XMM-Newton Calibration Technical Note

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EPIC "calibration+science" exposures: how to deal with them?

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History

Version	Date	Editor	Note
1.2	July 29, 2013	M.Guainazzi	§ 1 aligned to XSAv8.0
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1.0	March 13, 2013	M.Guainazzi	First version

The EPIC cameras on-board XMM-Newton (EPIC-MOS, Turner et al. 2001; EPIC-pn, Strüder et al. 2001) carry ^{55}Fe radiative sources. Their spectra exhibit strong Al and Mn fluorescence lines, illuminating essentially the whole field-of-view (see Fig. 1). They are used for continuous monitoring

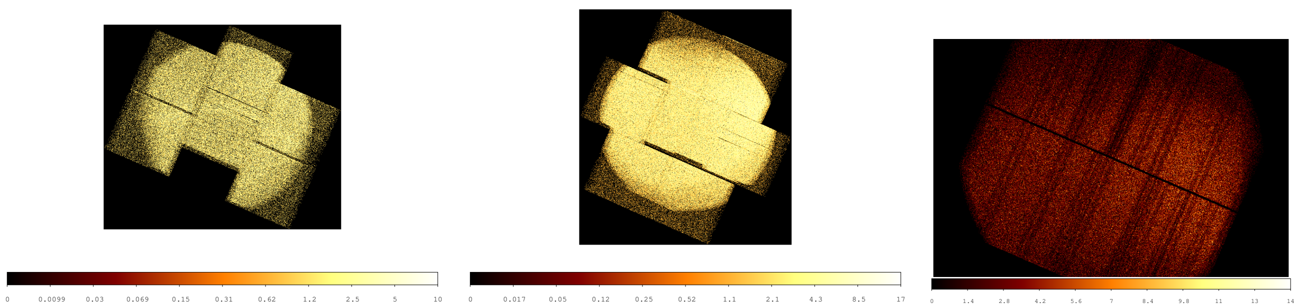

Figure 1: Field-of-view images of the calibration source (Obs.#0411781301; Rev.#2359). *Left panel*: EPIC-MOS1; *centre panel*: EPIC-MOS2; *right panel*: EPIC-pn.

of the energy scale. The Charge Transfer Inefficiency and instrumental gain are periodically recalibrated using these spectra.

The calibration sources are shielded during normal scientific observations. A specific optical blocking filter (`CAL-CLOSED`) must be selected to illuminate the instrument field-of-view with them, while at the same time impeding the view of the sky. This option is not available to guest users during the proposal submission "Phase 2". `CAL-CLOSED` exposures are routinely scheduled during intervals of high radiation close to the orbit perigee passage, or according to the pre-defined scheme described in the *XMM-Newton Routine Calibration Plan* (Guainazzi et al. 2013).

The possibility exists to illuminate the instrument field-of-view with the calibration source simultaneously to observing a celestial source. They can be selected through the options: `CAL-THIN`, `CAL-MEDIUM`, and `CAL-THICK`, corresponding to the standard `THIN`, `MEDIUM`, and `THICK` optical blocking filters.

Recently, a number of calibration observations employing these "calibration+science" filters have been performed to cope with the fading of the on-board calibration sources. In this document, we offer XMM-Newton users with guidelines on how to recognise these exposures in the science archive (XSA) and how to process the data, as well as with caveats to be born in mind when analysing the corresponding spectra.

1 How to recognise calibration+science exposures in the XSA

The "calibration+science" EPIC exposures are characterised by specific values of the optical blocking filters: `CAL-THIN`, `CAL-MEDIUM`, and `CAL-THICK`. In order to query them through the XSA user interface, the following steps must be followed:

- open the `Observation and proposal filter panel` panel
- open the `Instrument configuration` window
- select the `Non Science Modes/Filters` check-box
- select the filters of interest in the `Filter` menu

The query result is a list of all the observations in the XSA, that have at least one exposure with the selected combination of filter(s) and mode(s). At the time of the publication of this document, 31 observations have at least one EPIC exposure in a "calibration+science" filter.

