Swift-XRT Calibration Update

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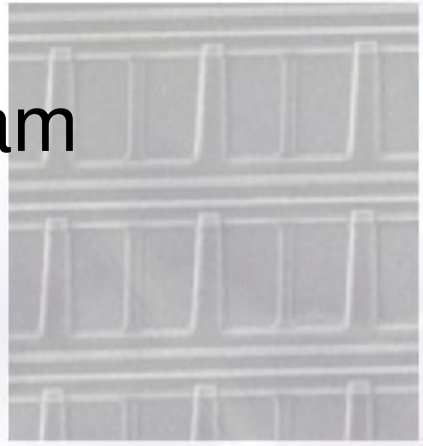
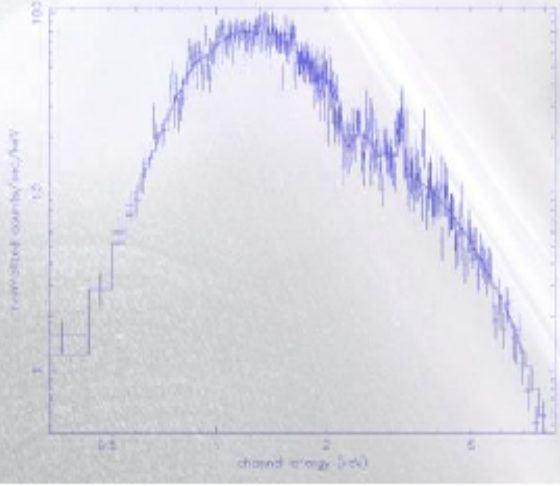
on behalf of *Swift*-XRT Team

University of Leicester

Avigliano Umbro, 2018-Apr-10



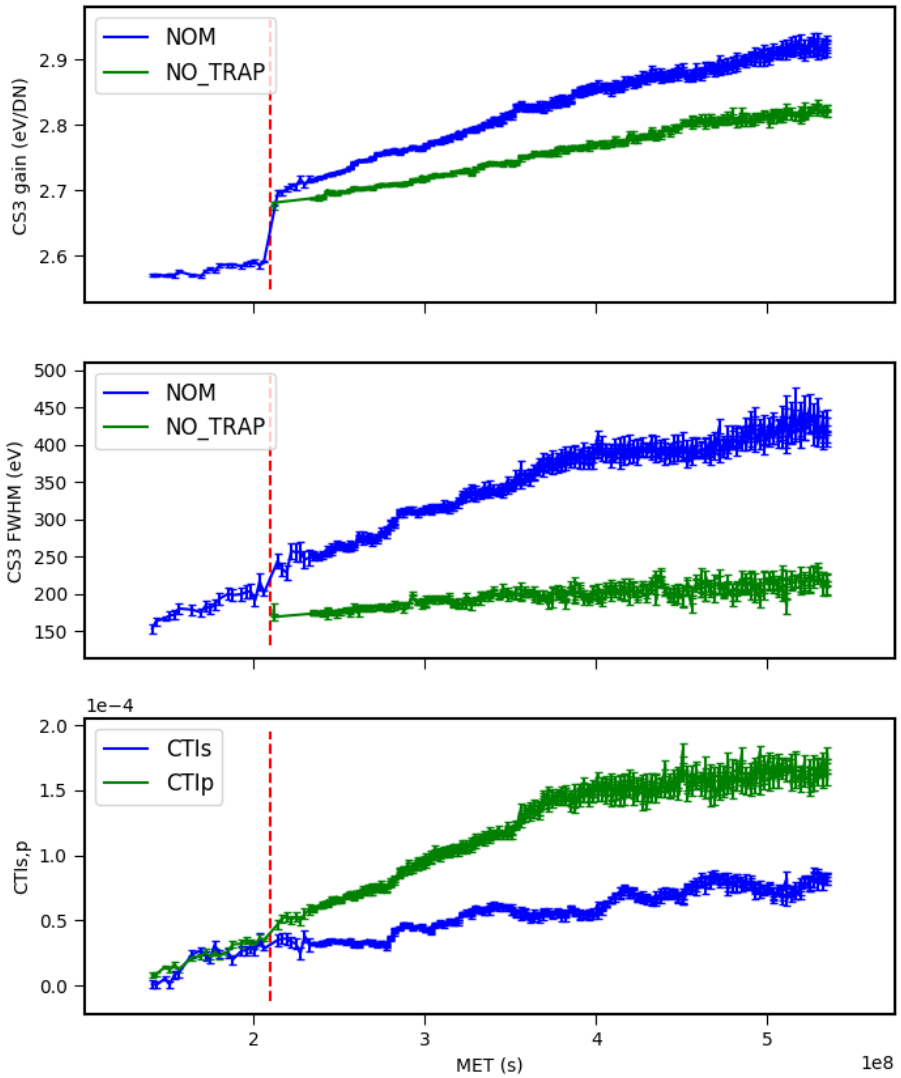


XRT Calibration

Gain Calibration

Gain/CTI:

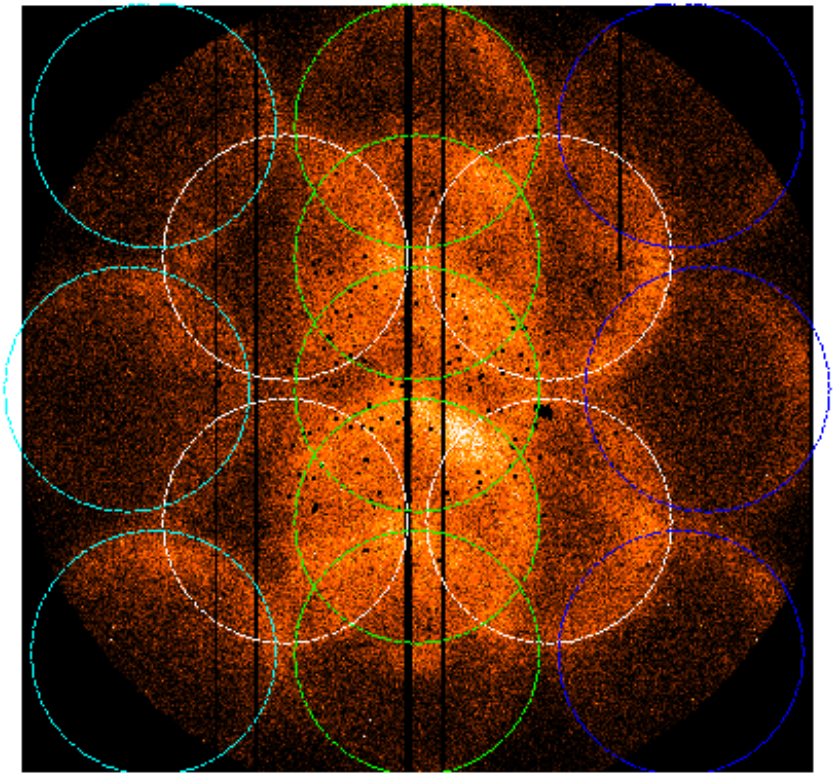
- Measured from Fe-55 corner source data (plotted at -60C)
  - NOM – all columns in CS
  - NO_TRAP – the best 5, trap free, columns
- Gain file is also CCD temperature dependent – CALDB parameters stored at 3 temperatures (-70C, -60C, -50C) and interpolated.



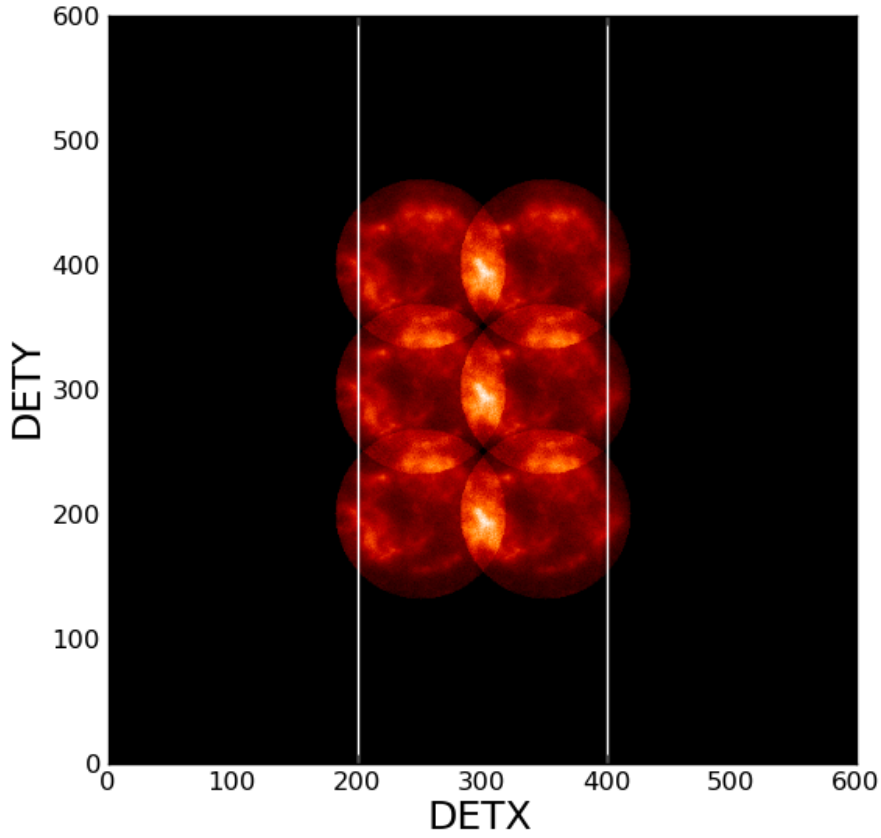
Charge Trap Mapping

- After $\sim$ 3 years, CTI became more and more dominated by the formation of deep charge traps in individual pixels
- Traps mapped yearly using Si-Kα line in Tycho & Cas A SNRs.

