Swift-XRT Calibration update

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With help from
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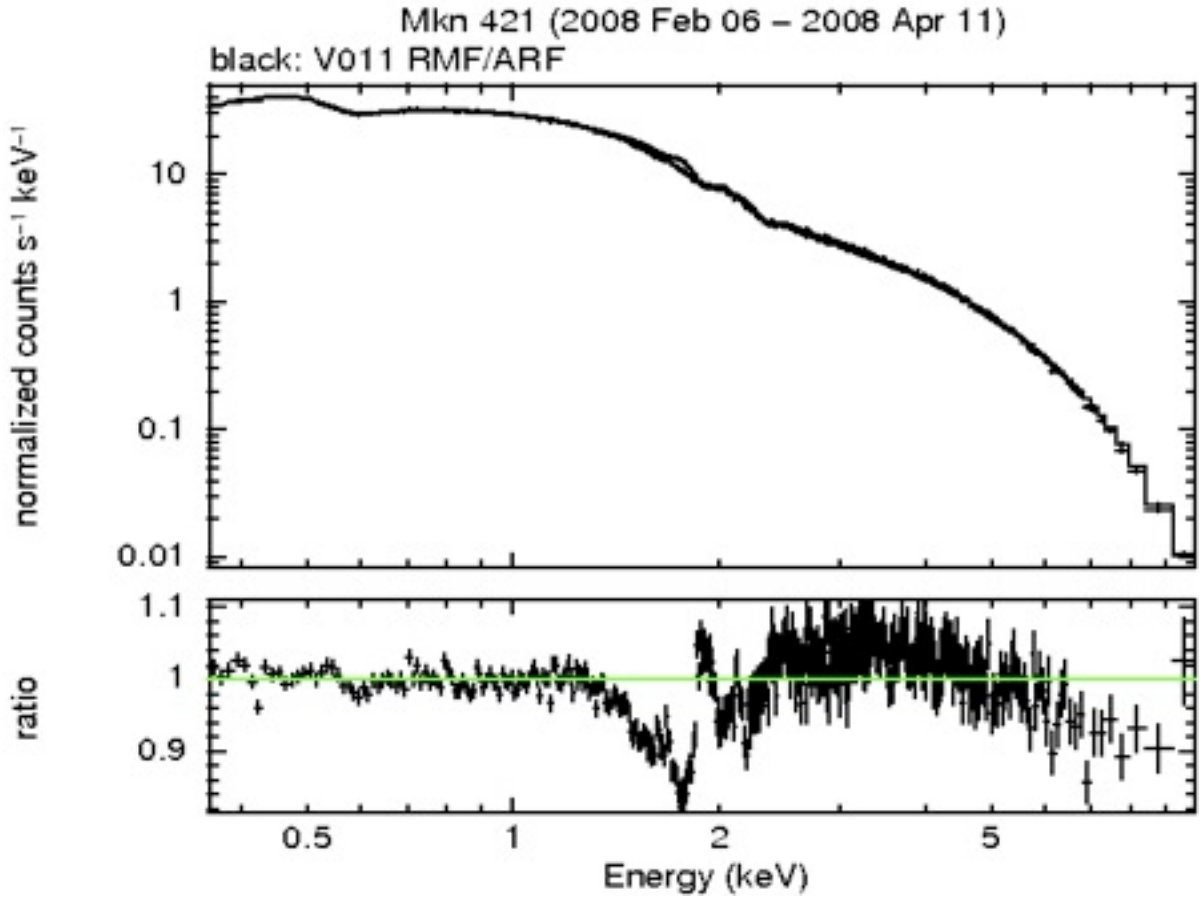
on behalf of the XRT cal team.

- RMF status
  - Windowed Timing (WT) broadened RMFs released 2009-Apr (for 2007-03 and post 2007-09 epochs)
  - Photon Counting (PC) broadened RMFs released 2010-Dec (for 2007-03 and epochs 2007-09)
- Outstanding issues
  - RMF QE deficiencies near Si since substrate voltaged change to Vss=6V (2007-Aug-30).

The Vss=6V Si QE problem

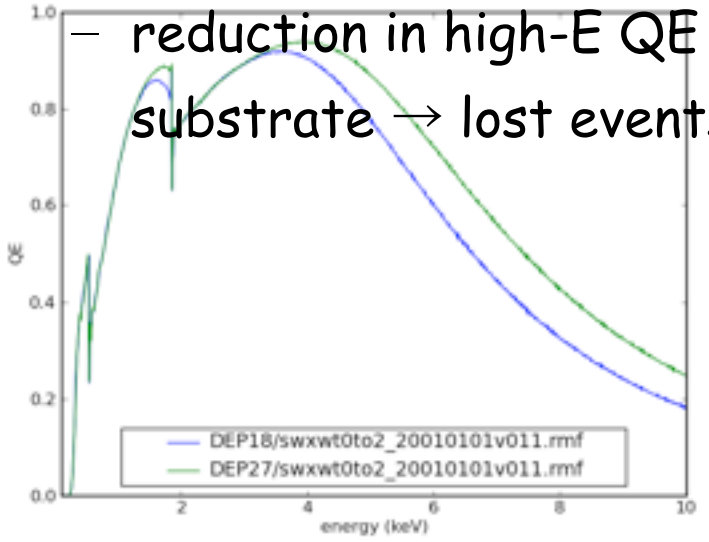
Mkn 421 - WT grade 0-2 (1 million counts)

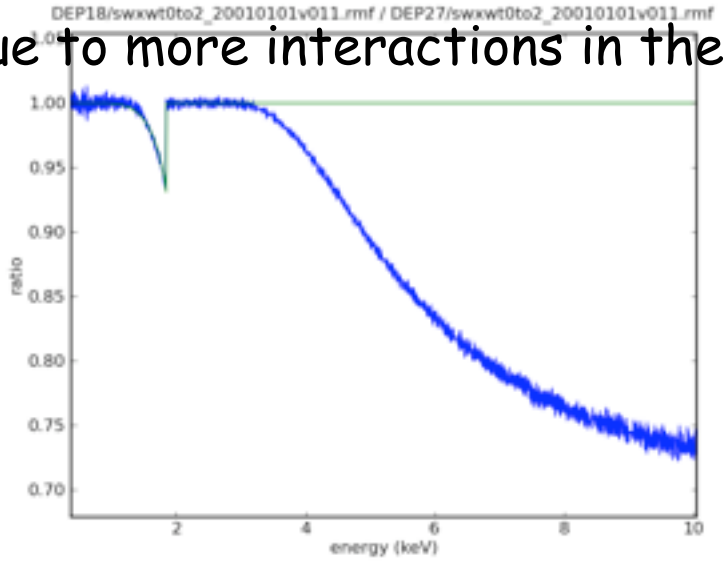


Current V011 RMF

Effect of reduced Depletion Depth

- Olivier computed RMFs with different depletion depths using our CCD22 Monte-Carlo simulation code
- Effect of smaller DD
  - reduction in QE shortward of Si edge due to more interactions in the field-free region → larger event sizes
    → more sub-threshold losses
  - reduction in high-E QE due to more interactions in the substrate → lost events



