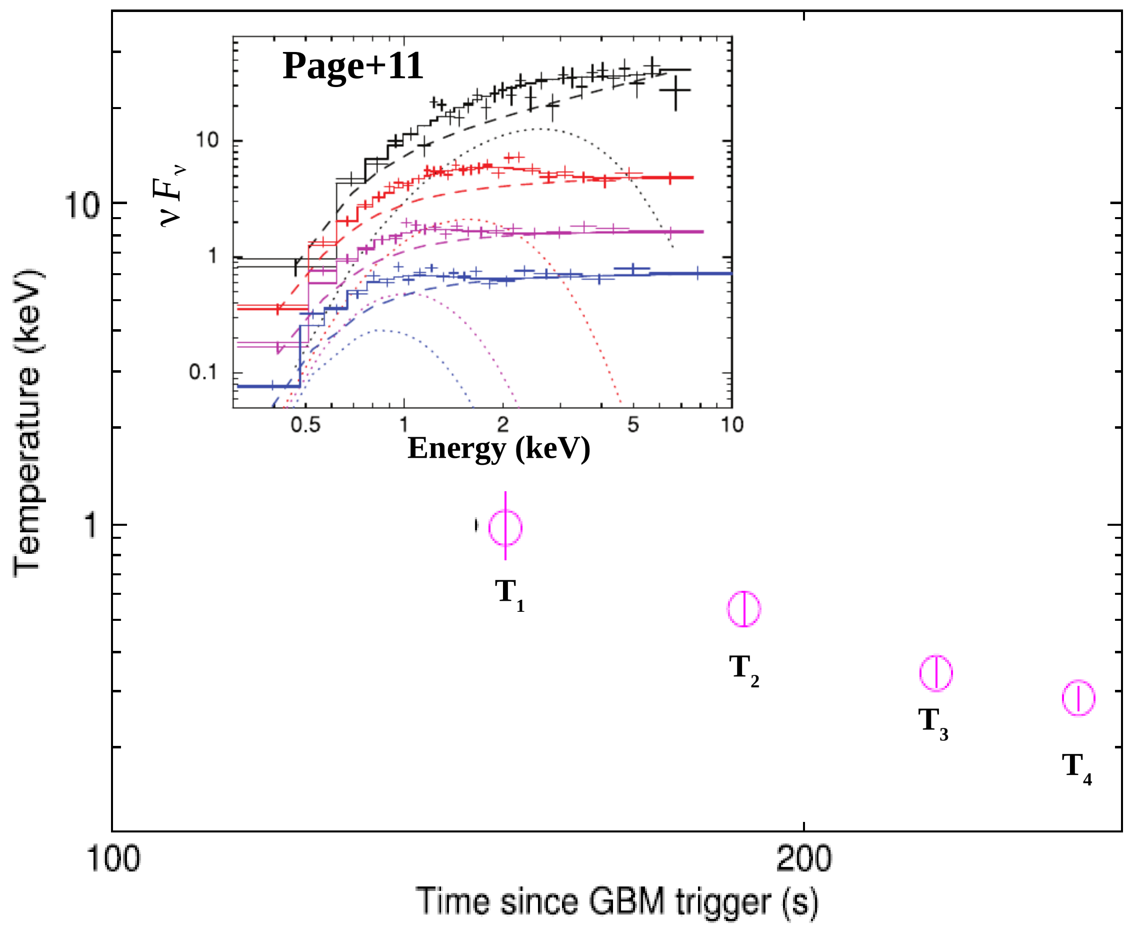
- **Fermi era:** wider band. Variety of models Ryde+10; Guiriec+11,13; Axelsson+12; Basak & Rao 13, 14; Burgess+14; Iyaani+15 (spectrum with two humps or broad top)
- Statistically difficult**, Novel strategy:** Exploit capabilities of different detectors at different phases



Example GRB I

1. GRB 090618 (Basak & Rao 2015a, ApJ)





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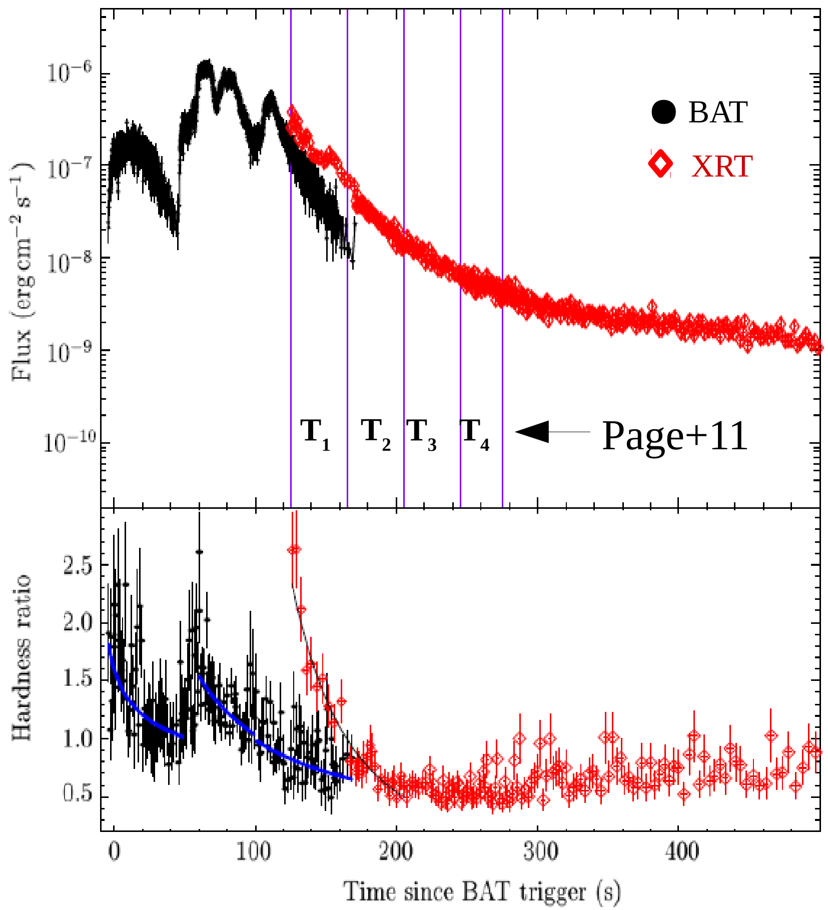

