XMM-Newton CCF Release Note

XMM-CCF-REL-0422

EPIC filter-wheel closed data

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1 CCF components

Name of CCF	VALDATE	List of Blocks changed	Change in CAL HB
EMOS1_FWC_0006.CCF	2000-01-01	EVENTS, EXPTIME	NO
EMOS2_FWC_0006.CCF	2000-01-01	EVENTS, EXPTIME	NO
EPN_FWC_0006.CCF	2000-01-01	EVENTS, EXPTIME	NO
EPN_FWC_EFF_0002.CCF	2000-01-01	EVENTS, EXPTIME	NO

2 Change

The EPIC CCD cameras on board XMM-Newton are equipped with a filter wheel system and 6 different filter setups. One of these is a CLOSED filter. Exposures taken with the filter wheel in the CLOSED position are dominated by the instrumental background and can be used to model and subtract the internal instrumental background.

Filter Wheel Closed (FWC) event lists exist and are available through the SOC web pages for EPIC-pn and EPIC-MOS and for the different EPIC modes. This CCF extends the FWC data currently available (see CAL-SRN-0344, CAL-SRN-0352, CAL-SRN-0379, CAL-SRN-0384 and CAL-SRN-0392) by adding events from revolutions made between 2022-04-06 (rev. 4089) and 2025-04-30 (rev. 4650). As in the previous release, for EPIC-pn, CCF files are available for events taken in Full Frame and Extended Full Frame mode. For EPIC-MOS, CCF files are available for events taken in Full Frame mode. As in the past release, the event files incorporate an additional column to the EVENTS extension. A column CCDNOISE, flags noisy chips according to: 0 - chip is good/not anomalous; 1 - chip is not good but not clearly anomalous; 2 - chip is clearly anonmalous; 3 - the chip is off.

An example of the EPIC-pn FF and EFF FWC CCF light curve, in bins of 100s, is shown in Fig. 1. The filter expression used to create these light curves was (FLAG==0 && PATTERN<= 4) and it shows the evolution of the non-sky background from early in the mission until revolution 4551 (2024-10-14).