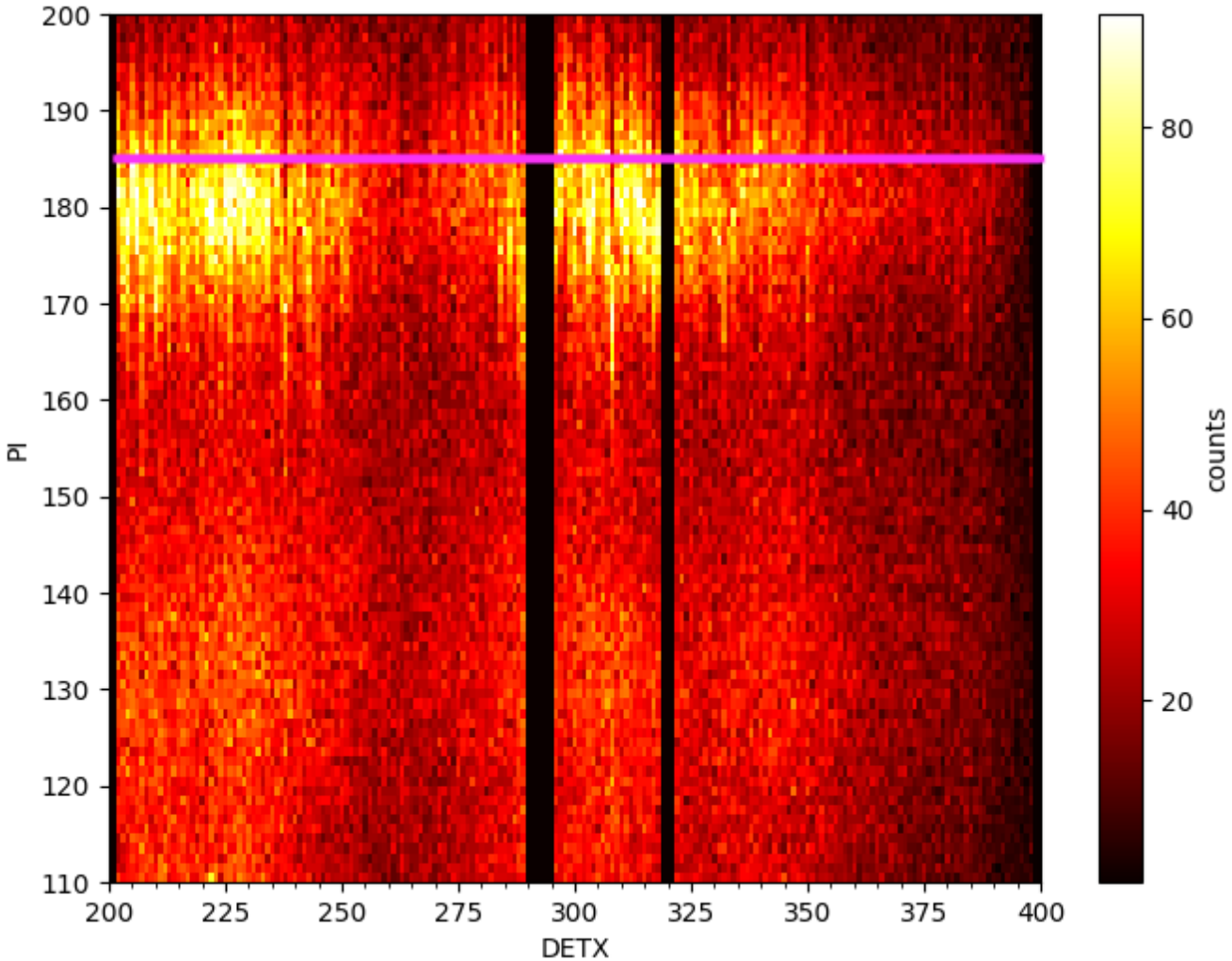
PC Mode - Tycho (15 x 20ks)



WT Mode - Cas A (6 x 10ks)

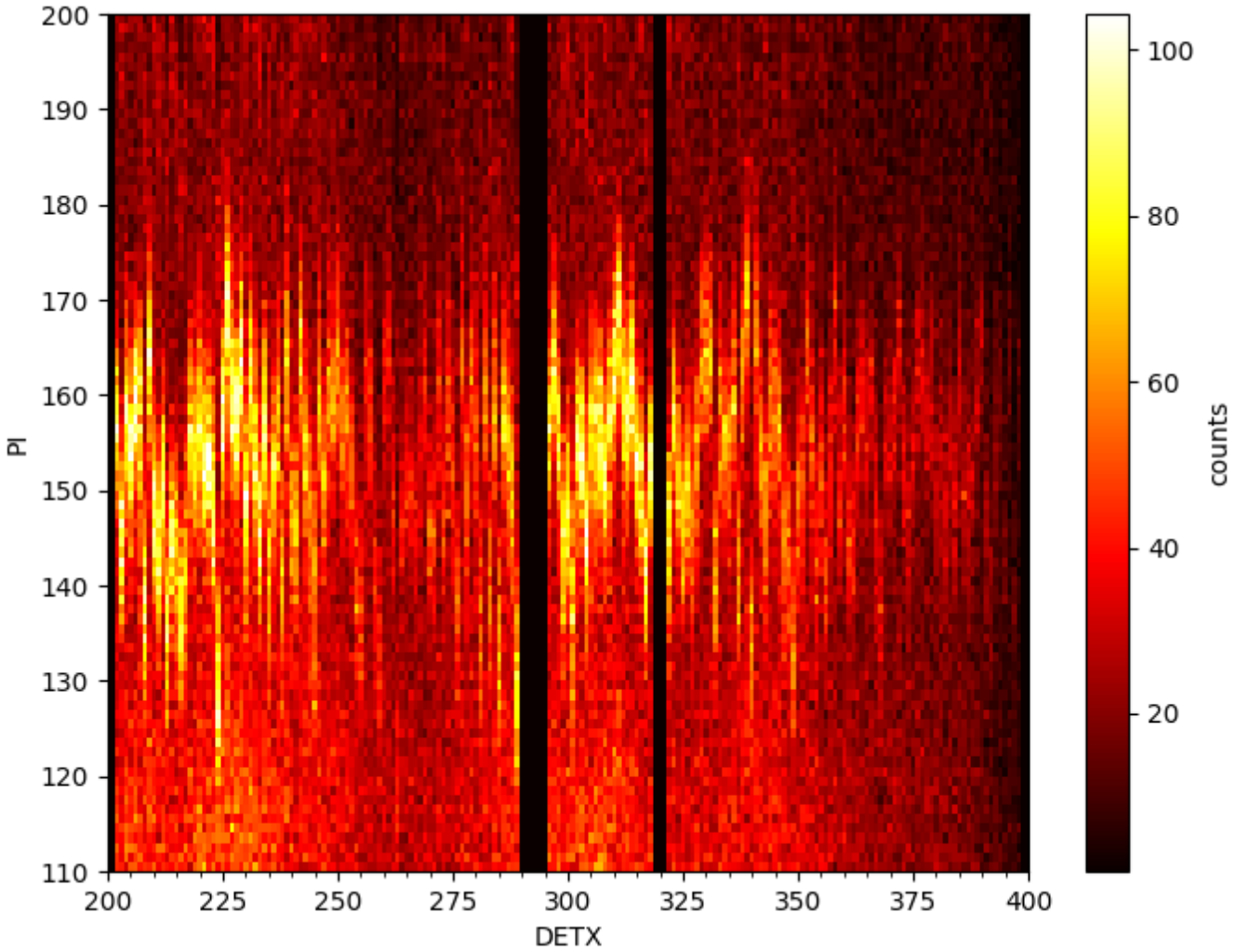


- Cas A trap mapping observations taken in 2018-Jan.
  - Current CALDB $\sim$ 1 year old – 'middle' shows average 50 eV offsets at Si-Kα (PI=186) $\rightarrow$ due to gain/trap evolution.



