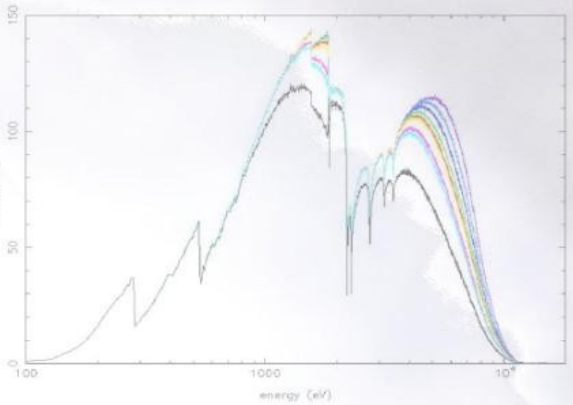
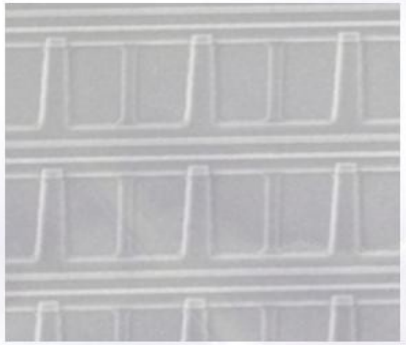
Swift-XRT Cal update

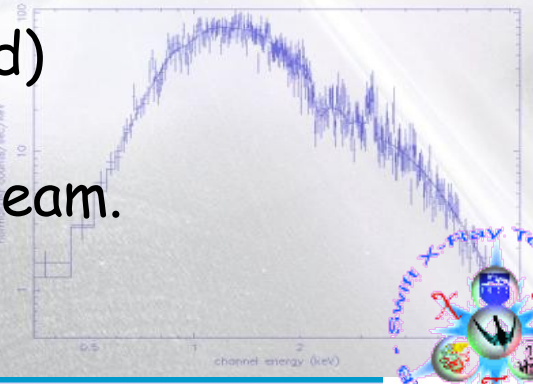




Andy Beardmore

With help from
Claudio Pagani,
Tony Abbey (now retired)

on behalf of the XRT cal team.

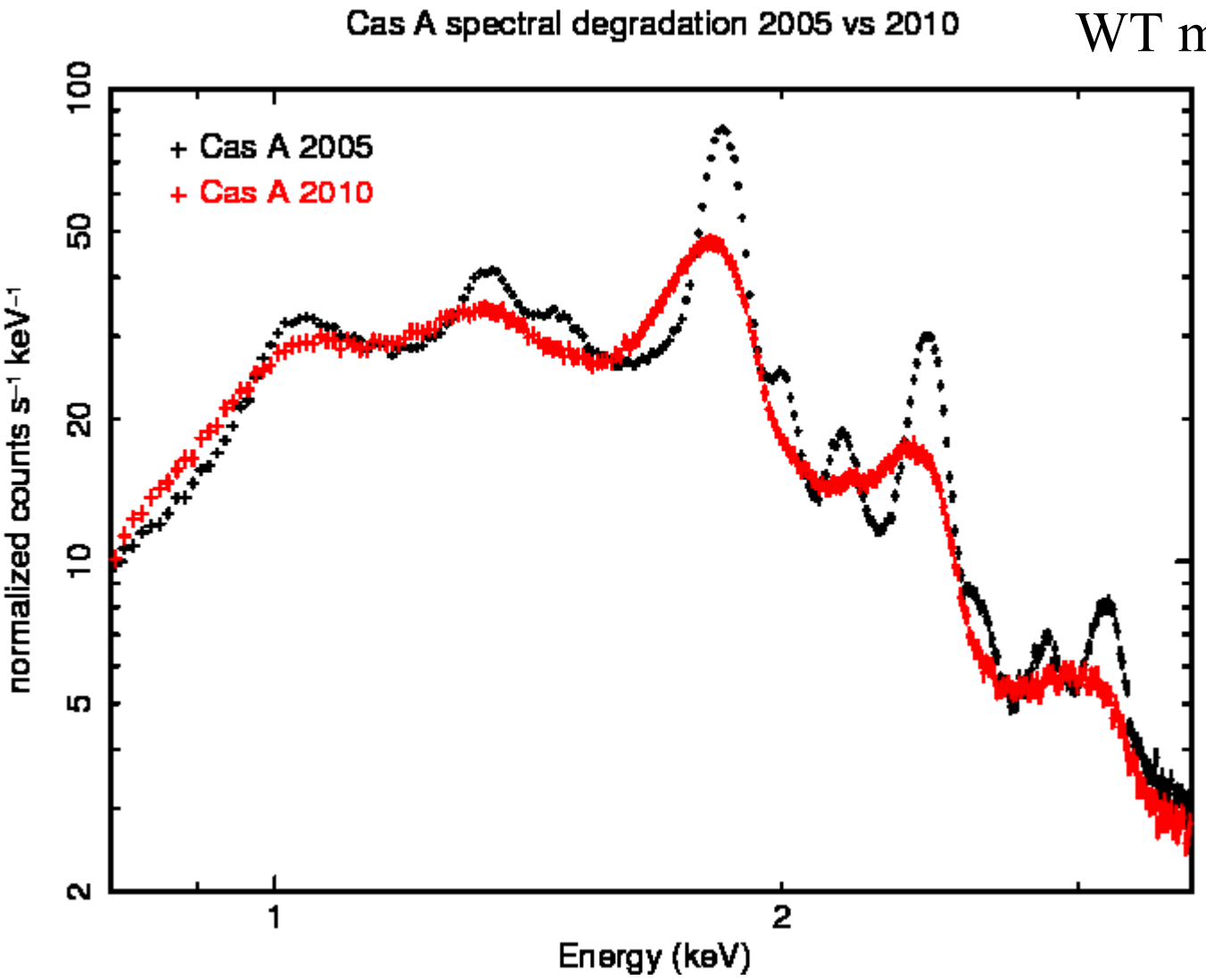


Trap Mapping

- Trap mapping progress
  - XRT CCD does not have the luxury of charge injection to improve spectral response now significant charge traps have formed
  - XRT has no internal calibration source which will illuminate the entire CCD to measure the traps
  - Largest charge traps in the central regions of the CCD have been identified using Si Ka observed in Cas A and Tycho
  - Updated gain CALDB file format and xrtcalcpi s/w to perform charge trap correction

Trap mapping – the damage

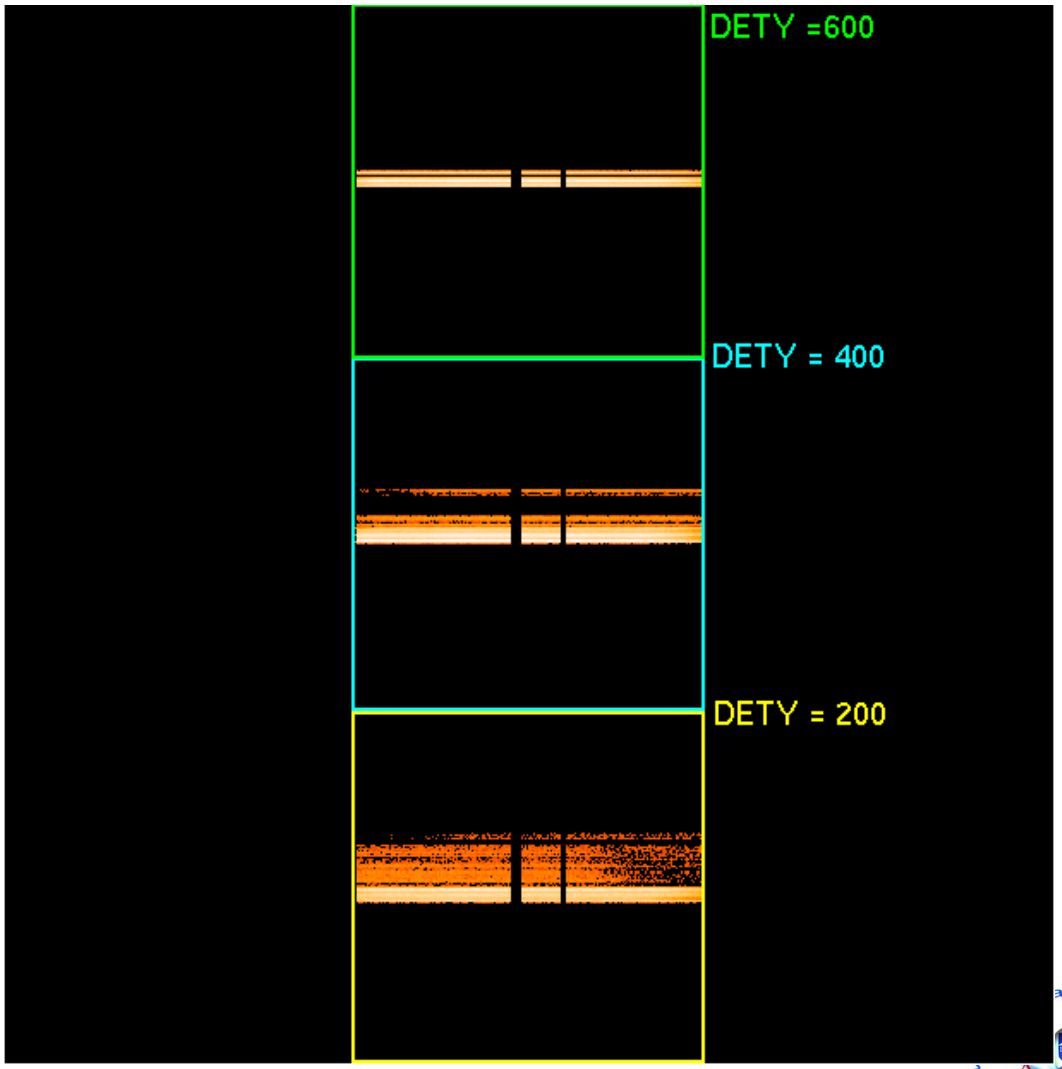
WT mode



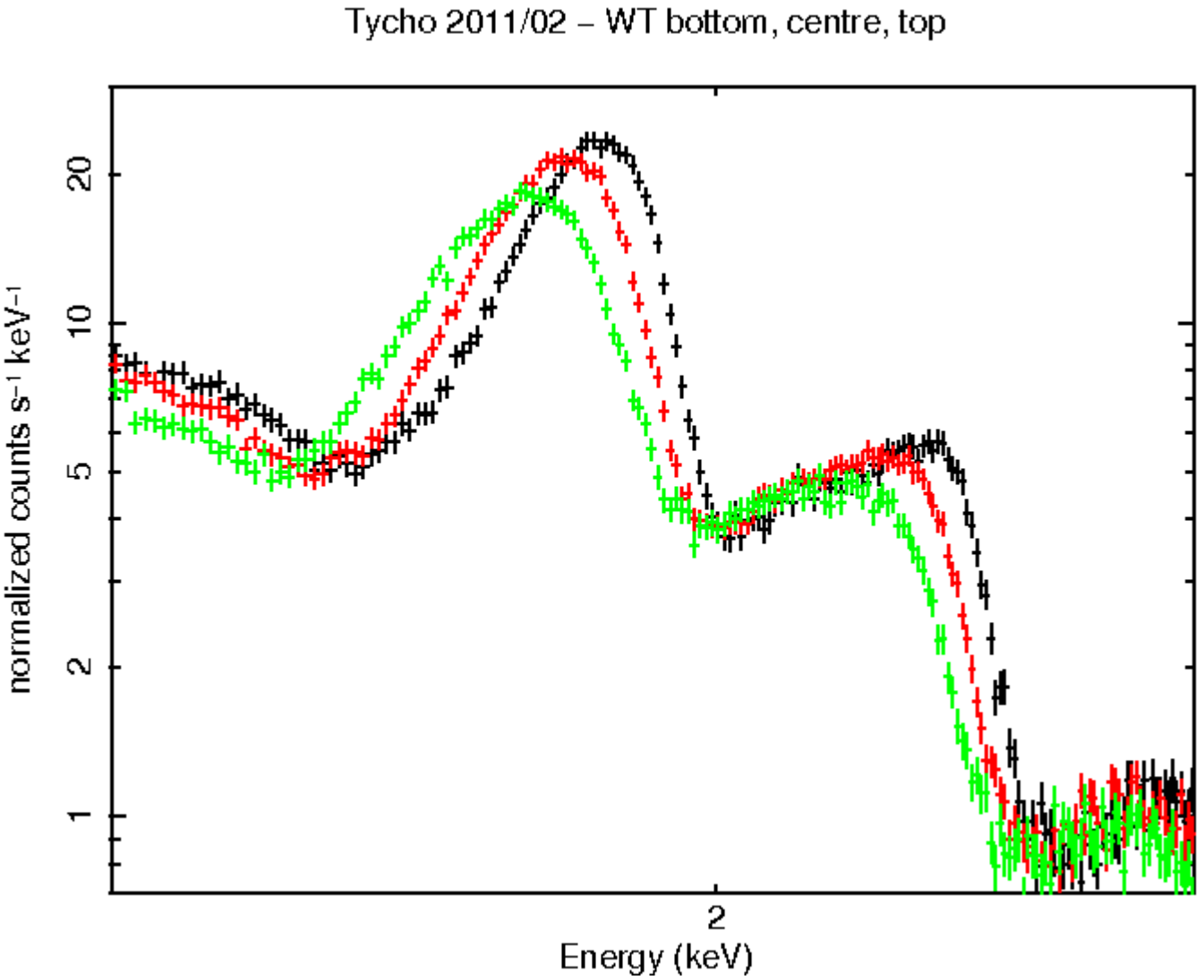
WT trap calibration

- Tycho observations on top, centre and bottom of the WT window (15ks each)
- For each column, we derive offsets in the 3 regions:

  DETY = [1-200], [201-400],[401,600]

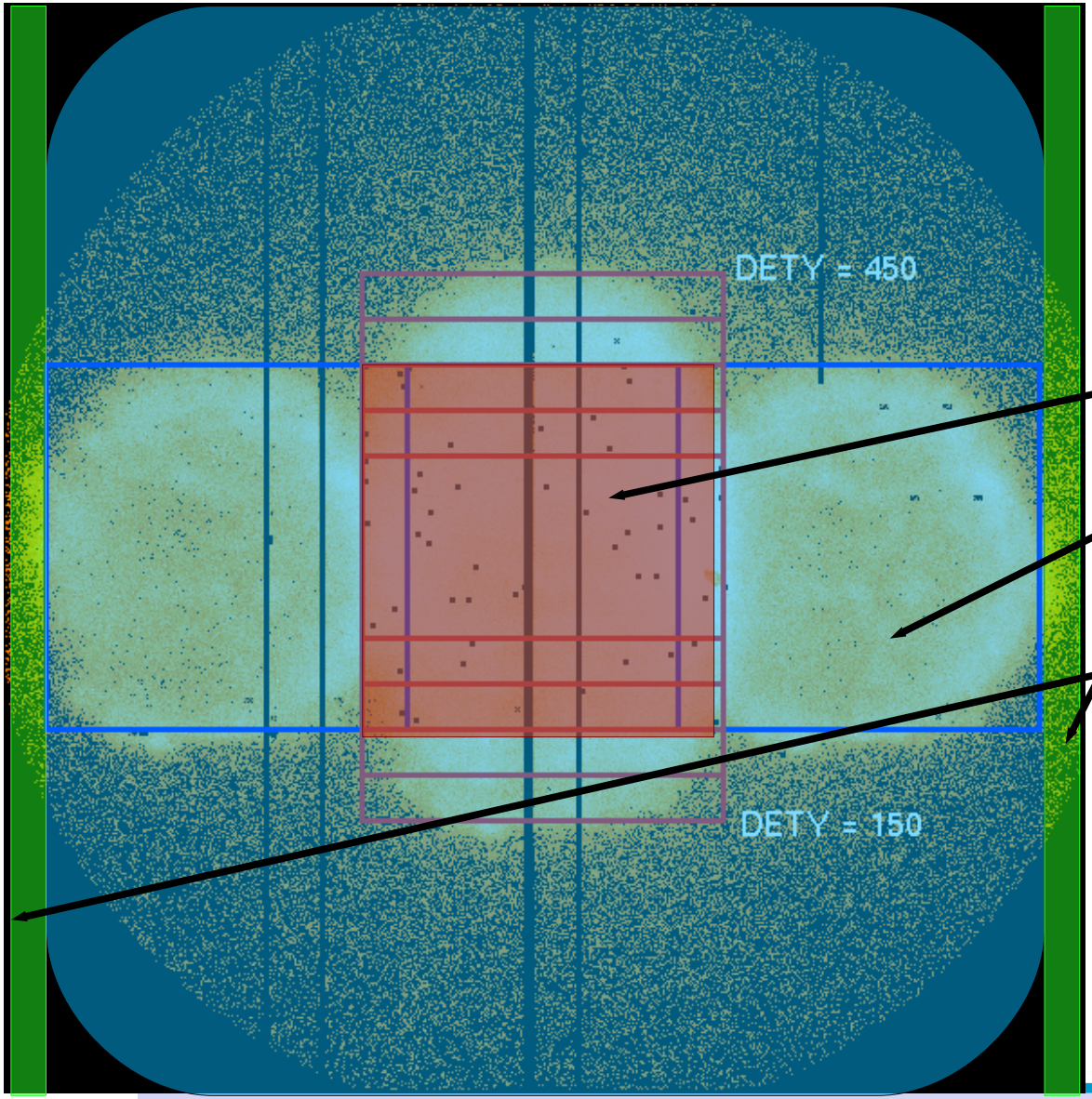


WT observed spectra



Spectral degradation as we move to the top of the CCD due to traps

PC trap calibration



5 pointings (15 ks each) to densely sample the central 200x 200 window

1 left + 1 right pointing (15 ks each)

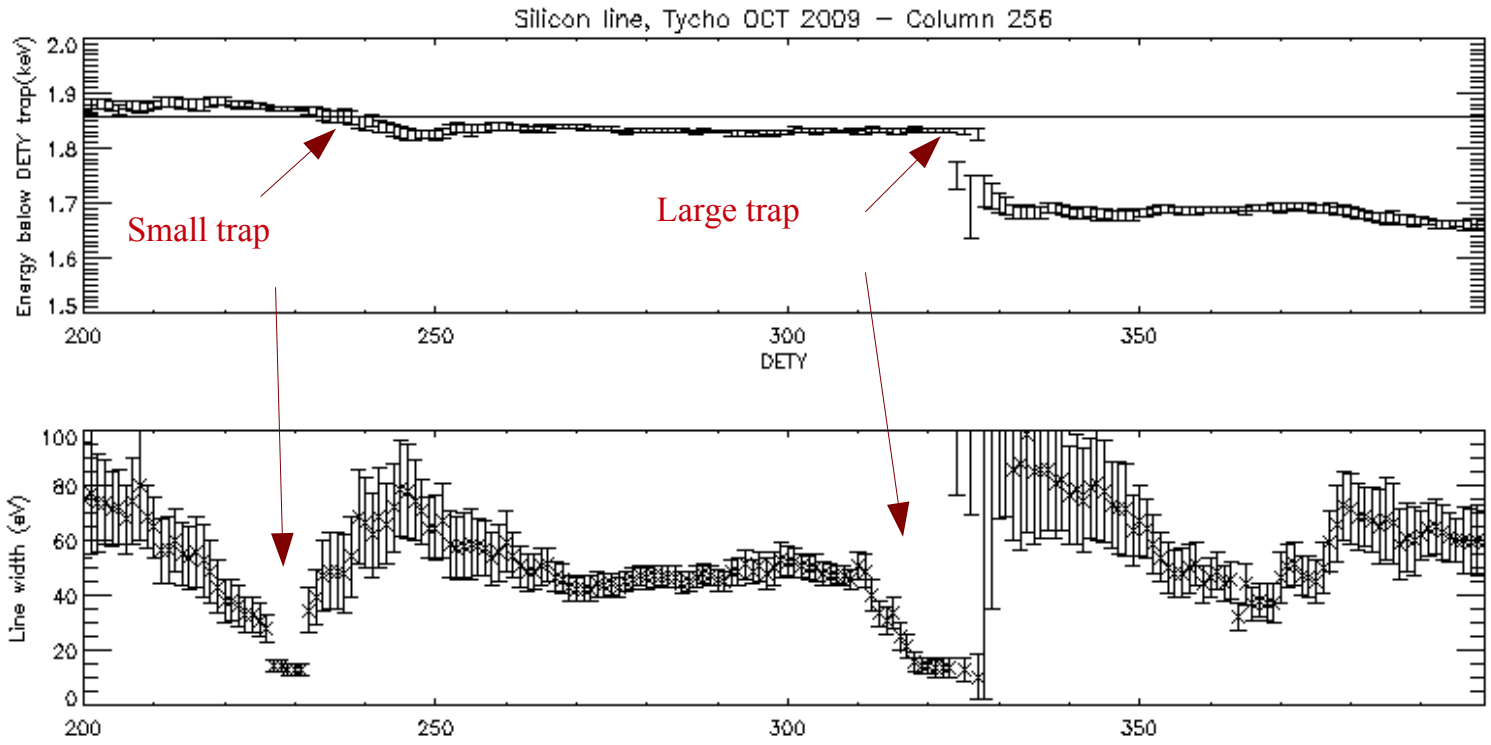
Traps identified in the central window

Column offsets outside the central window

Serial CTI column offsets at the very edges, where there are no Tycho data

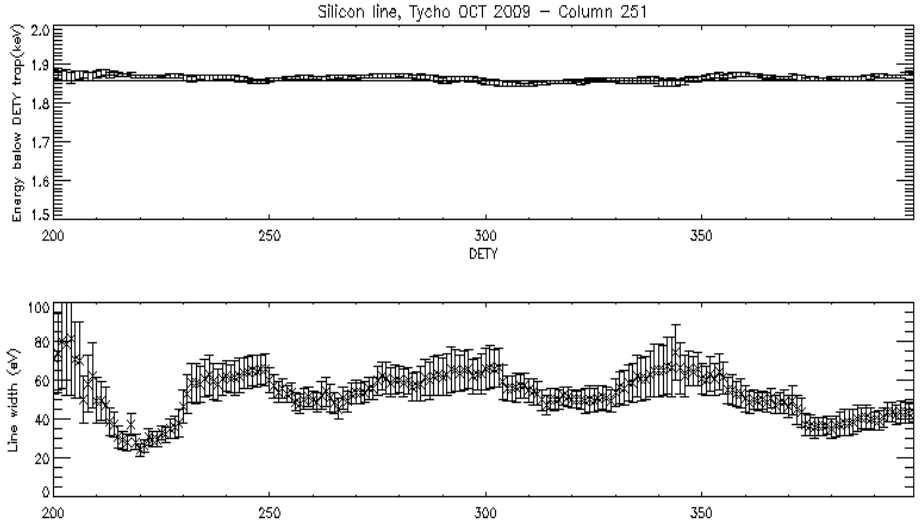
PC trap mapping method

"Incremental" fit of the Silicon line along the column, merging events from 20 pixels