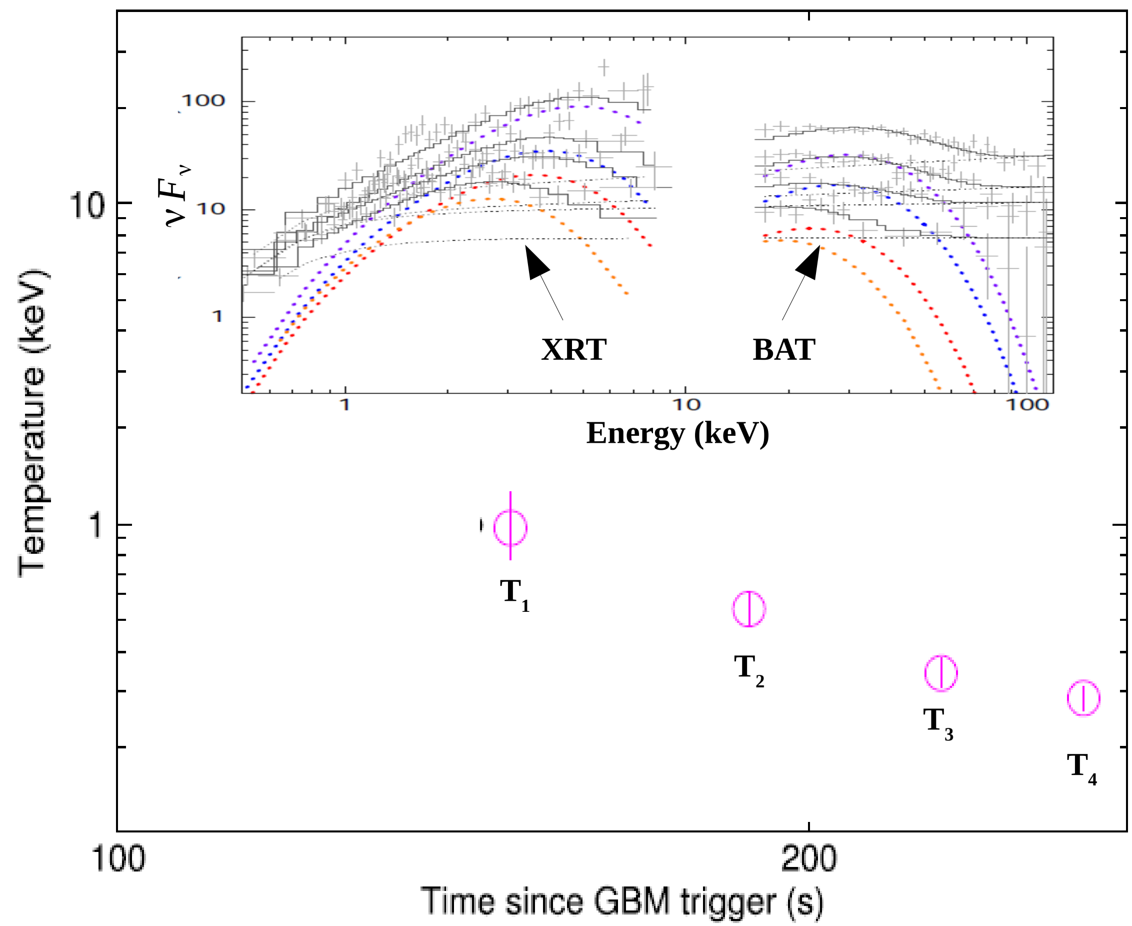

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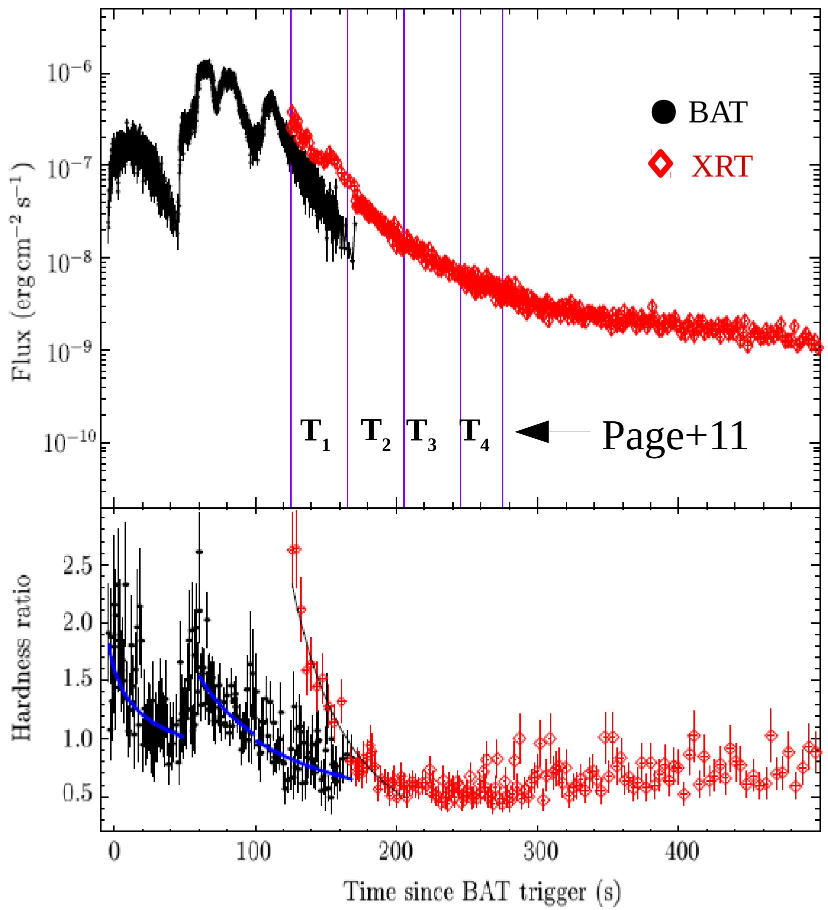
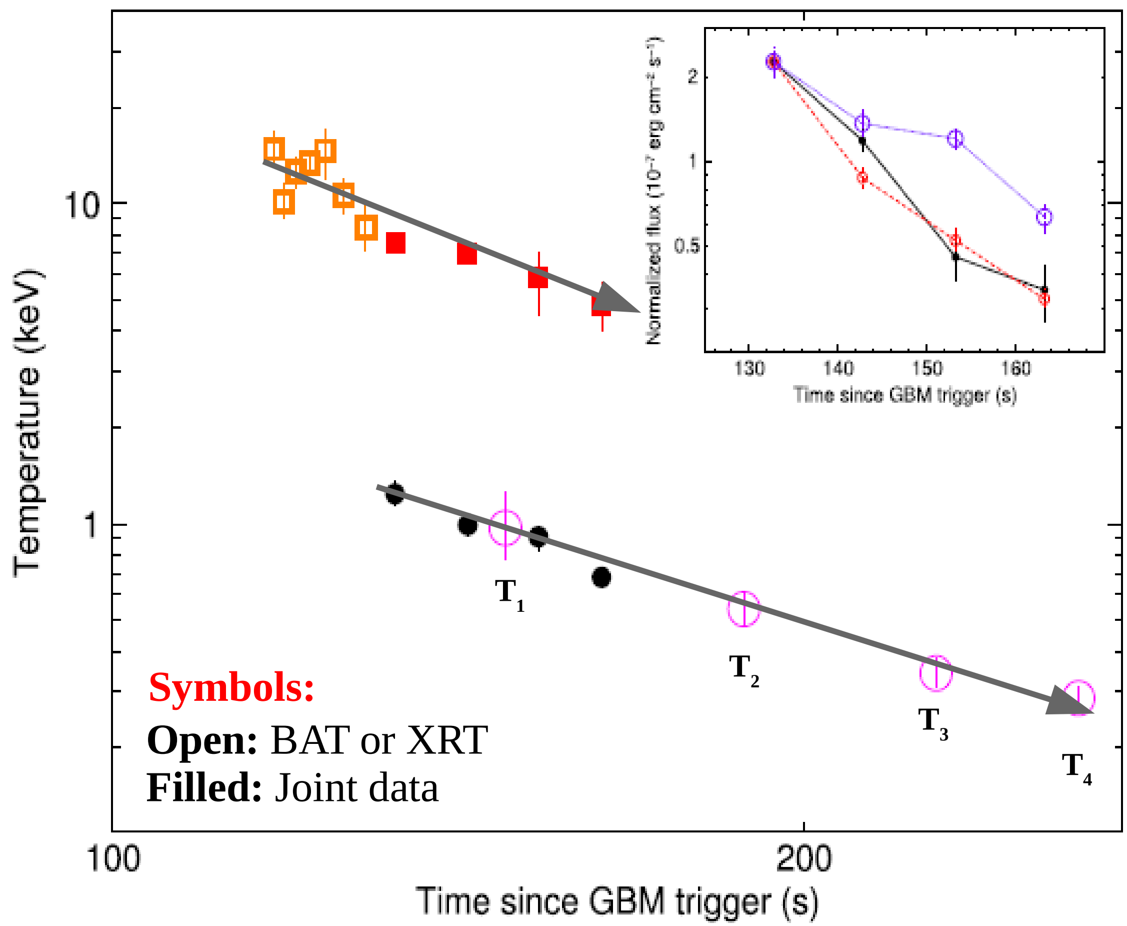