2 Data reduction

The Science Analysis System (SAS; Gabriel et al. 2004) recognises and properly reduces the data of "calibration+science" exposures. XMM-Newton users can use on them standard data reduction and analysis prescriptions. In particular, `rmfgen` and `arfgen` calculate correct responses.

3 Interpretation of the spectra

In Fig. 2 we show examples of calibration source spectra.

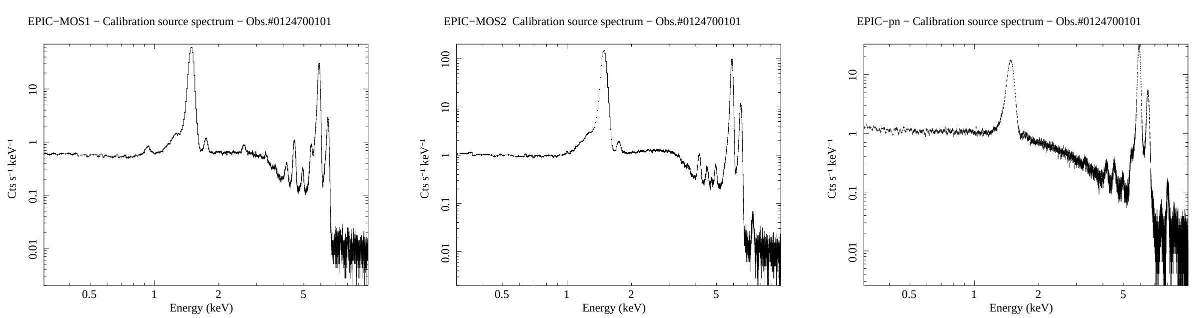

Figure 2: Spectra of the calibration source, extracted from the boresight CCD in Obs.#0124700101 (Rev.#80). *Left panel*: EPIC-MOS1; *centre panel*: EPIC-MOS2; *right panel*: EPIC-pn.

Spectra accumulated during "calibration+science" exposures are the superposition of the spectrum of the calibration source and of that of the celestial source. The calibration source spectrum adds up to the instrumental and sky background present in all observations. It contributes with a soft continuum as well as with strong emission lines, in particular the Al (1.486 keV) and Mn K_α (a doublet: 5.8876 keV, 5.8988 keV) together with its K_β (6.4904 keV). If not properly subtracted, this spectrum can affect the astrophysical results. While this additional background contribution can be subtracted in principle from the spectrum of point-like sources using standard procedures, the background subtraction is likely not accurate, due to the inhomogeneous field-of-view illumination by the calibration source. Exposures with "calibration+science" filters in Guest Observer observations are generally deprecated.

A specific calibration target has been observed routinely since 2010 using "calibration+science" exposures: the Vela SNR. This instrumental configuration was chosen following the results of two experiments performed on the Tycho (January 1, 2008) and the Vela SNR (November 12, 2008), aiming at evaluating the impact that the addition of the calibration source spectra yields on the measurement of astrophysical features in these objects. These SNR occupy a substantial fraction of the EPIC field-of-view (see Fig. 3), making background subtraction extremely challenging.

