In-flight calibration of the SWIFT XRT

G. Cusumano([1])on behalf of the XRT Calibration Team.

([1]) *INAF - Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo, Italy*

Summary. — The calibration of the Swift XRT effective area has been performed by analyzing cosmic sources observed during the in-flight calibration phase and by using laboratory results and ray-tracing simulations as a starting point. This work describes performance of the recent release of ancillary response files (ARF v8).

XRT supports four different read-out modes to cover the dynamic range and rapid variability expected from GRBs afterglows. The switch between modes, performed automatically, minimizes pile-up and optimizes the collected information as the flux of the afterglow varies. In Imaging mode the XRT produces an integrated image (no X-ray event recognition takes place) which, for a typical GRB flux, is highly piled up. No spectroscopy is therefore possible, but a very accurate position and a good flux estimate can be obtained. The Photodiode mode (PD) is designed for very bright sources and allows to observe GRB with high timing resolution (0.14 ms). However, this operational mode went lost because of a damaged in the CCD caused by a micro-meteorite. The Windowed Timing (WT) mode (1–600 mCrab) is obtained by binning and compressing 10 rows into a single row, and then reading out only the central 200 columns of the CCD. It covers the central 8 arcminutes of the field of view and provides one dimensional imaging and full spectral capability with a time resolution of 1.8 ms. The Photon Counting (PC) mode ($<$ 1 mCrab) allows full spatial and spectral resolution with a timing resolution of 2.5 seconds. Each read-out mode has a dedicated ARF file that contains the mirror effective area, the filter transmission, as well as the vignetting function and the Point Spread Function (PSF) correction (which depends on the source location and of the size of the extraction region) and residual correction of the CCD quantum efficiency.

In WT mode the Crab nebula was used as main calibrator. A moderate pile-up due the high count rate was partially mitigated extracting the off-pulse spectrum (mainly due to the nebula) with a phase-resolved selection. Figure 1 (left panel) shows the residuals obtained fitting the Crab nebula with an absorbed power law plus absorption features (Kirsch et al. 2005). The fit was carried out in the 0.45-10 keV energy range with the low energy boundary limited by the unacceptable increase in the residuals present in the spectrum below 0.45 keV. Such an increase is due to redistribution matrix problems. In the 0.45-10 keV energy range the χ^2_{red} is 1.83 (620 d.o.f.) and the mean systematic uncertainty was at a level of 3% (this is the systematic uncertainty to be added in order

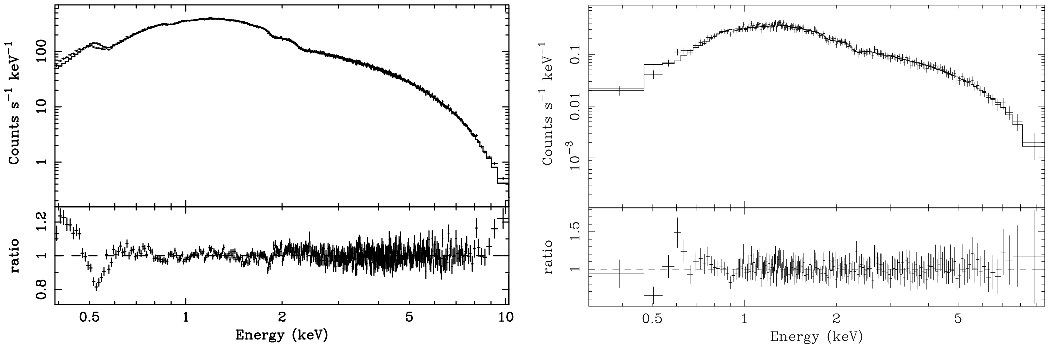

Fig. 1. – **Left panel:** The off-pulse phase resolved Crab spectrum (WT mode, grades 0-2), best fit model and the data/model ratio. **Right panel:** The spectrum of SNR B0540-69 (PC mode, grades 0-12), best fit model and the data/model ratio.

to obtain in the Crab spectrum a χ^2_{red} =1.0). The strongest features visible in the Crab spectrum are mainly below 2 keV. The main systematics is a broad absorption features at ∼0.5 keV. Residuals are also present at ∼1.5 keV and at ∼1.8 keV, while the systematics above 0.9 keV is due to the pile-up effect. There is also some instrumental Nickel contamination present in the 7-8 keV energy range which (sometimes) is not fully subtracted. The edge-like residuals could be due to energy scale offsets. We recommend to fit XRT WT spectra in the 0.3-10 keV energy range.

ARFs relative to the PC mode were mainly calibrated with the SNR B0540-69. The strongest features in the SNR 0540-69 spectrum (see Figure 1, right panel) are an absorption feature at ∼0.5 keV and an emission feature at slightly higher energies. The latter feature is large and might be related to the source itself as XMM-Newton spectra might indicate. Smaller features at larger energies are also present. The statistical uncertainty on the final RMF+ARF matrices in PC mode is estimated at 3% level in the 0.3-10 keV.

The on-going in-flight calibration has allowed to improve the effective area files for all observing modes and grade selections to a level that satisfies the mission requirements. Our current knowledge of the XRT response still implies a systematic uncertainty of the order of 3% in the 0.3-10 keV energy band and of about 10% in absolute flux. The following considerations apply to both WT and PC mode observations. For highly absorbed sources the response model showed an under-estimation of the redistribution below about 1 keV. This effect is clearly evident for $N_H > 10^{22}$ cm^{-2} but even for less absorbed sources small deviations are present. In case of bright sources we do experience small energy scale problem at low energies (E <1 keV). This problem is still under investigation and might be related to bright Earth contamination in PC mode and a bias subtraction problem in WT mode causing energy scale offsets.

REFERENCES

[1] Kirsh M. et al., *SPIE*, **5859** (2005) 22.