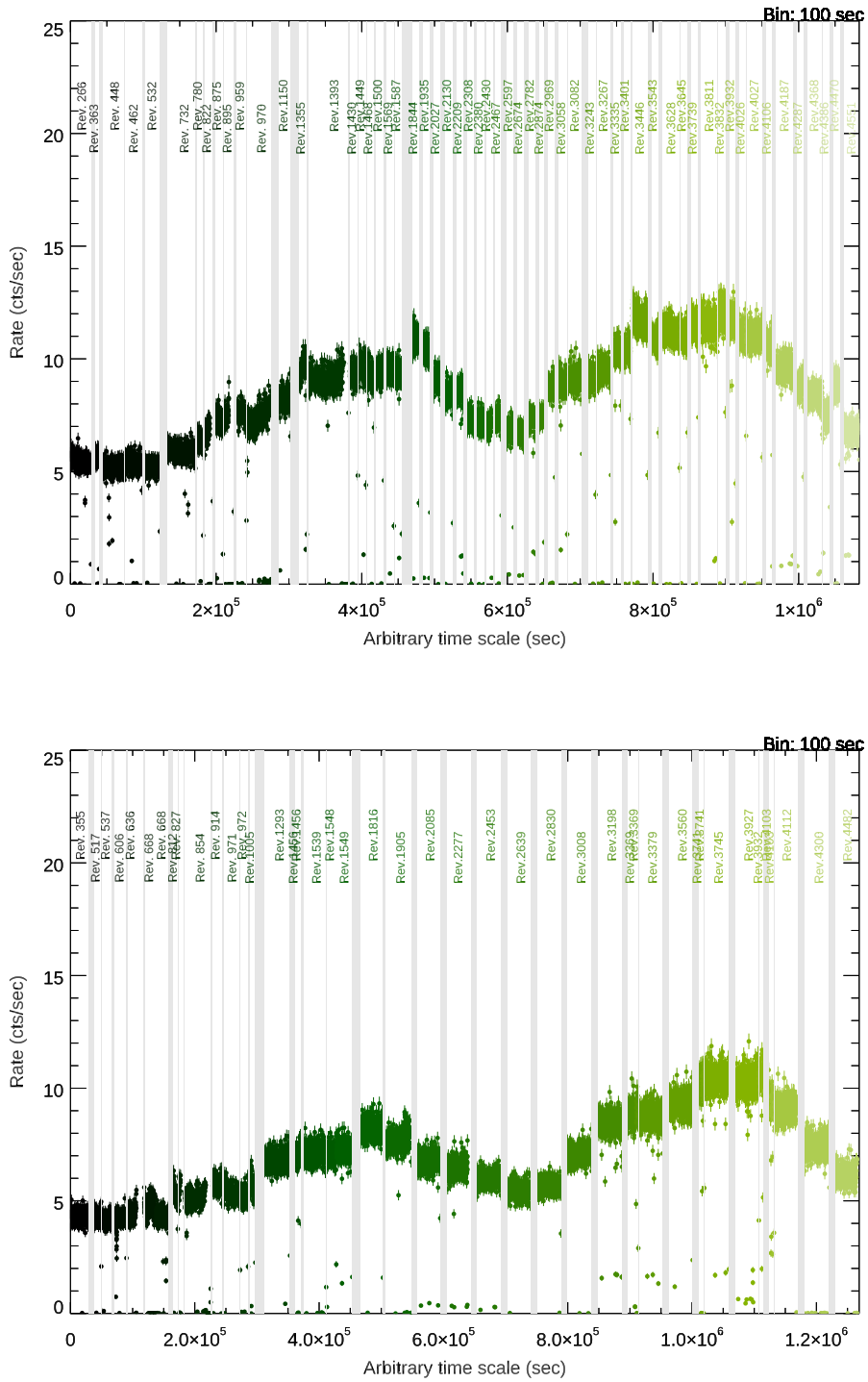


Figure 1: Sections of the EPIC-pn FF (top) and EFF (bottom) FWC events displayed in a 100s bin light curve. The figure represents the count rate, over the whole field of view and full energy range, extracted between revolutions 266 and 4551 (2001-05-22 to 2024-10-14). The X-axis times are arbitrary in the sense that the time origin corresponds to the time of the first available observation, and since the time gaps between observations are removed, the X-axis values only provide an approximation of the cumulative exposure duration. The width of the time gaps between exposures that is actually plotted is proportional to the real time gap been removed, i.e. some of the grey bands that mark the gaps are wider than others.

3 Scientific impact of this update

These CCFs can be used by several SAS tasks to generate an event file containing the expected instrumental background, or quiescent particle background (QPB), a QPB spectrum and a QPB image for a given observation and camera. The SAS task *evqpb* will do this by extracting the FWC data, for the given EPIC camera, from times closest to the science observation date. The generated FWC event file may be used to derive EPIC science exposure images with the QPB subtracted and to provide a better background subtraction for spectra and time series. *evqpb* supports EPIC FF mode data and for EPIC-pn also EFF mode data. The SAS task *qpbselect* (available since SASv19) expands the functionality of *evqpb* by using the number of discarded lines (NDISCLIN) to estimate the level of the QPB affecting a given science EPIC exposure. The task produces a corresponding QPB event file, image and spectrum that can be used to correct the science data. This last method is only valid for EPIC-pn, and as of SASv22, applicable only to FF and EFF mode data. In summary, with this CCF release, science observations in EPIC FF and EPIC-pn EFF made up until 2024-10-14 are fully supported by *evqpb*. For the case of *qpbselect*, all EPIC-pn FF and EFF science observations are fully supported for all dates.

The SAS task *qpbselect* uses the relation between the number of discarded lines (NDISCLIN) and the QPB rates. This relation is extracted from the data contained in the CCF. The relation between these two quantities takes the form:

$$Mean\ BKG\ Rate = Slope * Mean\ NDISCLIN + Intercept \tag{1}$$

where the Mean BKG Rate and Mean NDISCLIN are derived over the Good Time Intervals (GTI) of any given exposure. The coefficients (Slope and Intercept) for the three EPIC-pn modes, EFF, FF and LW are stored in the extension of the file EPN_FWC_0005.CCF and EPN_FWC_EFF_0001.CCF called DLCOEFF. Other useful information is also included in this extension;

EPIC-pn Mode	Slope	Intercept	Mean QPB Rate (cts/sec)	Exposure (ksec)
Extended Full Frame	0.0056	0.3827	2.942	885.6
Full Frame	0.0153	0.3650	3.066	757.5
Large Window	0.0241	0.1684	1.639	316.6

Table 1: Slope an intercept of the relation between the Mean BKG Rate and NDISCLIN for any given observation (see Equation 1). Mean QPB Rate and Exposure values derived from the full FWC respository for the indicated modes.

