# *Swift*-XRT Calibration Update

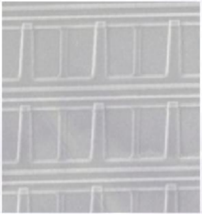

Andy Beardmore

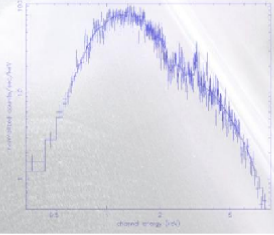
University of Leicester

on behalf of the

*Swift*-XRT Team


IACHEC, 2014



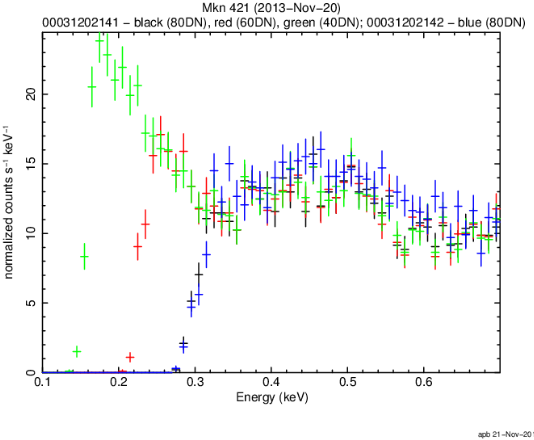


1. XRT Operations
   - Onboard Event Threshold
   - WT Bias Estimation
2. Calibration
   - Gain / CTI / Trap Mapping
   - RMF Status

# Onboard Event Threshold

- 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.

# Onboard Event Threshold

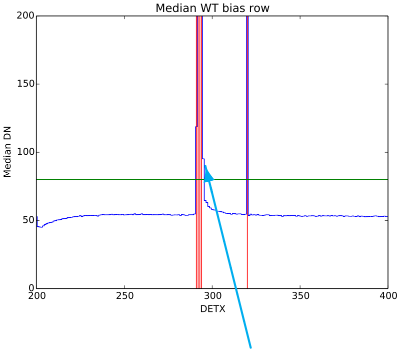
- Both the Windowed Timing (WT) and Photon Counting (PC) mode event thresholds were fixed at 80DN shortly after launch.
  - Originally set to 40DN, but pointings close ($\lesssim 45^\circ$) to the bright Earth cause excessive counts (optical loading) at low energies.
- Evolution of CCD gain/CTI/traps caused the effective energy of the threshold to increase from 210 $\rightarrow$ 320 eV by 2013-Dec.
- WT event threshold was reduced to 60 DN ($\sim$ 260 eV) on 2013-Dec-11.

# Onboard Event Threshold

- 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.
- 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

# WT Bias Row Estimation

- 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.



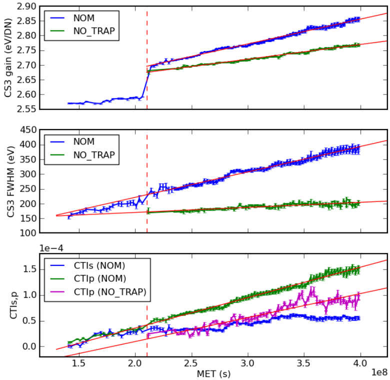

- Partially hot column at DETX=295 not masked out on-board.
  - Occasionally records values above the 80 DN ULD used in the bias-row calculation → insufficient charge in the bias-row estimate → residual events
  - Increasing the bias-row ULD to 150 DN ensures a better bias-row calculation and removes offending events from telemetry.

# WT Bias Row Estimation

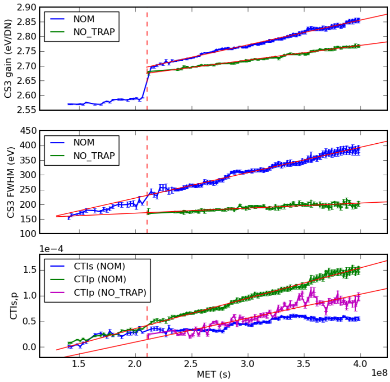
- After WT event threshold change, XRT occasionally stayed in WT mode when it should have automatically switched to PC mode.
- Origin was a hot-column in WT mode caused by inadequate bias row subtraction.
- Fixed by changing the on-board ULD used in the bias row calculation from 80 $\rightarrow$ 150 DN (2014-Jan-16).