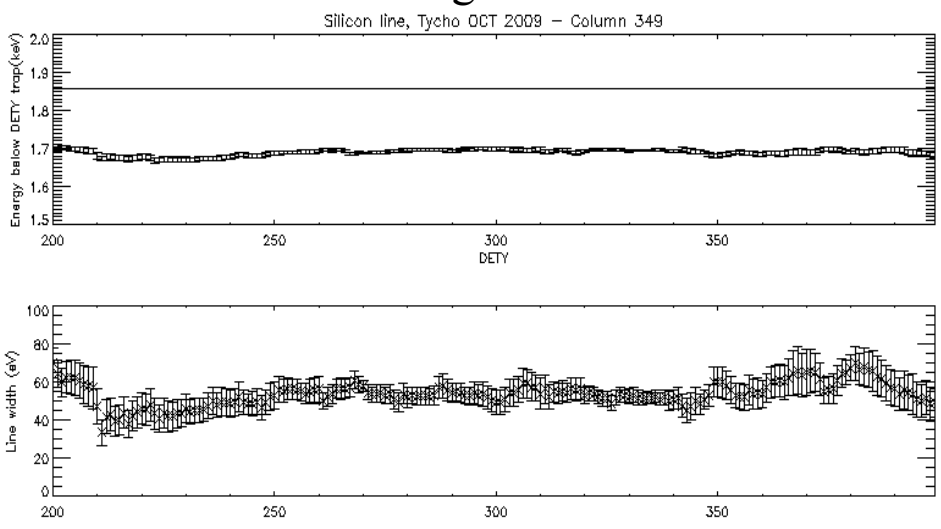


Trap mapping - Examples

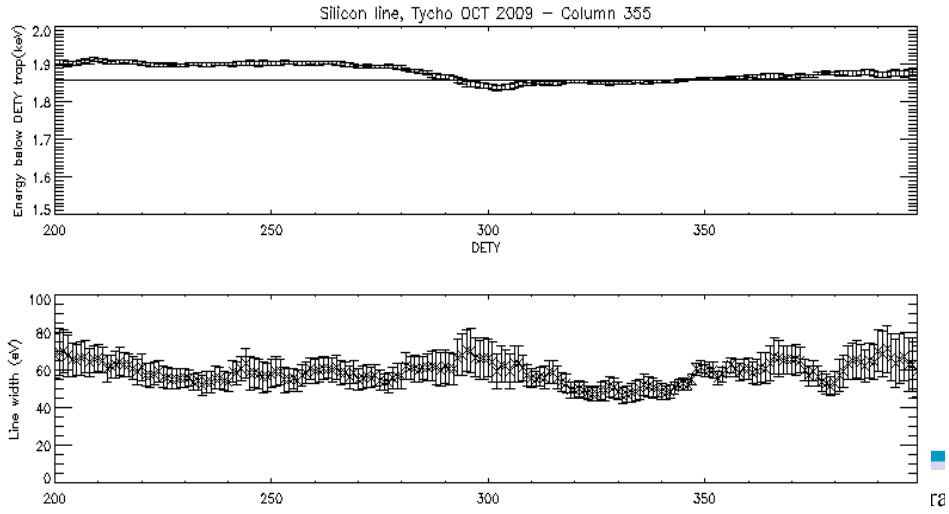
Good columns

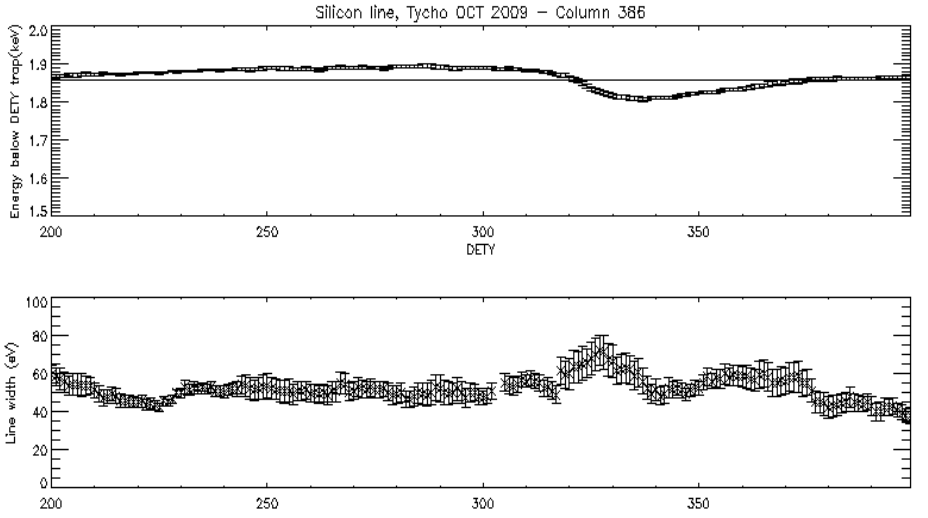


Large offsets



Annoying traps





Trap mapping – Energy dependence

Trap depths energy dependence

Trap depths and column offsets are a function of the observed event energy

$$Offset(E) = Offset(E_{break}) * (E / E_{break})^{\alpha}$$

where E_{break} is set to the Silicon energy of E = 1.863 keV.

Lines (Sulphur, Iron) in Cas A and Tycho used for the energy dependence above Silicon, Lines in E0102 used below Silicon.

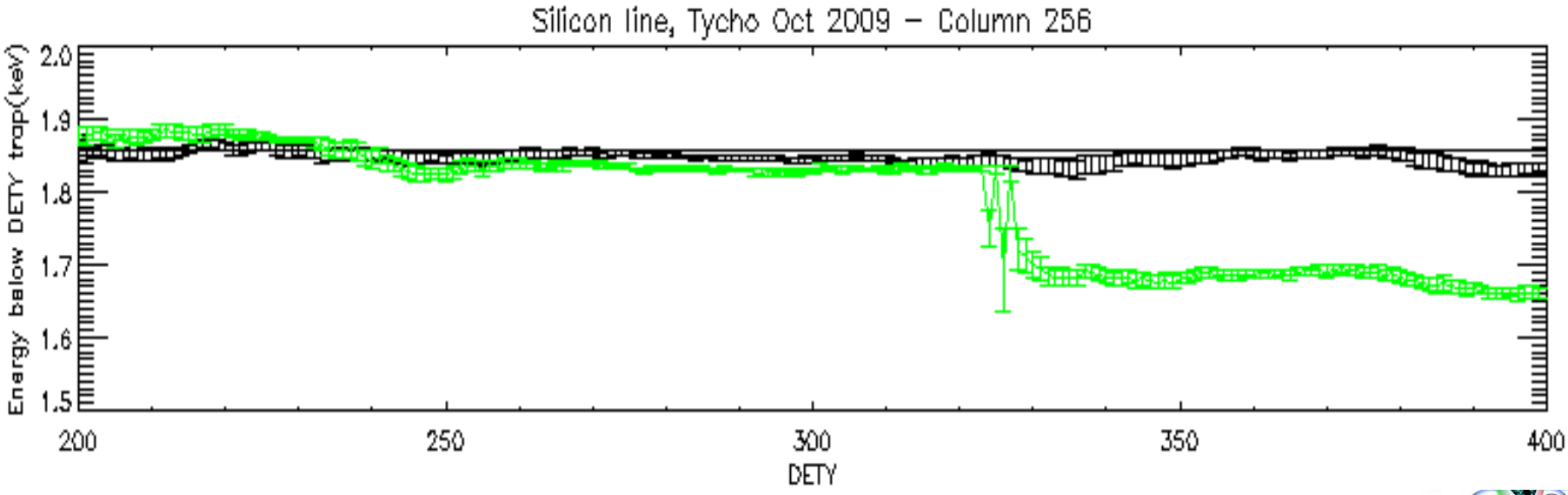
The derived energy dependence index **α = 0.75/0.8** above/below silicon for PC observations, while **α = 0.65** in WT mode obs.

Accuracy of energy dependence is still an open issue. There are some tests that might be useful to access this issue:

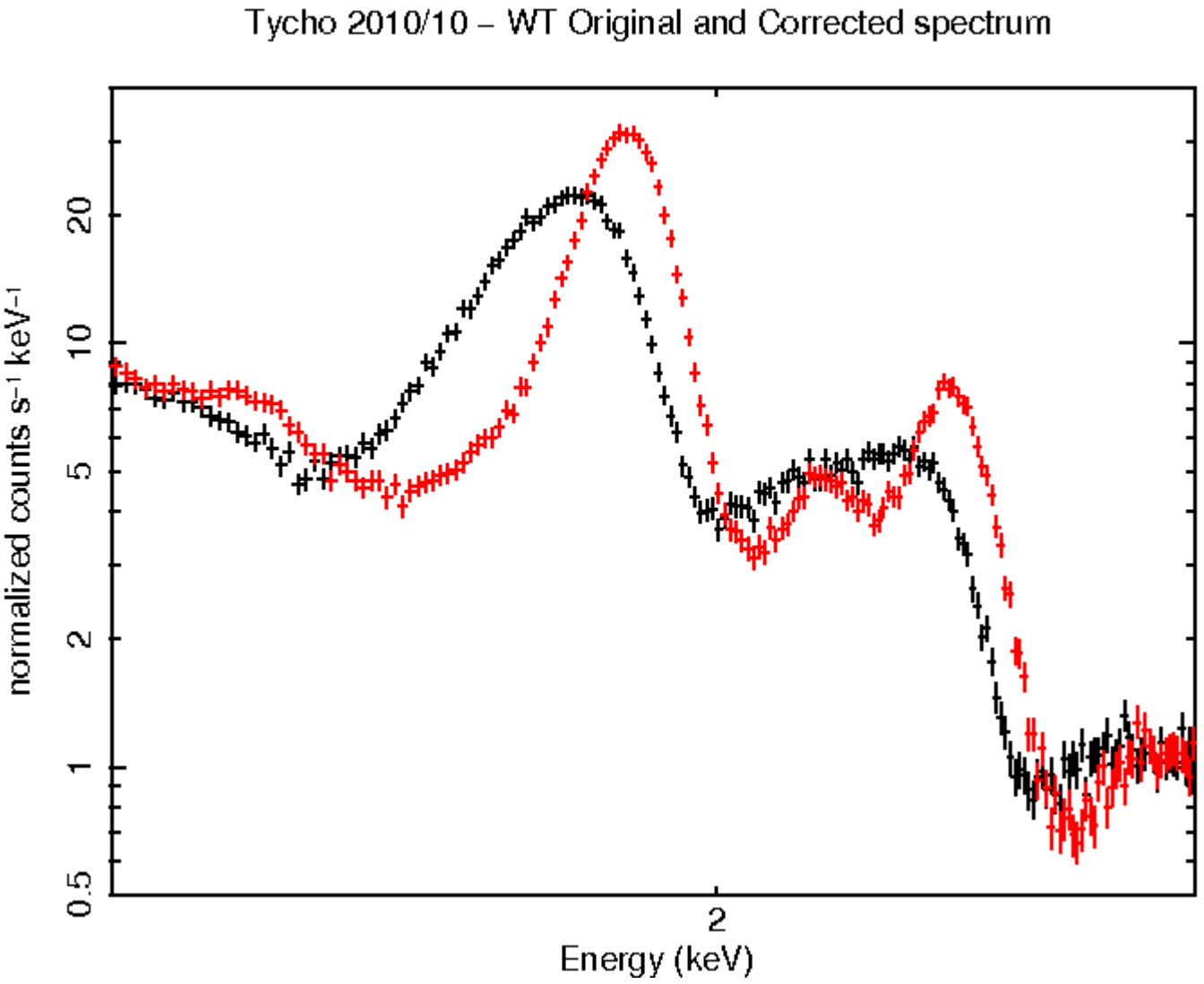
- Nickel line?
- Sources with Fe line?
- Corner sources

PC trap corrections

- IDL scripts to localize traps, measure trap depths
- Traps tables with traps coordinates, extensions and offsets generated
- Gain files updated with trap positions and offsets at ~6monthly intervals since 2007/09/01
- New version of *xrtcalcpi* run to correct spectra with the new gain files

