Search for the possible thermal emission from GRB100725B with *Swift* and *Suzaku* (P18)

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Abstract

Gamma-ray spectra of GRB prompt emission are often described with the Band function consisting of smoothly connected two power-law functions at a break energy . The break energy is recognized as the typical energy of each GRB prompt emission. Since the break energy varies in time and distributes in the wide range --- from keV-band to MeV-band, the wide band spectroscopy is necessary to investigate the prompt emission systematically. Additionally, it is thought that the prompt emission may include the thermal radiation from the explosion in the photosphere, however existence of the thermal component in the prompt emission have been largely uncertain yet. In this study, we carried out the timing analysis of Swift/XRT -Swift/BAT -SUZAKU/WAM joint spectra of GRB100725B. The data has enough statistics to determine spectrum parameters of the Band function. Most of the spectra was well described by Band function, but some of them deviate from typical Band function; their high energy spectral index (β) is larger than -2. Therefore, we examined additional thermal component in order to search for the radiation component from the photosphere. In this paper, we showed the broad band XRT-BAT-WAM joint spectra analysis and derived physics of the prompt emission, and discuss possible joint observation and expected results with Swift/XRT-Swift/BAT and HXMT.

1. Background

What is Gamma-Ray Bursts(GRBs)?

- The most luminous explosion in the universe
- A lot of γ-ray are emitted during a few msec - min, and then GRBs dim rapidly.
- GRBs are classified as the two types:
  - ✓Short GRB (duration < 2s, Origin: neutron stars or NS–BH merger)
  - ✓Long GRB (duration > 2s, Origin: Super or hyper nova)
- The jet (Lorentz factor $\Gamma > 100$) launched when the hyper nova or the merging occur.
- GRBs can be observed when the jets are toward the earth
- The emission mechanisms are still largely a mystery.

Standard model of long GRBs→Fireball model

Fig. 1

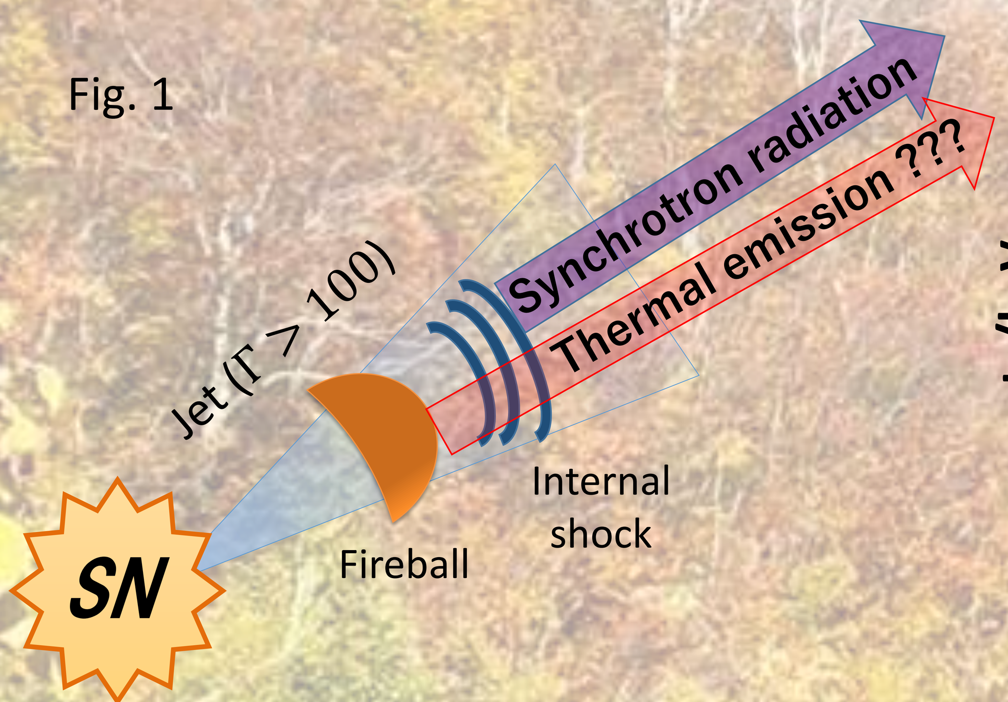
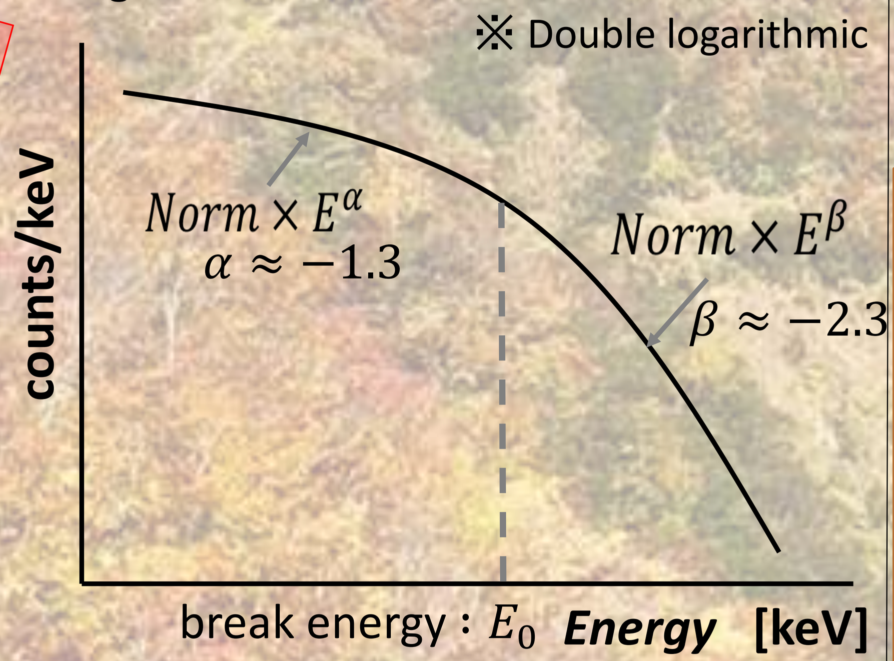


