In-flight spectral cross-calibration of ECLAIRs and GRM on board SVOM

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Parametric Physical model for the GRM background

- For persistent sources, background subtraction can be done using Earth occultation and emersion [1]
- Best background fitting method to safely extrapolate the background during the source emersion: **model P** [2]
  - The count-rate r in a given energy band I for each physical component of the background X (CXB, Reflection, Albedo) is obtained as a linear function of the Earth fraction f in the instrument field of view (see fig.1): $r_X(I) = p_{X,0}(I) + p_{X,1}(I)\,(f_X - f_D)$
  - For each component X and energy band I, $p_{X,0}(I)$ and $p_{X,1}(I)$ are derived by fitting the expected background in space estimated with simulations based on the Particle Interaction Recycling Approach (PIRA) [3]
- When fitted to real data, two pre-factors $(1+c_0)$ and $(1+e_0)$ are applied to account for possible discrepancies (see fig. 2): $r(I,t) = (1+c_0) \times r_C[I, f(t)] + (1+e_0) \times (r_R[I, f(t)] + r_A[I, f(t)])$

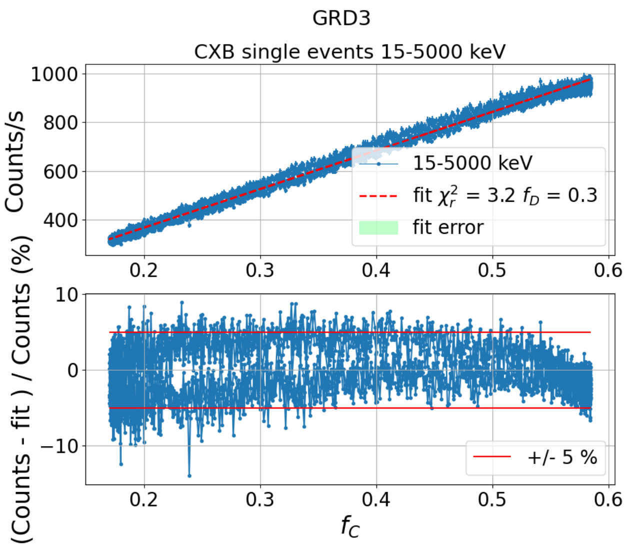


Figure 1: Count-rate for the CXB component in the 15-5000 keV energy band simulated with PIRA for GRD3, as a function of the FoV fraction that is free of Earth. The red line is the linear fit to the data, used to build modelP.

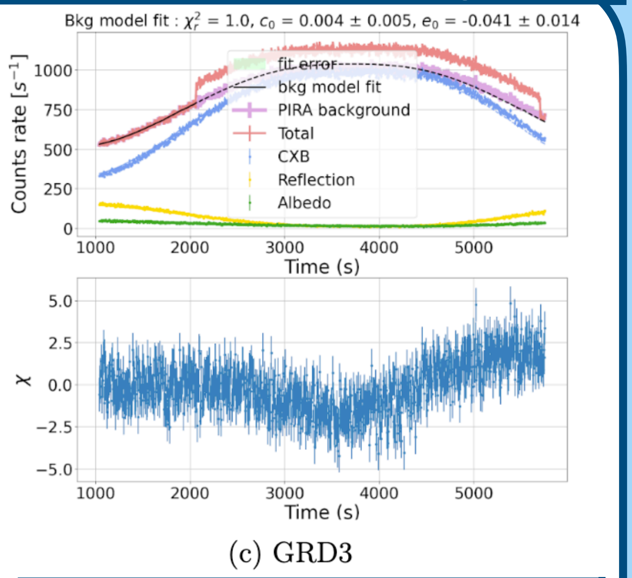


Figure 2: Crab Nebula emersion and occultation simulated with PIRA (red). The background during the occultation is fitted with the model P (black solid) and extrapolated after the emersion (black dashed). The color points are each background component simulated with PIRA. The bottom panel shows the normalized residuals of the background fit in the fit and extrapolation regions.