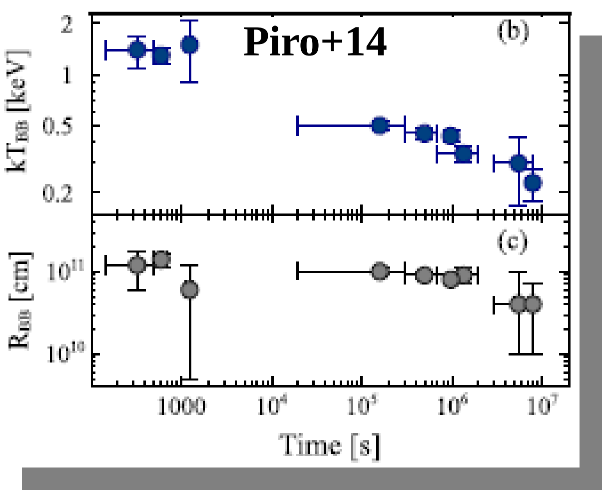
Example GRB II

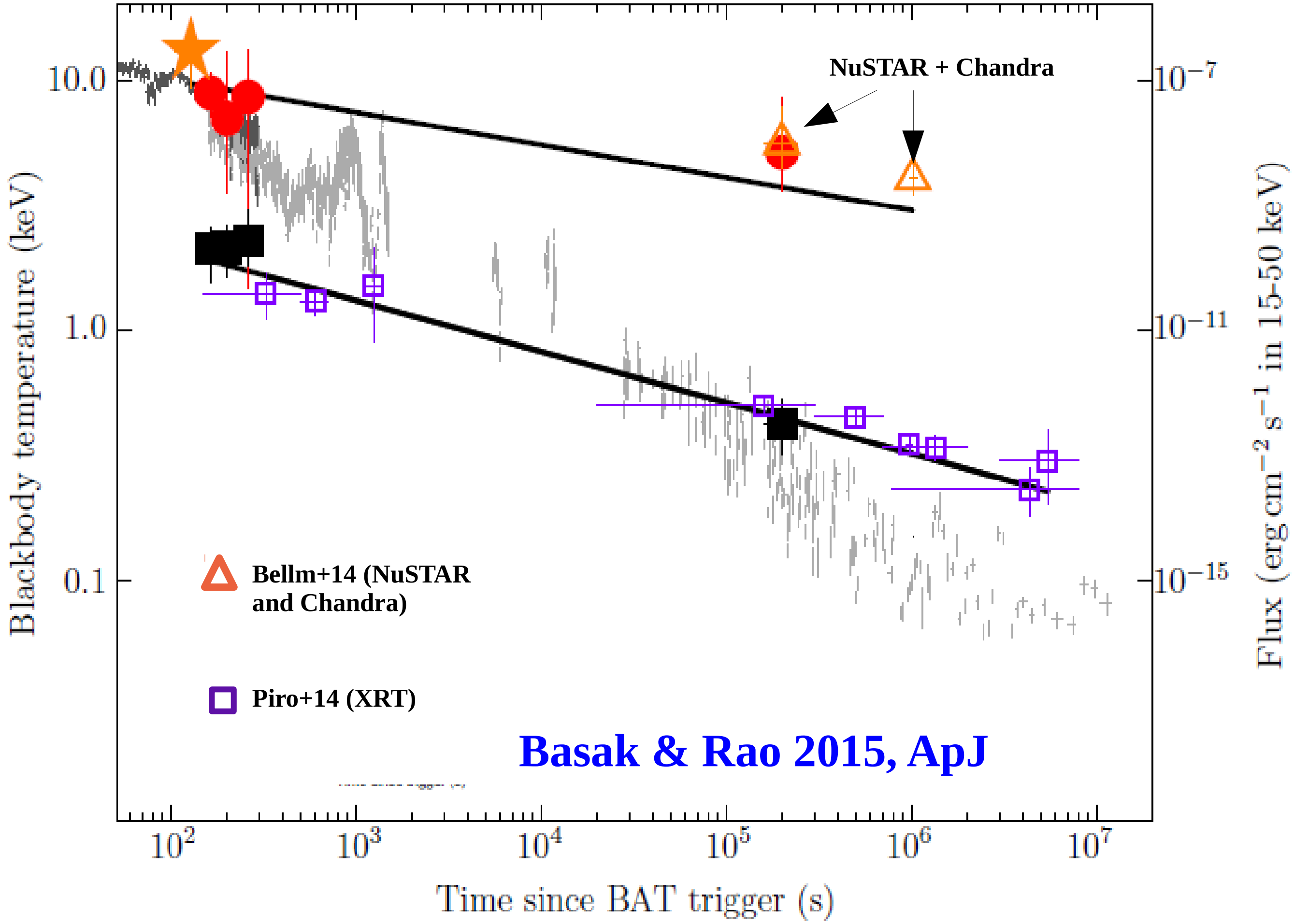
2. GRB 130925A (Basak & Rao 2015b), **Ultra-long GRB**

Debate: (1) GRB or a **TDE**? HST image shows 600 pc offset from the host. But, morphology of the host indicates recent major merger. Combine the knowledge from host study and emission process.