Fig. 2: Band function

※ Double logarithmic



1. Super Nova → relativistic jet is launched
2. Internal shocks take place when an inner shell overtakes a slower outer shell.
3. Electrons in the jet are accelerated by the shock.
4. The magnetic field is generated in the shock
5. The electrons are accelerated by the magnetic field, and emit the synchrotron radiation.
   - ➢ This spectrum is often described with Band function (Fig. 2)
   - ➢ The E_0 varies and distributes in the wide range --- from keV to MeV-band

→ The wide band spectroscopy is necessary to investigate the prompt emission.

✓ A quasi-thermal equilibrium between radiation and matter is reached because enormous energy ($\sim 10^{53}$ erg) was injected to the compact region (~ 10 km).

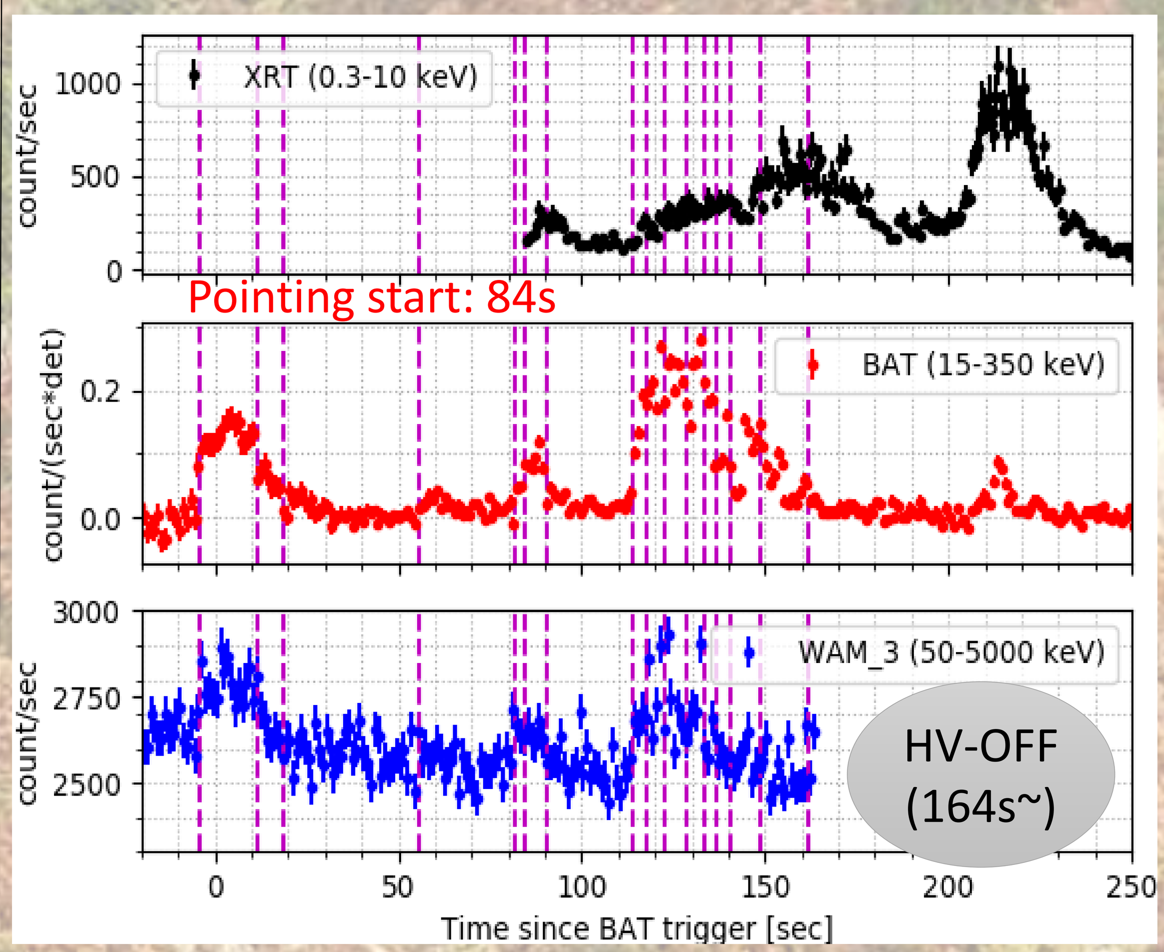
→"Fireball" is generated.