1. XRT Operations
   - Onboard Event Threshold
   - WT Bias Estimation
2. Calibration
   - Gain / CTI / Trap Mapping
   - RMF Status

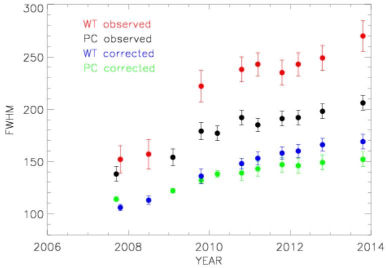
- Gain/CTI are tracked using Fe-55 ‘corner source’ data and continue to evolve
    - NO_TRAP derived from the best 5 trap free columns



- Gain/CTI are tracked using Fe-55 ‘corner source’ data and continue to evolve
    - NO_TRAP derived from the best 5 trap free columns




- CCD charge traps mapped using Si-K$\alpha$ line in Tycho SNR.
- Trap corrections ensure good recovery of the line FWHM
    - WT : FWHM 270 $\rightarrow$ 170 eV
    - PC : FWHM 210 $\rightarrow$ 150 eV



- Substrate voltage change (from 0V to 6V) on 2007-Aug-30 $\rightarrow$ reduction in depletion depth $\rightarrow$ QE change
  - Release different RMFs for Vss=0V and 6V

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

**Vss = 0V**

- 2013-Mar-13 release.
  2 epochs :
  - 2001-01-01 – 2007-01-01
  - 2007-01-01 – 2007-08-31

# Current CALDB RMFs

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

**Vss = 0V**

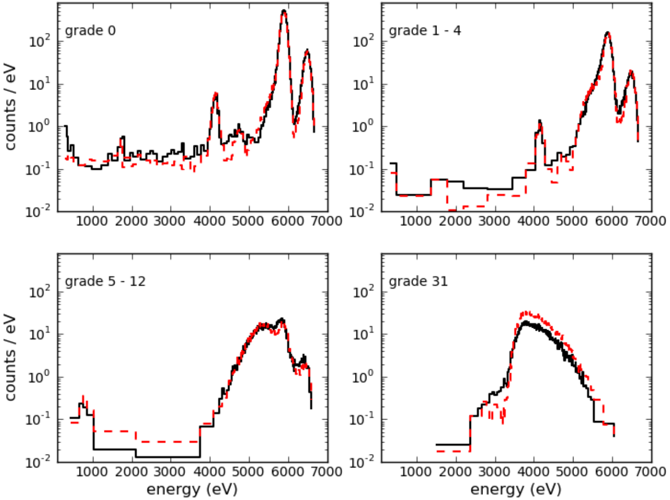
- 2013-Mar-13 release.
  2 epochs :
  - 2001-01-01 – 2007-01-01
  - 2007-01-01 – 2007-08-31

**Vss = 6V**

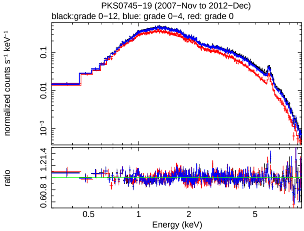
- 2013-Dec-20 release.
  - 2007-09-01 – . . .