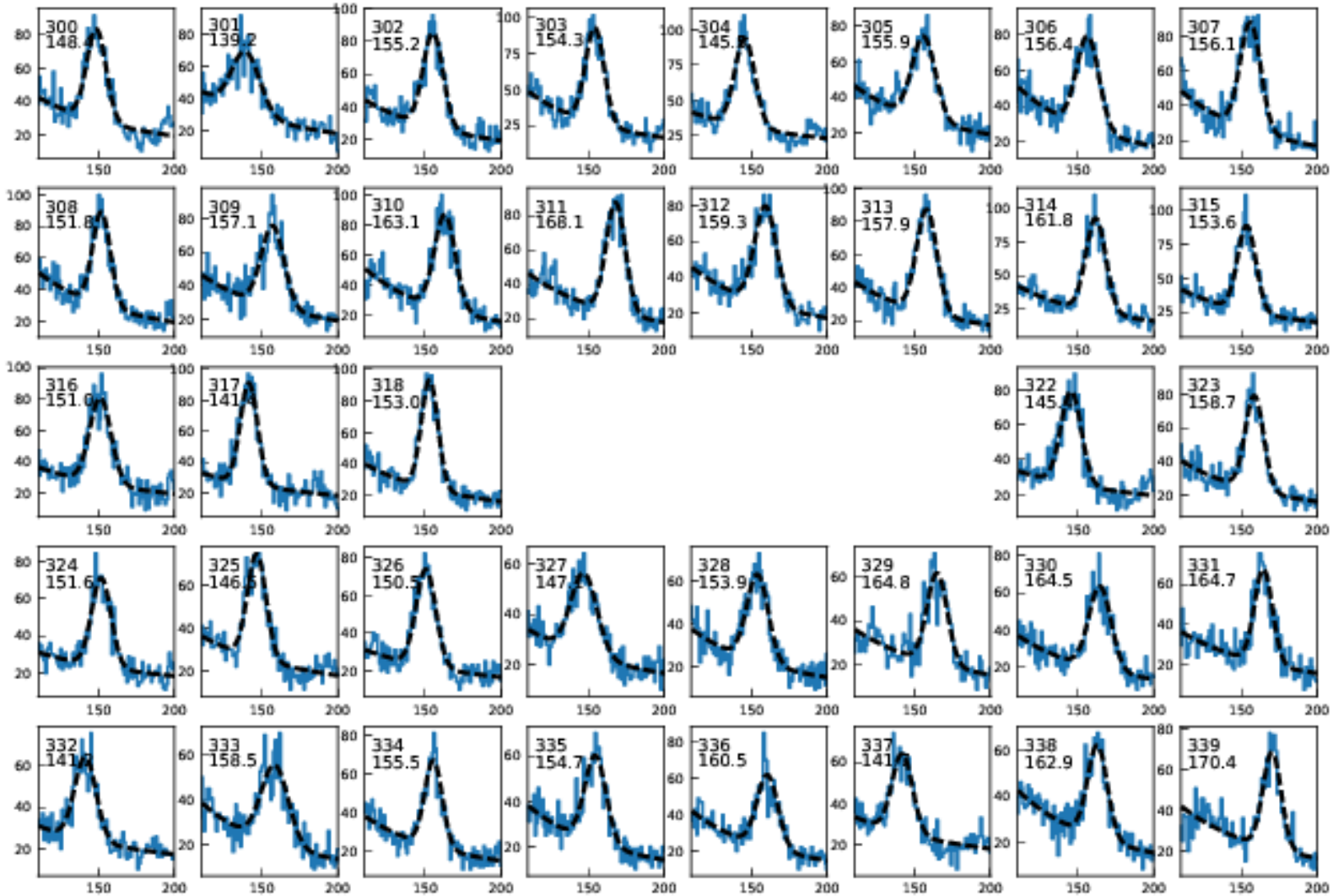
Charge Trap Mapping - WT Mode

- Existing trap offsets zeroed out and new ones derived
  - Deepest traps $\sim$ 600 eV

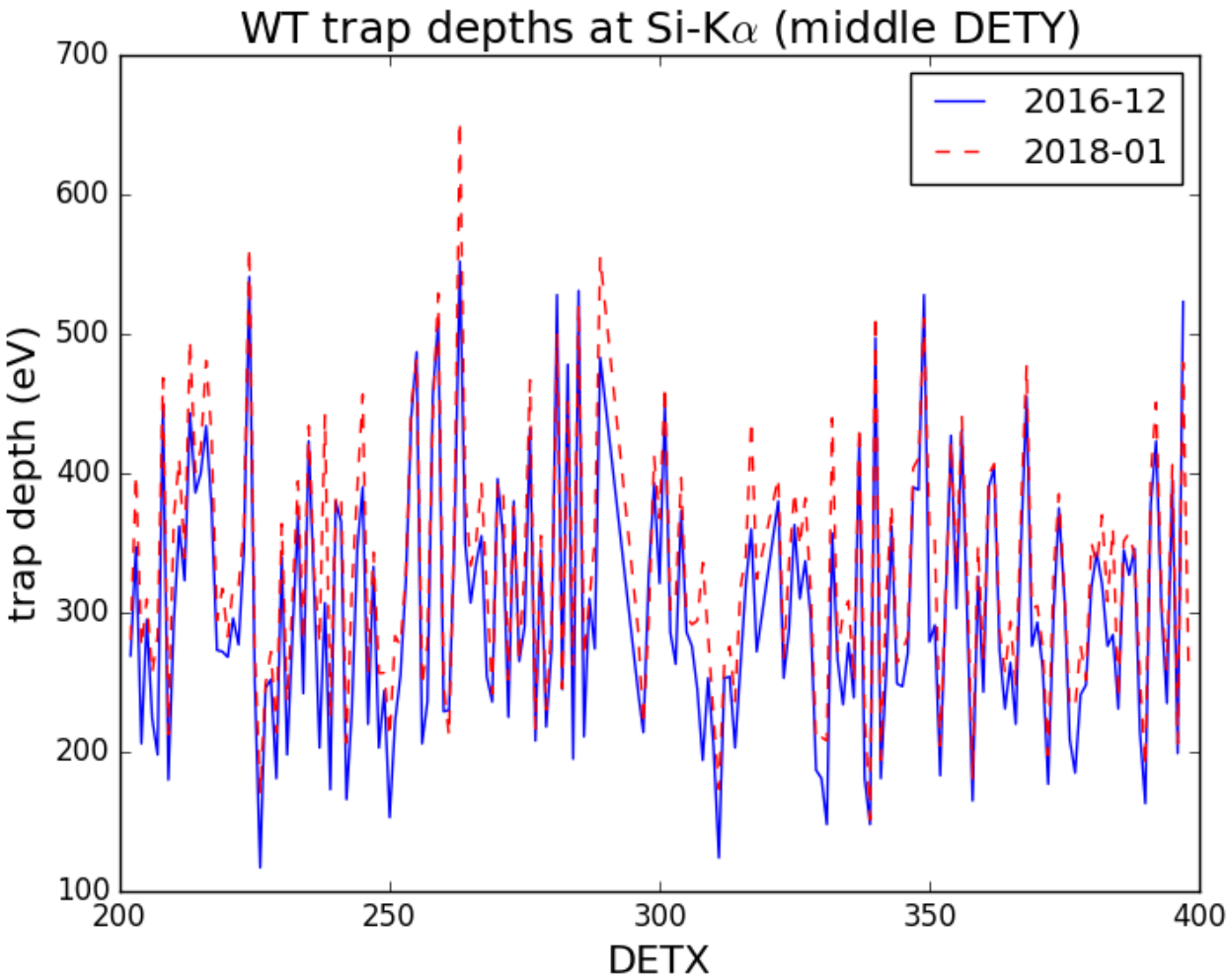


Charge Trap Mapping - WT Mode

- Existing trap offsets zeroed out and new ones derived
  - Trap corrections $\sim 120 - 650$ eV at Si-Kα

