Summary of the 2021 EPIC Calibration and Operations Meeting

Calibration Sessions: 6-7 April 2021 (virtual)
Operations Session: 5 May 2021 (virtual)

Attendees

J. Ballet, L. Ballo, P. Calderon, I. de la Calle, K. Dennerl, J. Ebrero, T. Finn, K. Forster, M. Freyberg, F. Fuerst, R. Gonzalez, F. Haberl, A. Ibarra, Z. Igo, M. Kirsch, K. Kuntz, G. Lisini, K. Madsen, H. Marshall, S. Migliari, C. Pommranz, A. Read, P. Rodriguez, C. Sanchez, M. Santos-Lleo, R. Saxton, N. Schartel, S. Sembay, M. Smith, M. Stuhlinger, C. Tenzer, A. Tiengo, L. Tomas, I. Valtchanov, E. Verdugo, C. Wang, U. Weissman

Calibration Sessions

1. Review of open actions (M. Smith)

EPIC TTD-030/1 on J. Ebrero:
In view of the recent absolute timing analysis of the Crab pulsar, formulate watchout describing discrepant results, and make public.
Closed. Watch-out published.

EPIC TTD-030/2 on J. Ebrero:
Involve MOC (M. Kirsch) in investigating a possible G/S origin of the recent discrepant results.
Closed. No G/S issues found – discrepant results remain unexplained.

EPIC TTD-030/3 on I. Valtchanov:
Investigate whether the PN doubles-to-singles offset derived at Cu-K requires an update to the energy resolution at this energy.
Open.

EPIC TTD-030/4 on I. Valtchanov:
Investigate impact of out-of-time events in central CCDs for the Cu-Ka LTCTI calibration.
Closed. A mask is now used to limit events to directly illuminated parts of the detector.

EPIC TTD-030/5 on I. Valtchanov:
Current PN LTCTI correction as function of energy is constant above highest energy calibration data point. Investigate spectral impact of using an extrapolated energy dependence (e.g. power law), through a change in S/W and /or change in LTCTI CCF.
Closed. Results presented at 2019 IACHEC (Detector WG).

EPIC TTD-030/6 on M. Smith:
Initiate NRCO of N132D observation in SW mode, with source in nominal and frame

store area, in order to investigate fast-shift CTI.
Closed. NRCO #109 performed.

EPIC TTD-030/7 on M. Smith:
Recommend the use of a gain fit (within reasonable range, e.g. < 10 eV) in PN spectral analysis in the EPIC Calibration Status document.
Closed. Comment added to document.

EPIC TTD-030/8 on R. Saxton and K. Dennerl:
Start investigating the implementation of the parameterised RMF into SAS S/W.
Open.

EPIC TTD-030/9 on M. Freyberg:
Provide list of eROSITA cross calibration sources to the SOC.
Closed. Source list provided.

2. MOS monitoring (M. Stuhlinger)

- MOS line width evolution nearly stable, a small increase of less than 2 eV/yr at Mn.
- Significant drop of reconstructed calibration line energies for several peripheral CCDs, more serious at Mn than at Al, less significant in focal CCDs.
- Recent epoch of CTI calculations shows large spread of data points for several CCDs. CTI monitoring of MOS1 at statistical limit for most recent times.
- Consideration of long term CTI evolution for individual epochs currently in implementation stage.
- Bad pixel levels still low for active CCDs: MOS1 3-6% (except CCD4), MOS2 up to 3%.
- MOS1 "meteorite column" currently on calibrated offset level and can be used for science purposes.
- Mission operations successfully avoid science observations being performed at non-nominal focal plane temperatures.

3. PN monitoring (M.Smith)

- MOS background map analysis shows on-board offset should be changed by 1 ADU for MOS2 CCDs 5 and 6, although there is no immediate urgency.
- PN bad pixel levels and offset map trends very stable.
- PN CTI shows continued smooth increase, can in general be well modelled with a 2^{nd} order polynomial at Mn, whereas a linear model is sufficient at Al. Decay of calibration source means there are ever fewer observations of sufficient length to determine the CTI.
- CCD averaged energy reconstruction at Mn and Al within calibration requirements, although recent trend for CCD1 at Mn needs some adjustment.
- Steadily decreasing intrinsic energy resolution, by about 0.03-0.05 ADU/yr at Al and 0.1-0.2 ADU/yr at Mn.