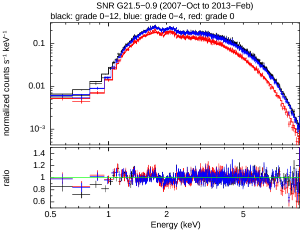
- MC code input parameters (e.g. depletion depth) calibrated on

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



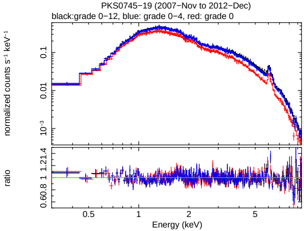
- MC code input parameters (e.g. depletion depth) calibrated on
  - Fe-55 (trap free) corner source data (PC) $\rightarrow$ redistribution
  - PKS0754–19 and SNRG21.5, RXJ1856 (PC effective area)

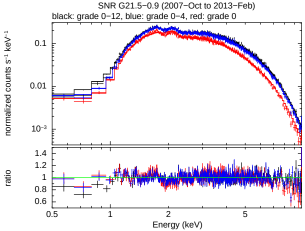


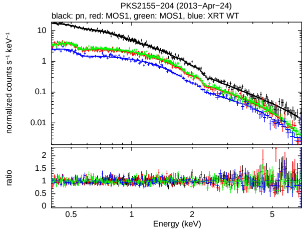



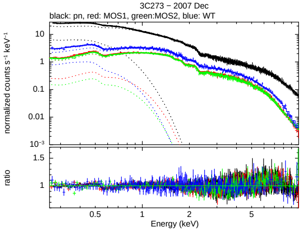
# $V_{ss} = 6V$ RMFs

- MC code input parameters (e.g. depletion depth) calibrated on
  - Fe-55 (trap free) corner source data (PC) $\rightarrow$ redistribution
  - PKS0754–19 and SNRG21.5, RXJ1856 (PC effective area)
  - PKS2155–304, 3C273, RXJ1856 (WT effective area)



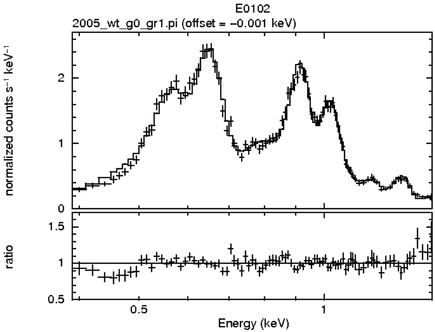



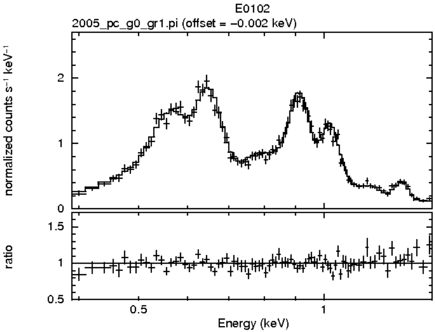



- Epoch dependent RMFs created for Vss=6V, tracking line broadening (by increasing CTI and electronic noise) and effective event threshold evolution.
- Now have $\mathrm{V}_{\mathrm{ss}} = 6\mathrm{V}$ RMFs for the following epochs ready to release :
  - 2007-09-01 – 2008-12-31 (WT/PC)
  - 2009-01-01 – 2010-12-31 (WT/PC)
  - 2011-01-01 – 2012-12-31 (WT/PC)
  - 2013-01-01 – 2013-12-11 (WT) 2013-01-01 – . . . (PC)
  - 2013-12-12 – . . . (WT)

# Epoch Dependent RMFs (cont'd)

- SNR E0102 used to calibrate the trap-correction energy dependence at low-E and verify line broadening :



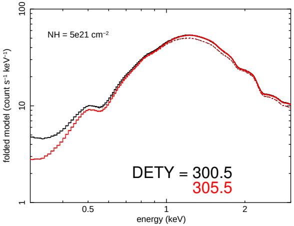



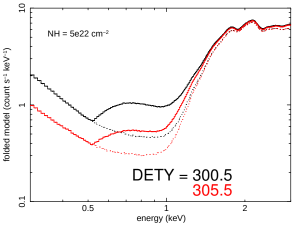
# Position Dependent WT RMFs

- WT readout clocks 10 rows into the serial register which is then read-out.
  - Causes event splitting at the 10-row binning boundaries $\rightarrow$ 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 $\rightarrow$ more splitting
  - Depends on the DETY location of the point source centre