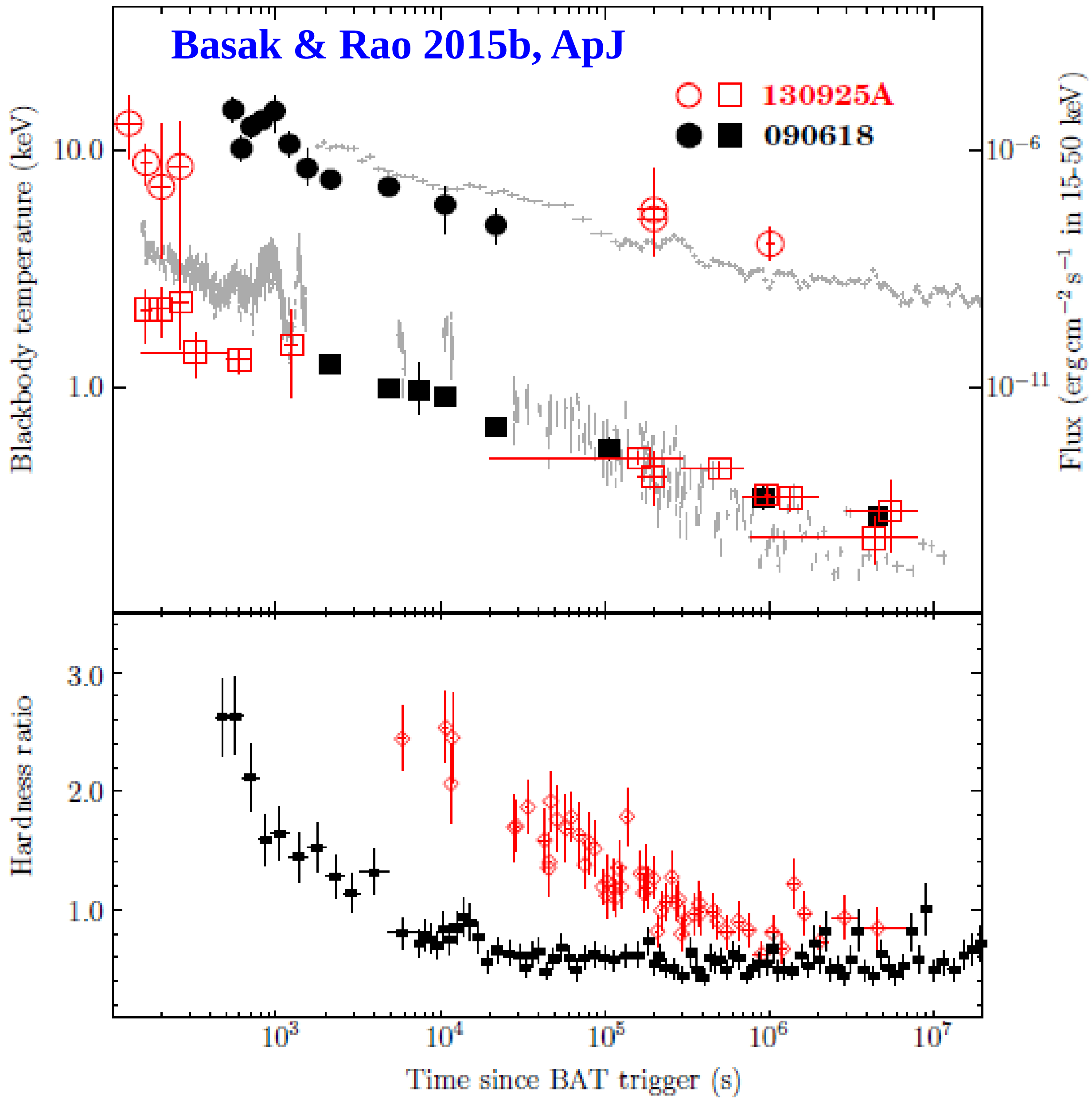
(2) Emission: **Single BB:**
Piro+14 ~0.5 keV (cocoon),
Bellm+14 ~5 keV,

Dust scattering: Evans+14





130925A (ultra-long) vs 090618 (long)



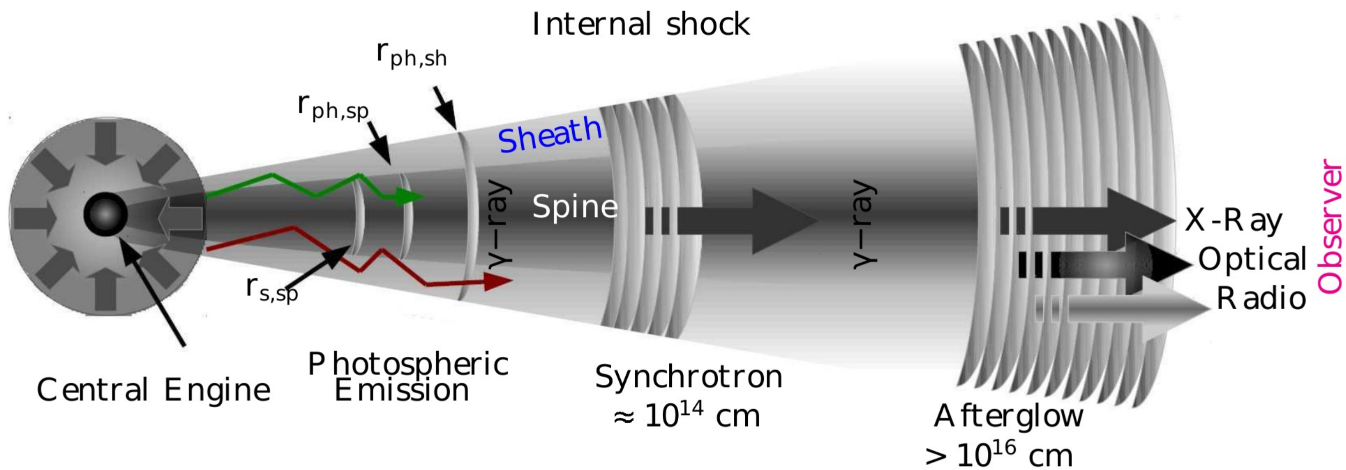
- Comparison: 130925A with 090618. Time axis of 090618 is stretched.
- Upper panel: kT evolution of the two blackbodies.
- Lower panel: Hardness ratio (ratio of counts in 1.5-10 keV to that of 0.3-1.5 keV)
- **Slower evolution of ultra-long GRB.** Crude estimates: accretion timescale from free-fall time scale

$$t_{acc} \sim t_{ff} \approx 10^4 R_{12}^{3/2} M_{50}^{-1/2} s$$

Origin of 2BBPL: spine-sheath jet?

Process:

Interaction with envelop
(Ramirez-ruiz+02; Zhang+04)



Radiation:

(1) Thermal emission – photosphere
(2) Non-thermal – two processes

Basak & Rao 2015a, ApJ

Other groups:

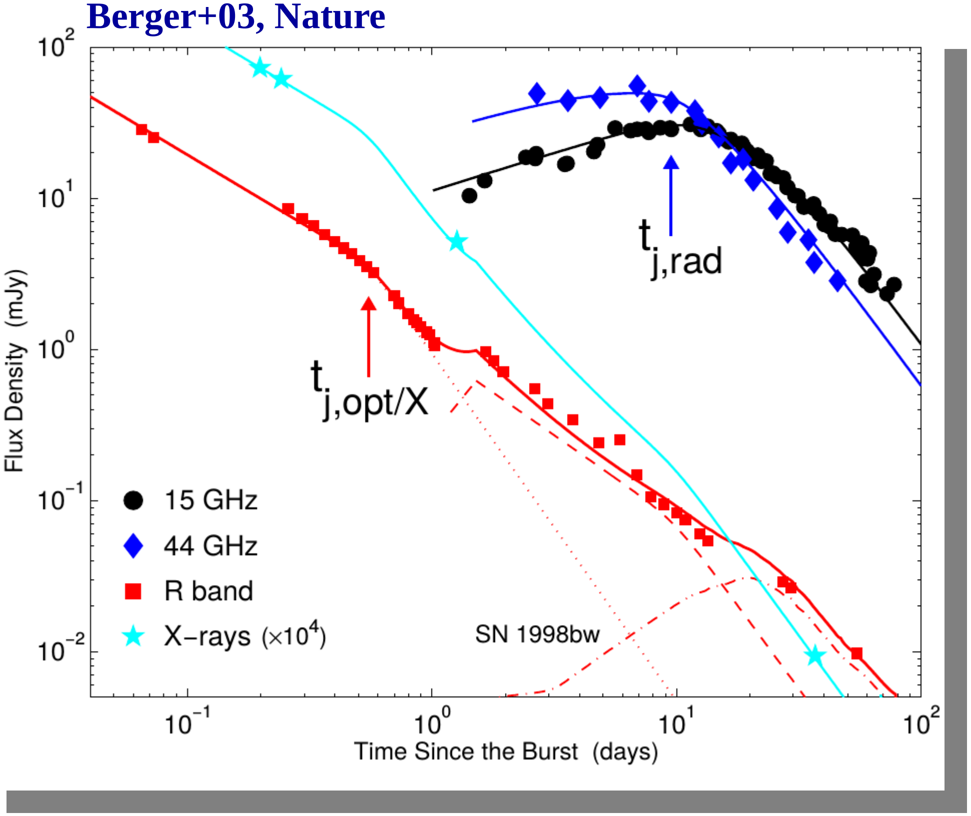
Ito + 13: Simulation in a stratified jet. Found the double hump and non-thermal component.
Iyyani + 15: Comptonization of thermal photons that mimics the shape.