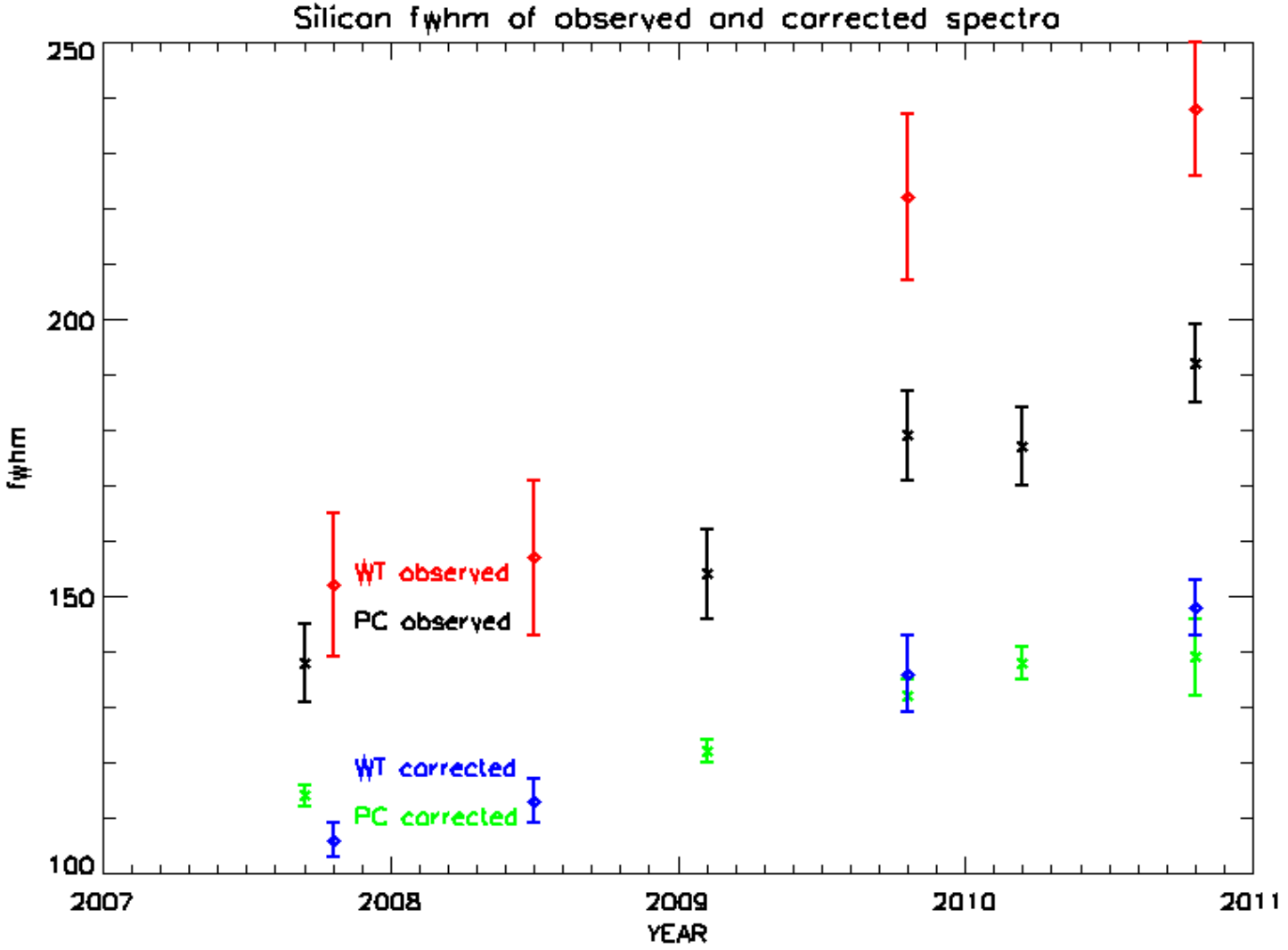


WT trap corrected spectra

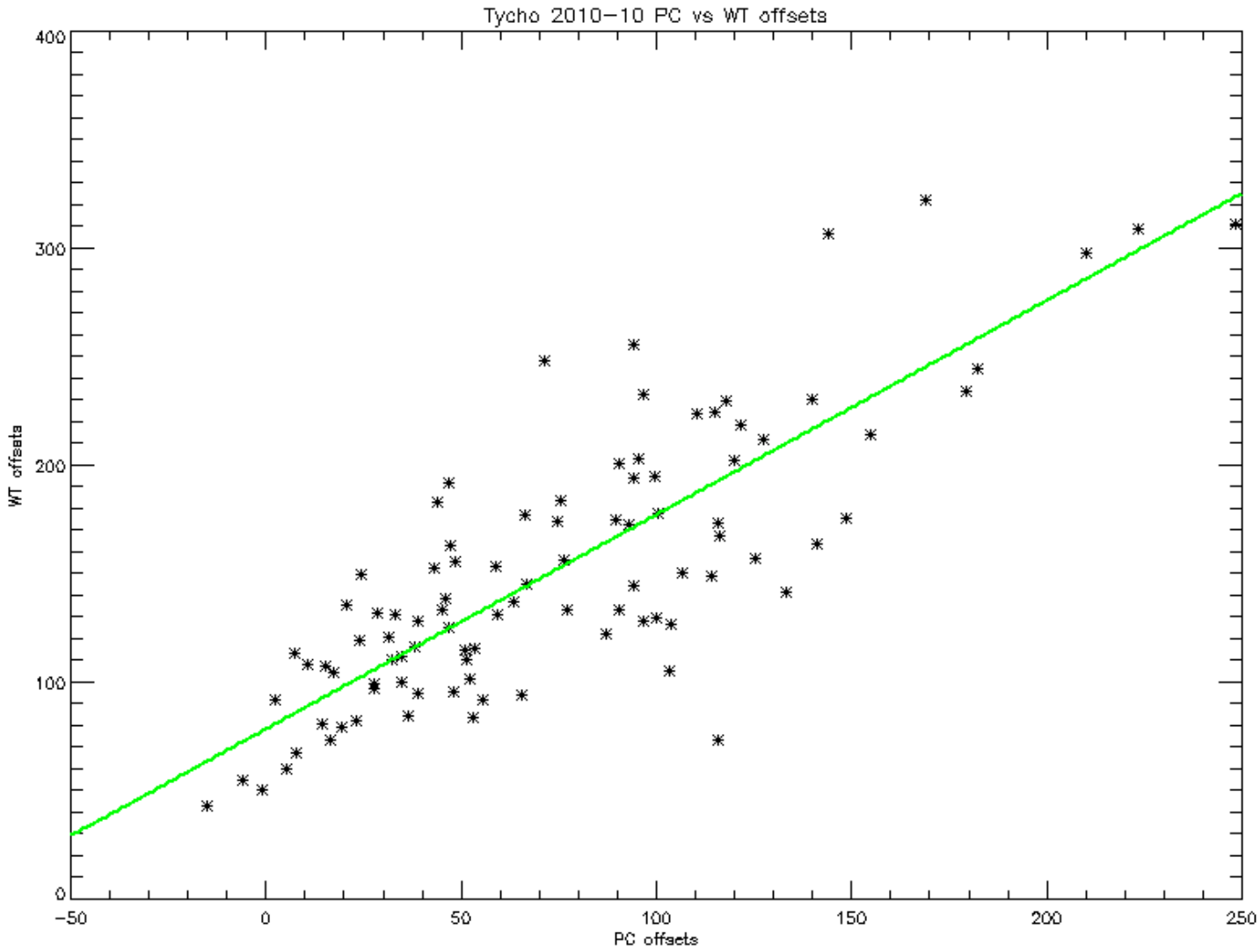


Trap mapping – FWHM

Evolution of FWHM of the observed and corrected Silicon line in Cas A & Tycho



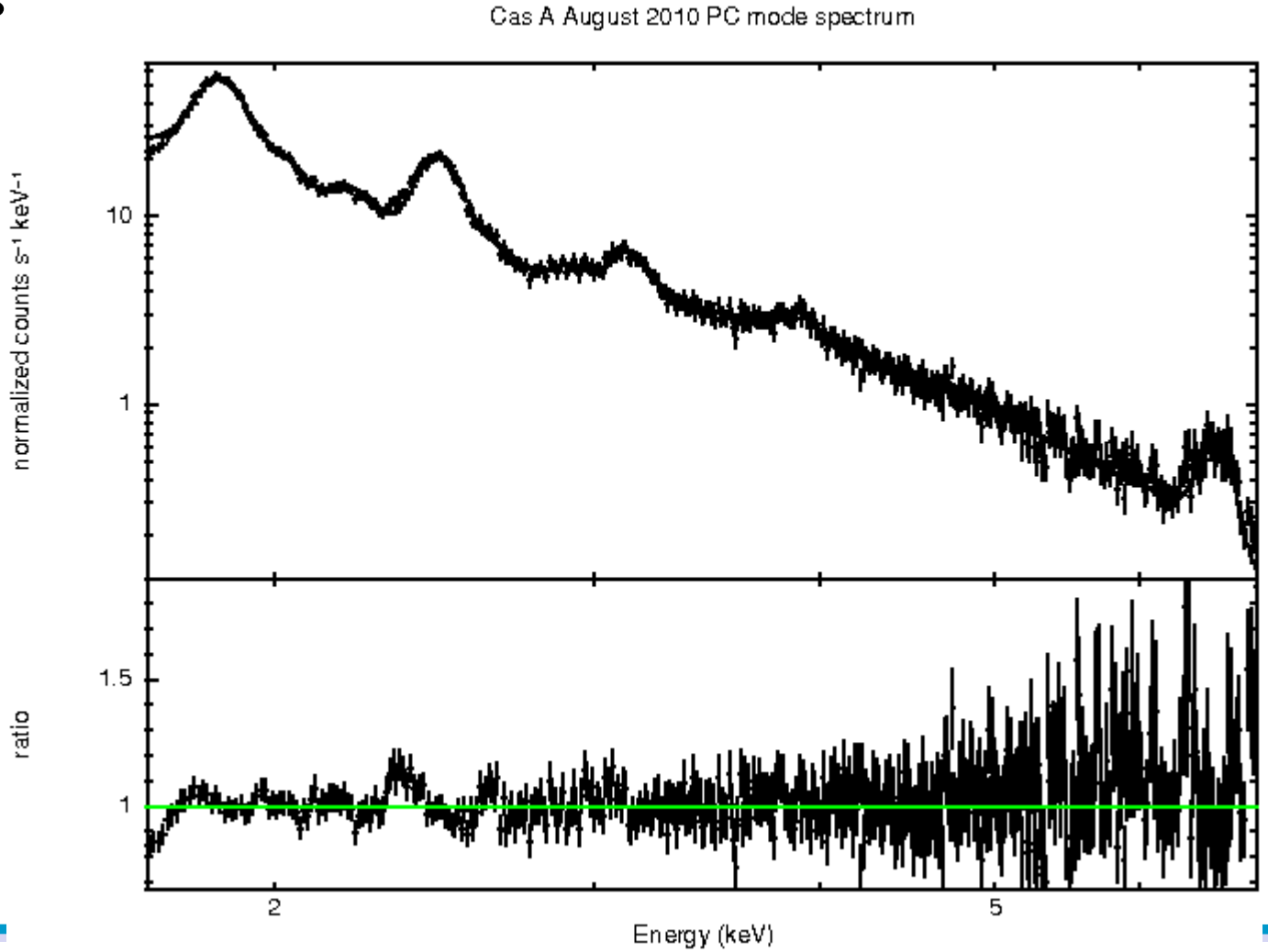
Trap mapping – WT v PC offsets



WT_OFFSET = 78 ev + 0.98 * PC_OFFSET ==> A Shift more then a scaling factor !