An example of the improvement which may be gained in image contrast by subtracting the QPB is shown for the supernova remnant, SN 1006-1, in Fig. 2.

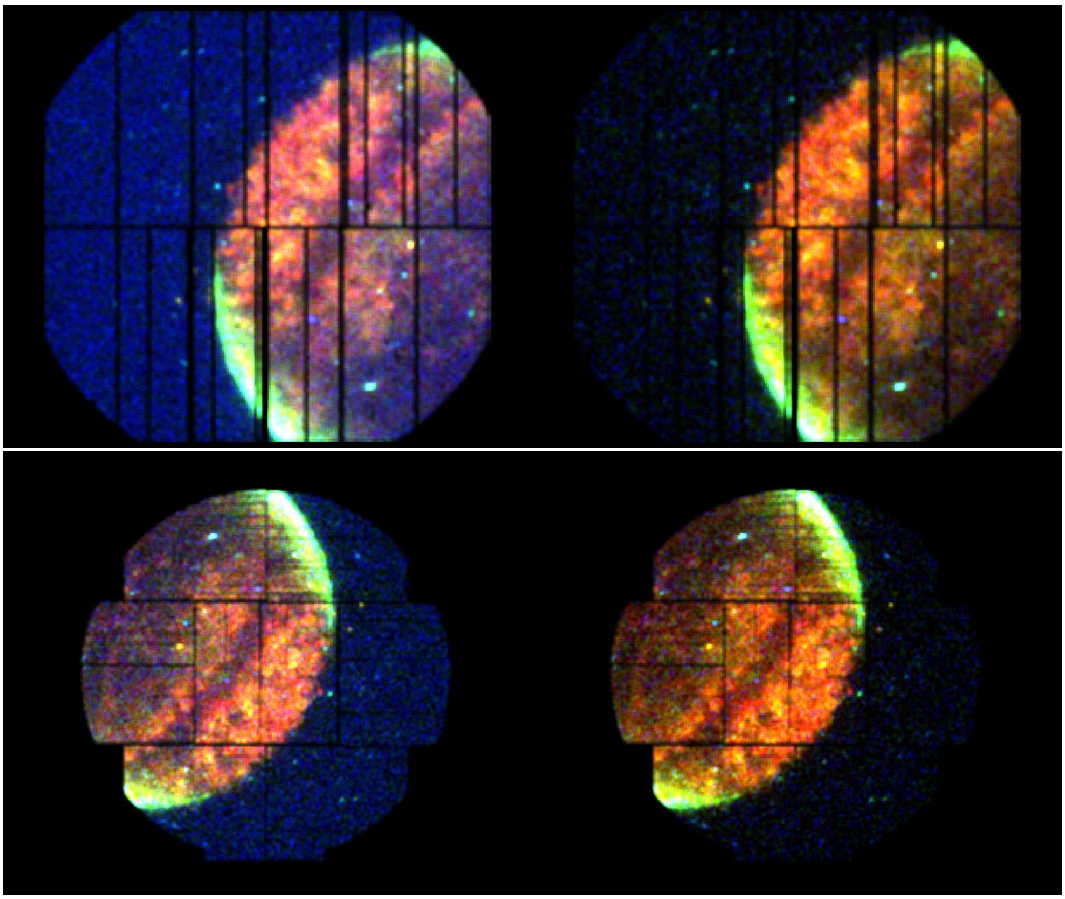


Figure 2: A PN EFF (top) and MOS-2 FF (bottom) image of SN 1006-1 from observation 0555630101 before (left) and after (right) correction for the QPB.

4 Estimated scientific quality

The quality of the results which can be derived from this FWC CCF release can be gauged by comparing the data found in the out-of-FOV regions of science observations to the correspondant data extracted from the CCF files.