Crab Nebula observations

- Crab Nebula observed several times in Fall 2024 by SVOM instruments for calibration purposes, also coordinated with other observatories (Swift, INTEGRAL)
- For ECLAIRs-GRM intercalibration, Crab Nebula observed on-axis for ECLAIRs, i.e. 30° off-axis for each GRD
- In real data, the background is more complex than in simulations, with the contribution of high-energy particles (see fig. 3)
- Approach: select shorter time intervals within the observation without strong particle background

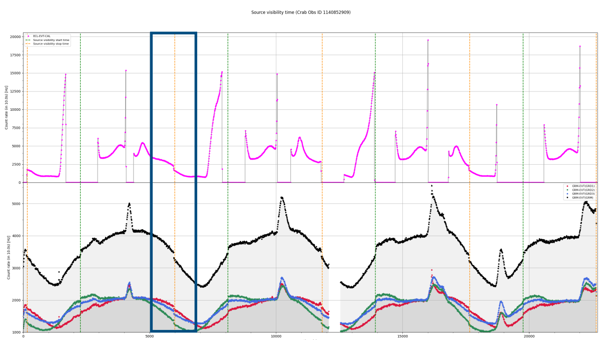
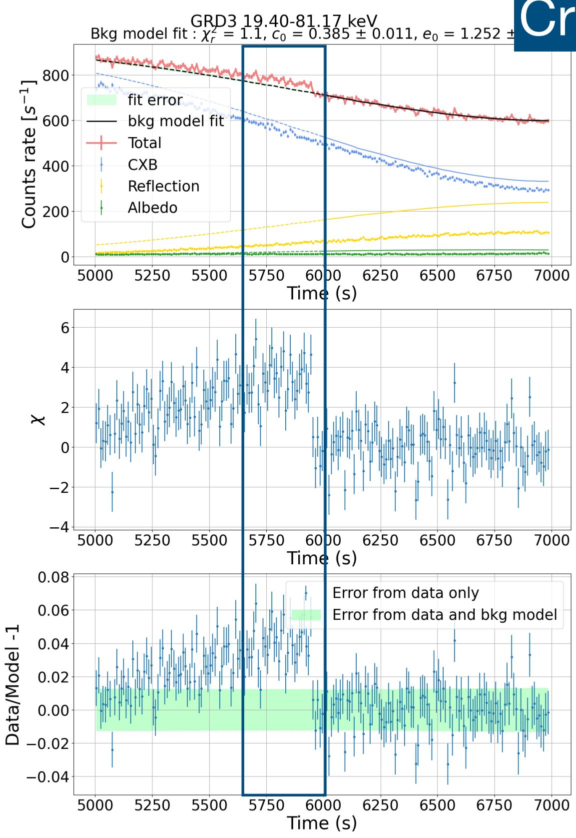


Figure 3: Crab Nebula observation with ECLAIRs (upper panel) and with GRM (middle panel, black line; colored lines are the three GRDs) from DATE-BEG: 2024-10-04T10:22:04 and DATE-END:2024-10-04T16:39:43. The dotted orange (green) vertical lines mark the occultation (emersion) of the Crab Nebula. For the preliminary analysis we selected the time interval 5000-7000 s after TSTART.

Example of model P applied to the Crab Nebula GRM observations



Background fit with model P in the energy band 20-80 keV:

- Crab occultation at ~6000s:
  - Source: 5000-6000 s
  - Background: 6000-7000 s
- Discrepancies between the simulated and real background adapted via the free parameters c_0 and e_0
- Model P is in good agreement with the background data in the selected time interval (see fig. 4). However, it cannot be safely extrapolated backwards for 1 ks
- We extrapolate the background on a shorter time window (~350 s)

Figure 4: Fit with ModelP (black solid) to the Crab Nebula occultation observed by GRD3 in the selected time interval (red) and its extrapolation (black dashed), together with each background component of the model compared to the PIRA simulations. The middle and lower panels portray the Chi square and residuals of the fit and extrapolation. The blue box marks the time interval selected for the extraction of the spectrum.