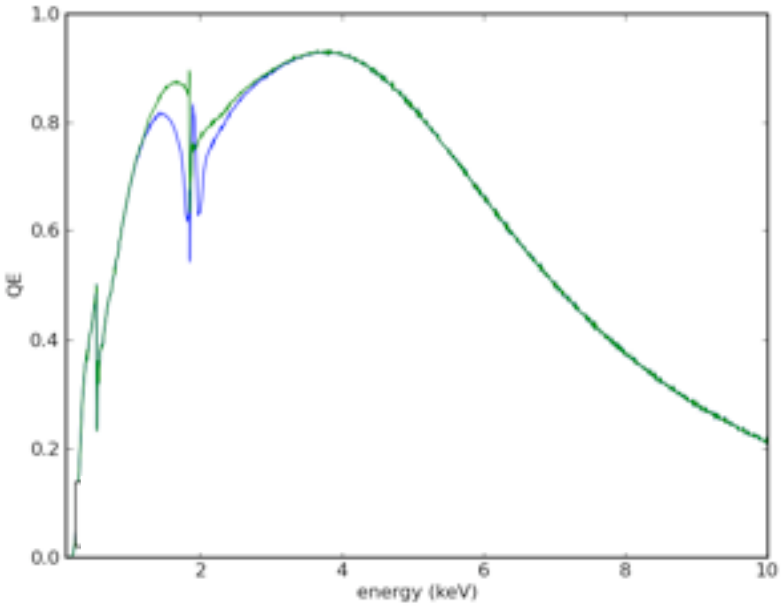


Toward a new Vss=6V WT RMF/ARF

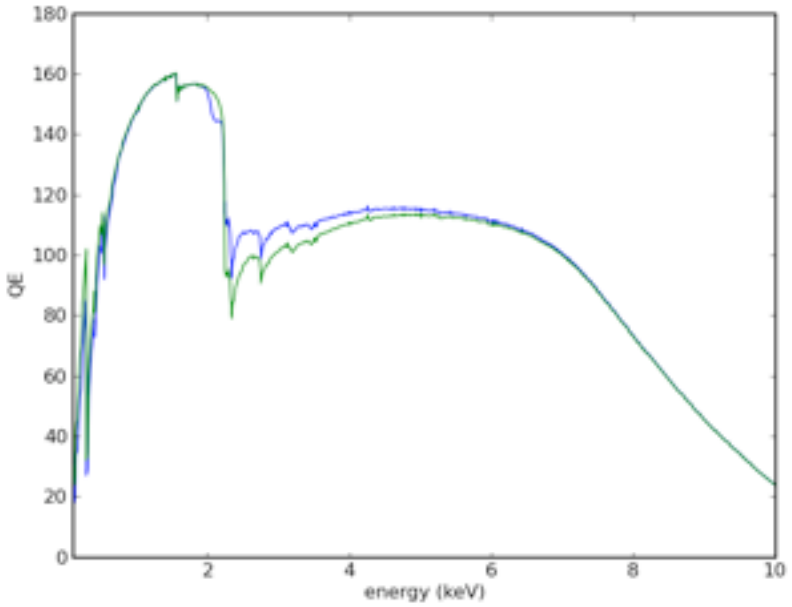
- Use observation of Cyg X-1 taken simultaneously with Suzaku in 2009 May (thanks to Yamada-san)
  - Enforce strict simultaneity → 920s of data; not great S/N (90000 counts XRT, 75000 XIS0/3)
- Use theoretical (unmodified) mirror * filter ARF
- Fit simple model: phabs*(bbody+powerlaw) but apply modifying model components for the Si QE and Au corrections
- Test different DD RMFs → DD 22 micron RMF gave good agreement to the XIS0/1 PL index

QE and ARF corrections

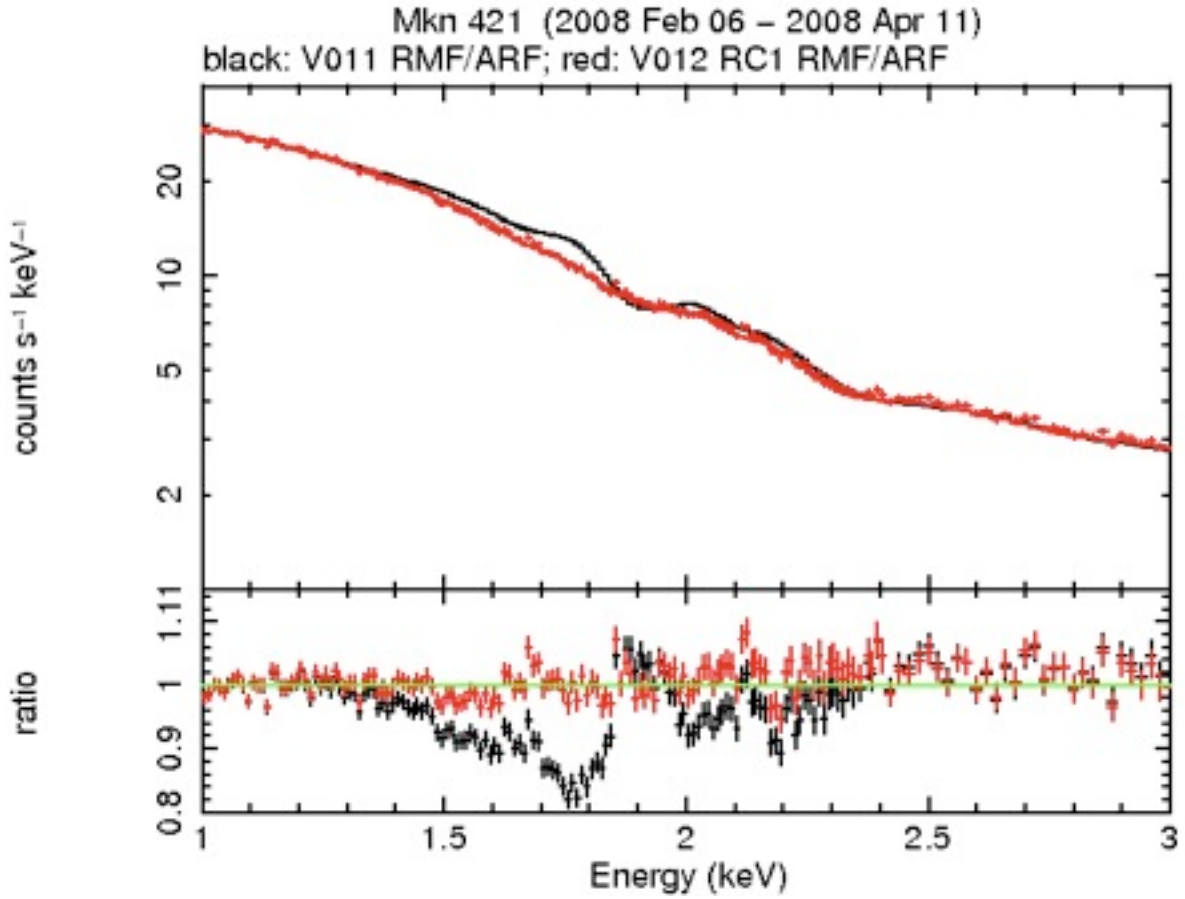
Original QE
Corrected QE



Original mirror area*filter trans
Corrected mirror area*filter trans



New WT RMF / ARF



Check on Cyg X-1

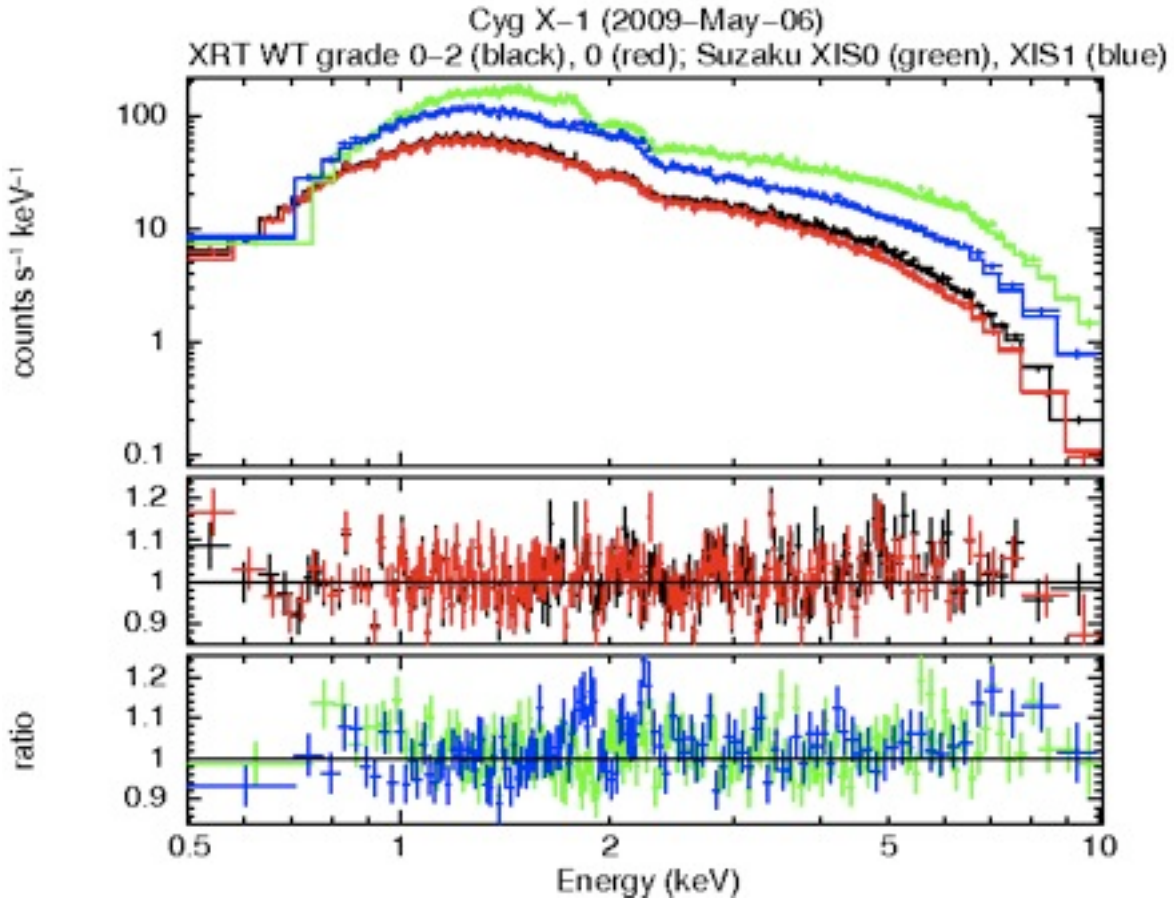
- Cyg X-1 : 920s simultaneous with Suzaku