Outlook: A Few Observations

1. Double jet break: GRB 030329

Granot + 03, Nature (refreshed shock)
Opt/X-ray break: 0.55 d. Radio break: 9.8 d.
Jet opening angle (θ_J) = f(t_j, n, E).
(Sari+99, Panaitescu & Kumar 02).
Inner: θ_J = 5^0, Outer θ_J= 17^0.

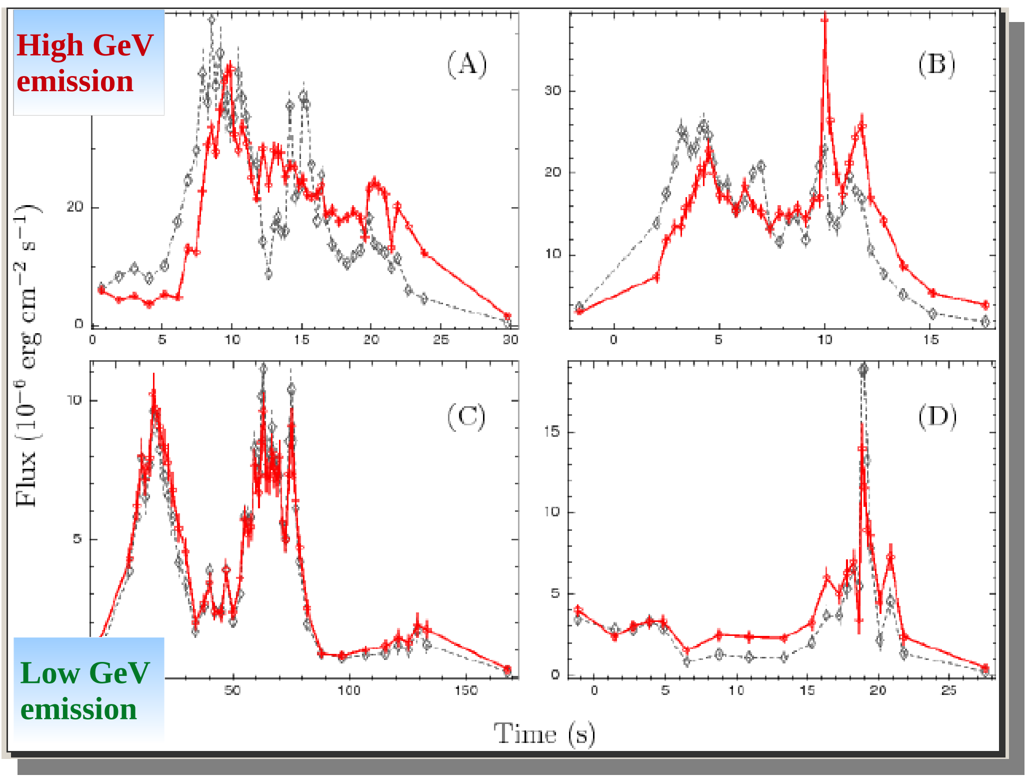
Berger+03, Nature



2. GRBs with LAT detection:

GeV emission: delayed, long lasting. External forward shock during afterglow (Kumar & Barniol Duran 10).
Two class: Hyper-fluent LAT and low-fluent LAT class (Ackermann + 13).

Basak & Rao 2013, ApJ

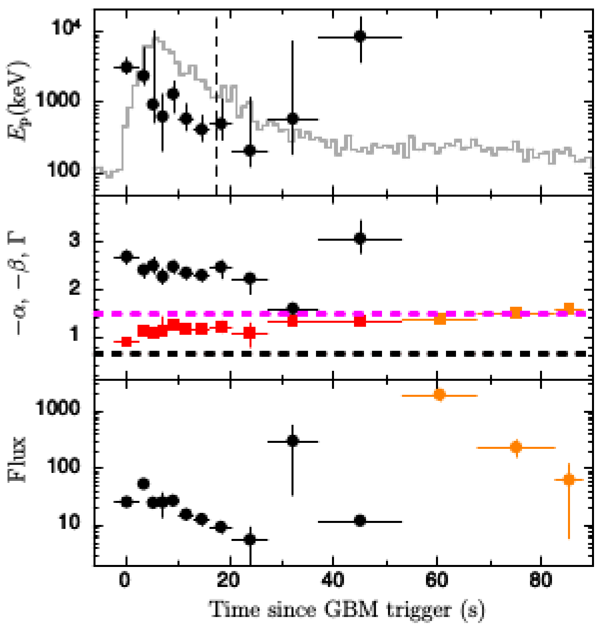


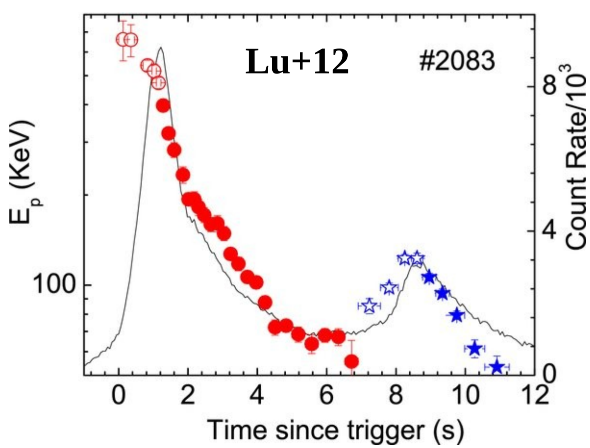
A Few Observations

3. **Surprising** **Spectral evolution** in Single Pulse GRB 151006A.

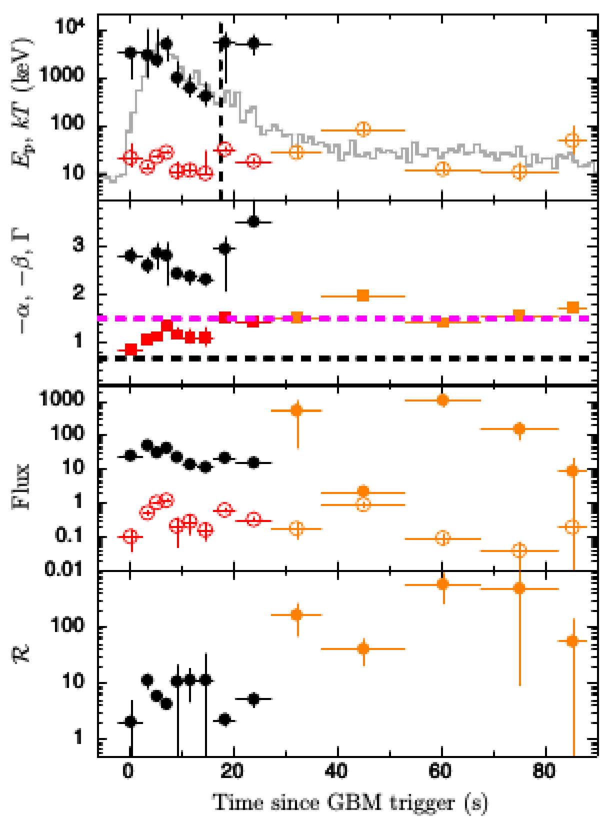
The first GRB detected by Astrosat (Bhalerao+16, Rao+16).
Unusual spectral evolution seen (Basak+17, MNRAS submitted).