✓ The "fireball" expands by thermal pressure, and then optical depth (τ) becomes $\tau < 1$

→It is possible to find the additional thermal component.

2. Steps of GRB100725B analysis

3-band light curves of GRB100725B (Fig.3)



Energy range

- *Swift*/XRT: 0.3-10 keV
- Swift/BAT: 15-150 keV
- Suzaku/WAM:150-5000 keV

BAT & WAM → 15-5000 keV

XRT & BAT & WAM→0.3-5000keV

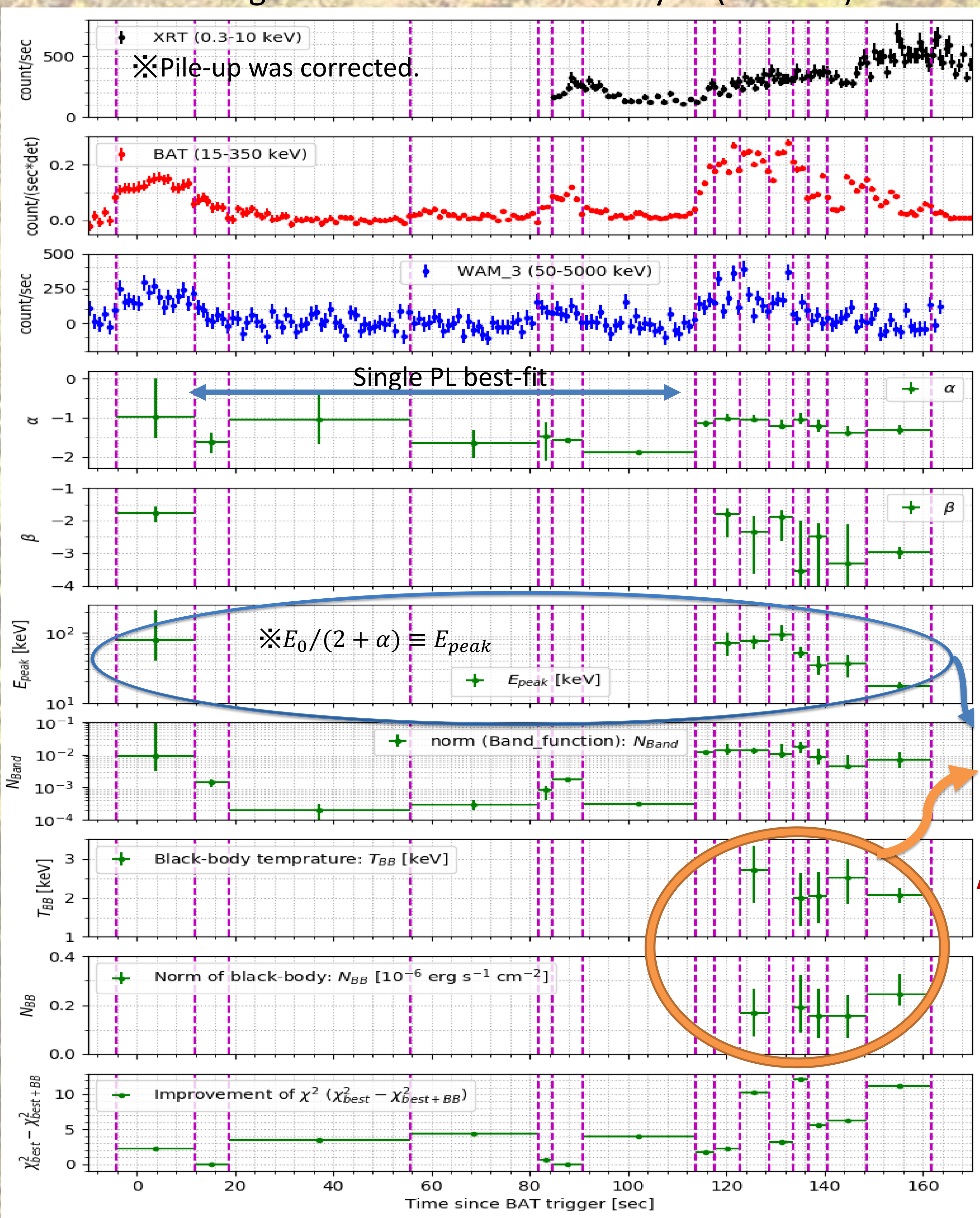
- Duration (BAT): $T_{100}^{BAT} = 231$ s
- Trigger time (BAT): 11:24:34.5UT
- Differences among light curves:
  - ✓XRT ≠ BAT & WAM
- Spectral evolution study:
  - ✓Until WAM HV-OFF
  - ✓Time sliced spectra in 15 intervals
  - ✓BAT & WAM (< 84s)
  - ✓XRT & BAT & WAM (>84s)