In Fig 3, the spectra extracted from the FWC (pink) and another science exposure of an extended source, SN 1987-A (grey) taken with EPIC-pn in FF, from out-of-field-of-view events are compared. Ideally, the two spectra would be identical and the ratio of one to the other equal to 1 across all energies (yellow curve). However, the out-of-field data from the science exposure is contaminated by flux from the extended source SN 1987-A, hence, at low energies the agreement is not as expected, but at higher energies where there is no contribution from SN 1987-A, the spectra agree to within 10%, consistent with the previous CCF release.

5 Test procedure and results

Tests were run as part of the annual release of the FWC repository. For testing, the output of an IDL code that handles files from the FWC repository is checked against the output of the SAS tasks *evqpb* and *qpbselect*.

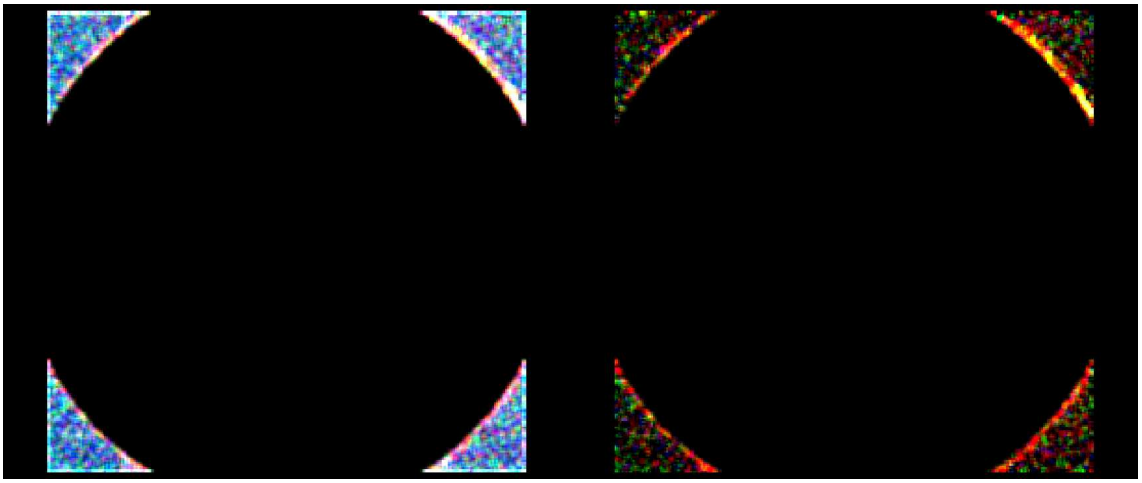
The test involves comparing the results obtained from the analysis of a science observation when using the FWC repository files directly against those obtained when running the SAS tasks *evqpb* and *qpbselect* in conjunction with the draft CCF files.

In particular, two science observation are used;

- obsid 0555630101 from rev 1594 (Source SN 1006-1). This observation is used to test the results of the EPIC-MOS exposures in FF mode and the EPIC-pn exposure in EFF mode.
- obsid 0690510101 from rev 2382 (Source SN 1987-A). This observation is used to test the results for the EPIC-pn exposure in FF mode.

In particular, the following things are checked:

- For *evqpb*, that the derived QPB spectra from the updated FWC repository provides a good representation of the chosen science spectra by checking that the scaling factor remains the same as in previous releases.
- For *qpbselect*, that the derived QPB spectra from the updated FWC repository provides a good representation of the chosen science spectra by checking that the derived Slope and Intercept provide consistent values with those derived in previous releases.