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	0.902 +/- 0.053	0.862 +/- 0.054
diskbb kT	0.210 +/- 0.016	0.220 +/- 0.020
diskbb norm	(2.48 +1.9 -1.1)e5	(1.58 +1.45 -0.77)e5
PL Gamma	1.786 +/- 0.030	1.792 +/- 0.033
Fx (0.5-10)	(9.38 +0.06 -0.16)e-9	(9.25 +0.08 -0.22)e-9

Cyg X-1 with Suzaku



Check on PKS2155-305

- PKS2155-305 : 9ks simultaneous with XMM

Model: phabs * E**(-alpha + beta*log(e)) with NH = 1.48e20 (fixed)

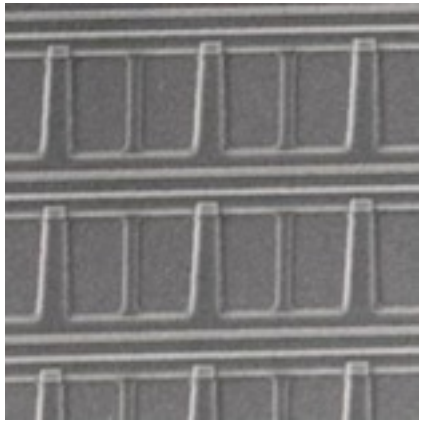
XMM	M1	M2	PN
alpha	2.689 +/- 0.016	2.691 +/- 0.017	2.778 +/- 0.006
beta	-0.186 +/- 0.050	-0.323 +/- 0.053	-0.147 +/- 0.020
Fx (0.3-10) e-10	1.20 +/- 0.015	1.20 +/- 0.015	1.268 +/- 0.005

XRT WT	grade 0-2	grade 0
alpha	2.629 +/- 0.017	2.628 +/- 0.017
beta	-0.330 +/- 0.055	-0.329 +/- 0.056
Fx (0.3-10) e-10	1.253 +/- 0.015	1.262 +/- 0.016

- Include Chandra results here too

Todo

- High S/N PC mode Vss=6V data also show residuals in Si region
  - Need to apply similar QE corrections here
- CCD22 open electrode may have a very different



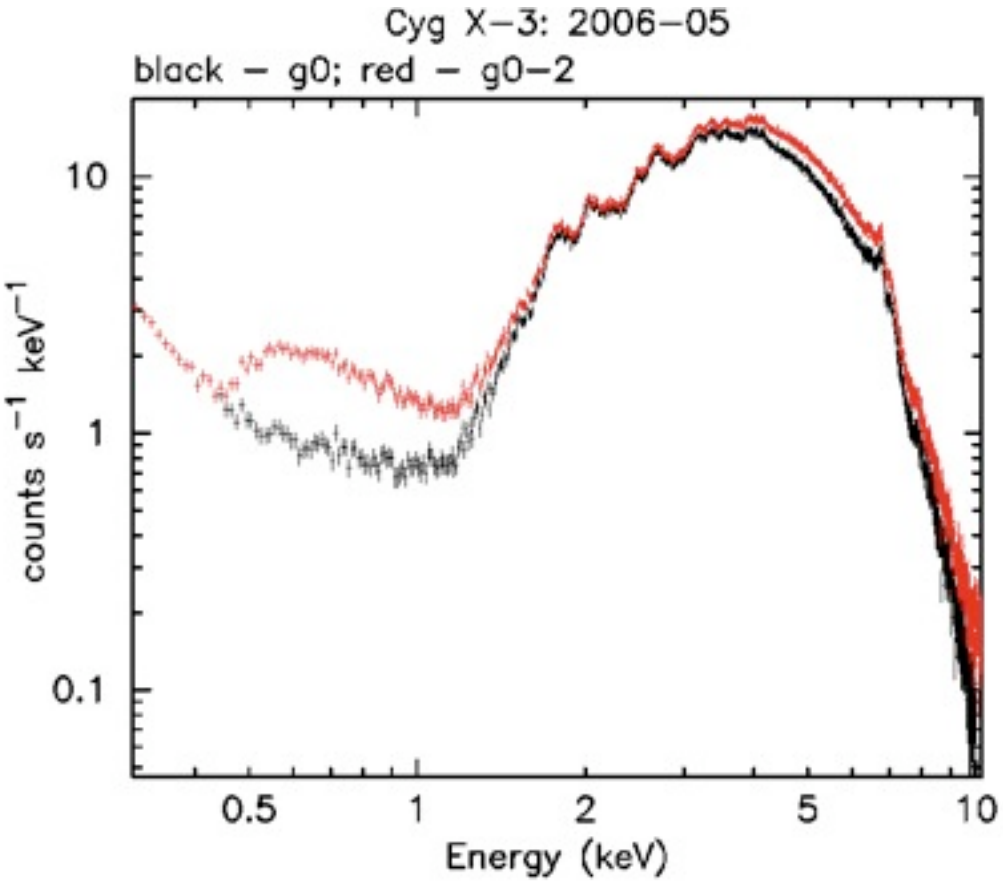
- Experiment with shallower DD under open electrode to reduce QE below Si edge

WT redistribution problem from heavily absorbed sources

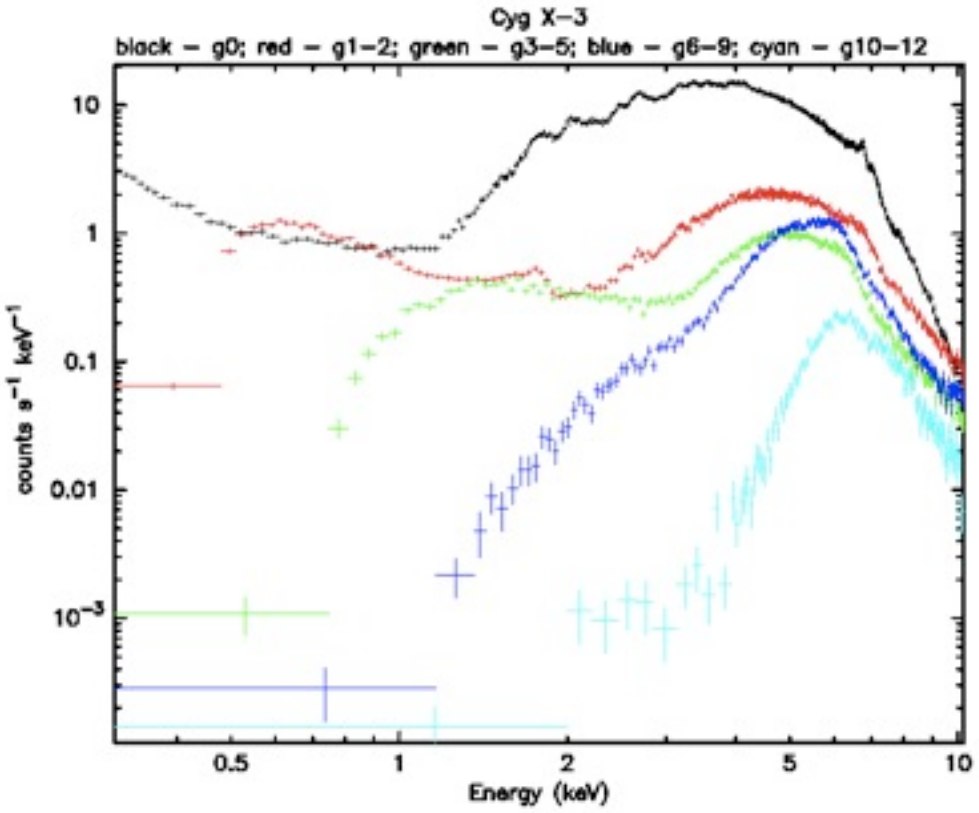
- Current (V011) WT redistribution tail (of high E incident photons down to low E) was refined on sources with a column density ~1-3e22 cm^-2
- Hints from absorbed transients that there might be issues with this.
- Also, observations of G21.5 (post-substrate voltage change) revealed a problem