Band

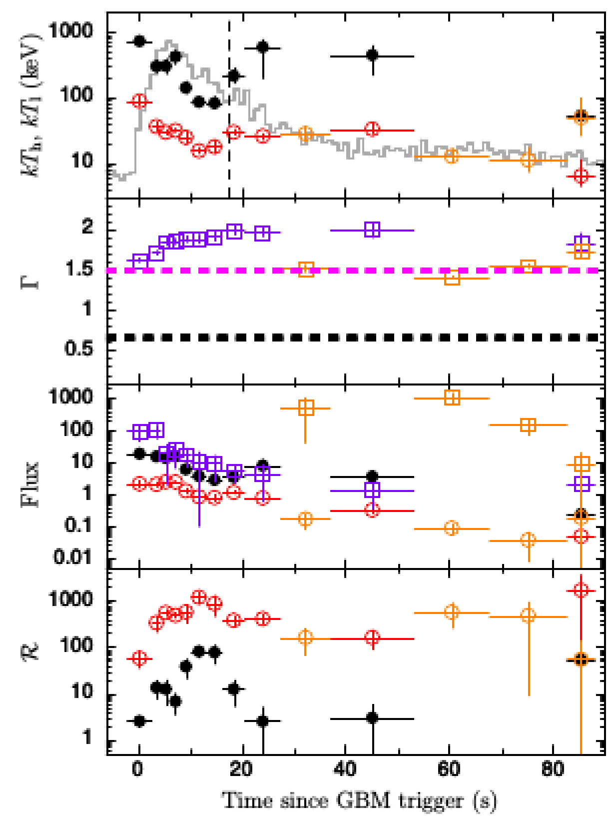




Band + BB



2 BB + PL



Basak+17, MNRAS submitted

What causes the unusual evolution?

Two possibilities: (1) Afterglow Phase, (2) A second pulse hidden in the data

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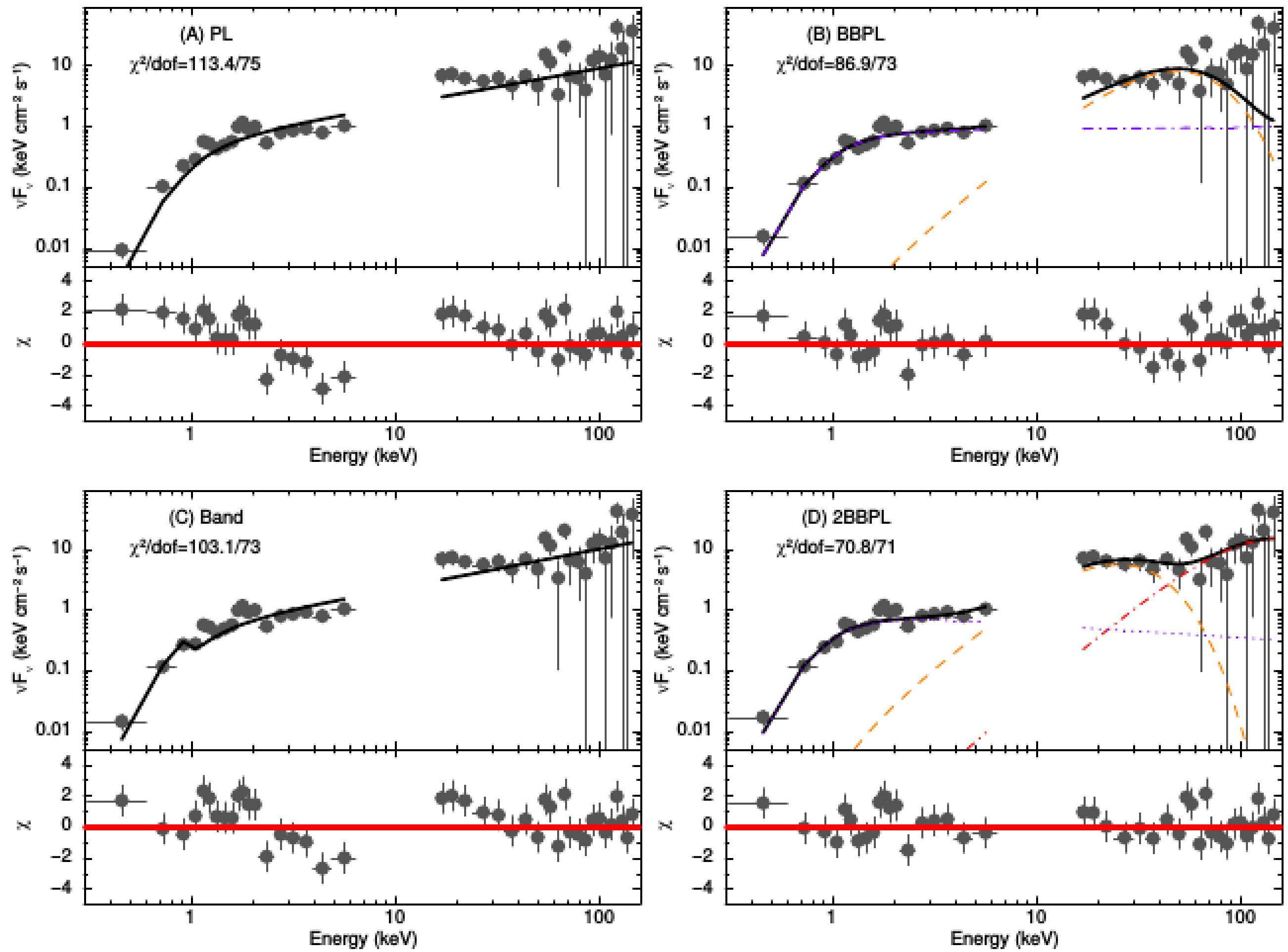
I. Spectral curvature at late time