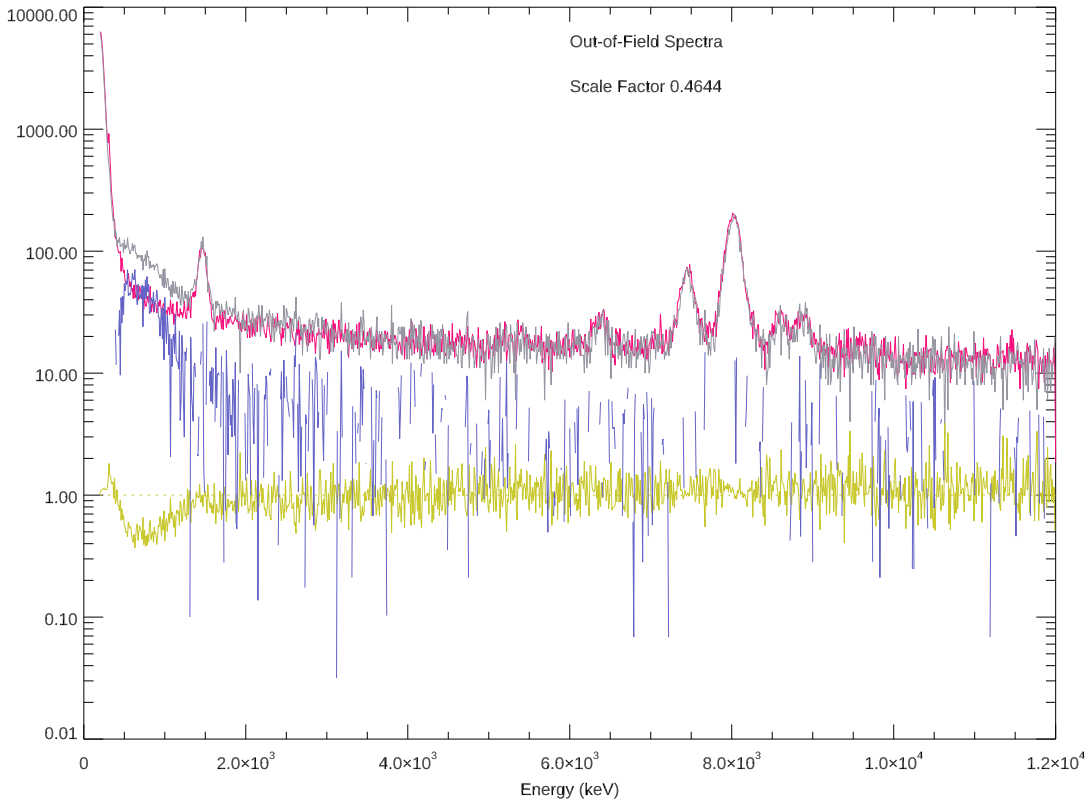


Figure 3: Top figure, an EPIC-pn FF image of SN 1987-A out-of-field-of-view events before (top left) and after (top right) QPB correction for observation 0690510101. Bottom figure, comparison of the spectrum of events from the out-of-field-of-view, of the same science observation 0690510101 (grey) and the spectrum derived from the EPIC-pn FF FWC data (pink) for this observation and extracted from the same spatial region. The yellow curve gives the ratio FWC / observation and should be equal to 1 across the entire energy range. The blue curve corresponds to the science spectrum minus the QPB spectrum. The excess emission from the science exposure seen at low energies ($< 2\ keV$) is due to contamination from the source SN 1987-A into the out-of-field-of-view region of EPIC-pn, as seen in the images above the spectra (top right corner of the camera).

- For *evqpb*, that the range of revolutions drawn from the FWC repository to build the FWC event file corresponding to the science observations are identical when extracting these files directly from the FWC repository (IDL code) as those extracted when using the SAS task in conjunction with the draft CCF files.
- For *evqpb*, that the derived FWC spectrum is identical when extracting it directly from the FWC repository (IDL code), and when using the SAS task *evqpb* in conjunction with the draft CCF files.
- For *qpbselect*, that the derived FWC spectrum is identical when extracting it directly from the FWC repository (IDL code), and when using the SAS task *qpbselect* in conjunction with the draft CCF files.

6 Future changes

This set of CCFs will continue to be updated periodically to include the most recent FWC data. Although the coefficients for EPIC-pn LW mode are included in this CCF release, FWC data for these two modes needs to be included in the release for *qpbselect* to work over this mode.

7 References

delaCalle et al. 2016, CAL-SRN-0344.
delaCalle et al. 2017, CAL-SRN-0352.
delaCalle et al. 2020, CAL-SRN-0379.
delaCalle et al. 2021, CAL-SRN-0384.
delaCalle et al. 2023, CAL-SRN-0392.