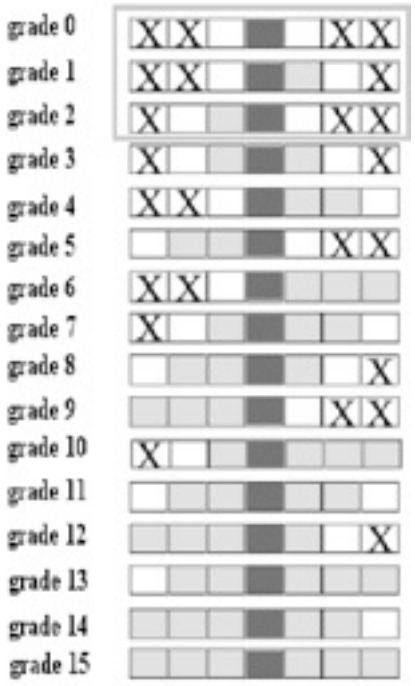
Redistribution from absorbed sources

Exemplified by Cyg X-3

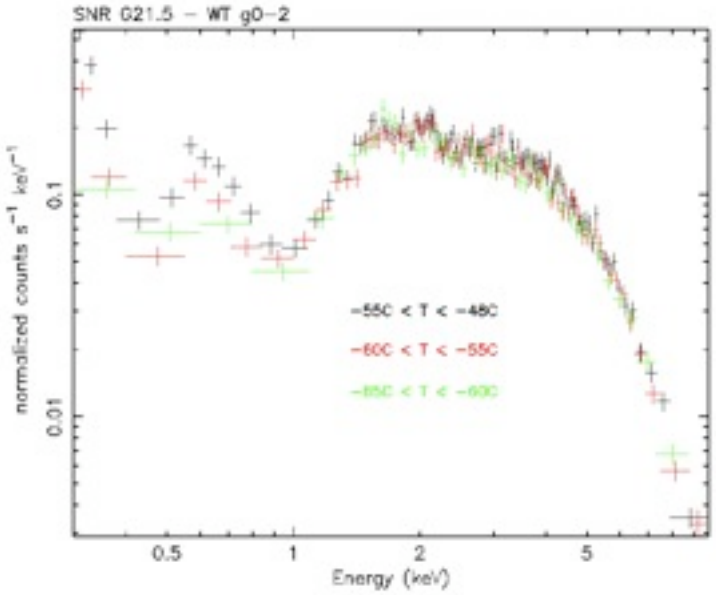


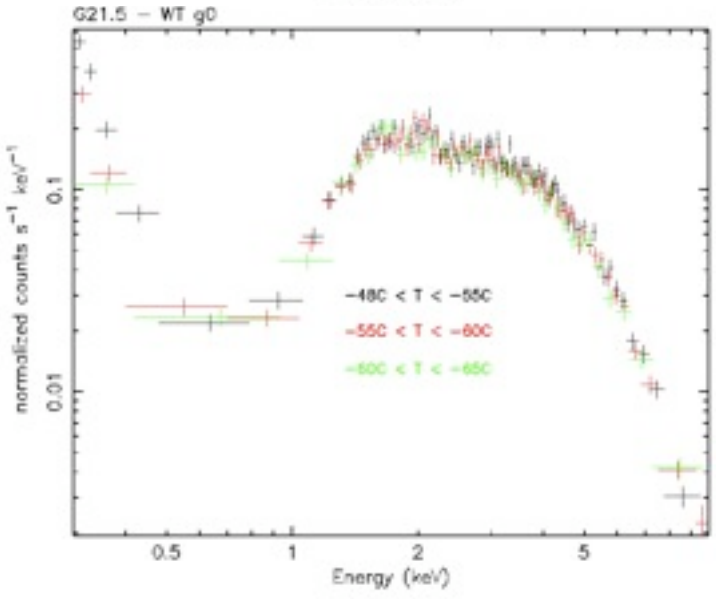
WT Grade dependence

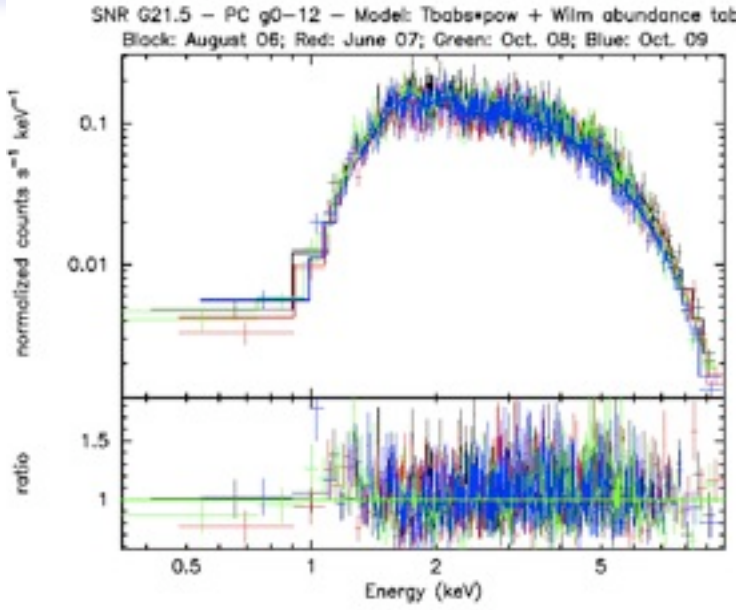




G21.5







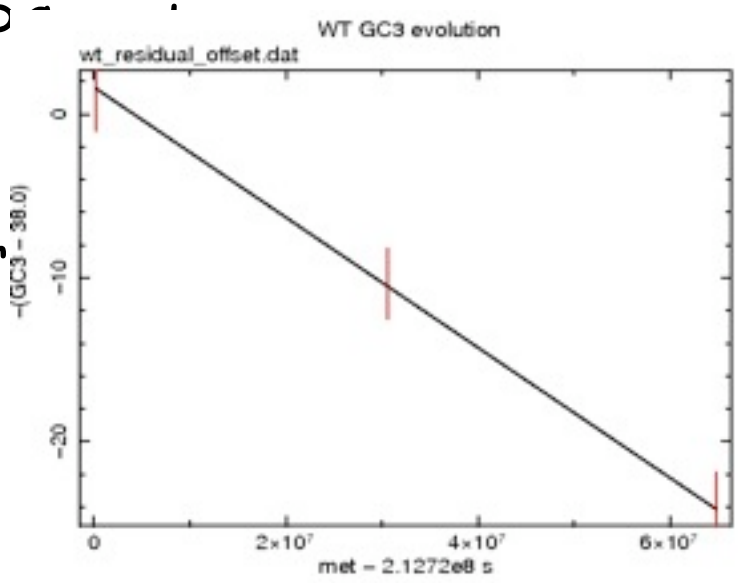
- Present in WT, but not PC
- Hints that there might be a CCDTemp dependence
- However, charge traps (ie position of source on detector) may be more important

Still under investigation

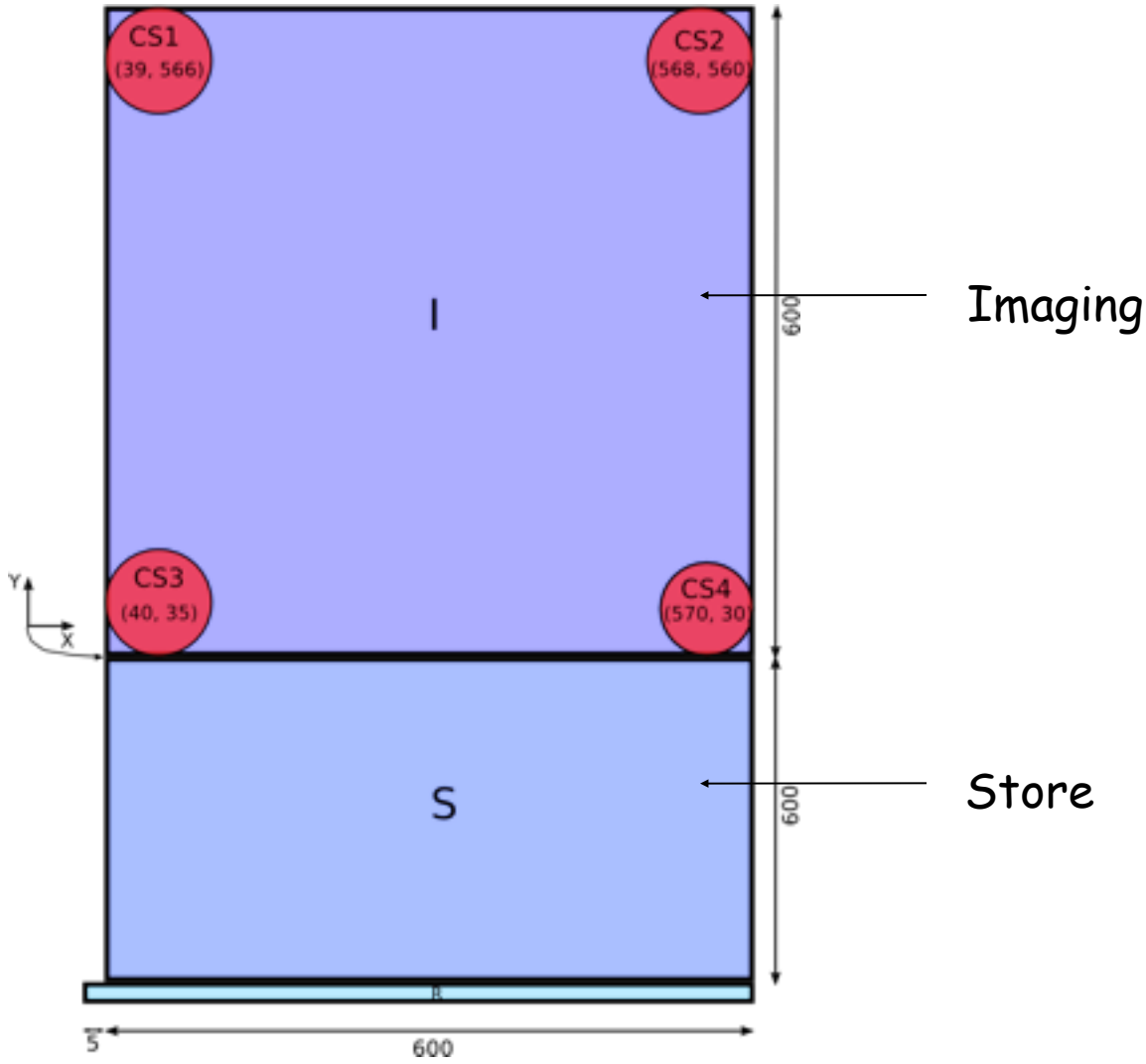
- Questions
  - Why is it so prominent and variable in G21.5?
  - Is source intensity important?
    - Bright sources fill traps, reducing subthreshold losses
  - Is there a temperature dependence? Or
  - Is there a trap dependence ? Or
  - Is there a background dependence ? (SAA fringes)
- Warning put on XRT digest page to warn users about this problem
  - Simply compare grade 0-2 and grade 0 spectra