The methods to the spectral fitting

1. The uncertainty in the cross-instrumental calibration was corrected based on BAT data.
2. Interstellar extinction was considered. Values of nH in "tbabs" model were fixed at:
   - ✓ Galactic nH = 7.5×10^{20} cm^{-2} (from [5])
   - ✓ Intrinsic nH = 5.8×10^{21} cm^{-2} (From the afterglow analysis in [3])
3. Fitting models (non-thermal) are:
   - ✓ Single Power-Law (PL, free parameters: 2)
   - ✓ PL with exponential cut-off (CPL, free parameters: 3)
   - ✓ Band function (free parameters: 4)
4. Determining the best-fit non-thermal model based on following definitions (From [1])
   - ✓ PL best-fit: $\chi^2_{PL} - \chi^2_{CPL} < 6$
   - ✓ CPL best-fit: $\chi^2_{PL} - \chi^2_{CPL} \geq 6$ && $\chi^2_{CPL} - \chi^2_{Band} < 6$
   - ✓ Band function best-fit: $\chi^2_{PL} - \chi^2_{CPL} \geq 6$ && $\chi^2_{CPL} - \chi^2_{Band} \geq 6$

   ※Number of bins→XRT:59, BAT: 51, WAM: 16
5. Adding the black body (bbody) model to the best-fit non-thermal model

Fig.4: The results of this analysis (90% err)



3.Results of the analysis

Best-fit intervals

- PL: 6/15
- CPL: 1/15
- Band function: 8/15

Adding the black body model

χ^2 was improved adding the black body:

✓ 5/15 intervals

※P-values of F-test: p < 0.1

Fig.5: The spectra fitted by Band function (134s-137s)