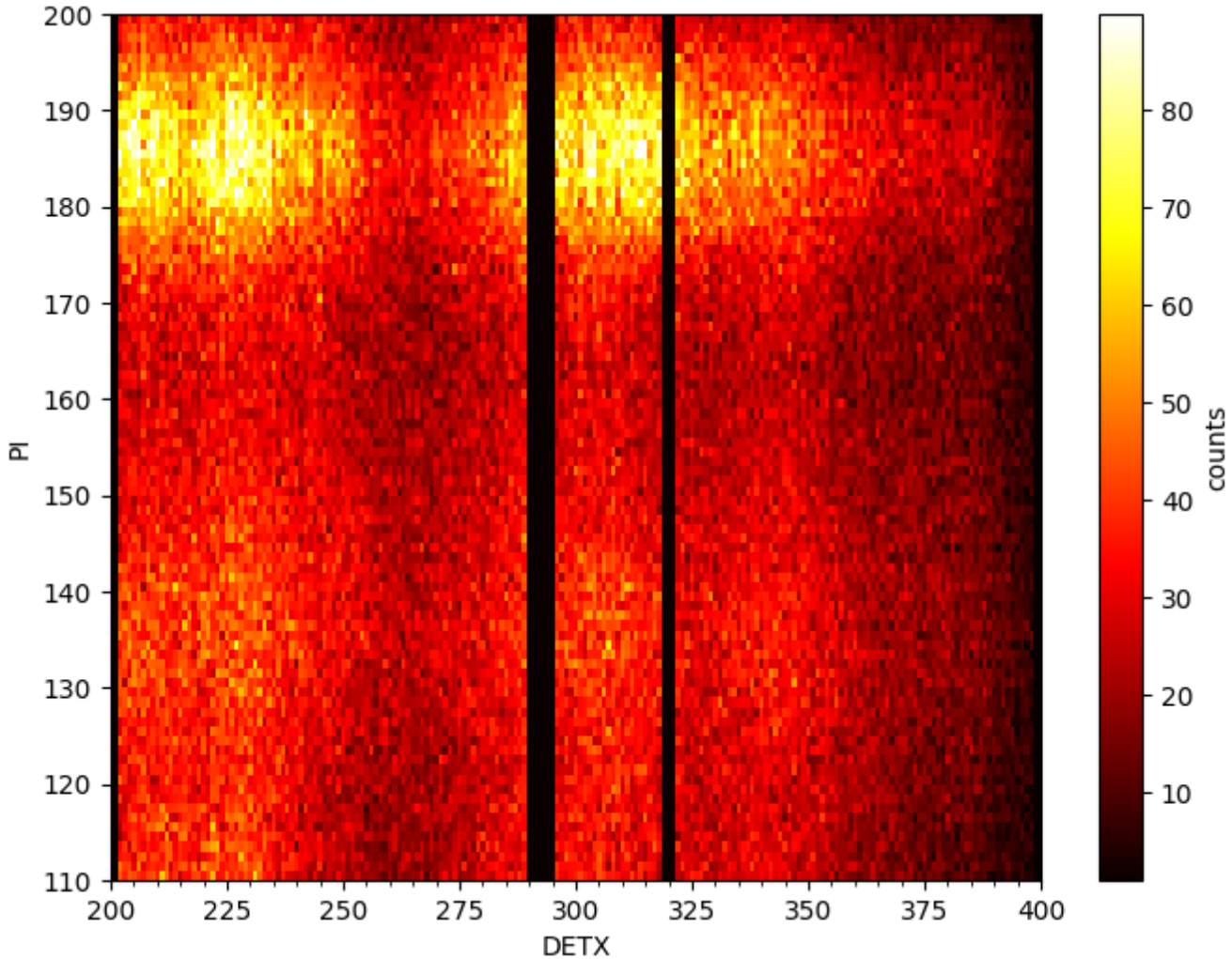


- Trap depths from 2016-12 and 2018-01 compared
  - Trap corrections $\sim 120 - 650$ eV at Si-Kα



Charge Trap Mapping - WT Mode

- New gain file with updated trap depths
  - Spectral variations across the SNR limit accuracy to $\pm 10 - 15$ eV



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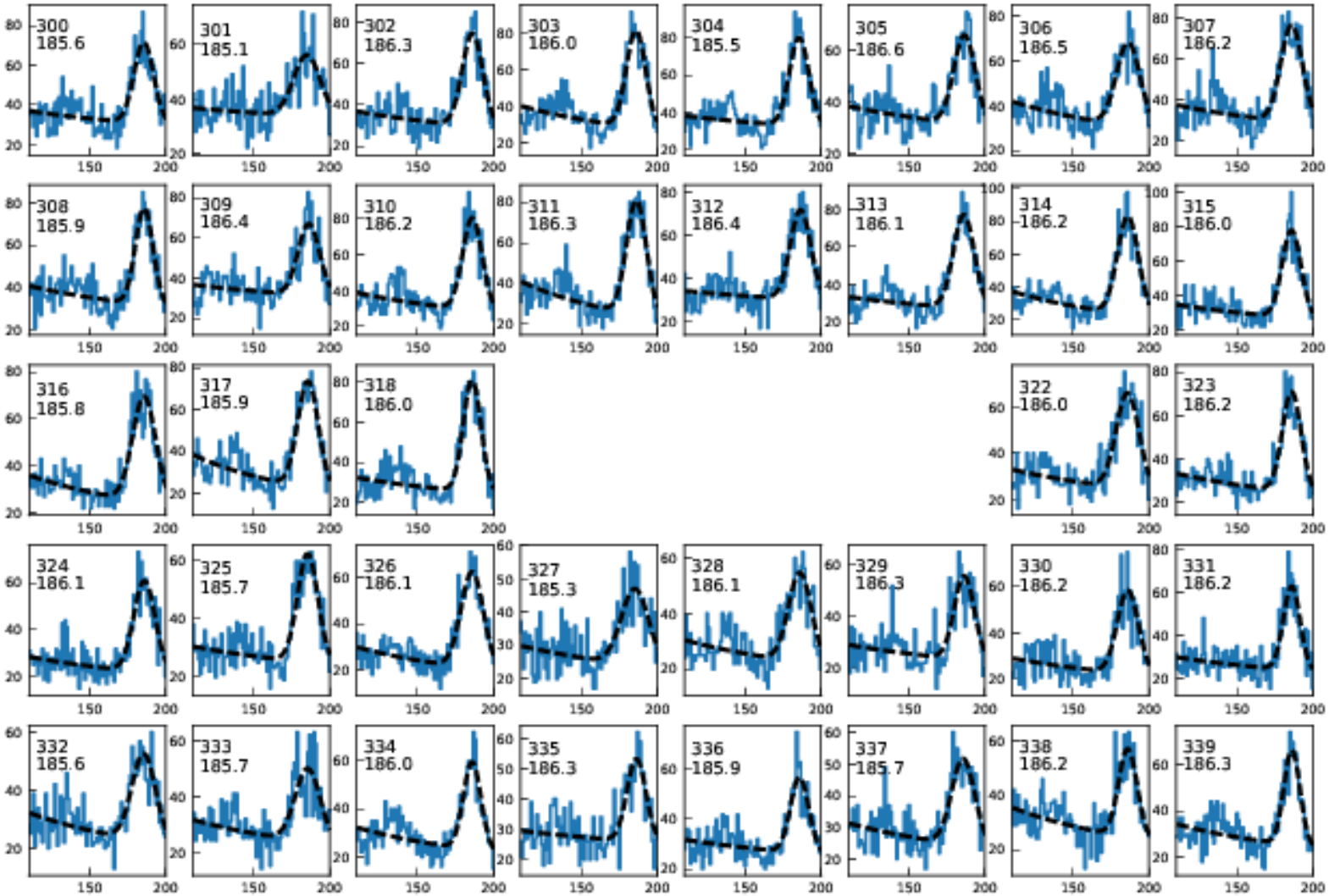
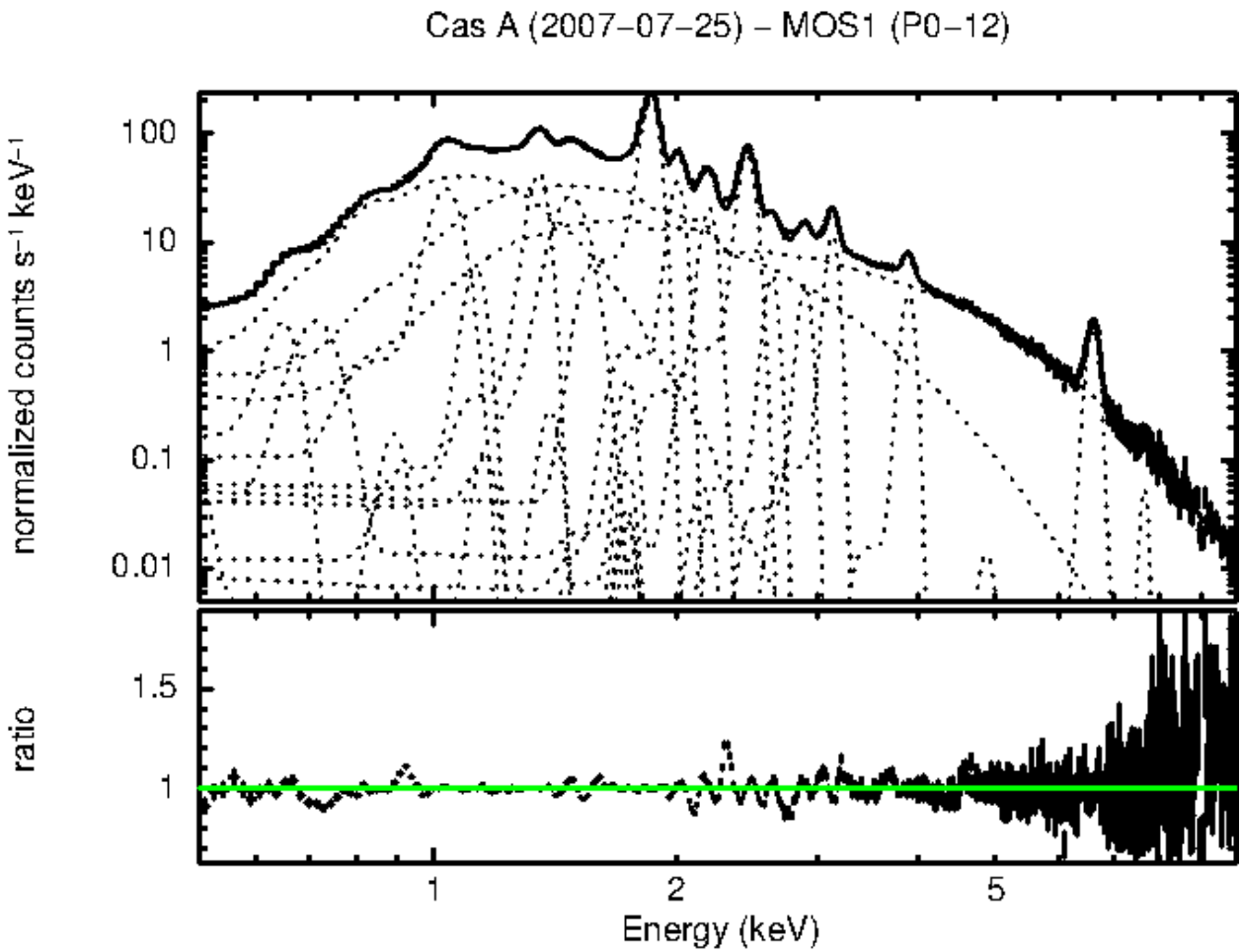