Gain file status

- Updated PC & WT Vss=6V gain files released in 2009-Dec
  - Gain/CTI Coefficients valid to 2009-Oct-30
  - Gain coefficient shows a number of changes of slope
  - Included 10 eV offset for P
  - Included a time dependent offset for WT mode required for 2007, 2008, 2009

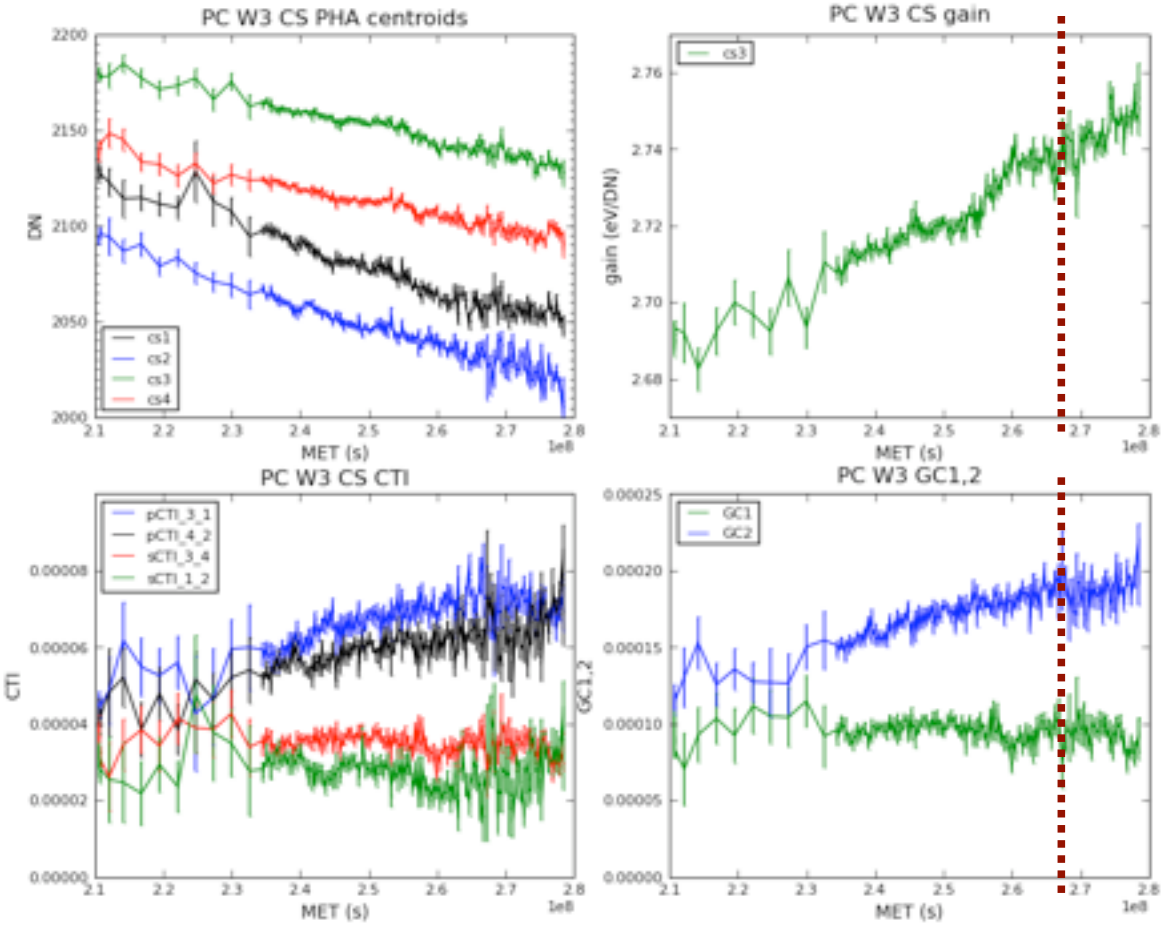


XRT CCD schematic



Corner source analysis

From 2007-09-01 to 2009-10-30 at -57C



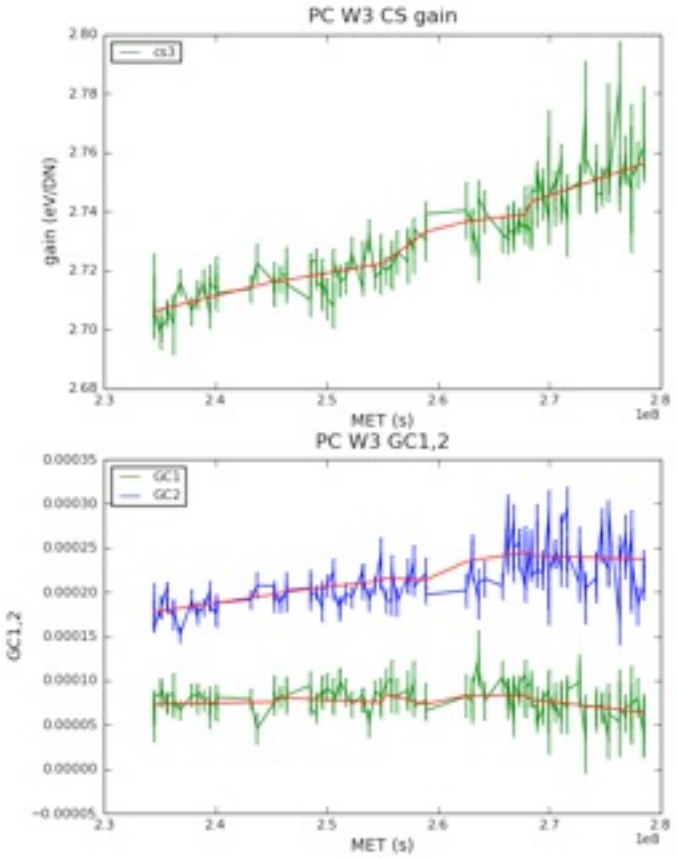
Gain coefficients

- Reminder : gain file GC0,1,2 coefficient parameterisation
  - f(t,T) = a +b t +c T + d t^2 + e T^2 + f t T

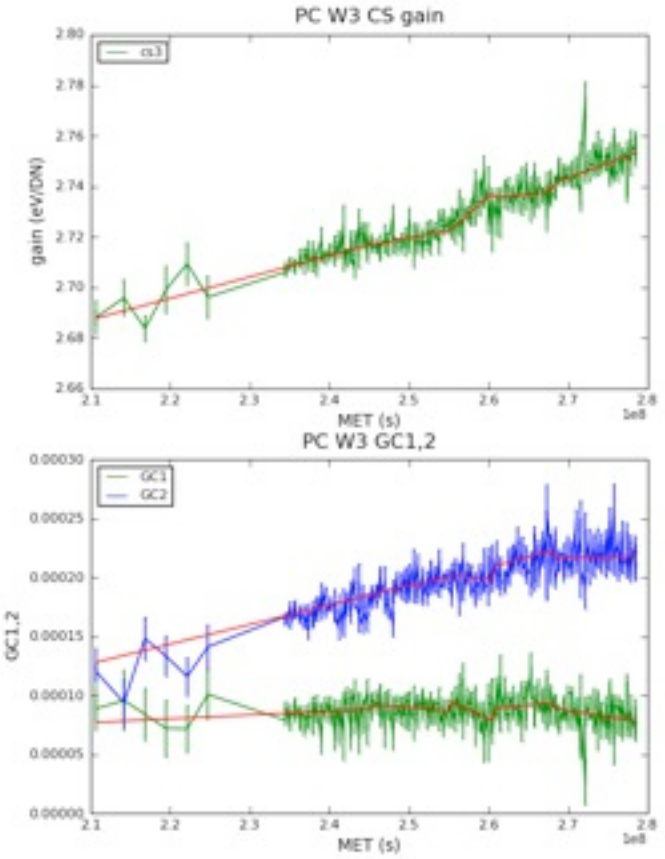
    with d = 0 (GC0,1,2) e = 0 (GC0)
- Gain coefficients calculated over 5 epochs:
  - 210670000. to 245410000.
  - 245410000. to 255203225.
  - 255203225. to 260632258.
  - 260632258. to 267845000.
  - 267845000. to 278472000