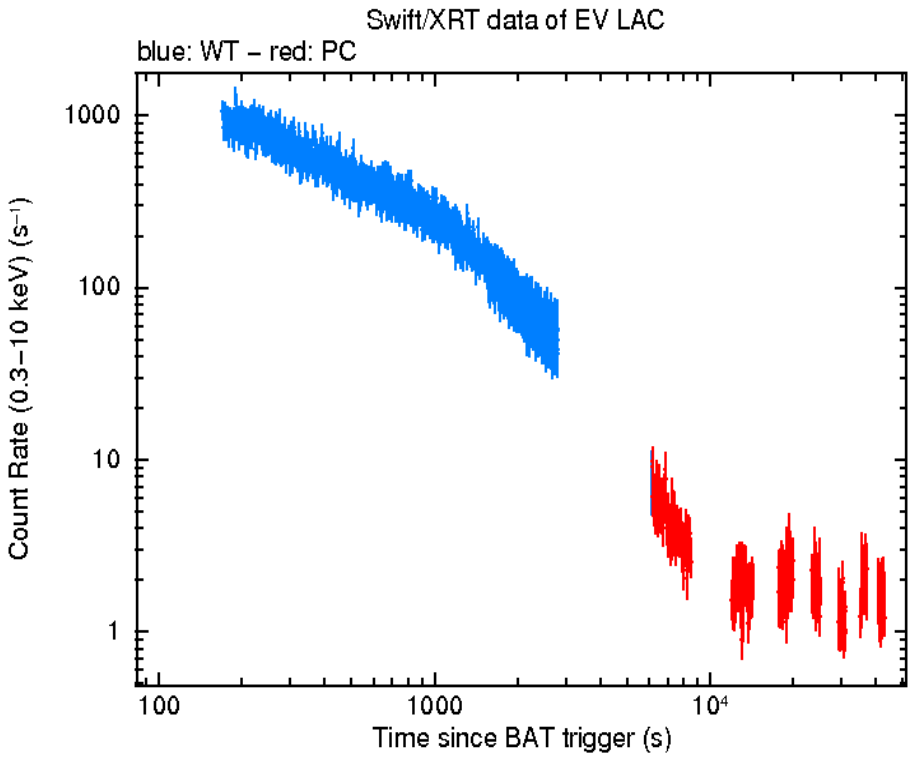
Trap mapping – Tests

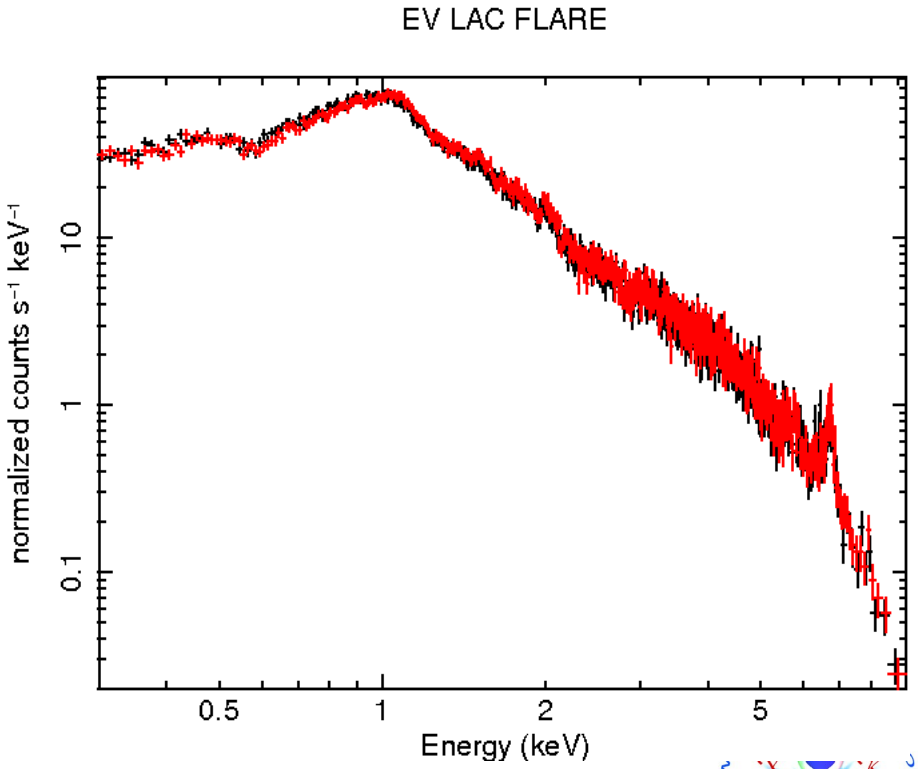
- Cas A fitted with XMM model with new RMF – Fixed line energies and widths



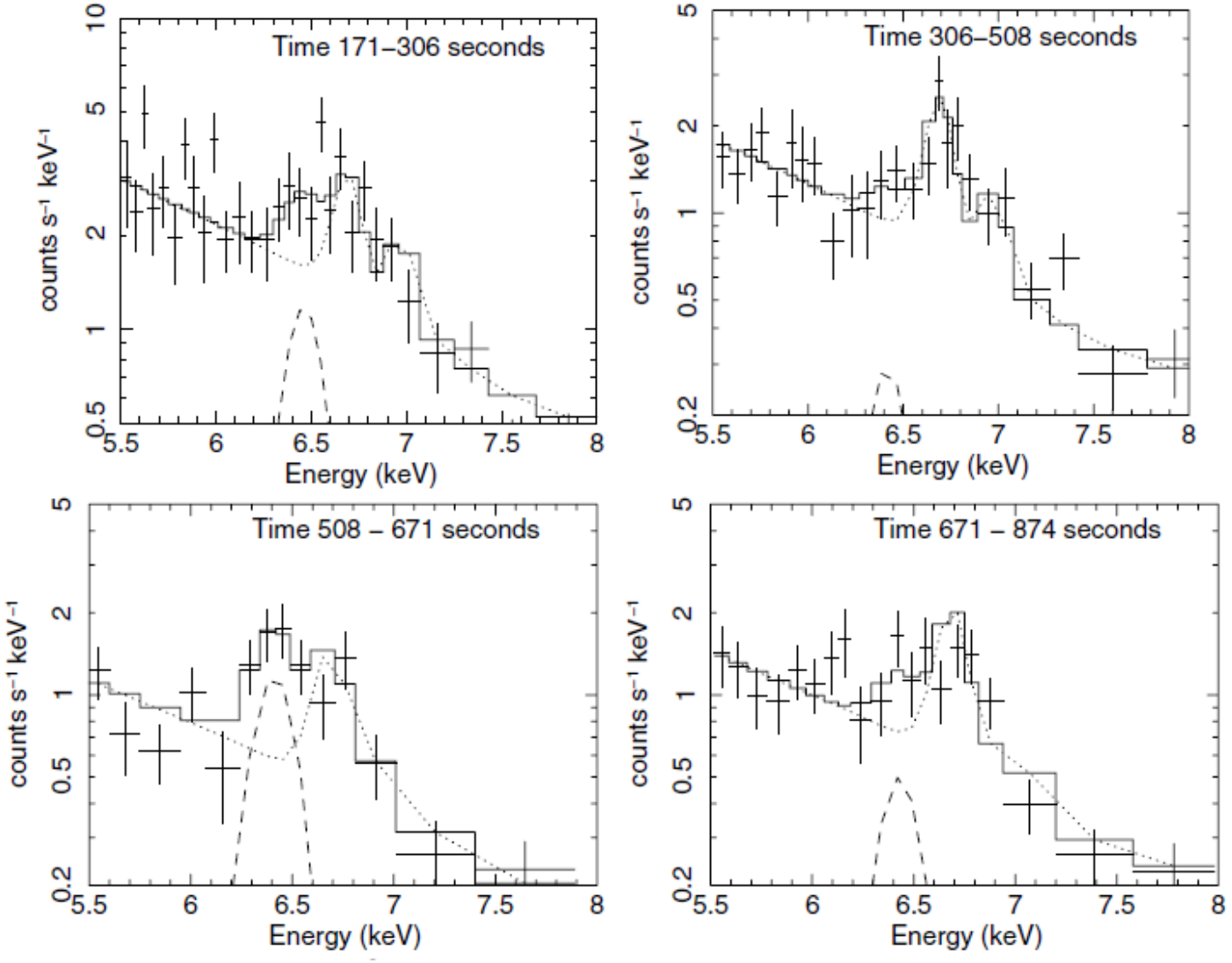
Real World Example

Ex: **EV LAC**, recent flare star (Osten et al 2010, http://adsabs.harvard.edu/abs/2010ApJ...721..785O)



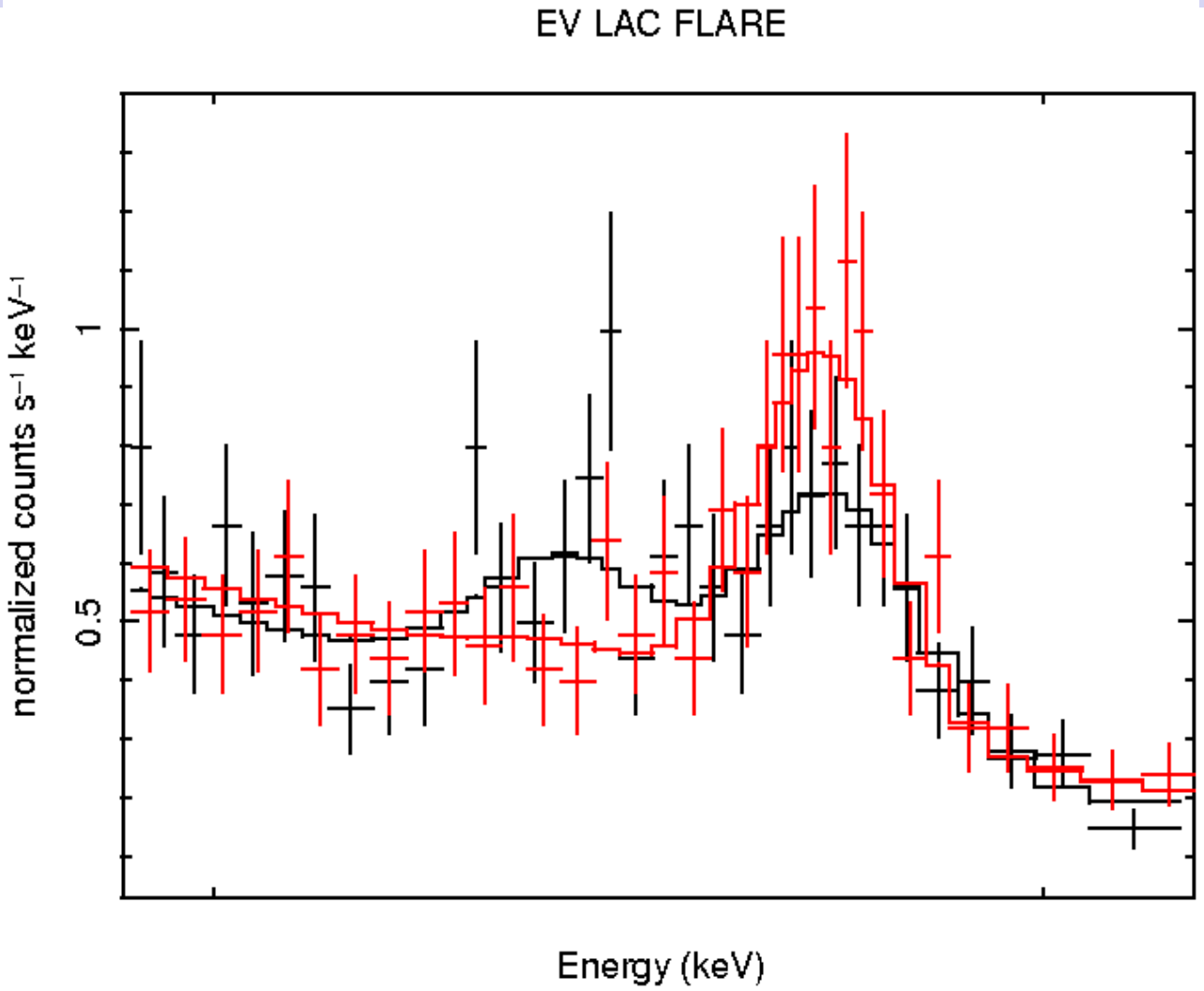


Real World Example (cont)



Osten paper fitting: 2 temperature APEC model + extra Fe fluorescence line

Real World Example (cont)



Trap correction seems to recover the main line, while the possible fluorescence line seems to disappear

Towards a new PC Vss=6V RMF

- Goals - obtain a total effective area consistent with data for post 2007-09 (Vss=6V) observations
- Use trap corrected data – to provide the best energy resolution possible
- Match the resolution to the data by refining the RMF code CTI description → energy dependent.
- Switch to ACIS linear absorption coefficients
- Match the high energy QE to data by changing the depletion depth → SNR G21.5 (IACHEC source).
- Correct remaining Si residuals and low E QE.