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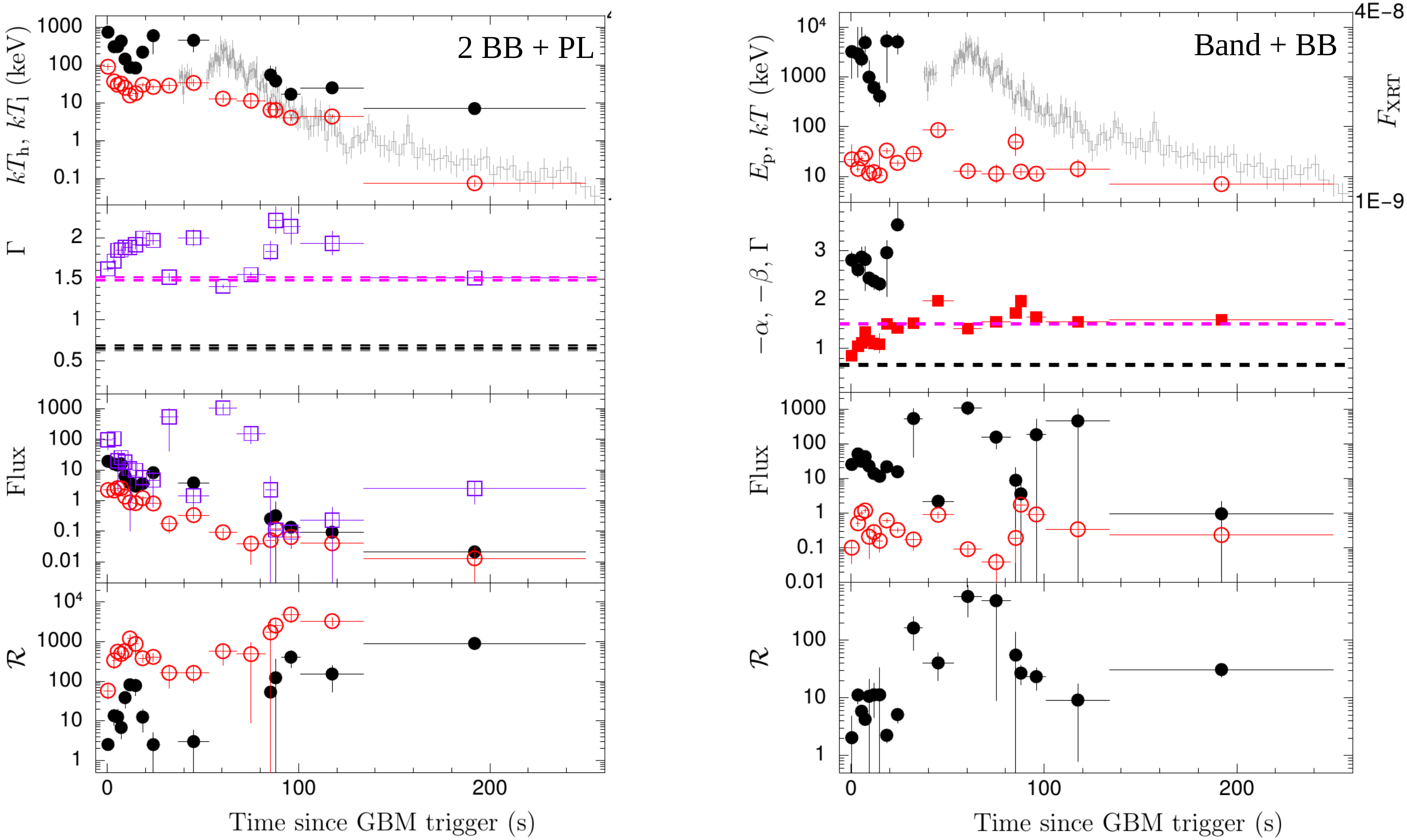
II. Long term evolution



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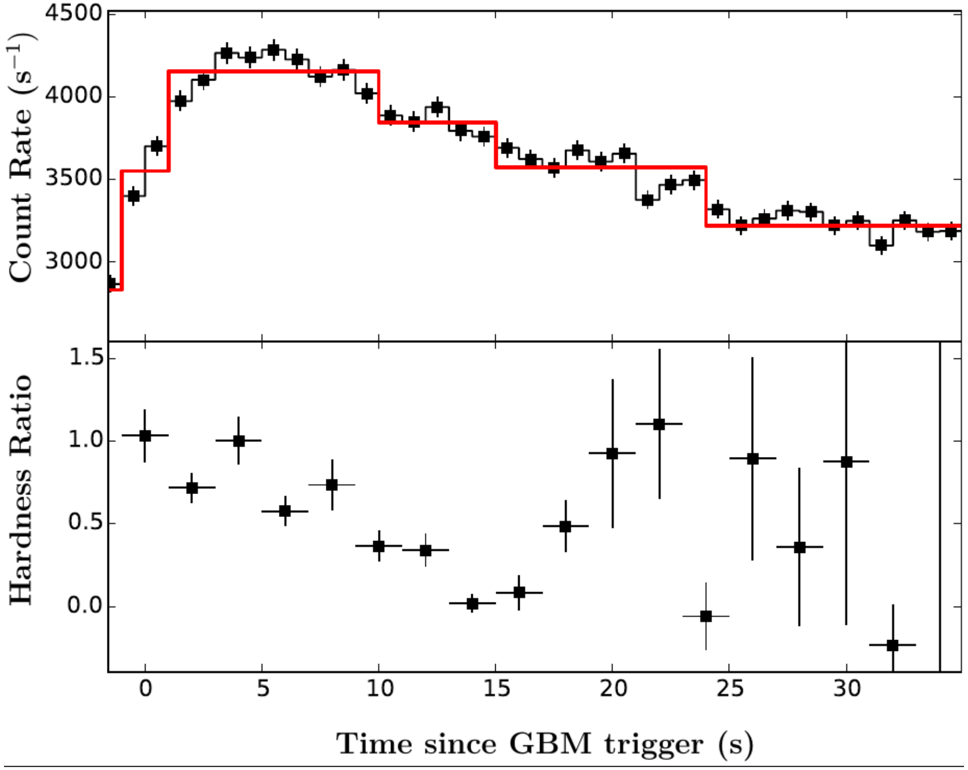
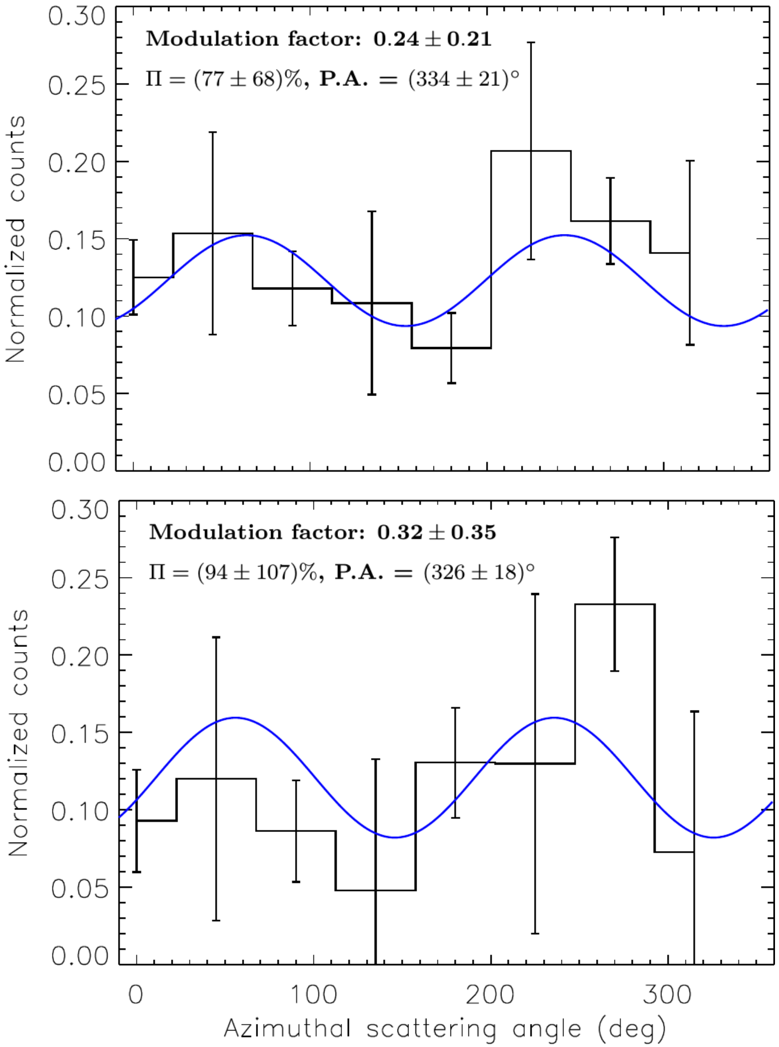
III. Bayesian block and Hardness evolution



IV. Evolution of Polarization



Summary and Conclusion

- Prompt Emission spectral shape still debated. Degeneracies.
- Multi-wavelength and Multi-instrument required.
  Long term spectral evolution. Better sensitivity and resolution.
- Spectrum has double hump.
  Phenomenological model: Two blackbodies and a power law (with cutoff)
- A spine-sheath jet fits in the observations.