By CCD Temperature

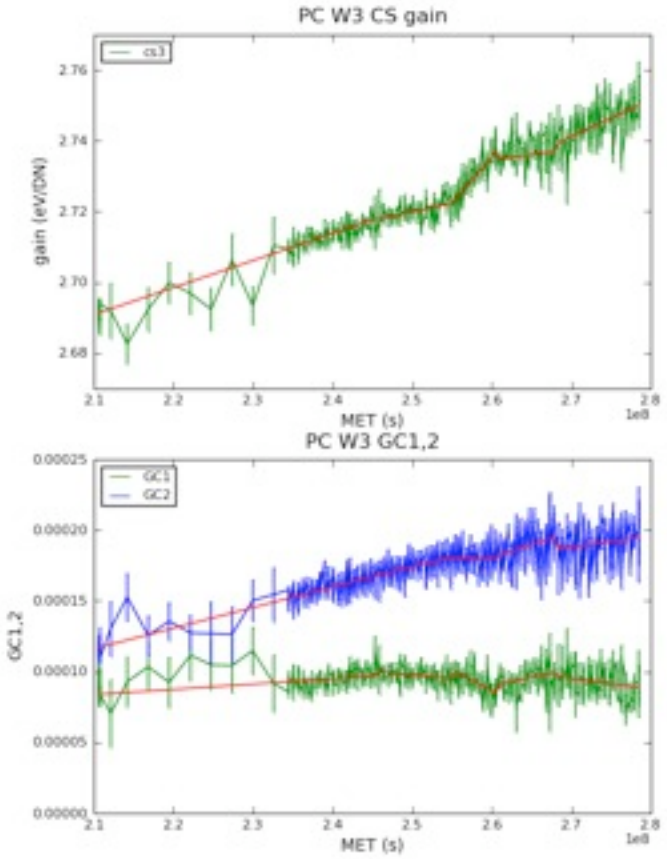
-70 to -65 C



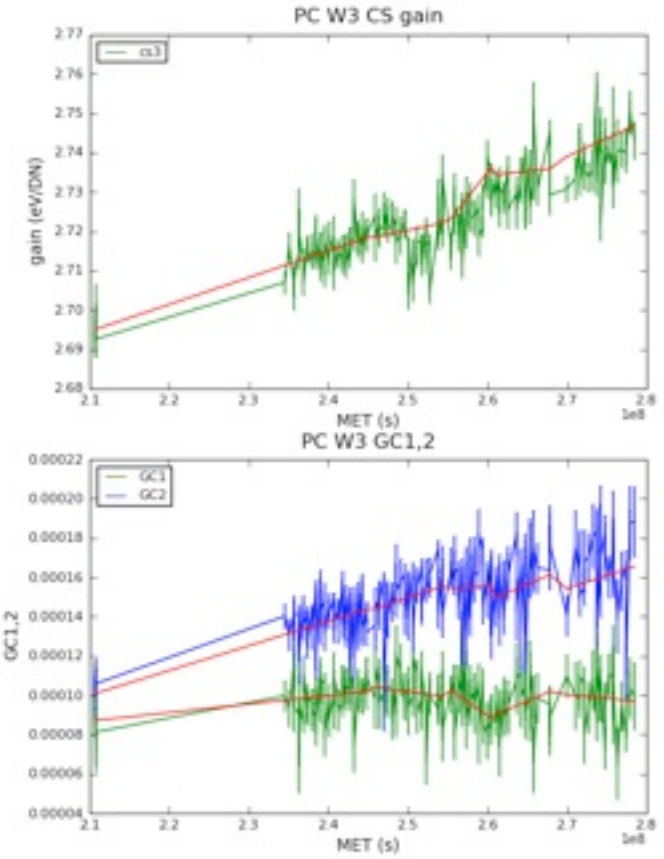
-65 to -60 C



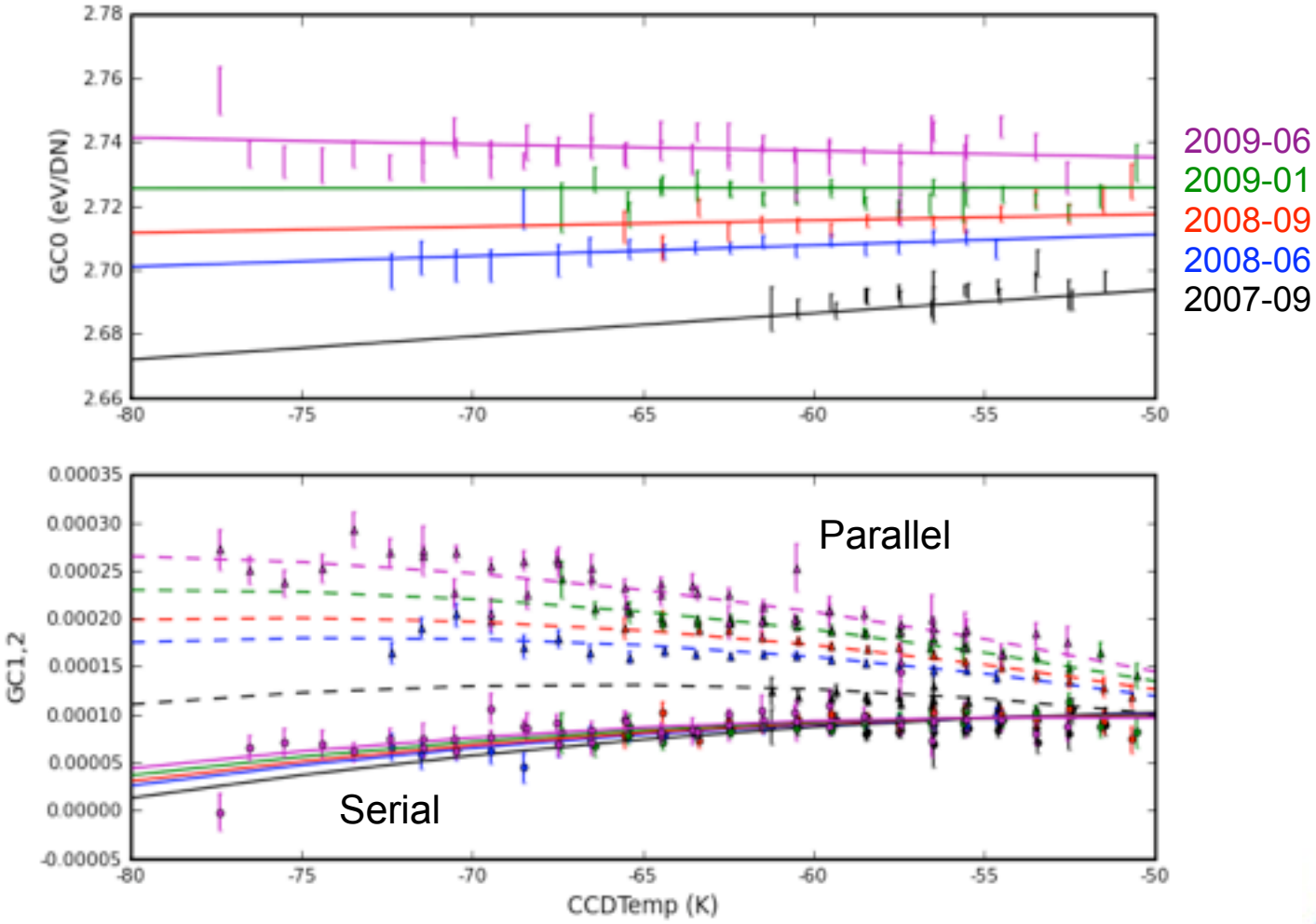
-60 to -55 C



-55 to -50 C



CCDTemp dependence



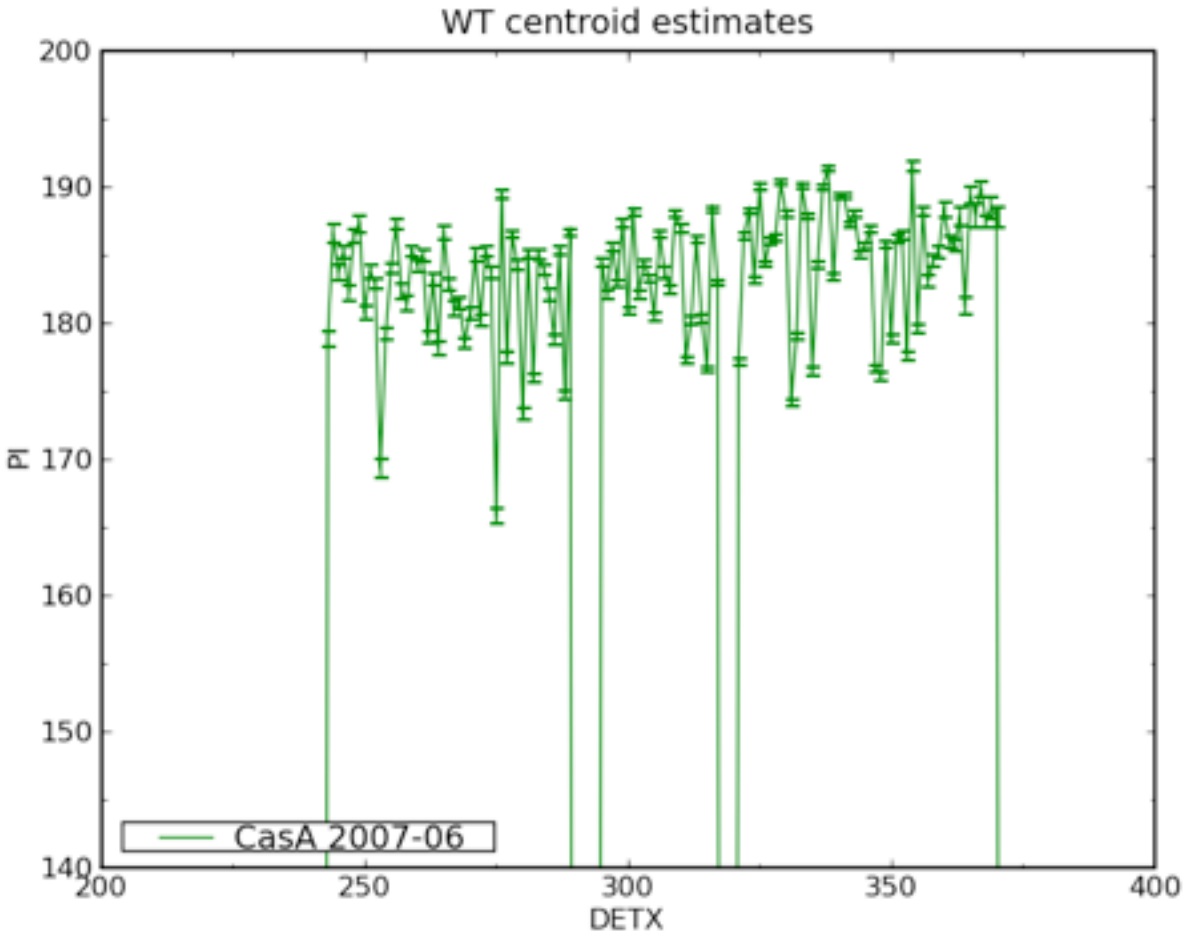
Gain/CTI Todo

- Include an energy dependent CTI correction
  CTI = CTI(5.895keV)*(E/5.895)**alpha
  - What is alpha ? (simple theoretical argument suggests 0.33)
- WT CTI coefficients are assumed to be the same as PC.