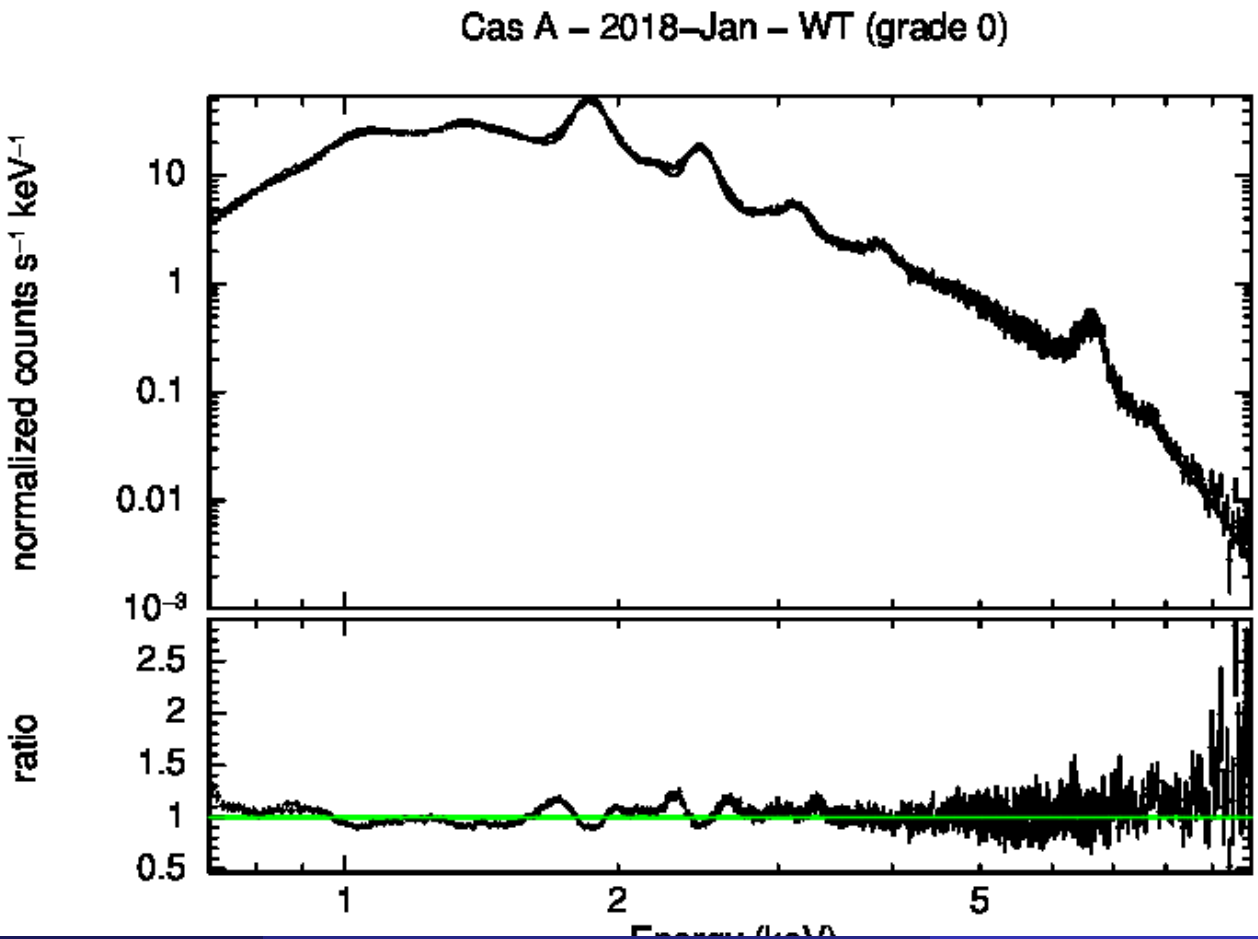
Cas A Remnant Averaged Model

- In the spirit of IACHEC
  - MOS1 small window spectrum
  - model tbabs * (3 brems + 15 gaus)

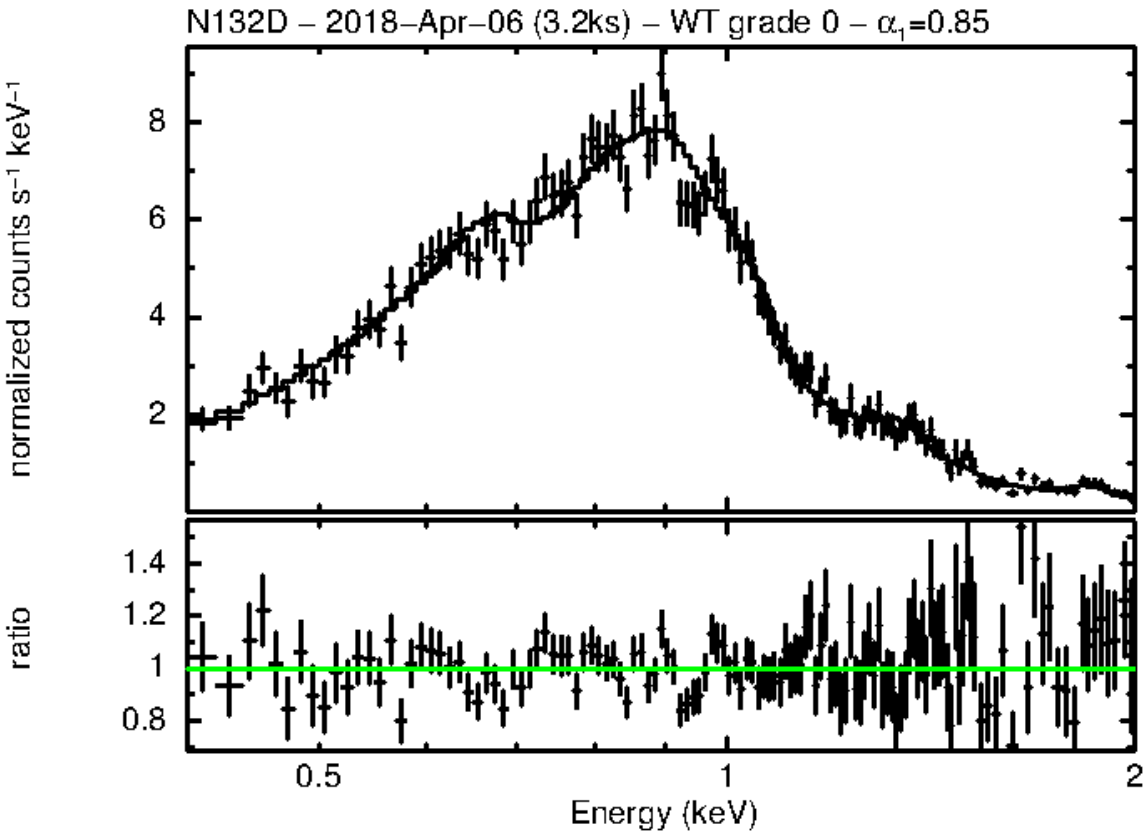


Cas A Remnant Averaged

- Trap depth energy dependence - broken powerlaw :
  - $E_T = D_{ref} \left(\frac{E}{E_{ref}} \right)^{\alpha}$
  - Shift E_{ref}, D_{ref} from 1.86 $\rightarrow$ 3 keV, $\alpha_1 = 0.85$, $\alpha_2 = 0.55$
  - Const = 1.02