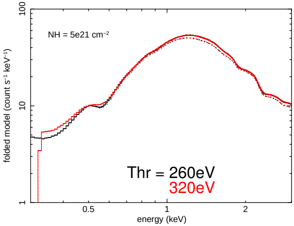
- Point source position dependence and event threshold evolution alter the redistribution properties of absorbed sources in WT :

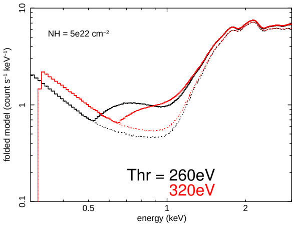
## Position dependence :




## Threshold dependence :

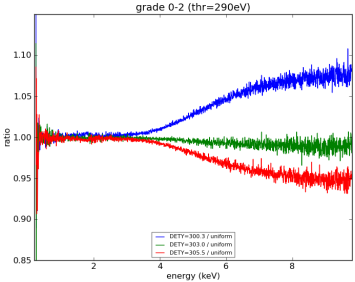


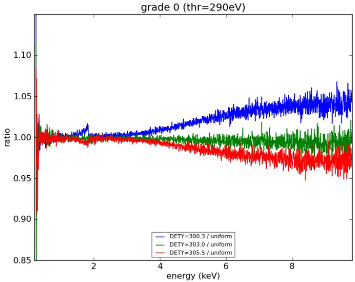
- WT readout clocks 10 rows into the serial register which is then read-out.
  - Causes event splitting at the 10-row binning boundaries → strong redistribution tail in absorbed sources
- RMFs originally created assuming an uniform intensity distribution for the incident photons in the MC simulation
- 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
- 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

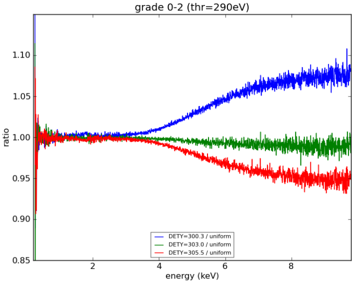



Grade 0

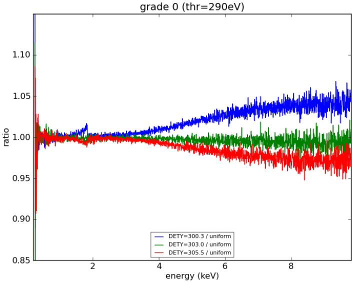


- QE changes slightly with position → grade migration
- Ratios of QEs from position dependent RMFs to uniform RMFs :

Grade 0 – 2

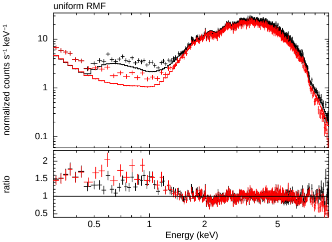


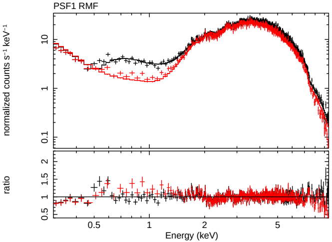

Grade 0



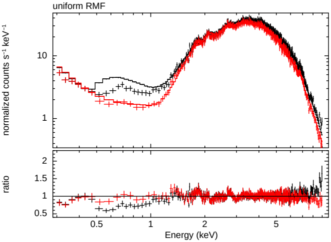
- Cyg X-3 observations (2008-Apr)

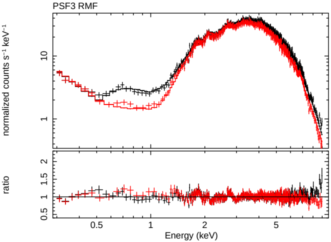
Snapshot 1 :




Snapshot 2 :



- XRT still operating nominally, with slight spectral degredation after trap-corrections.
- Expect a lot more RMFs in the CALDB soon !