Lessons learnt from GRB 151006A

- There could be surprises even in single pulse GRBs. GRB 151006A is unusual.

- How can CZTI contribute?

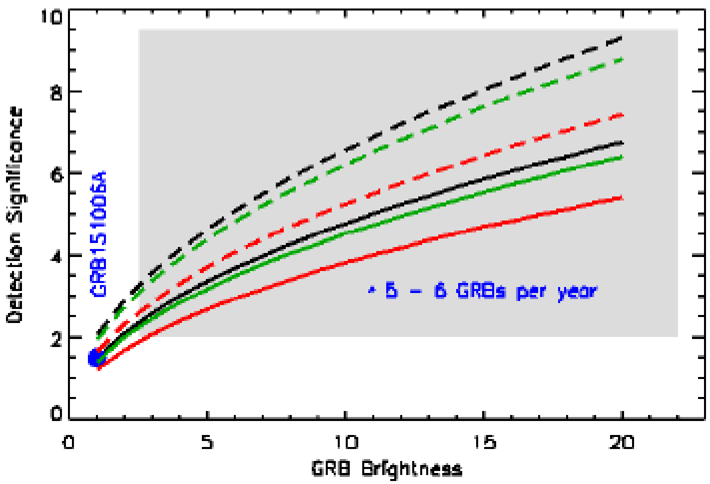
  - Will require brighter GRBs. Not very rare.

  - Current sample – >50 detections. 11 with significant polarization. (Talks by Tanmoy and S. V. Vadawale)

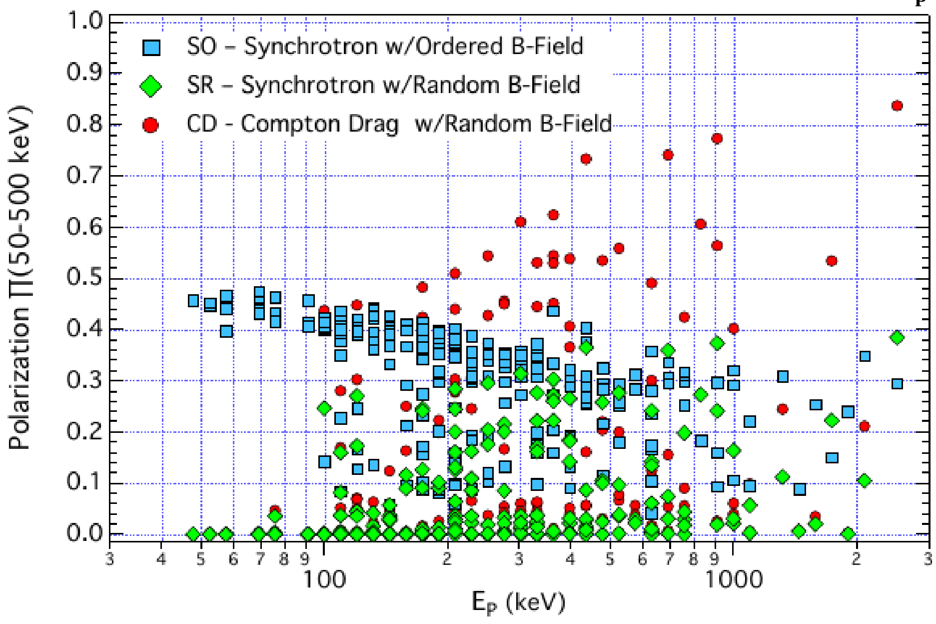
  - Interesting cases: two >3sigma detections. One very high, other very low.

  - Statistical sample: polarization degree and angle.

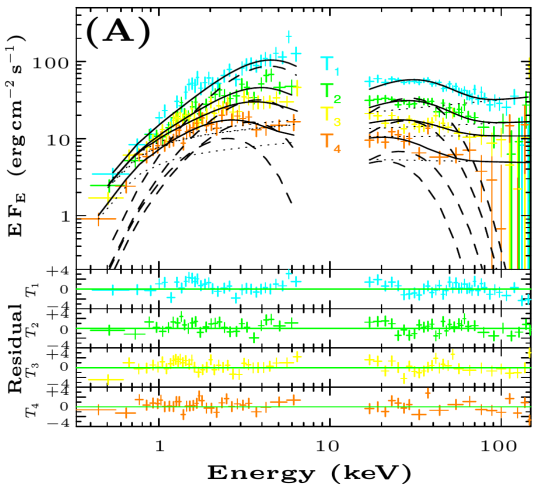
Rao + 16, ApJ



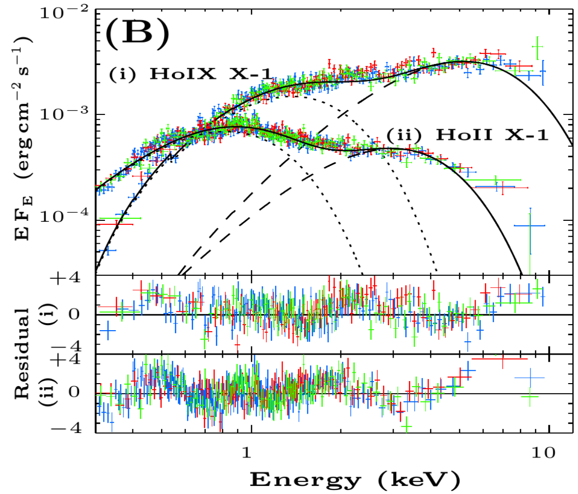
Toma+09: Predicted polarization (50-500 keV) w.r.t E_p



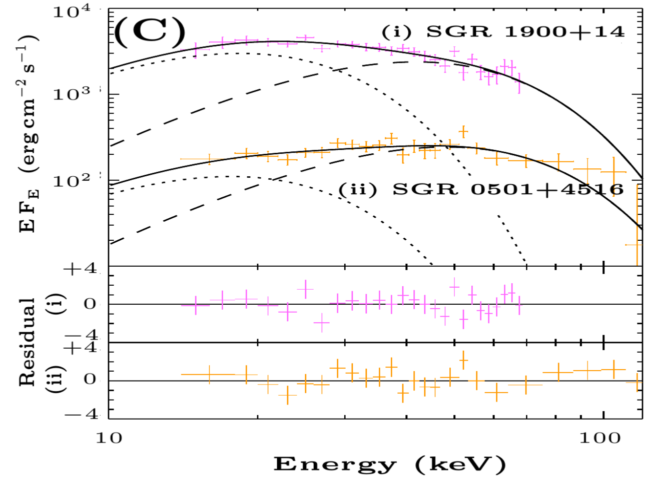
A common feature?



GRB 090618
(Basak & Rao 2015a, ApJ)



Ultraluminous X-ray sources
(Kajava & Rico-Villas 2016)



Soft Gamma Repeaters

Spine-sheath jet:
e.g., Powerful blazars (Ghisellini 2005).

A very recent image of M87 jet.
(K. Hada, Malaga conference)
Info: 15 GHz, VLBA, pc scale.