  - Trap mapping observations suggest this cannot be true

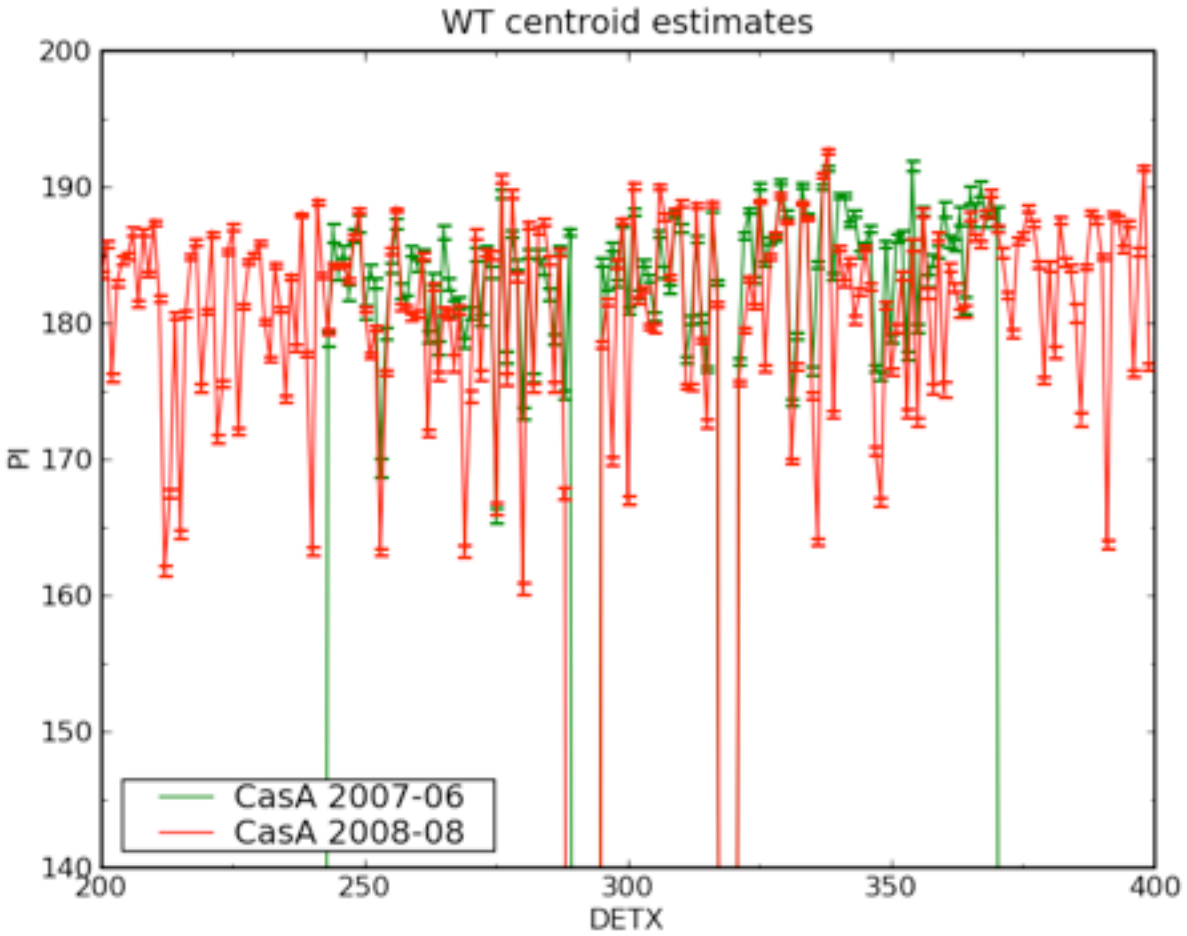
Charge Trap Mapping

- With no calibration source to illuminate the entire CCD, XRT has no in-built capability to measure charge trap locations and depths
- Have begun ~ 6 monthly observations of extended SNR (initially Cas A, more recentlyTycho) to estimate charge trap depths.

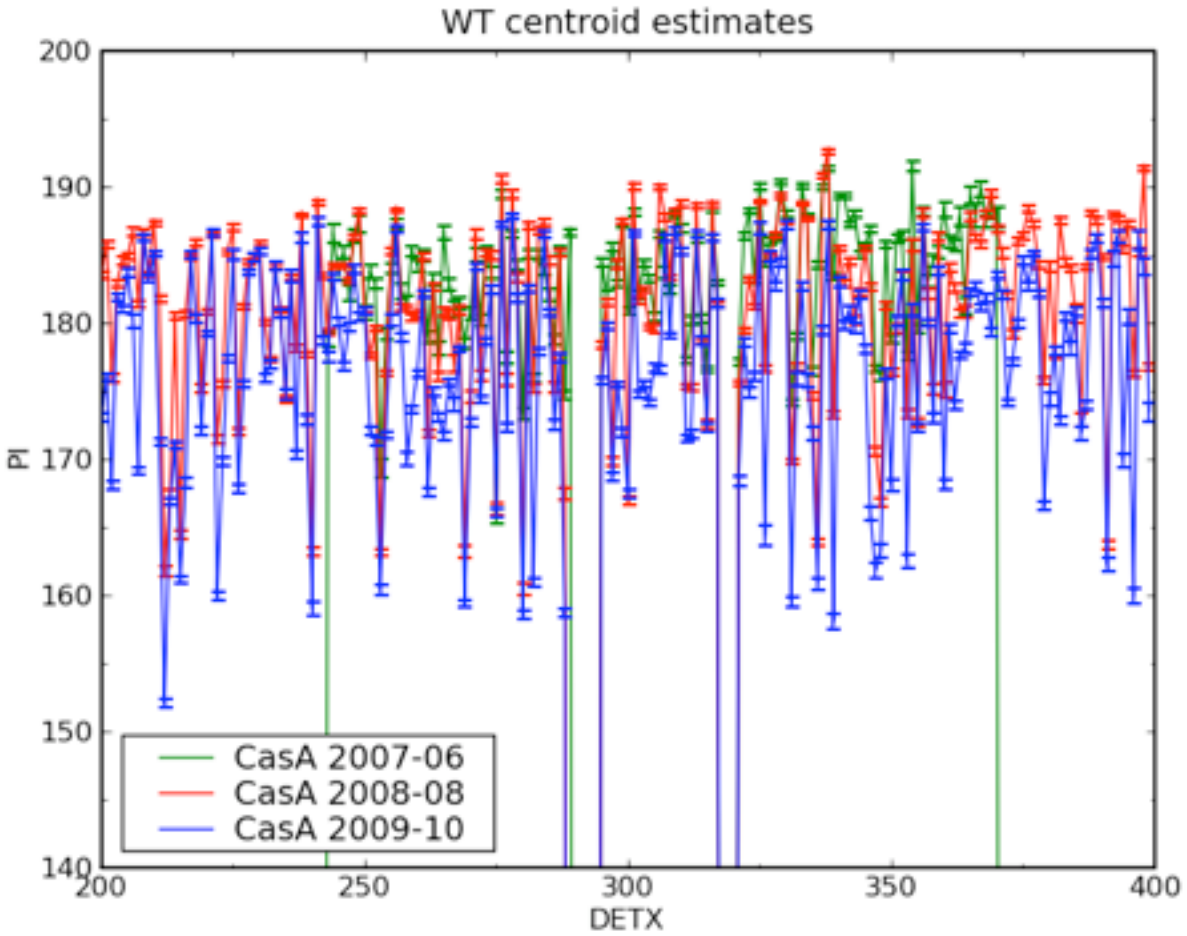
WT Trap Evolution (i)