4. Analytic modelling of the PN particle background spectrum (C. Wang)

Objective is to find analytic PN background model from filter wheel Closed spectra. The PN particle background is difficult to characterise due to the small out-of-FOV area. Residuals of up to 5 sigma in the background modelling are acceptable.

Previous work modelled the single pixel event background in the 0.2-13.9 keV band with

- a powerlaw at low energy
- two powerlaws + step function for continuum emission > 1.5 keV
- Gaussian emission lines

Double pixel events show differing spatial distributions, especially a complementary feature in the 0.7-13.9 keV band for patterns 1 versus 3 (vertical double events). Horizontal pixel events are modelled with:

- K-velocity distribution
- broken powerlaw
- linear model
- Gaussians for each fluorescence line

Vertical pixels events are modelled with:

- K-velocity distribution
- broken powerlaw (pattern==1) or double broken powerlaw (pattern==3)
- Gaussians

The combined model describes the pattern<=4 events to within 5 sigma. Future work includes improving the model and looking at time variation.

5. Backgrounds seen with XMM-Newton EPIC-pn and eROSITA (M. Freyberg)

Although eROSITA uses shielding in its design to avoid fluorescence, some impurities in the graded shield result in residual emission features (nevertheless, weaker than those seen in EPIC-pn).

In contrast to column-wise MIP rejection in EPIC-pn, the eROSITA MIP rejection is per region. Temporal analysis shows all cameras show similar variability. There is a coherent variability pattern which is close to the solar rotation period but also the lunar orbital period.

Situated at L2, eROSITA is affected by soft proton flares, although with lower occurrence rate than XMM-Newton or Chandra. The solar wind structure is highly variable, and corresponds at some level to that seen by XMM-Newton.

eROSITA has already suffered 4 micrometeoroid impacts, albeit with minor damage. Although the numbers are low, given its fewer than 2 years in orbit, this implies a significantly higher rate than that affecting XMM-Newton.

6. qpbselect: a SAS task to estimate the quiescent particle background (I. de la Calle)

Two tasks are used for estimating the QPB affecting EPIC data:

- evqpb: accumulate FWC data close in time as proxy for QPB level (for MOS and PN)
- qpbselect: use NDISCLIN parameter as proxy for level of QBP (for PN, currently only FF mode); new as of SAS 19.

The discarded line rates are stored in the PN event files (NDSLIN parameter in the HKAUX extensions) for FF, EFF and LW mode data. The temporal behaviour is generally similar across quadrants, although there can be significant differences. There is a strong correlation between mean background rate and mean NDSLIN value, although with mode-dependent linear coefficients.

Advantages of using NDSLIN data:

- evqpd is for FF mode only, whereas the NDSLIN method can be expanded to EFF and LW modes (for PN).
- The NDSLIN method uses the full FWC repository as opposed to evqpb which uses a subset.

However, using the full FWC repository requires the QPB spectra to be stable with time and level of QPB. Also, the scaling is dependent on mode and event selection. Investigations show fairly similar FWC spectra in different epochs, with largest change being a dip / emission at ~ 8 keV. There is a hint that the spectrum may be softening over time.

qpbselect is available as of SAS 19, currenly only for PN FF mode although this can be extended to EFF and LW modes.

Comment by M. Freyberg: although for SW mode the discarded lines are not calculated on-board, as the SAS processing does produce these values they could be propagated to the event files (just as for FF, EFF and LW modes).

ACTION EPIC TTD-031/1 on R.Saxton:
Propagate the PN SW mode discarded line rates to the calibrated events file (similarly to FF, EFF and LW modes). In addition, verify that the SW mode discarded line related exposure time correction is properly accounted for.

Comment by K. Kuntz: the MOS particle background shows a spectral change as function of the S/C with respect to the magnetopause. The hope is to analyse the PN data for a similar correlation.

7. NuSTAR calibration updates (K. Madsen)

Latest nustadas and CALDB updates include:

- A change in metrology duty cycle
- Temperature dependent ARF

- Improved astrometry
- MLI correction

Discrepancies are seen between FPMA/B spectra (although not always). Empirically this could be corrected through a reduced MLI fraction. Temperature sensor data also confirmed missing MLI; appears to be related to a micrometeoroid “event” (August 2017).