PC RMF update (i) - Resolution

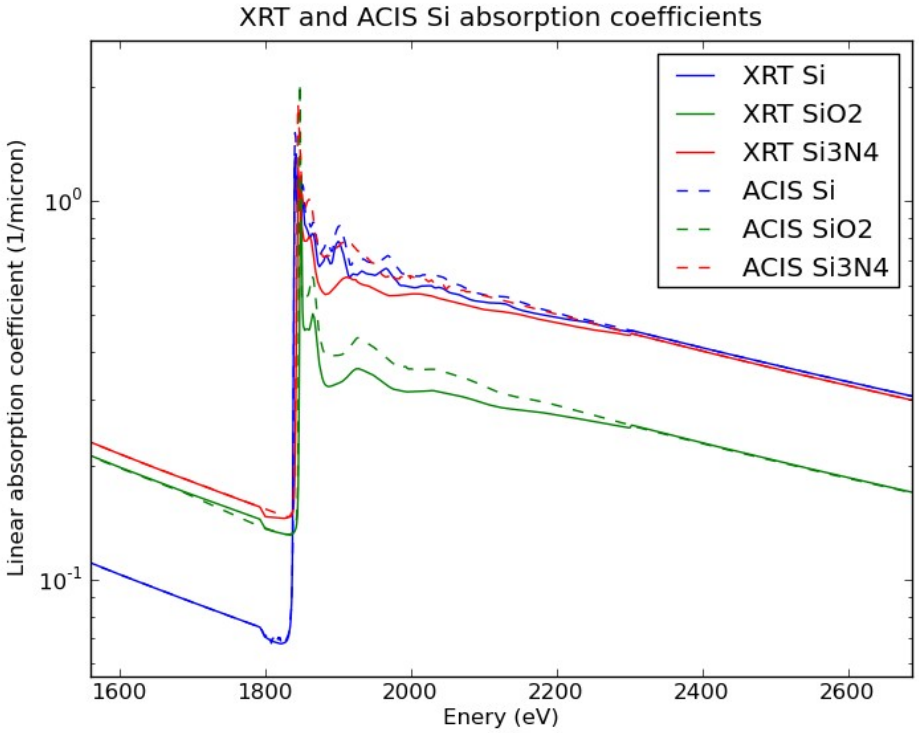
- Simulation code CTI coefficients were updated to be more representative for trap corrected data
  - PCTI(5.895keV) = 8e-5, SCTI(5.895keV) = 5e-5
- Update electron noise, EN = 7.5e
- Introduced a powerlaw energy dependence
  CTI(E)=CTI(5.895) (E/5.895)**(-alpha)
  expect alpha ~ 0.2 to 0.7 from other missions.
- Aim to match the measured (trap corrected) resolutions
  - 125 eV @ 1860 eV (estimated from Tycho)
  - 200 eV @ 5895 eV (see next slide)
- Found alpha = 0.2 worked best when tried on E0102 and Tycho

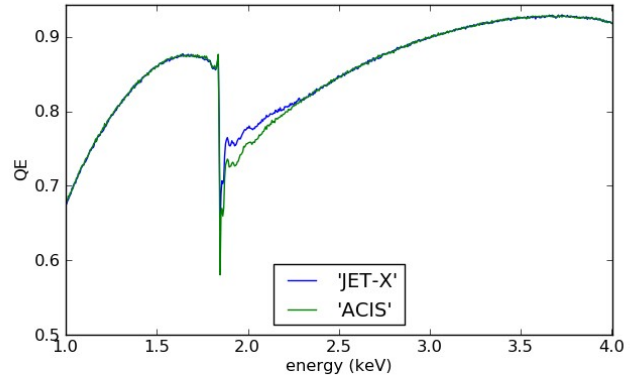
Fe-55 FWHM of CS 3 (eV)

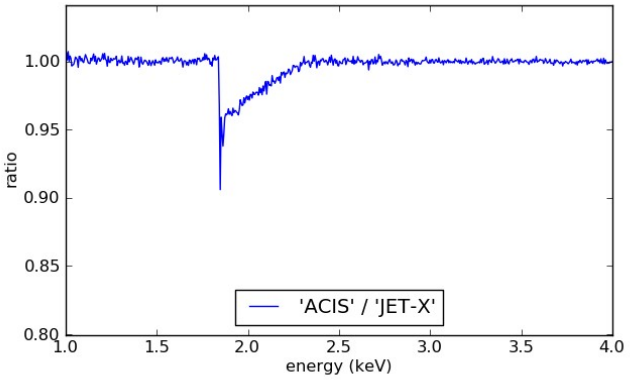
Date	Grade 0	Grade 0-12	
2004-12 (launch)	140	145	
2008-06	251	264	all columns
	184	192	many good columns
	146	153	4 good columns
2010-09	273	296	all cols
	191	205	many good cols
	174	182	4 good cols

PC RMF update (ii) - Linear Absorption Coefficients

- Obtained ACIS lin. abs. coeff's from Catherine Grant
  - EXAF structure similar but coeff. higher, with different slope than the Owens et al. Jet-X ones just above Si edge
  - Gives ~5% deeper edge in QE







PC RMF Update (iii) - QE

- Changing the substrate voltage to 6V caused a change in depletion depth (DD).
  - WT V012 suggested DD=22micron (compared with DD=27micron for Vss=0V).
- Computed PC RMFs at different DDs
- Fit the IACHEC source SNRG21.5 to decide which one matches data best:

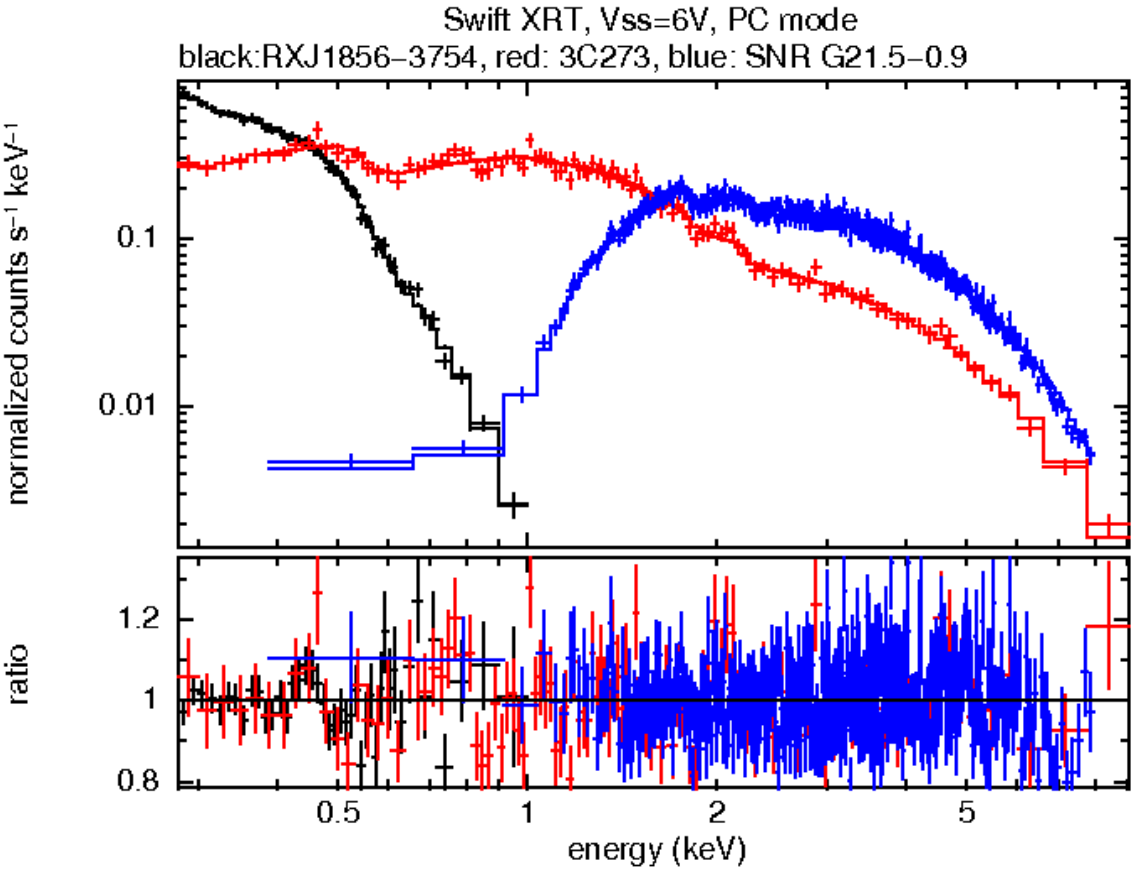
DD(micron)	Gamma (g0-12, g0)
20	1.84, 1.86

PC RMF update (cont.)

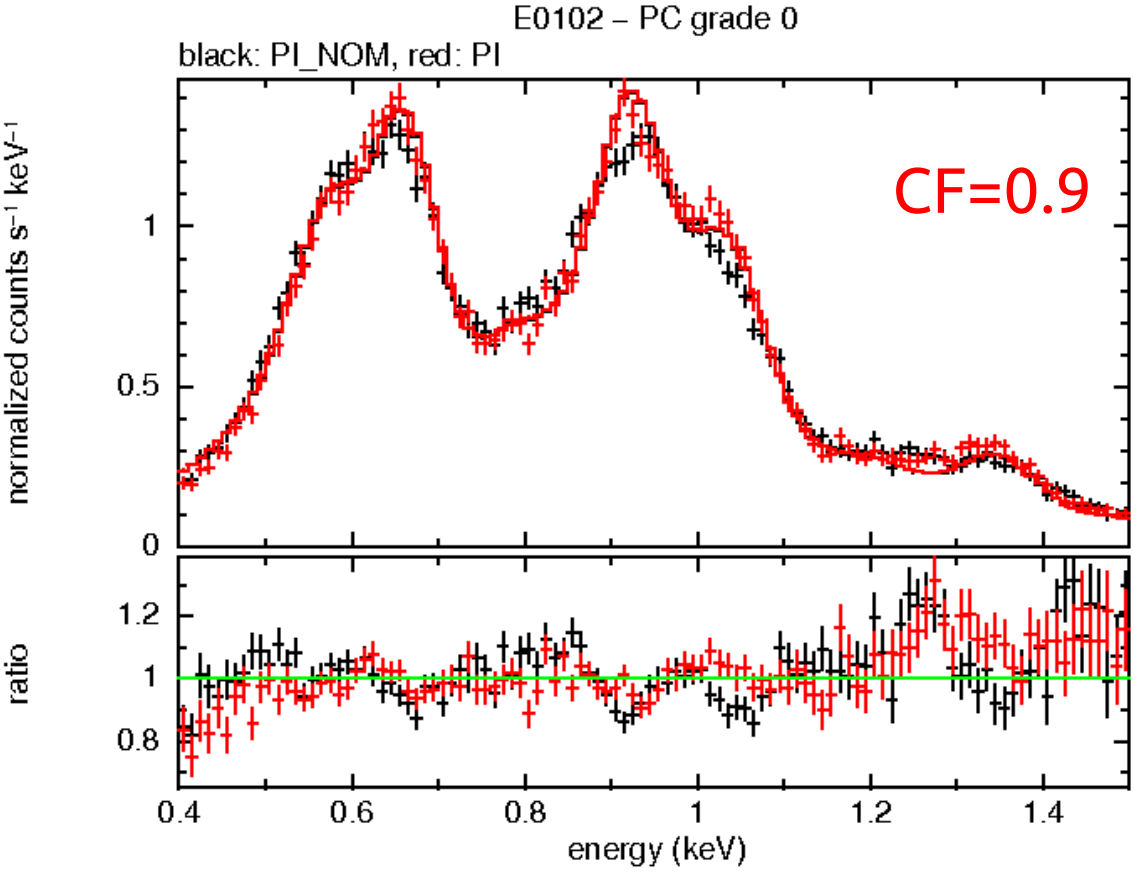
- Further corrections needed for the
  - redistribution shelf (based on Fe-55 source + SNR G21.5, tested on GRS1741-2853)
  - Si edge (on SNR G21.5 + 3c273)
  - Low E QE (on RXJ1856), as traps ultimately cause lost events below event threshold at lowest energies

PC RMF update (cont.)

- QE corrections made on the basis of a joint fit to RXJ1856, 3c273 (sim. with XMM), SNR G21.5



PC RMF update (cont.)