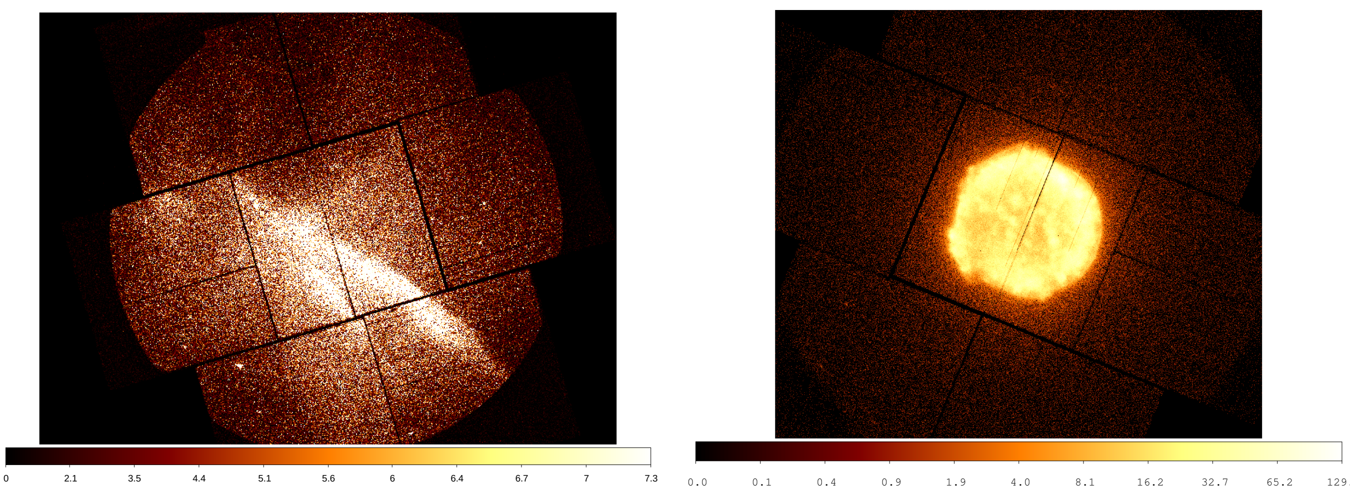

Figure 3: MOS2 images of the Vela (*left panel*) and Tycho (*right panel*) SNR in the 0.3–10 keV energy band.

In Fig. 4 EPIC-pn "calibration+science" exposure spectra of these targets are compared to spectra extracted in standard science exposures. In Tycho the calibration source spectra affect primarily the energy bands where the calibration emission lines are the strongest. In Vela, however, the calibration source spectrum adds continuum flux as well, especially below $\simeq$0.7 keV and above $\simeq$2 keV. In Tab. 1 we compare the measured energies of the closest astrophysics atomic transitions to the Al and Mn calibration lines. In Vela the energies are consistent within 3 eV. In Tycho, the Si XIII line centroid energies exhibit an even better agreement. However, the iron line best-fit centroids differ by 15–45 eV, the difference being stronger for those cameras where the calibration Mn K_β emission line is comparatively stronger with respect to the underlying SNR spectrum. One needs to include explicitly the calibration source line spectrum in the astrophysical model in order to recover an agreement between the measured line centroids and the laboratory energies close to the nominal systematic uncertainties in the energy reconstruction of the EPIC-cameras.