A possible incorrect budgeting of relevant components affecting the ARF, including MLI fraction and detector absorption layer, could affect the interpretation of straylight observation data. These results are also affected by the low energy RMF, which showed a peak ascribed to “shaper noise”. An improvement was obtained by fitting the RMF to straylight Crab data.

The ARF is being improved by fitting to average Crab straylight data in radial energy bins.

8. Updating the EPIC-pn effective area with the help of NuSTAR (F. Fuerst)

Aim is to correct the EPIC-pn ARF to reduce cross-calibration features seen with NuSTAR. Correction is derived using simultaneous observations of Crab and 3C 273, and tested on a sample of AGN observations.

Correction can be split into:

- Correction of spectral slope (and features)
- Normalisation correction

The stacked residuals of the PN-to-NuSTAR model shows a spectral “bump”. The residuals are corrected through a spline model (anchored at 3 and 12 keV); the correction is applied upwards of 3 keV and is ~ 5% at 9 keV.

NuSTAR focused / straylight correction factor is 0.866.

Applying the shape correction and NuSTAR straylight correction to 7 simultaneous observations of 3C 273 results in a total correction factor of 0.78.

A multiplicative XSPEC table model has been derived to apply the corrections in spectral fits.

Comment by F. Haberl: 20% effective area discrepancy is very difficult to explain. Note there may be mode dependencies between e.g. FF and TI modes, but only of up to ~ 5%. Only the mirror efficiency could explain the flux discrepancies. Also noted that the eROSITA fluxes are close to those of PN (although those of eROSITA are perhaps slightly higher).

Comment by K Madsen: the straylight normalisation should not be too much affected by the NuSTAR RMF adjustment.

9. Results from the IACHEC concordance analysis (H. Marshall)

The concordance analysis aims at an in-flight calibration of X-ray telescopes without absolute references. A main goal is to derive estimates of instrument effective areas for optimal agreement through “multiplicative shrinkage”.

Input data used so far includes observations of the SNR 1E0102 (at O and Ne), a sample of 42 2XMM catalog targets and ~107 bright XCal targets. Results were published.

A new paper will include above samples plus additional data of Capella with Chandra gratings, and take into account correlation of fluxes in different bands or of emission lines.

Besides correlations of effective areas across energy bands, an additional complication concerns assessing the priors. Current values used are those supplied by the respective instrument calibration teams.

Concordance works in simple comparisons, and yields reasonable answers. More complex situations will need to handle outliers, global correlations of band fluxes and time dependency of effective areas.

10. CORRAREA pipeline (C. Pommranz)

CORRAREA provides an empirical correction of the EPIC on-axis effective areas to address the energy dependent flux differences seen (of up to ~10% between MOS and PN at higher energies).

Correction determined by cross-calibration of the EPIC effective areas and to be implemented as energy-dependent multiplicative factor in the ARFs. The reference instrument is PN as it appears to be very stable over the XMM-Newton lifetime. The method adopted is the “fit-and-stack” approach.

The CORRAREA pipeline provides a high degree of automation in selecting, reducing and analysis the calibration data. Main source selection criteria are:

- Point-like
- Imaging modes
- Mode dependent count rate limits
- Near on-axis
- Out of galactic plane
- Non-crowded fields

Observations are visually screened for several factors, e.g. pile-up, source location, chip loss, source extent.

From the 3XMM catalog, ~163 good observations have been identified.

Fit-and-stack method:

- fit each spectrum to PN

- apply model to MOS
- stack source and model counts per instrument
- derive stacked data-to-model ratios

Automation is important in validation and recalibration resulting from additional data or future calibration changes.

The highly flexible, automated pipeline combined with large sample of modelled sources is not necessarily limited to the analysis of the CORRAREA correction, but can potentially be used to investigate other calibration issues, including cross-mission calibration.

Comment by N. Schartel: would it be possible to include an empirical correction of the MOS RMFs, similarly to that being doen for the ARFs?
Comment by R. Saxton: the parameterisation of the MOS RMF was performed by S. Sembay, and although some s/w tools are available to potentially continue this effort, there is no expertise at the SOC.

11. CORRAREA correction (M. Smith)

Fit-and-stack method applied to a sample of ~120 sources (near bore-sight, non-piled-up). Stacked residuals are normalised to those of PN.