- Energy dependence at low E proved problematic as E0102 shows large (~ 30 eV) offsets $\rightarrow$ symptomatic of bright Earth.
- Requested 5ks N132D TOO on Mar-30, clobbered by GRBs on Apr-04, repeated on Apr-06.
- Shows low E $\alpha_1 = 0.85$



PSF Matters

- XRT uses JET-X (spare) mirrors : HEW 18 ± 2 arcsec (at 0.5-4.0 keV); flat across central 7 arcmins.
- CCD22 pixel scale 2.357 arcsec
- PSF calibrated pre-launch at Panter
  - Parameterised as King (wing + core) + Gaussian (core)
- Initial post-launch in-orbit tests – Gaussian term dropped
  - King params : $r_c = 5.5$ arcsec, $\beta = 1.526$ (on-axis at 1.5 keV)
- PC mode PSF measurements not easy
  - Pile-up above ~ 0.5 count/s distorts PSF
  - *Swift* snapshots $\sim 1 - 2$ ks long; star-tracker accuracy 3.5 arcsec; s/c attitude drifts after long slews.
  - Dust scattering halos sometimes seen around even moderately absorbed sources broaded PSF
- Evidence that PSF wings (beyond ~ 50 pixels radius) are underestimated

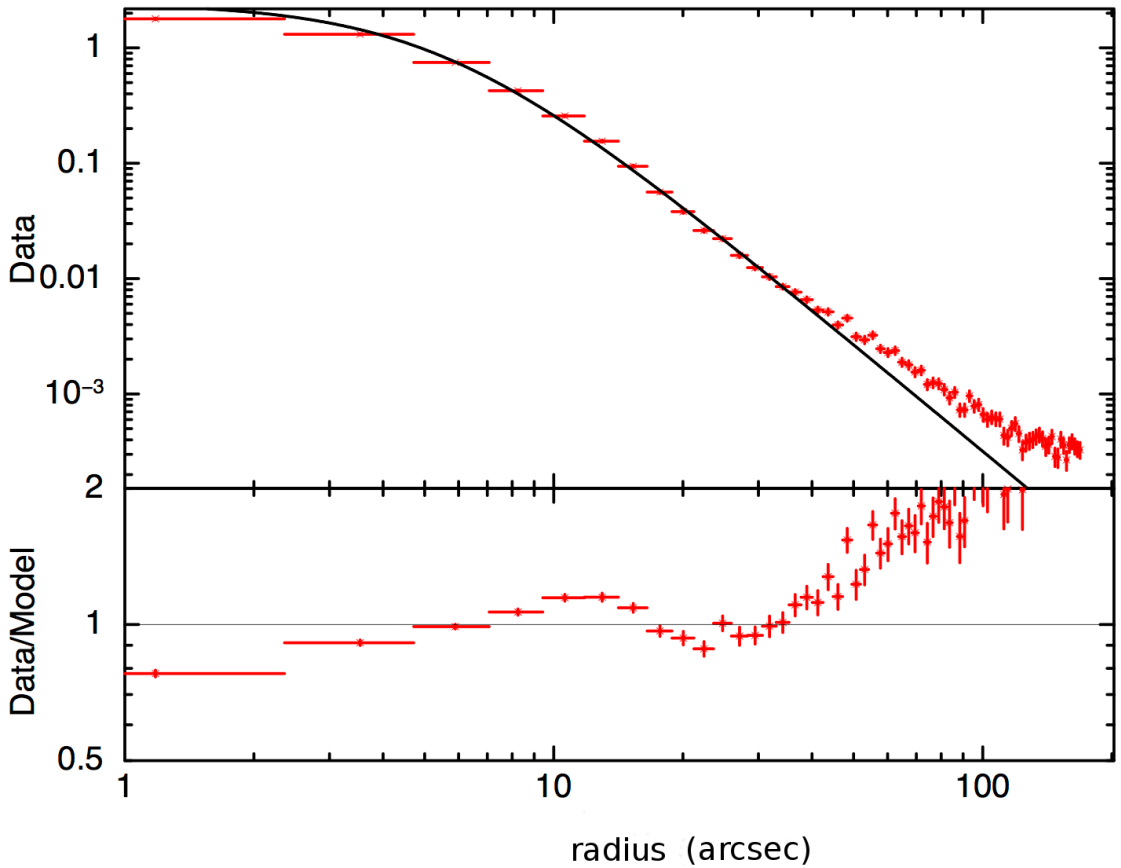
PSF Revisited

Two approaches :

- PC – Simultaneously fit the same 2D profile to multiple images containing a given source (in SKY coords). Note: PC background is low ($\sim 10^{-6}$ count/s/pixel). (Phil Evans)
- WT – Fit short durations of data (in DET coords), stack, refit
  - WT is a 1D readout $\rightarrow$ use the 2D PSF model then collapse it down (over 600 pixels) in the DETY dimension
  - Fit for DETX centroid position. Predict DETY (for the 2D model) from s/c attitude, telescope/CCD alignment (*pointxform* FTOOL)
  - Randomise events over pixel width during shift-n-stacking.
  - Background level can be tricky as WT background has been increasing with time ($0.001 - 0.005$ count/s/column; see Trailing Charge talk last year).

