Swift-XRT Calibration Update

Andy Beardmore
University of Leicester
on behalf of the
Swift-XRT Team
IACHEC, 2014
1. XRT Operations
   - Onboard Event Threshold
   - WT Bias Estimation

2. Calibration
   - Gain / CTI / Trap Mapping
   - RMF Status
Both the Windowed Timing (WT) and Photon Counting (PC) mode event thresholds were fixed at 80DN shortly after launch.

- Originally set to 40DN, but pointings close ($\lesssim 45^\circ$) to the bright Earth cause excessive counts (optical loading) at low energies.

- Evolution of CCD gain/CTI/traps caused the effective energy of the threshold to increase from $210 \rightarrow 320$ eV by 2013-Dec.
Test observation of Mkn 421 performed with and without a reduced event threshold.

Suggests reducing threshold to 60DN would recover the low E events.
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WT event threshold was reduced to 60 DN ($\sim 260$ eV) on 2013-Dec-11.
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WT event threshold was reduced to 60 DN ($\sim 260$ eV) on 2013-Dec-11.

PC mode shows smaller trap depths — its effective threshold is still below 300 eV.

- Evaluating future PC threshold reduction
After WT event threshold change, XRT occasionally stayed in WT mode when it should have automatically switched to PC mode.

Origin was a hot-column in WT mode caused by inadequate bias row subtraction.

Fixed by changing the on-board ULD used in the bias row calculation from 80 → 150 DN (2014-Jan-16).
Partially hot column at DETX=295 not masked out on-board.

- Occasionally records values above the 80 DN ULD used in the bias-row calculation → insufficient charge in the bias-row estimate → residual events
- Increasing the bias-row ULD to 150 DN ensures a better bias-row calculation and removes offending events from telemetry.
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Outline

1. XRT Operations
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Gain/CTI are tracked using Fe-55 ‘corner source’ data and continue to evolve

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- CCD charge traps mapped using Si-Kα line in Tycho SNR.
- Trap corrections ensure good recovery of the line FWHM
  - WT : FWHM 270 → 170 eV
  - PC : FWHM 210 → 150 eV
Substrate voltage change (from 0V to 6V) on 2007-Aug-30 → reduction in depletion depth → QE change

Release different RMFs for Vss=0V and 6V
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- Release different RMFs for Vss=0V and 6V

Current CALDB RMFs (generated by CCD22 MC code):

\[\text{Vss = 0V}\]

  - 2 epochs:
    - 2001-01-01 – 2007-01-01
    - 2007-01-01 – 2007-08-31
Substrate voltage change (from 0V to 6V) on 2007-Aug-30 $\rightarrow$ reduction in depletion depth $\rightarrow$ QE change

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- Current CALDB RMFs (generated by CCD22 MC code):

**Vss = 0V**
- 2 epochs:
  - 2001-01-01 – 2007-01-01
  - 2007-01-01 – 2007-08-31

**Vss = 6V**
- 2013-Dec-20 release.
  - 2007-09-01 – …
V_{ss} = 6V \text{ RMFs}

- MC code input parameters (e.g. depletion depth) calibrated on
\( V_{\text{SS}} = 6 \text{V} \) RMFs

- MC code input parameters (e.g. depletion depth) calibrated on
  - Fe-55 (trap free) corner source data (PC) → redistribution

\[
\begin{array}{c}
\text{grade 0} \\
\text{grade 1} - 4 \\
\text{grade 5} - 12 \\
\text{grade 31}
\end{array}
\]
MC code input parameters (e.g. depletion depth) calibrated on
- Fe-55 (trap free) corner source data (PC) → redistribution
- PKS0754–19 and SNRG21.5, RXJ1856 (PC effective area)
$V_{SS} = 6V$ RMFs

- MC code input parameters (e.g. depletion depth) calibrated on
  - Fe-55 (trap free) corner source data (PC) → redistribution
  - PKS0754–19 and SNRG21.5, RXJ1856 (PC effective area)
  - PKS2155–304, 3C273, RXJ1856 (WT effective area)
Epoch dependent RMFs created for $V_{ss}=6V$, tracking line broadening (by increasing CTI and electronic noise) and effective event threshold evolution.

Now have $V_{ss} = 6V$ RMFs for the following epochs ready to release:

- 2007-09-01 – 2008-12-31 (WT/PC)
- 2009-01-01 – 2010-12-31 (WT/PC)
- 2011-01-01 – 2012-12-31 (WT/PC)
- 2013-12-12 – … (WT)
SNR E0102 used to calibrate the trap-correction energy dependence at low-E and verify line broadening:
Position Dependent WT RMFs

- WT readout clocks 10 rows into the serial register which is then read-out.
  - Causes event splitting at the 10-row binning boundaries → strong redistribution tail in absorbed sources
- RMFs originally created assuming an uniform intensity distribution for the incident photons in the MC simulation
- Point-source distribution can concentrate a higher fraction of photons on the 10-row binning boundary → more splitting
  - Depends on the DETY location of the point source centre
Point source position dependence and event threshold evolution alter the redistribution properties of absorbed sources in WT:

**Position dependence:**

![Graph 1](image1)

- NH = 5e21 cm$^{-2}$
- DETY = 300.5

![Graph 2](image2)

- NH = 5e22 cm$^{-2}$
- DETY = 300.5

**Threshold dependence:**

![Graph 3](image3)

- NH = 5e21 cm$^{-2}$
- Thr = 260eV

![Graph 4](image4)

- NH = 5e22 cm$^{-2}$
- Thr = 260eV
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- Point-source distribution can concentrate a higher fraction of photons on the 10-row binning boundary → more splitting
  - Depends on the DETY location of the point source centre
- Led to the creation of WT RMFs at 3 positions with respect to the 10-row binning boundaries
- Factor in additional epoch (7) and grade (2) dependence → $7 \times 3 \times 2 = 42$ additional WT RMFs
- However, can’t (currently) predict source DETY position accurately enough in WT mode
  - RMFs to be used to explore any systematic effects associated with the 10-row binning when spectral fitting WT data.
- QE changes slightly with position
- Ratios of QEs from position dependent RMFs to uniform RMFs:

  **Grade 0 – 2**

  ![Graph showing energy versus ratio for Grade 0 - 2](image)

  **Grade 0**

  ![Graph showing energy versus ratio for Grade 0](image)
QE changes slightly with position $\rightarrow$ grade migration

Ratios of QEs from position dependent RMFs to uniform RMFs:

Grade 0 – 2

Grade 0
Cyg X-3 observations (2008-Apr)

Snapshot 1:

- **Position Dependent WT RMFs**
- **Cyg X-3 observations (2008-Apr)**

- **Snapshot 2:**
  - **Position Dependent WT RMFs**
  - **Cyg X-3 observations (2008-Apr)**
XRT still operating nominally, with slight spectral degradation after trap-corrections.

Expect a lot more RMFs in the CALDB soon!