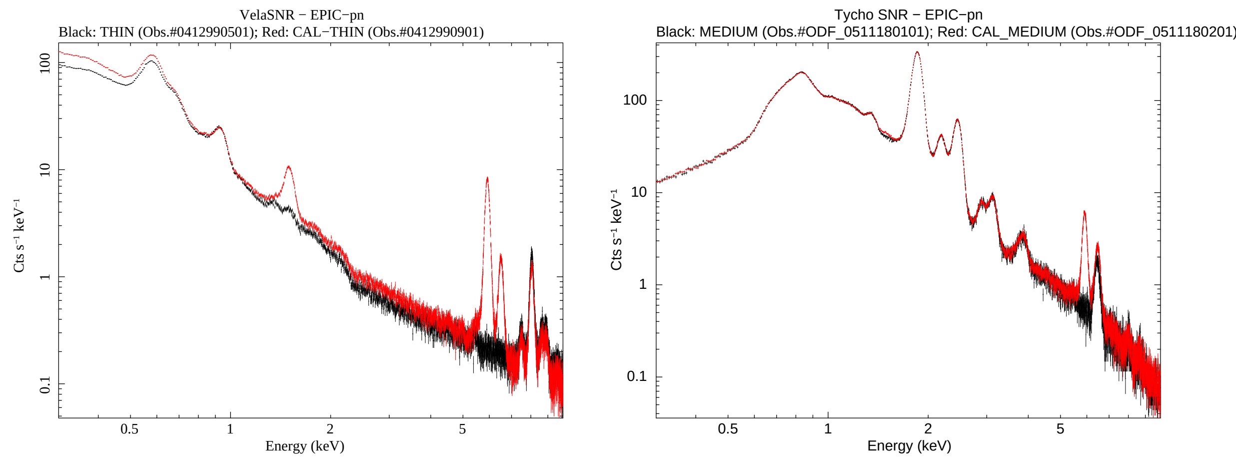

Figure 4: Comparison between the EPIC-pn spectra of a standard science (*black*) and a "calibration+science" (*red*) exposure. *Left panel*: Vela SNR (`CAL-THIN/THIN`); *right panel*: Tycho SNR (`CAL-MEDIUM/MEDIUM`)

4 Conclusions

XMM-Newton users should almost never encounter in their XMM-Newton active life "calibration+science" exposures. If this occurs, users are recommended to exercise care in interpreting the corresponding spectra. The calibration source spectra imprint both strong narrow-band emission lines and a soft continuum. The region in energy close to the Al K_α (1.468 keV) and the Mn K_α and K_β (5.9–6.5 keV) are the most strongly affected. Inhomogeneous illumination of the camera may hamper accurate background subtraction even for astrophysically point-like sources.

We show in this document two examples of astrophysical sources observed with "calibration+science" filters: the Vela and the Tycho SNR. In spectra extracted from the latter observation, the best-fit centroid energy of the Fe emission line is shifted by 15–45 eV if a model for the spectrum of the calibration source is not included in the fit. While the energy of the soft X-ray lines in Vela are not substantially affected by the calibration source spectra, the latter ones add a substantial continuum contribution. A proper subtraction of this additional continuum component is problematic due to Vela extension. Once again, users are recommended to exercise care before drawing any astrophysical conclusions from these data.

Acknowledgments

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Table 1: Comparison of best-fit line energies (in eV) between standard and "calibration+science" exposures for the observations performed in January 2008 (Tycho) and June 2011 (Vela).

Observation type	EPIC-pn	EPIC-MOS1	EPIC-MOS2
Tycho - Si XIII			
Science filter	$1856.98\pm^{0.20}_{0.14}$	$1856.83\pm^{0.18}_{0.11}$	$1857.02\pm^{0.15}_{0.12}$
Calibration+science filter	$1856.89\pm^{0.16}_{0.11}$	1856.93 ± 0.11	$1857.31\pm^{0.12}_{0.10}$
Tycho - Fe			
Science filter	6446 ± 5	6432 ± 5	6427 ± 6
Calibration+science filter[a]	6476 ± 4	6446 ± 3	6473 ± 2
Calibration+science filter[b]	6449 ± 3	6437 ± 3	$6449\pm^{7}_{3}$
Vela - O VII			
Science filter	587.89 ± 0.11	569.8 ± 0.3	572.9 ± 0.4
Calibration+science filter	$588.6\pm^{0.2}_{0.7}$	567.5 ± 0.5	570.0 ± 0.4
Vela - Ne IX			
Science filter	937.01 ± 0.10	$920.8\pm^{0.7}_{0.5}$	922.5 ± 0.4
Calibration+science filter	$940.01\pm^{0.20}_{0.10}$	919.9 ± 0.7	$920.9\pm^{0.5}_{1.2}$

[a]the Fe line is fit with a simple Gaussian profile
[b]an empirical model of the calibration source spectrum is included in the fit: three unresolved Gaussian profiles, where the distance in energy between the Mn $K_{\alpha 1,2}$ and Mn K_{β}, and the intensity ratio between the Mn K_{α} doublet and the Mn K_{β} is set by the atomic physics.

References

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Guainazzi M., et al., 2013, XMM-SOC-CAL-PL-0001 (available at: `http://xmm2.esac.esa.int/docs/documents/CAL-PL-0001.pdf`)

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Turner M.J.L., et al., 2001, A&A 365, L27