Left: Count spectrum *Right*: νF_ν spectrum

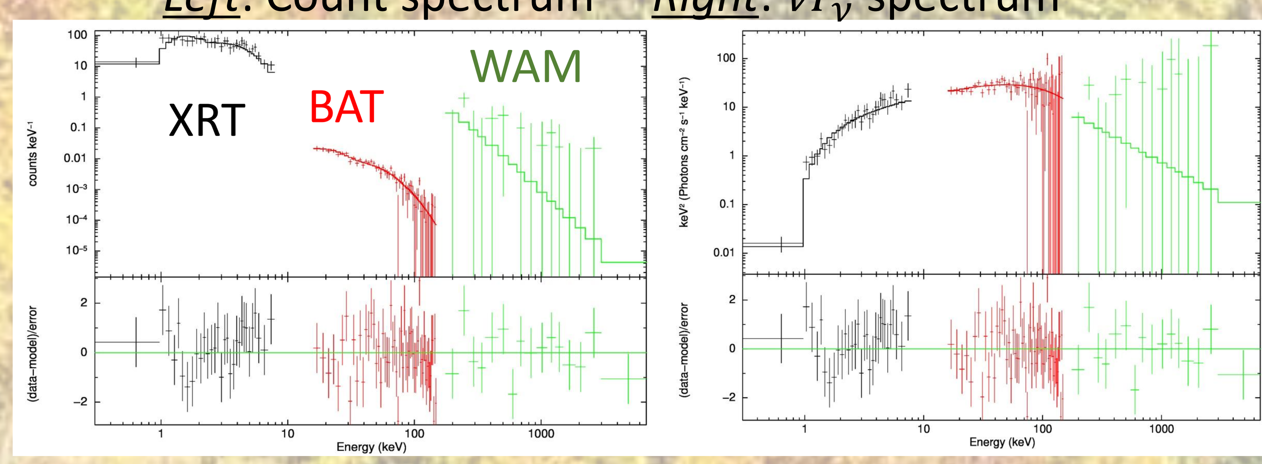
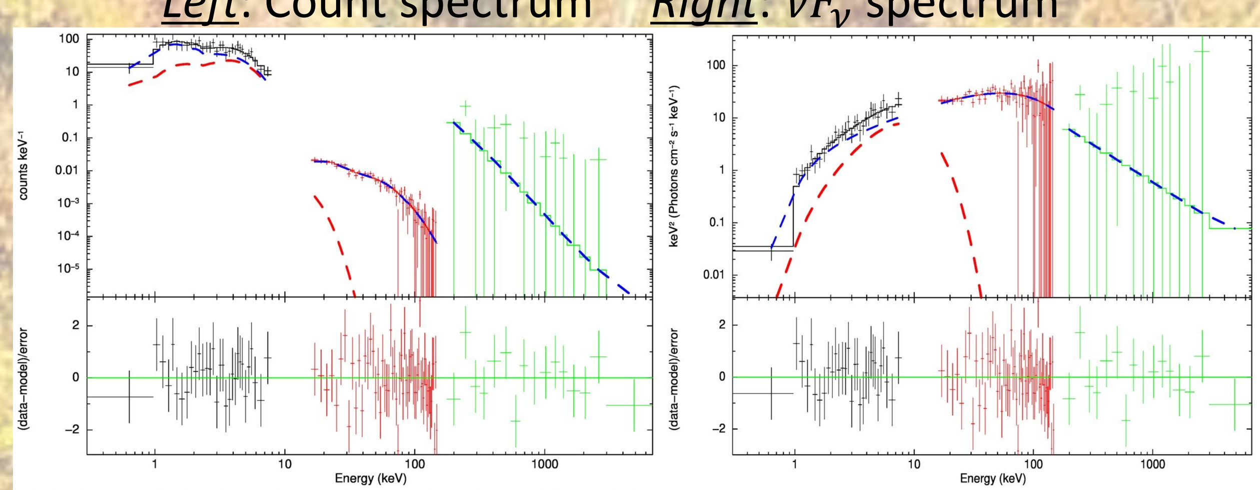


Fig.6: The spectra fitted by Band (blue) + black body (red line)

Left: Count spectrum *Right*: νF_ν spectrum



- The E_{peak} decreases from 100 to 10 keV.
- Band function + black body were best-fit model after 122s.
- The temperature kT~2 keV, and the norm of black body $N_{BB} \sim 0.2$ [10^{-6}erg s^{-1} cm^{-2}]

4. Summery and future

- Joint analysis of XRT & BAT & WAM data in wide-band allow us to investigate the decrease of E_{peak}
- Additional black body component improved chi-squared values significantly after 122s. but careful treatment of systematic errors among different instruments will be required in future analysis.

→It is necessary to analyze the spectra of GRB100725B after 160s in order to study the variation of kT & N_{BB}

- The method in this poster is also available with (XRT &) BAT & HXMT data instead of WAM data.

5. References

[1] Sakamoto, T. et al. 2008, ApJ. [2] Tashiro, M. et al. 2012, PASJ. [3] Evans, P. et al. 2009, MNRAS. [4] Rees, M. & P. Mészáros. 1994, ApJ. [5] Willingale, R. et al. 2013, MNRAS. [6] Yamaoka et al. 2009, PASJ. [7]Romano, P. et al. 2006, A&A. [8]Mangano, V. et al. 2007, MNRAS