Preliminary spectral analysis of GRD3 Crab Nebula observations

- For each energy channel, we apply the analysis described above to build the count spectrum for the source and the background for an exposure of 350 s
- We analyzed these preliminary results with Xspec (see fig. 5):

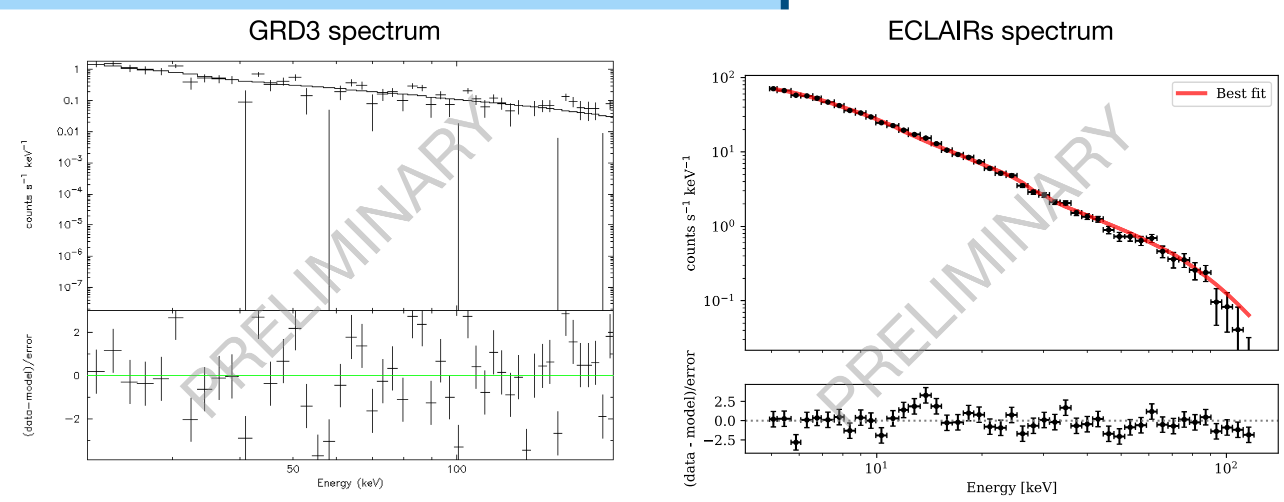


Figure 5: Crab Nebula count spectrum of GRD3 (left) and ECLAIRs (right).

	SVOM/ ECLAIRs	SVOM/GRM (GRD3)	INTEGRAL/ SPI [4]
Best model	Power law	Power law	Band model
Photon index	2.11+/-0.02	$1.83^{+0.11}_{-0.12}$	1.99+/-0.01
Flux@100keV [10^{-4} ph/keV/cm²/s]	6.6+/-0.3	6.2+/-0.6	7.5+/-0.2

- Fair agreement with the measurements of the spectrum from INTEGRAL SPI but no sign of the break observed at 500 keV [4]
- Spectral index consistent within 3 sigma to the one measured by ECLAIRs (see fig.5). Flux consistent within 1 sigma

Next steps:

- Add further components to the background for a more accurate modeling
- Use more occultations to increase the exposure
- Add GRD1 and GRD2 observations

REFERENCES:
[1] Wilson Hodge ApJS 201, 33 (2012)
[2] A. Maiolo, Ph.D. thesis (https://theses.hal.science/tel-04536577v1)
[3] S. Mate et al. Experimental Astronomy 48, 171 (2019)
[4] E. Jourdain & J.P. Roques, ApJ 899, id.131 (2020)