Joint observation of GRBs detected by BeppoSAX/WFC and Konus-Wind

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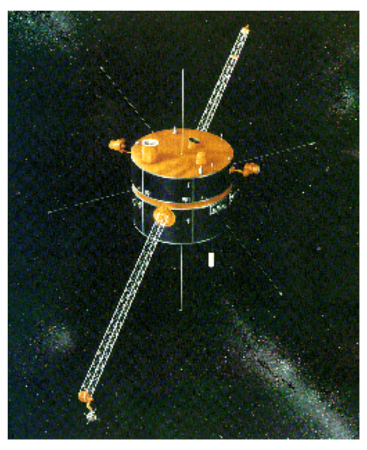
Introduction:
Although decades have passed since the discovery of gamma-ray bursts (GRBs), many aspects of this astrophysical phenomenon remain unknown. E.g., the main radiation process producing the prompt emission is still debated. Within the internal shock and ICMART models, the Band component can be interpreted as the synchrotron radiation from an optically thin emission region, while the thermal component represents the emission from the photosphere. GRBs have different balance between the thermal and non-thermal components, which can be explained within the hybrid central engine framework (see Zhang 2016, Zhang 2018 and references therein for further details) characterised by different dimensionless entropy (for the fireball component) and magnetisation parameter (for the Pointing component). In this work, we are carrying out joint Konus-Wind and BeppoSAX/WFC spectral analysis to shed light on this exciting question.



BeppoSAX Wide Field Cameras

(WFCs; Jager et al. 1997)

- Italian/Dutch X-ray satellite (1996-2002)
- The WFCs were two identical coded mask instruments for the imaging of the hard X-ray sky
- Effective area: 140 cm²
- Energy range: 3–28 keV
- FOV: 40° × 40° each
- Spectral resolution: 20% at 6 keV (FWHM)
- Time resolution: 0.5 ms
- Among the most important results obtained with the WFCs is the discovery of the X-ray afterglow phenomenon of Gamma Ray Bursts in 1997 (Costa et al. 1997)

Konus-Wind (Aptekar et al., 1995)

- Launched on November 1, 1994: >30 years of continuous operation
- Two NaI detectors (S1 and S2) are located on opposite faces of spacecraft, observing correspondingly the southern and northern celestial hemispheres
- Effective area: ~100–160 cm² Wide energy band: 20 keV – 20 MeV
- TIme resolution of spectral data: 64 ms - 8 s
  Time resolution of light curves:
- The orbit of s/c (now near L1) excepts interferences from radiation belts and the Earth occultation: continuous observations of all sky, exceptionally stable background, duty cycle 95%

Methodology

- The sample of GRBs simultaneously detected by KW and WFC counts 23 events
- Based on the temporal binning of the spectral data, we formed a set of spectra with optimal overlap in time subject to further analysis.
- We fitted the data with several models: Band function, smoothly broken power law (SBPL) and double SBPL (2SBPL, see Ravasio et al. 2018 for further details), and SBPL + Blackbody (BB).

$$N_E^{\mathrm{SBPL}} = AE_j^{\alpha}\left[\left(\frac{E}{E_j}\right)^{-\alpha n} + \left(\frac{E}{E_j}\right)^{-\beta n}\right]^{-\frac{1}{n}},$$

where

$$E_j = E_{\mathrm{peak}} \cdot \left(-\frac{\alpha+2}{\beta+2}\right)^{\frac{1}{(\beta-\alpha)n}}.$$

$$N_E^{\mathrm{2SBPL}} = A\,E_{\mathrm{break}}^{\alpha_1}\left[\left[\left(\frac{E}{E_{\mathrm{break}}}\right)^{-\alpha_1 n_1} + \left(\frac{E}{E_{\mathrm{break}}}\right)^{-\alpha_2 n_1}\right]^{\frac{n_2}{n_1}} + \left(\frac{E}{E_j}\right)^{-\beta n_2} \cdot \left[\left(\frac{E_j}{E_{\mathrm{break}}}\right)^{-\alpha_1 n_1} + \left(\frac{E_j}{E_{\mathrm{break}}}\right)^{-\alpha_2 n_1}\right]^{\frac{n_2}{n_1}}\right]^{-\frac{1}{n_2}},$$