The correction function consists of energy dependent multiplicative factors to the MOS effective areas. A simultaneous fit of a spline with equidistant nodes in log(E) is performed to minimise the normalised residual ratios for each MOS camera independently. Two correction functions are highlighted:

- a more conservative correction down to 2 keV
- a less conservative correction down to 0.15 keV

Both corrections work well on average, down to their respective energy cut-offs. However, in some individual cases, the less conservative function results in worsening fits below ~ 2 keV. This is ascribed to redistribution discrepancies which cannot be properly corrected through an effective area modification alone. The spectral classes with worsening fits tend to be those where the low energy counts are dominated by redistribution effects.

Additional validation needs to be done, comparing modes, time dependency and pattern selection. Discrepancies seen between MOS mono- and multi-pixel events will affect the shape of the respective correction.

Comment by J. Ballet: are there systematics in the flux ratios for the spectra where the correction yields worsening results?
Comment by M. Smith: this has not yet been looked at.

12. Updates on the EPIC vignetting from new raster observations of SNR G21.5-09 (I. Valtchanov)

Sources with multiple observations in 4XMM-DR7 were reported in the literature to show flux variations with off-axis angle, with larger variations towards larger angles. This was confirmed by repeating a similar analysis using 4XMM-DR10 data. However, the results are not straightforward to interpret due to the vignetting uncertainties.

A re-analysis of raster scan observations of the SNRs 3C58 and G21.5-09 was performed. These sources are relatively compact, not piled-up, non-variable and have emission above 2 keV. To complement the archival observations, for G21.5-09 additional raster scan observations were recently performed to fill gaps in phi and theta.

Preliminary results confirm the agreement with the empirical vignetting function for PN and MOS1 for the soft (0.2-2 keV) and hard (2-10 keV) bands. Also confirmed are the deviations for MOS2 for G21.5-09 seen in previous observations, characterized by systematically higher count-rates of ~10% in the soft band.

Comment by K. Dennerl: in vignetting analysis it is important to use consistent photon extraction radii.
Comment by I Valtchanov: confirms that care was taken to do just that.

13. EPIC-pn Full Frame and Extended Full Frame modes: long-term CTI correction at 8 keV (I. Valtchanov)

The fluorescent Cu-Ka emission is used to extend the energy scale calibration up to 8 keV. The emission is fairly homogeneous across the detector, except for a lack of emission in the detector centre. This region is masked to avoid including OoT events. For the non-central CCDs the full CCD area is used.

All FF and EFF mode science observations are used in the analysis: ~9000 FF and ~1600 EFF observations. Some filtering on acceptable line fit results reduces the final sample somewhat. In order to derive a suitable LTCTI modelling, data are reduced applying the QBG correction, but without applying the LTCTI correction.

Although deriving the LTCTI correction on the full CCD area (for non-central CCDs), when applying the derived correction the best results are obtained in the central region of the CCDs. This result is unexpected and not well understood, but a similar trend in spatial residuals can be seen in the Sanders et al. paper describing their correction.

These results need further investigation, and perhaps the LTCTI correction should be optimised for the regions furthest from the read-out (e.g. RAWY in 181-200).

The future steps for the implementation of the Sanders et al. correction are:

- 1st order gain correction for Cu Ka (along the lines of this presentation)
- 2nd order gain correction, with spatial modelling of Cu Ka residuals
- E scale correction using the “6-lines” model (time and position dependent).

14. EPIC duplicated frames issue (A. Ibarra)

Initially, two observations in revs 3789 and 3792 were found to contain duplicated events (but with a "valid" frame counter). In rev 3789, at a certain time data was being received from the past. All instrument processing was affected, albeit in different ways:

- RGS showed frame jumps and inconsistencies between GTI and EXPOSU extensions
- MOS processing did not produce correct event files
- PN processing produced event files, but warning messages related to time gaps were thrown
- OM exposure was missing

MOC reported G/S problems in those two revolutions.

A systematic check for duplicated frames in the revolution range 20-3896 was run. The procedure to remove duplicated rows in MOS and RGS is to delete duplicated rows in the AUX file and also the associated events from the duplicated frames. For PN a different procedure needs to be devised – work in progress.

For RGS and MOS a few 100s of cases of duplicated frames were found.

For RGS, ~95% of affected exposures show < 1% events affected. Light curve generation problem has been solved.