PC RMF summary

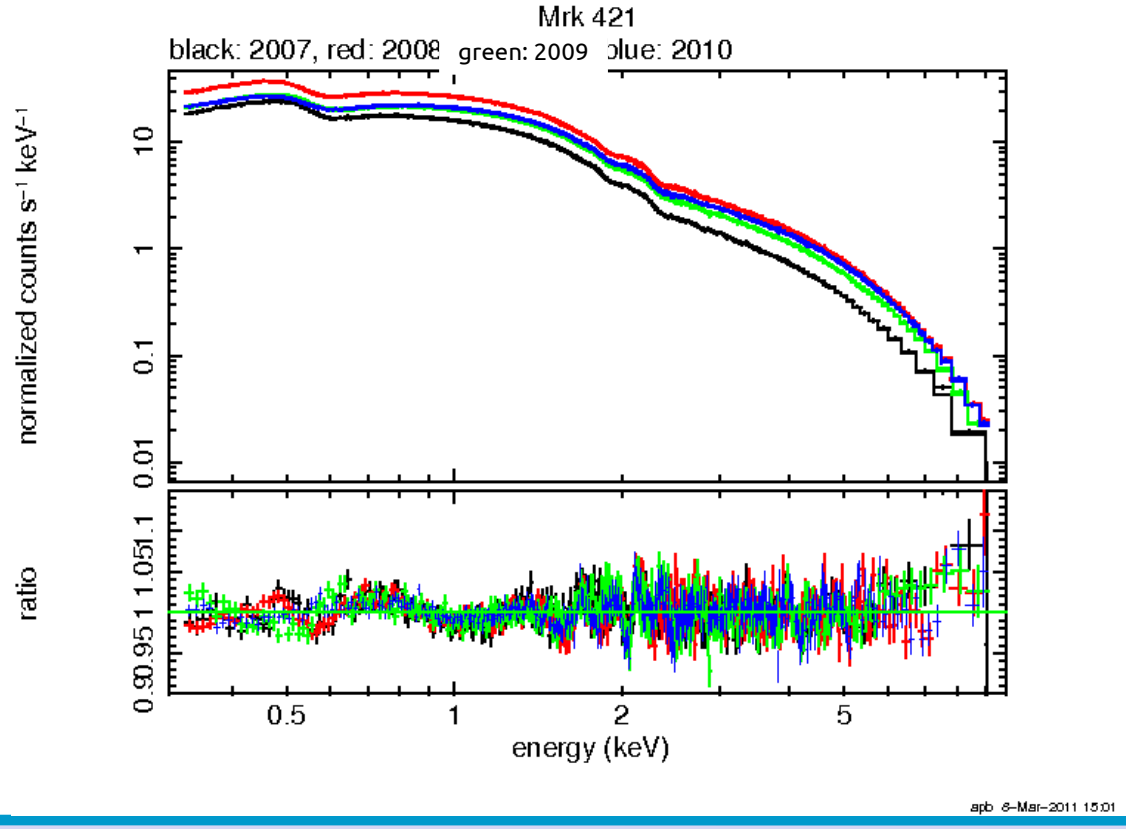
- New PC mode RMF is ready (v012), suitable for trap corrected, Vss=6V data (post 2007-09-01)
- Expect powerlaw slopes to increase by ~0.1 to 0.15 compared with current RMF
- Good agreement with cross-calibration sources

WT RMF revisted

- Found the current v012 WT broadened RMF works quite well on trap corrected data.
  - Suggests level of broadening applied in 2007-09 is good for trap corrected data in 2008-2010.
- However, comparison of unbroadened and broadened RMF made us realise a ~16-18 eV shift (to lower energies) exists, caused by the broadening function
- Corrected this shift (by 2 PI channels, 20eV)
- Further cosmetic corrections applied around the Si edge

Mrk 421

- Used to refine the Si residuals
- NB – gain fit with offset of ~10eV required to fit around the O-edge in 2008 and 2010



Check on Cyg X-1

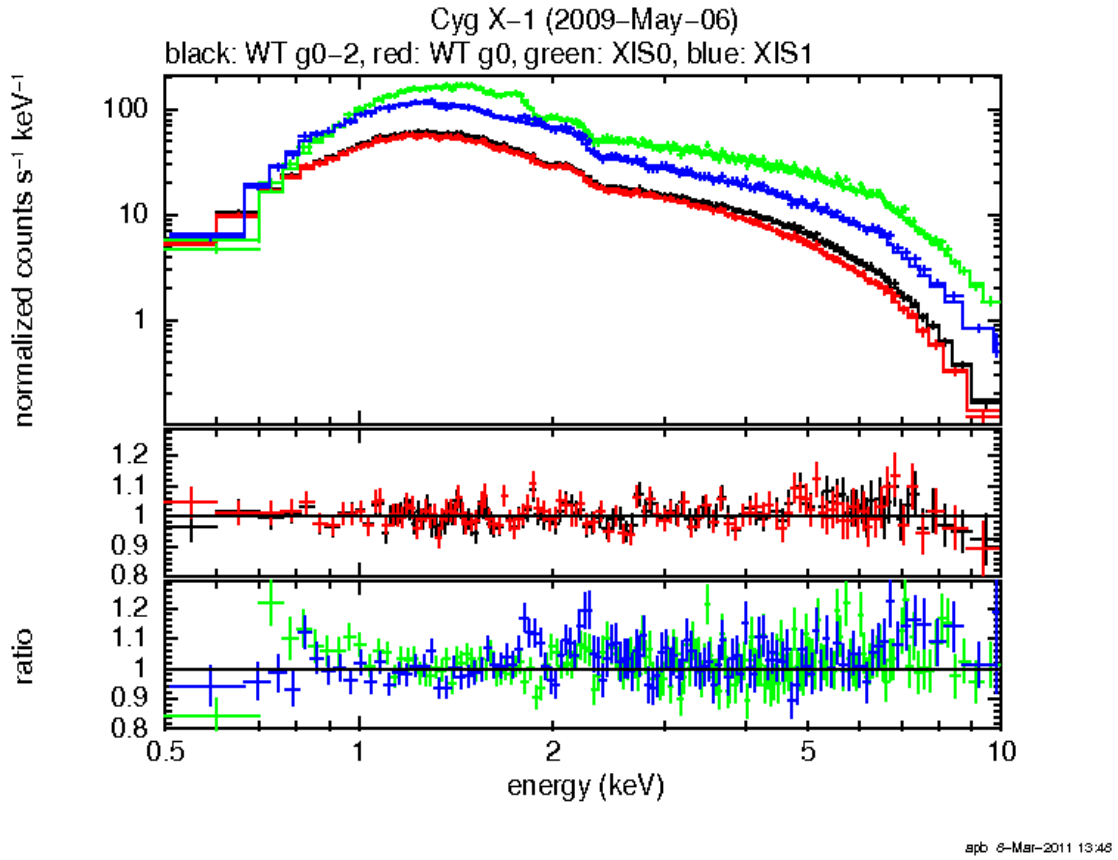
- Cyg X-1 : 920s simultaneous with Suzaku

Suzaku XIS0/1 (tied)

NH	0.857 +/- 0.054	
diskbb kT	0.223 +/- 0.017	
diskbb norm	(2.05 +1.58 -0.92)e5	
PL Gamma	1.795 +/- 0.028	
Fx	(11.08 +0.07 -0.22)e-9	XIS0
(0.5-10)	(10.55 +0.07 -0.22)e-9	XIS1

XRT WT	grade 0-2	grade 0
NH	0.852 +/- 0.052	0.799 +/- 0.050
diskbb kT	0.218 +/- 0.020	0.234 +/- 0.025
diskbb norm	(1.57 +1.38 -0.76)e5	(0.82 +0.86 -0.43)e5
PL Gamma	1.736 +/- 0.031	1.737 +/- 0.033
Fx (0.5-10)	(9.46 +0.06 -0.14)e-9	(9.35 +0.07 -0.19)e-9

Cyg X-1 with Suzaku



Check on PKS2155-304

- PKS2155-305 : 9ks simultaneous with XMM (2009 May)

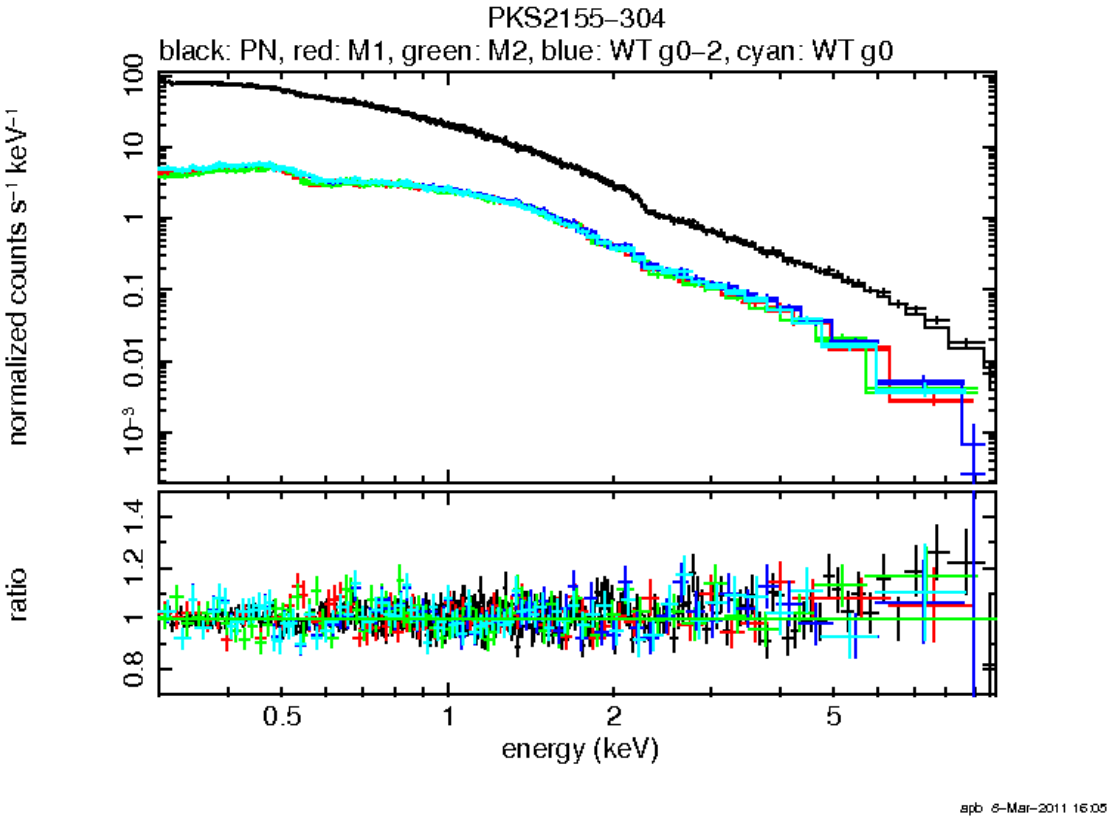
Model: phabs * bkpow

XMM	PN	M1	M2
NH	(1.29 +/- 0.03)e20	(0.09+/-0.01)e20	(1.03+/- 0.09)e20
Alpha1	2.688 +/- 0.030	2.509 +/- 0.035	2.540 +/- 0.115
Ebreak	1.03 +/- 0.070	1.211 +/- 0.12	1.176 +/- 0.18
Alpha2	2.882 +/- 0.015	2.844 +/- 0.048	2.925 +/- 0.060
Fx (0.3-10) e-10	1.27 +/- 0.015	1.23 +/- 0.015	1.22 +/- 0.005