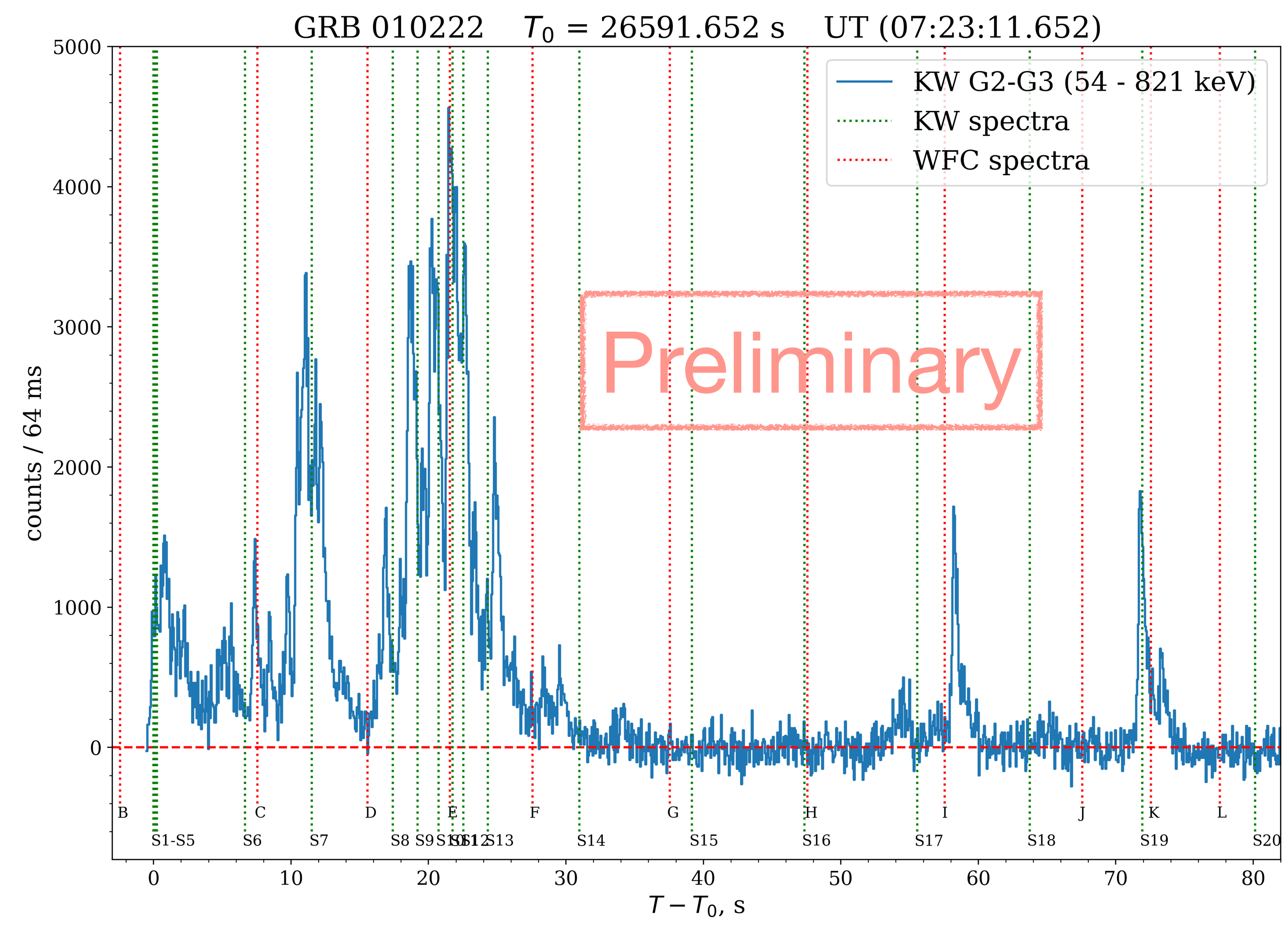
where

$$E_j = E_{\mathrm{peak}} \cdot \left(-\frac{\alpha_2+2}{\beta+2}\right)^{\frac{1}{(\beta-\alpha_2)n_2}}.$$