For MOS, ~95% of affected exposures show < 1% events affected. 3 observations show considerably more events. Part of the exposures can be recovered by deleting the duplicated frames.

A SAS task to handle this issue for RGS and MOS is in testing phase, with more detailed analysis ongoing.

15. Calibration of eROSITA (K. Dennerl)

SRG/eROSITA was launched in mid 2019. Whereas XMM-Newton is a satellite, eROSITA is a "payload", which implies operational differences. The 7 "telescope modules" together constitute one telescope, covering a substantially wider FOV than XMM-Newton. An advantage of the large FOV combined with the eRASS is the smearing out of the PSF.

Compared to XMM-Newton/PN, eROSITA has a:

- frame store region
- similar PSF
- similar effective area
- ~ 5 times larger grasp
- far more suppressed redistribution

Compared with expectations:

- The satellite is very stable and reliable.
- The observing efficiency is very high, at ~ 96%.

- The particle background is higher than expected (although the variability is less than expected).
- The radiation induced CTI increase is slightly higher than expected.
- The CCDs are operating at higher than expected temperatures.
- There have been several micrometeoroid damages.
- Frequent camera resets are required.
- No sign of contamination, even after orbit corrections with associated combusted fuels.

On-axis PSF is determined using sub-pixel information; the 16” HEW is close to the specification.

Off-axis PSF determined by operating the CCD in “charge accumulation mode”. In this mode, the suppression of MIP events is a challenge.

The eROSITA plate scale is energy dependent due to different mirror shells contributing at different energies (e.g., high energies are dominated by the innermost shells).

In-flight energy calibration utilises an internal Fe55 source yielding emission lines at Mn-K, Al-K and Ti-K.

The expected rate increase for the eROSITA CTI is slightly higher than that seen for EPIC-pn, although the absolute eROSITA CTE is significantly lower. The CTI and gain can be measured for individual columns, and shows some column-to-column temporal variation.

There remain important synergies between eROSITA and EPIC-pn calibration, e.g. the energy scale and redistribution calibration.

<u>Operations Session</u>

1. XMM-Newton MOC and S/C status (M. Kirsch)

Since mid March 2020, XMM-Newton is being operated under COVID restrictions. Very smooth transition to home-office due to the flexibility of the team.

Mission performance indicators remain well above KPI requirements, even under COVID limitations:

- Ground segment availability > 85%
- Data recovery > 95%
- Science operations efficiency > 70%

SPACON merger required counter measures to mitigate science impact. Some level of science loss was predicted as acceptable cost of merger. Science loss has been significantly reduced after automation in 2019, and lies below 0.5% for all instruments except OM.

Spacecraft subsystems are all healthy and with good margins. Number of thruster pulses is nearing the qualification level. Although a fully redundant B-system is available, industry recommendation is to stay on the A-system.

With respect to the orbit, the perigee is healthy, and radiation is not going to be a problem until the 2030s. However, there will be two periods (in 2021-2023 and 2027-2028) with elevated debris flux in GEO equator – this necessitates operational collision prediction and avoidance.

Solar cell power still within health margins: power generation nominal and no signs of unexpected degradation.

The 2021 fuel estimates predict a lifetime into the 2030s (assuming no ESAMs). Fuel consumption is 2.5 kg/year (down from the 6 kg/year before the 4WD implementation).

Fuel migration operations replenish the main tank from the auxiliary tanks. This is done through controlled thermal excursions. The whole process takes approximately a week, with the S/C pointing constrained with respect to the Sun to aid thermal control. The first replenishment was successfully performed in 2020 (under COVID conditions). Further replenishments will need to be performed every ~2 years (although not in 2021).

Mission operations are running smoothly, with several procedures being automated to increase safety and efficiency. XMM/INT hardware migration planned for 2021-2022 should cover the ensuing decade.

2. XMM-Newton SOC status report (M. Santos-Lleo)

Since February 2020, measures were being taken to address the COVID pandemic. Despite the new conditions, within a few weeks operations were working nominally.

The 2019 and 2020 Nobel Prizes for physics were awarded for advances in fields where XMM-Newton science has contributed significantly (black holes, exoplanets and cosmology).

The 20th anniversary of XMM-Newton's launch was celebrated in 2019. Unfortunately, the X-ray Universe 2020 conference had to be cancelled due to the pandemic. There was a special XMM session at the EAS virtual meeting.