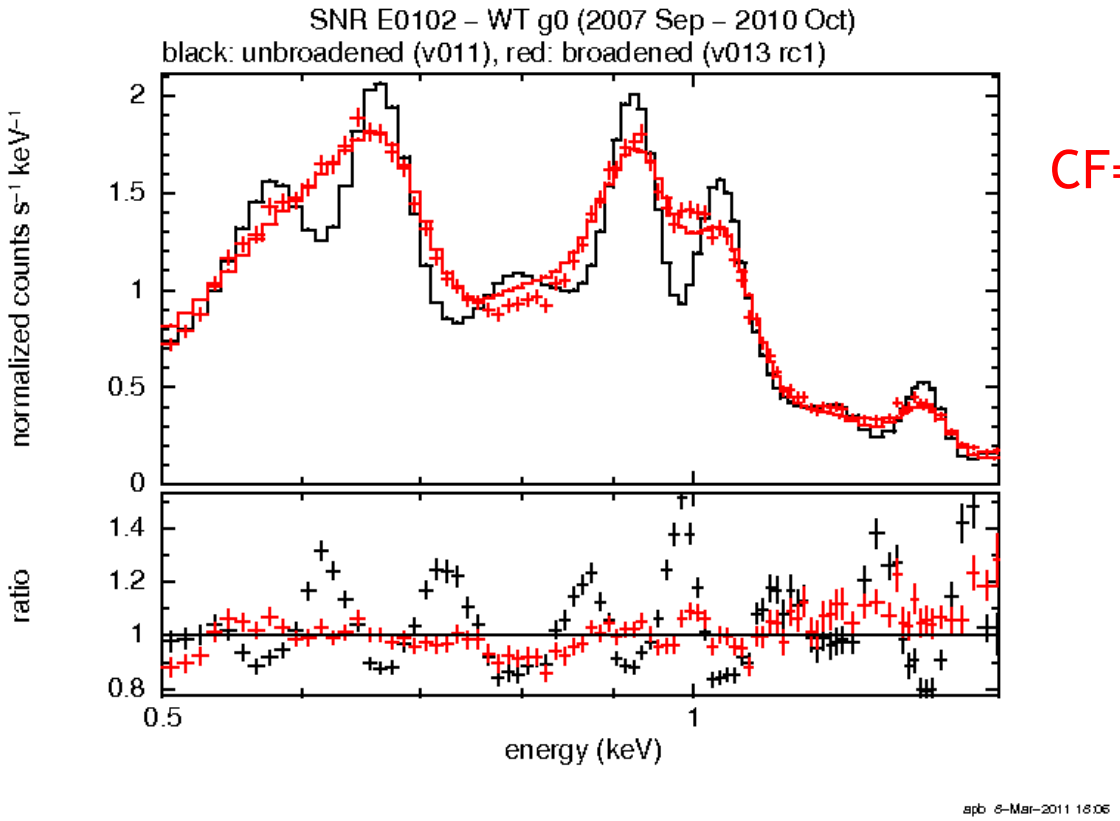
XRT WT	grade 0-2	grade 0
NH	(2.11+/-0.8) e20	(2.30+/-0.7)e20
alpha1	2.404 +/- 0.10	2.426 +/- 0.094
Ebreak	1.130+/-0.17	1.160+/-0.16
Alpha2	2.816 +/- 0.055	2.830 +/- 0.056
Fx (0.3-10) e-10	1.17 +/- 0.015	1.17 +/- 0.016

Cf Galactic NH = 1.48e20 cm^-2

PKS2155-304 cont



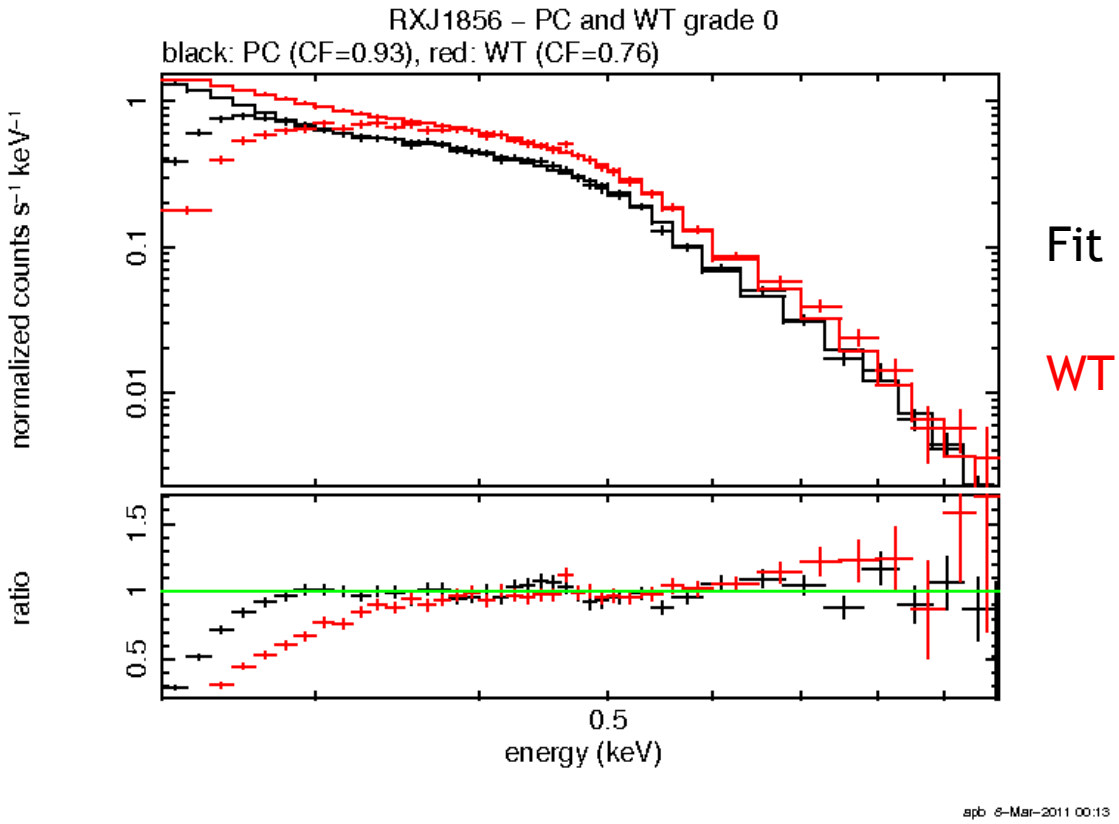
E0102 (WT)



CF=0.88

RXJ1856 (WT)

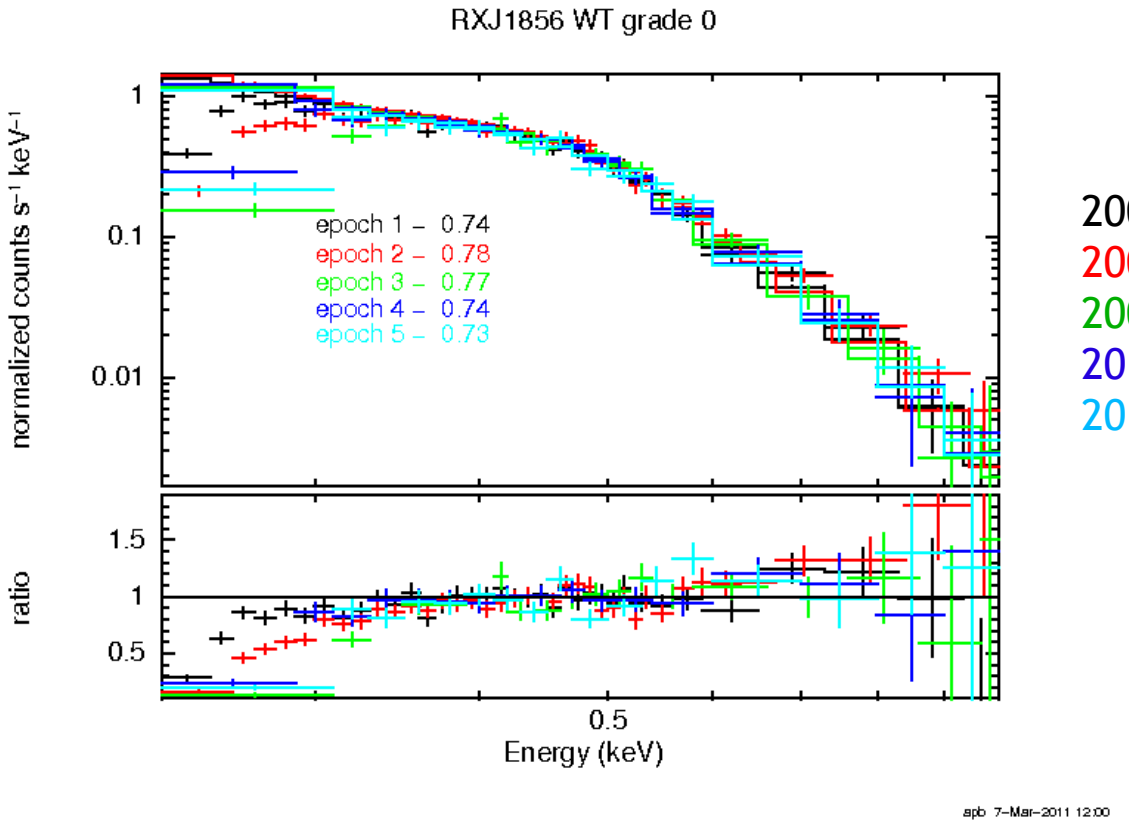
2007-09 to 2010-08



Fit > 0.4 keV

WT CF = 0.76

RXJ1856 (WT)



2007-09/11
2008-09
2009-10/11
2010-04
2010-08

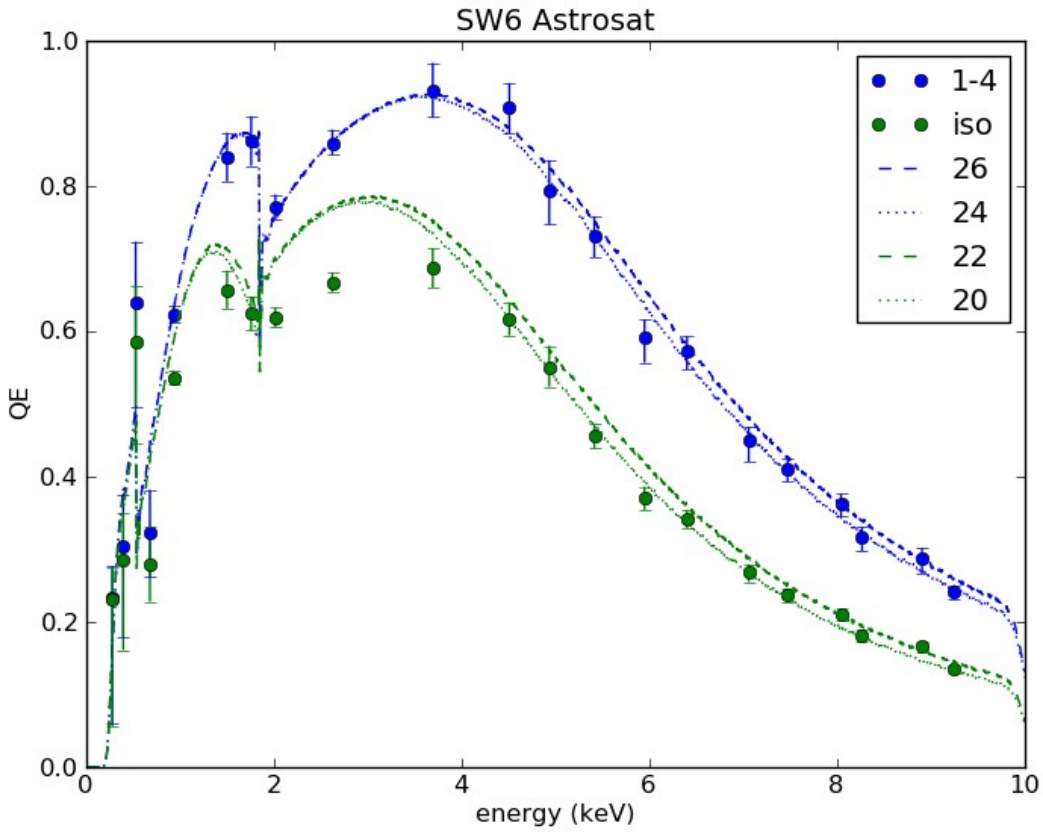
- Performance degrading at low E due to events disappearing below the 80DN (~0.225 keV) event threshold

WT RMF summary

- WT RMF (v013) ready for trap corrected, Vss=6V (post 2007-09-01) data
- Based on v012 broadened RMF, but tweaked to correct a 2 channel shift in response, and refine the Si edge residuals
- Fits agree well with cross-cal targets
- Except soft Ns RXJ1856 – const fact ~0.75
  - Propose to leave this as is simply document this in release note
- Data now less reliable below 0.35 keV due to loss of events below threshold caused by traps
- Residual offsets of order 10eV can still be present in some observations

Future

- Astrosat CCD22 lab. QE measurements from Graeme Hansford



Grade 0 QE → open electrode → reduced DD

Future

- Simple QE model = electrode transmission * Si absorption probability
- Allow different depletion depths under different parts of the electrode