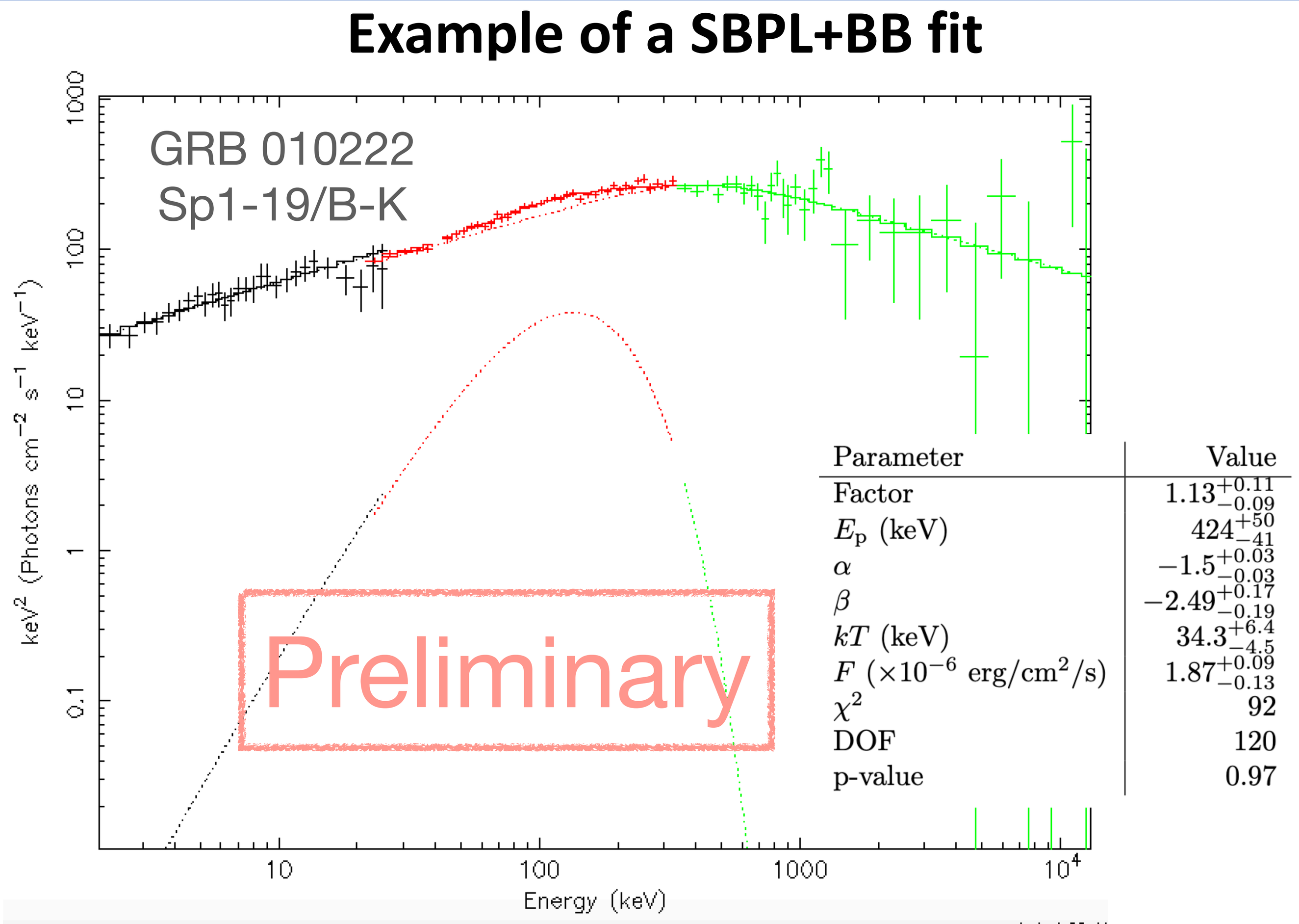
Results

- The SBPL+BB fits the data better ($\Delta\chi^2 > 6$) than Band or SBPL (2SBPL) for ~50% (25%) KW+WFC spectra, while for KW data alone, the ratio is ~15% (0).
- The kT values span the range 15-65 keV.
- The 2SBPL model is preferred over SBPL in >50% of spectra.
- The break energies span the range up to 300 keV (in this case, E_p~1MeV).
- The typical ratio E_{br} to E_p is ~0.3.
- The typical values of α_1 and α_2 are ~0.8 and ~-1.8, correspondingly.