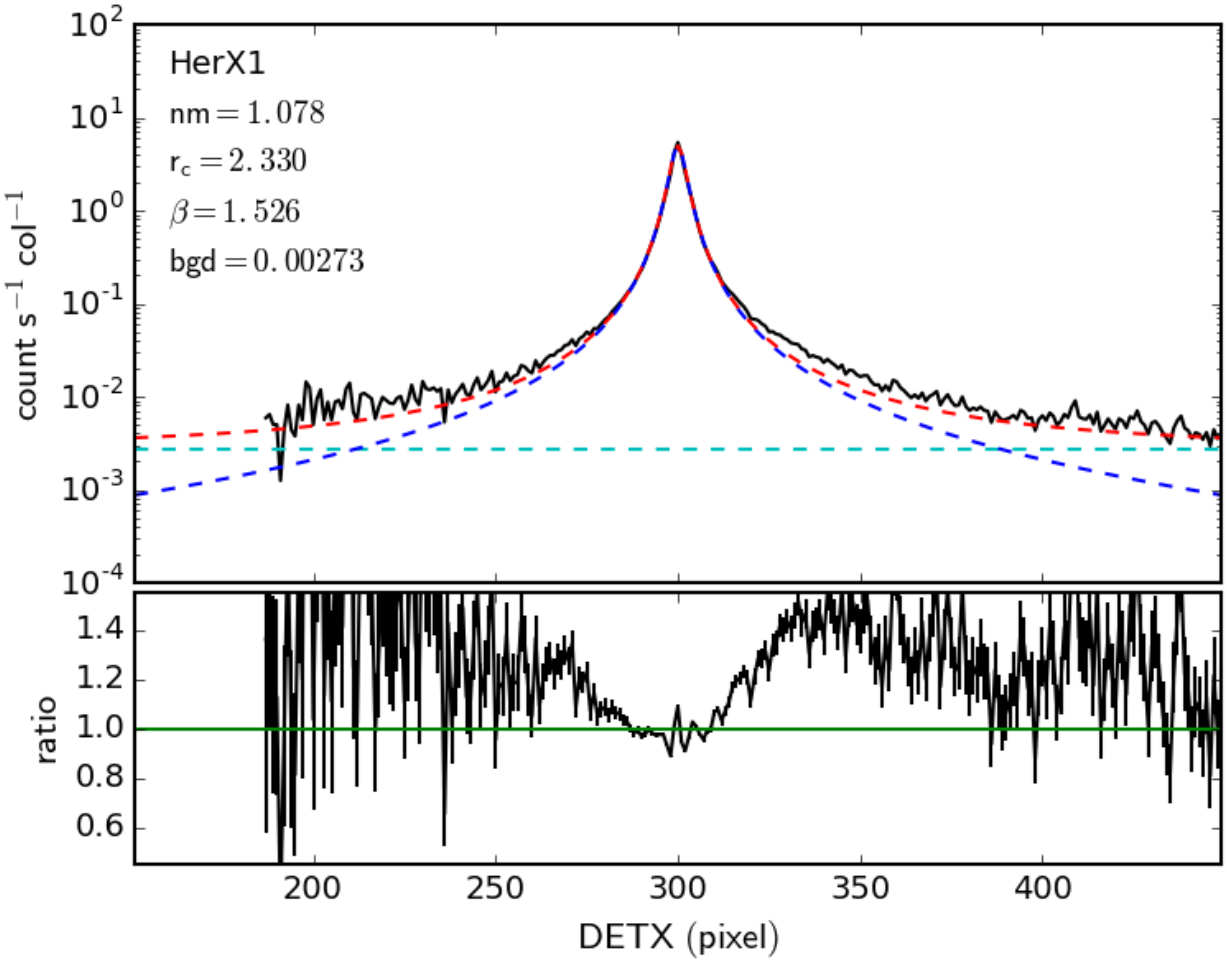
PC PSF

- RXJ1856 – grade 0 data.
- Fit with CALDB PSF parameters

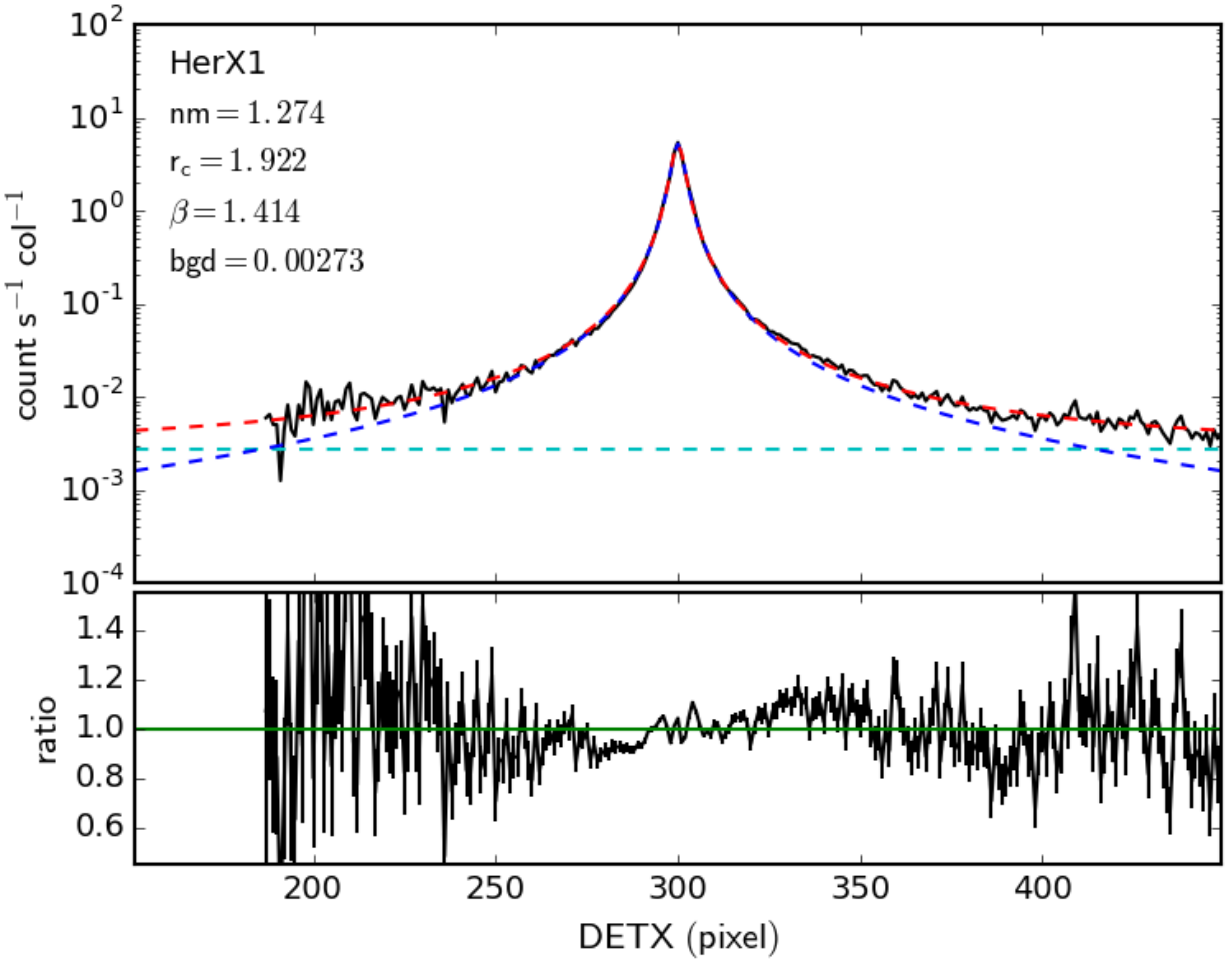


- Ratio show evidence for Gaussian component & extended wings.
- However, RXJ1856 is a soft source. Repeat on other sources
  - 'good' (unbsorbed, not piled-up) sources are difficult to find.

- Her X-1 (2012-2017) – unabsorbed, minimal halo
- Fit with CALDB PSF parameters.

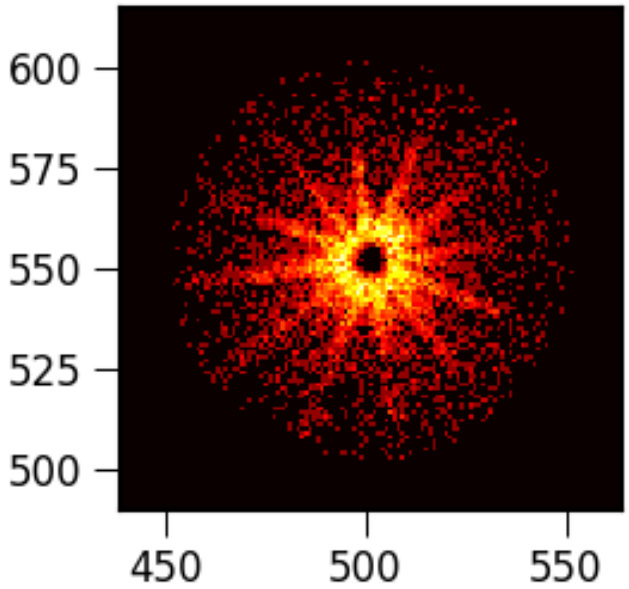


- Her X-1 (2012-2017)
- King parameters allowed to vary



Piled-up PC PSF

- Her X-1 also observed in PC mode when bright ($\sim$ 40 c/s)
- Pile up causes good events (grade 0–12) to migrate to bad events (grade 13–31) leaving a hole in the PSF



- PSF modification function to account for pile up :

$$PSF_{pu}(r) = m(r) \times PSF(r)$$

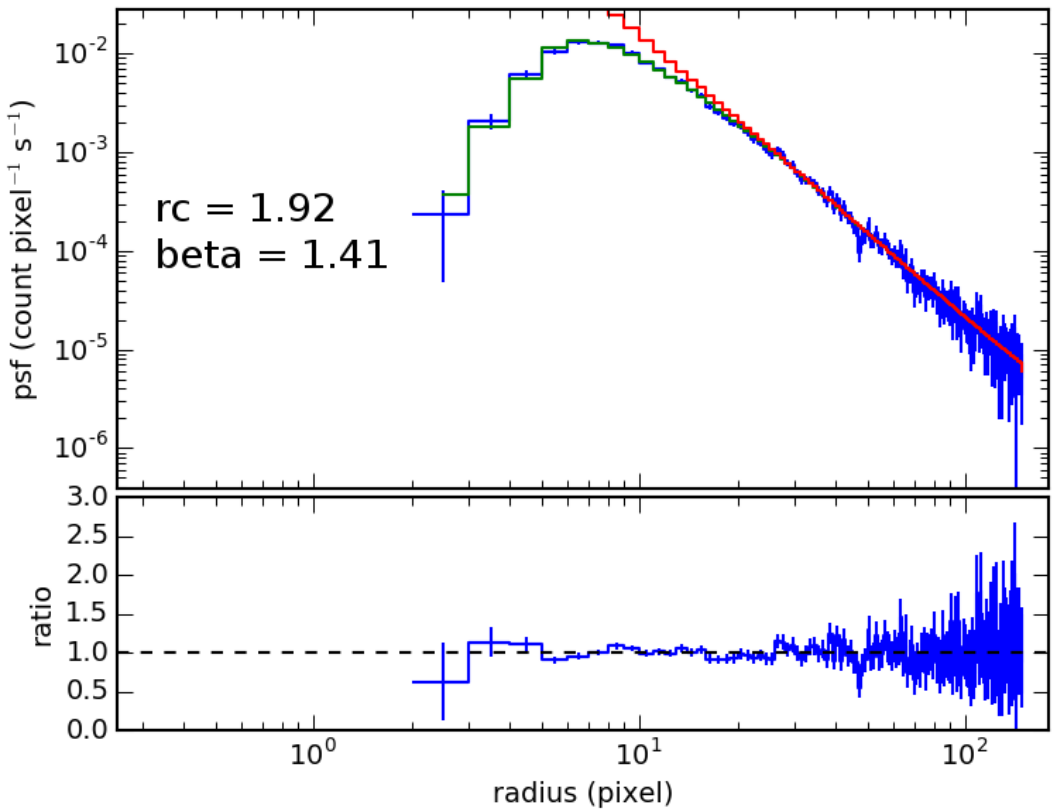
$$\text{where } m(r) = s + A\left(\frac{r}{I}\right)^{\alpha} \qquad \text{for } 0 \leq r < I$$