The AOs remain heavily oversubscribed, by factors of 7.7 and 6.9 for AO19 and AO20 respectively.

The S/C subsystems and instruments remain healthy.

Due to COVID, scheduling is being performed remotely. Although it is now routine, the implementation was not easy.

Mission extensions now occur on a rolling 3-year basis. The XMM-Newton mission extension has been formally approved until 2022, with an indicative extension until the end of 2025.

Recent scientific discoveries show the power of the synergy of XMM-Newton with other observatories.

3. Status of EPIC operations (P. Calderon)

The EPIC instruments continue to be working well. Routine operations continue to run automatically from SOC Mission Planning products. Non-nominal operations are divided between MOS and SOC, with MOC taking care of immediate actions and SOC giving expert support.

Several instrumental incidents to be noted:

- MOS 1 EMCR SW crash and auto reboot to ROM version (22 May 2019).
- PN EPCE warm reset (16 Sep 2019). First instance in more than 3 years.
- MOS 1 voltage lines drop to 0 (11 Oct 2019). This was a recurrence of NCR#126 with the previous case in 2015.
- MOS 2 voltage line drop to 0 (27 Jan 2020). Instrument switched to OFF with substitution heaters on. Slow recovery (as both SOC Instruments Experts were unavailable, on flights to ESOC) with resulting large temperature excursions, especially for MOS (+40 deg C excursion). Another case of NCR#126.
- MOS 2 voltage line drop to 0 (8 Aug 2020). Recovery started on the next morning The maximum CCD temperatures were PN -80.0 deg C, MOS1 -69.23 deg C and MOS2 -76.92 deg C.
- MOS 1 on-board SW crash (6 Dec 2020). Instrument stopped sending telemetry.
- MOS 1 message indicating Annealing Circuit Current Limiter Activation (8 Mar 2021). SEU in the current limiter, or on the reporting HW / SW.
- MOS 2 voltage line drop to 0 (17 Mar 2021). Another occurrence of NCR#126.

Since March 2019 there have been 4 eclipse seasons, with very few incidents. The favourable orbit evolution means eclipses with fewer GS gaps and sufficient time for automated operations windows.

4. Instrument automation 2.0 (U. Weissman)

Possible instrument operations contingencies:

- SCOS TimeLine interruption, while on-going instrument commanding, or Slew commanding. Accounts for ~ 70% of contingencies.
- High radiation while ready for observation. Accounts for ~ 30% of contingencies.
- Instrument misbehaviour. Occurs quite rarely.

Instrument contingency recovery consists of:

- Decouple from running TimeLine
- Set to Safe configuration
- Analyse the cause

- Recover from Safe configuration
- Rejoin operation to running TimeLine

A Beta version of automation has been operational since 2015. It consists of the automation of OM related issues, ERM crash recovery, End of revolution Safety TTAGs check and deletion, and eclipse operations.

Automation 1.0 was started due to merger with Gaia operations, when SPACONS were released from XMM instrument operations requiring real-time decision making. Contingency procedures were developed to ensure instrument safety. Recovery and rejoinder was left to Ops Analyst.

Timeline rejoinder procedures require awareness of current and next planned windows, and instrument mode and filter configurations. Implementation of this functionality constituted a leap from plain to intelligent automation.

Next steps in Automation 2.0 are:

- EPIC rejoin procedures depending on whether the exposure is the same. Will save time (up to 40 min for PN and 15 min for MOS).
- ERM rejoin depending on revolution phase.
- Detect radiation going low and trigger rejoinder procedures.
- Enable all instruments at the start of critical windows.
- Automation of instrument recovery after eclipse problems.

Ideas and implementation require close cooperation between MOC and SOC.

Future plans for Automation 3.0 include executing timeline rejoinder procedures for all instruments in parallel, and handle potential instrument degraded mode operations.

<u>Summary of open actions</u>

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Investigate whether the PN doubles-to-singles offset derived at Cu-K requires an update to the energy resolution at this energy.

EPIC TTD-030/8 on R. Saxton and K. Dennerl:
Start investigating the implementation of the parameterised RMF into SAS S/W.

EPIC TTD-031/1 on R. Saxton:
Propagate the PN SW mode discarded line rates to the calibrated events file (similarly to FF, EFF and LW modes). In addition, verify that the SW mode discarded line related exposure time correction is properly accounted for.