Example of a light curve

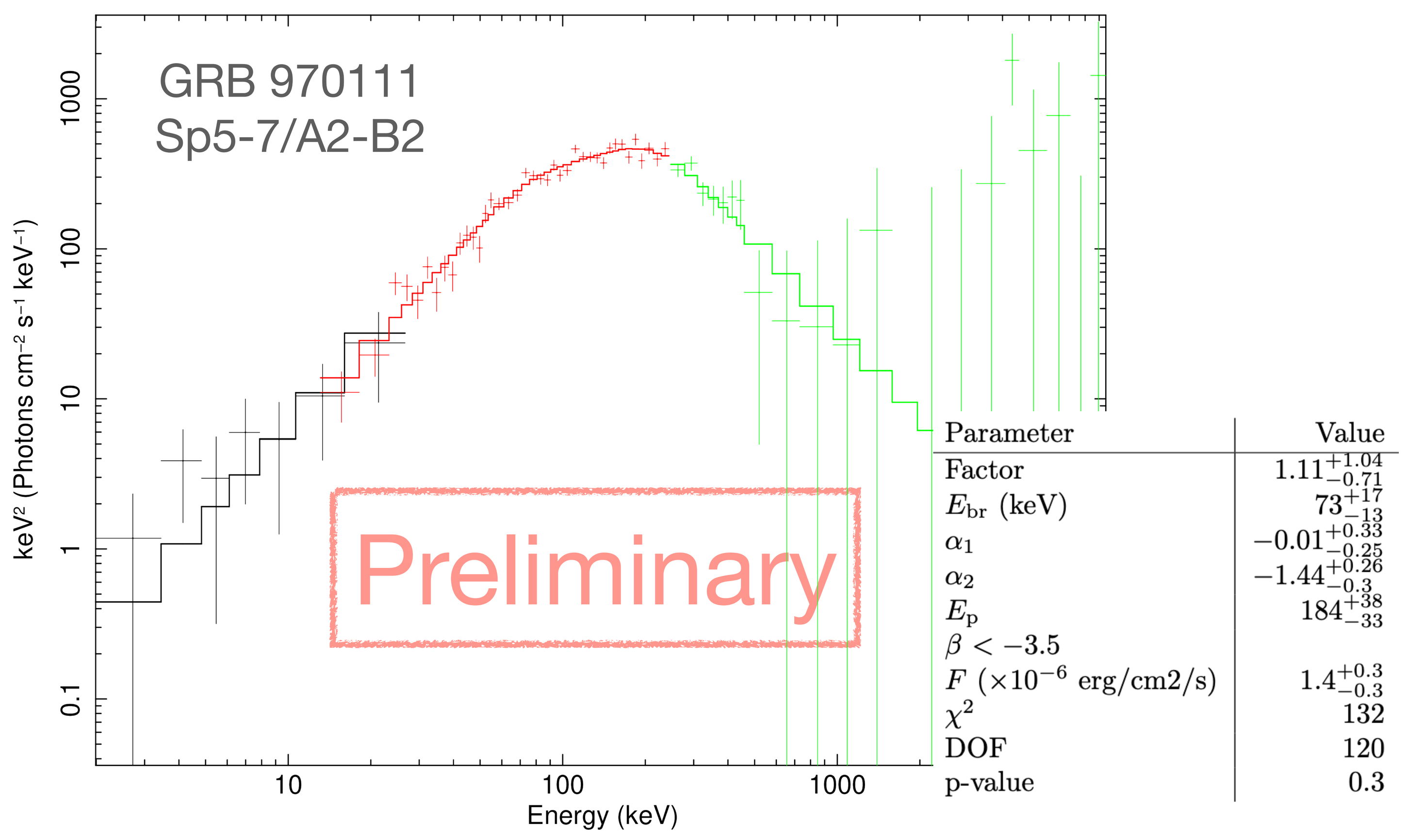


Example of a SBPL+BB fit



Parameter	Value
Factor	$1.13^{+0.11}_{-0.09}$
E_p (keV)	424^{+50}_{-41}
α	$-1.5^{+0.03}_{-0.03}$
β	$-2.49^{+0.17}_{-0.19}$
kT (keV)	$34.3^{+6.4}_{-4.5}$
F ($\times10^{-6}$ erg/cm²/s)	$1.87^{+0.09}_{-0.13}$
χ^2	92
DOF	120
p-value	0.97

Example of a 2SBPL fit



Parameter	Value
Factor	$1.11^{+1.04}_{-0.71}$
E_{br} (keV)	73^{+17}_{-13}
α_1	$-0.01^{+0.33}_{-0.25}$
α_2	$-1.44^{+0.26}_{-0.3}$
E_p	184^{+38}_{-33}
$\beta < -3.5$	
F ($\times10^{-6}$ erg/cm2/s)	$1.4^{+0.3}_{-0.3}$
χ^2	132
DOF	120
p-value	0.3

References:
Aptekar, R. L., Frederiks, D. D., Golenetskii, S. V., et al. 1995, SSRv, 71, 265
Costa, E., Frontera, F., Heise, J., et al. 1997, Nature, 387, 783
Jager, R., Mels, W., Brinkman, A., et al. 1997, A&AS, 125, 557
Ravasio, M. E., Oganesyan, G., Ghirlanda, G., et al. 2018, A&A, 613, A16
Zhang, B., Lü, H.-J., & Liang, E.-W. 2016, SSRv, 202, 3
Zhang, B. 2018, The Physics of Gamma-Ray Bursts by Bing Zhang, Vol. 2018 (Cambridge: Cambridge Univ. Press)