$$= 1 - B\exp\left(-\frac{(r-I)}{\tau}\right) \qquad r \geq I$$

with $A = I(1-s)/(I+\alpha\tau)$, $B = 1 - s - A$. Free parameters : s, I, τ, α

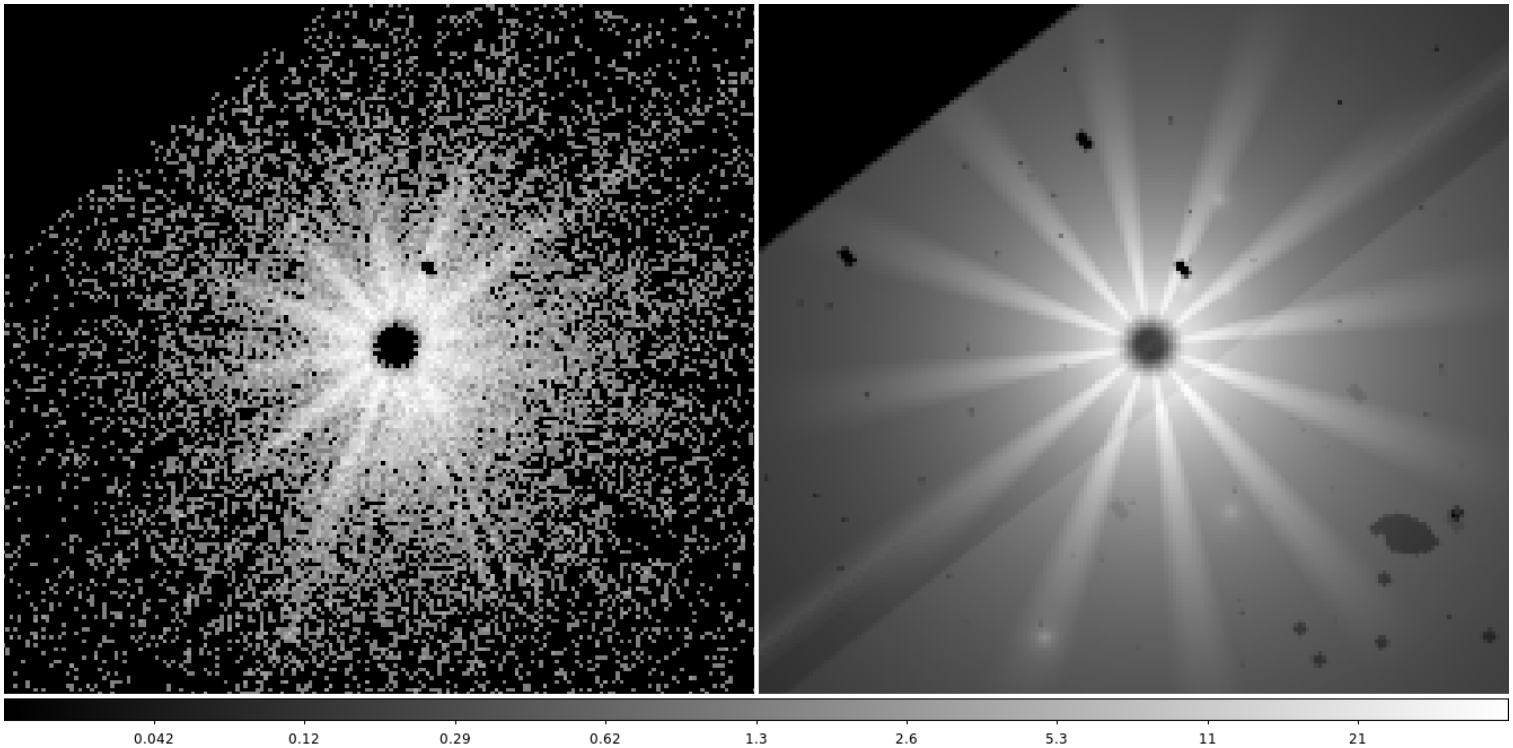
Piled-up PC PSF

- Her X-1 PC at 40 count/s
- King + pile up parameters allowed to vary



- r_c, β consistent with WT estimate.
- Get pile up corrected rates for free (with correct errors !)

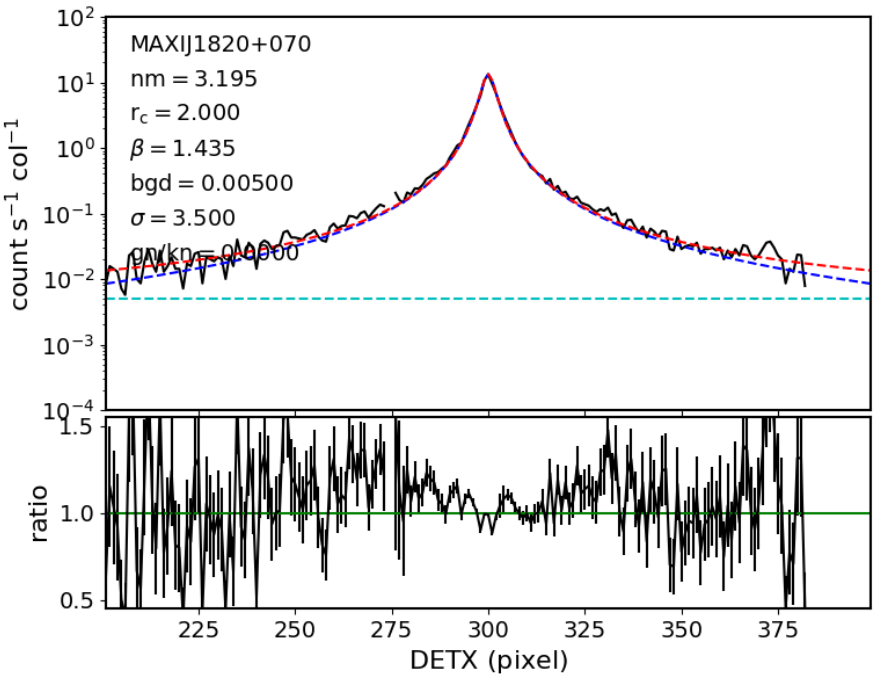
- Phil Evans implementing the new PU-PSF model into the 2SXPS catalogue reprocessing.



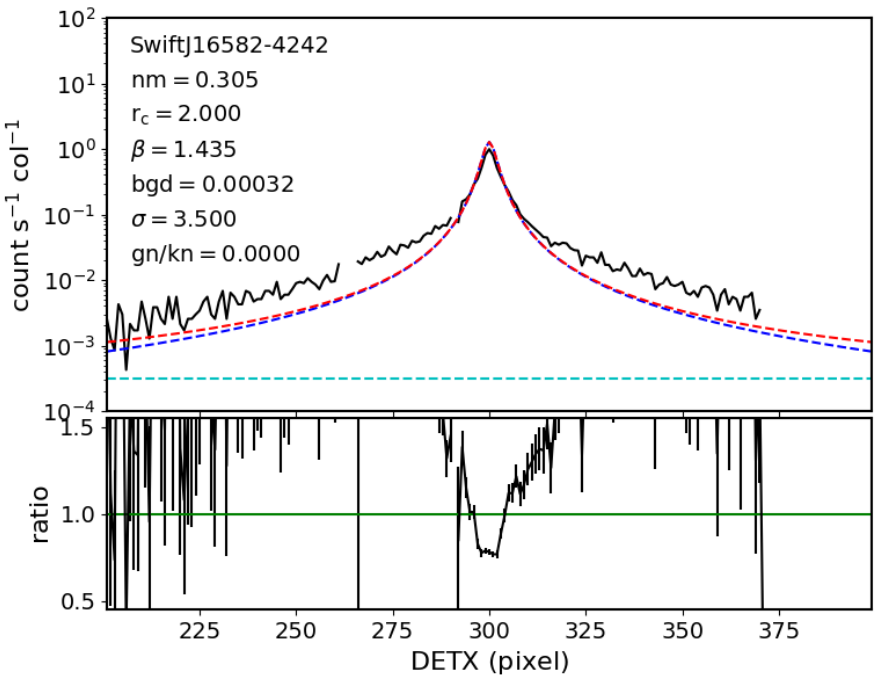
Non-halo v halo

- Example WT PSF profiles from a low column density source (MAXIJ1820+70), with no/minimal halo, and a heavily absorbed source (SwiftJ16582-4242), with a visible halo.
- XRTMKARF correction will be underestimated (const factor > 1) for a source with a scattering halo.

MAXIJ1820+70



SwiftJ16582-4242



Summary

- New WT mode gain file ready for release anytime.
- PC mode gain file will follow shortly.
- Investigate use of trap DETY positions derived from PC for WT.
- Looks like new WT RMF is needed (broader response).
- PSF model improvements are under investigation.
- No cats were harmed in the making of this production !