WT Trap Evolution (ii)

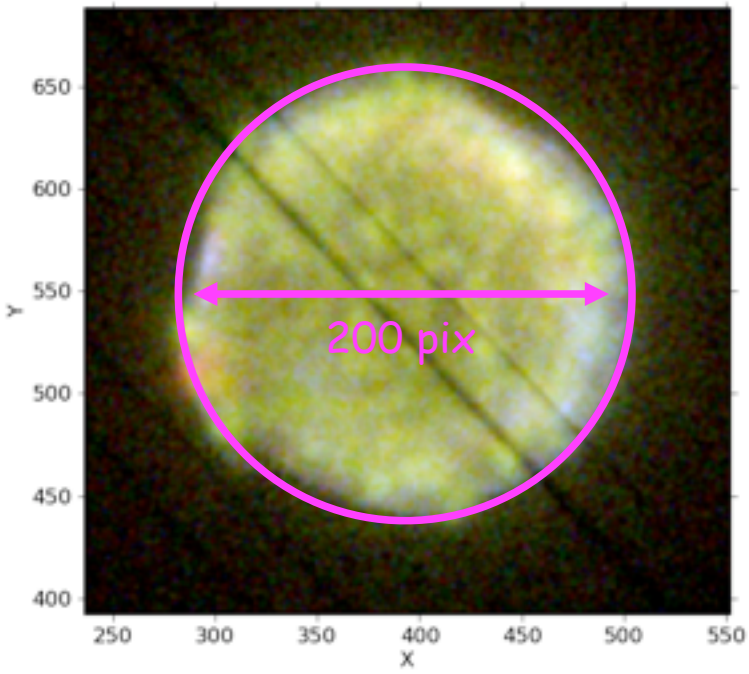


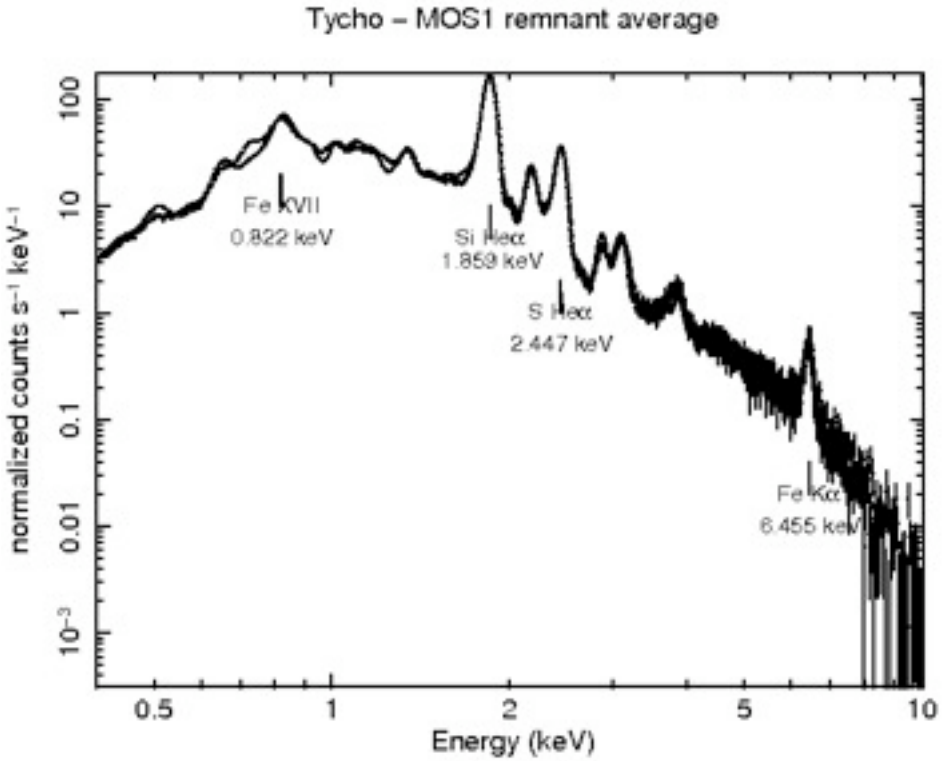
WT Trap Evolution (iii)



Trap mapping with Tycho

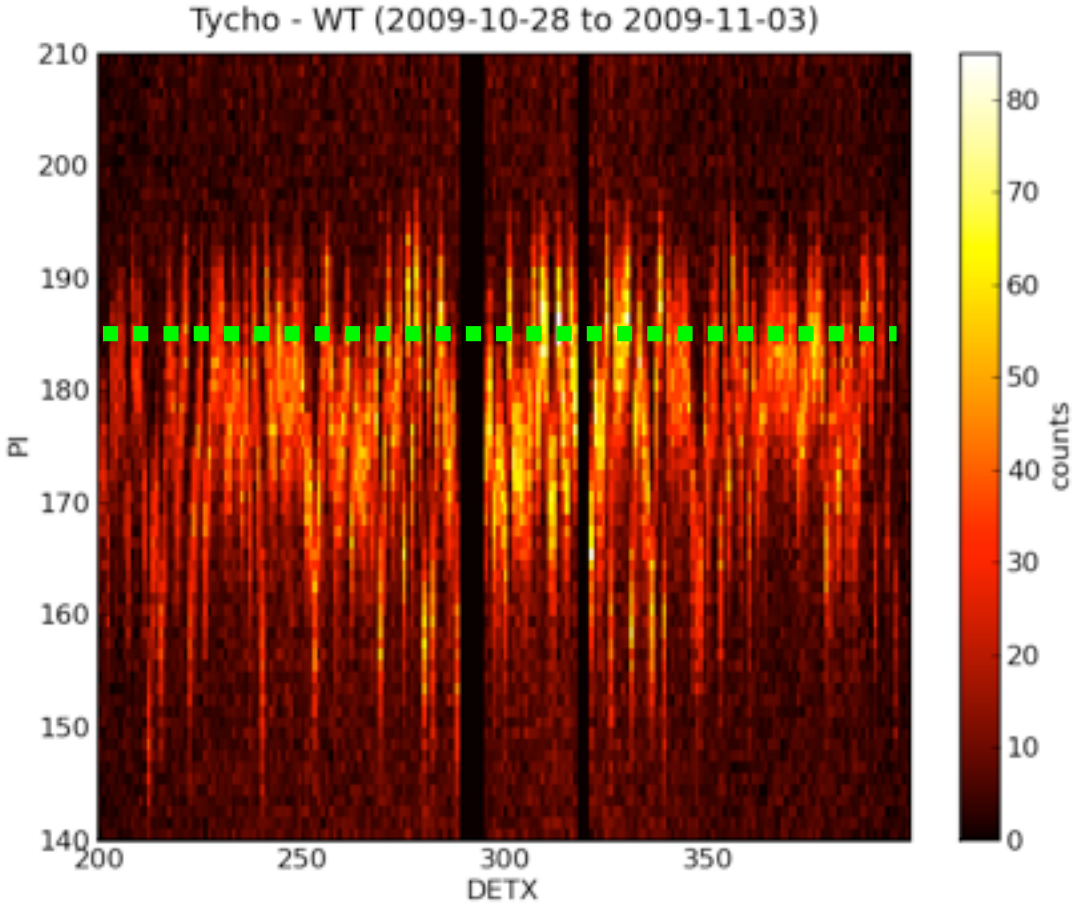
- Decided the Tycho SNR would be a more efficient use of time for trap mapping



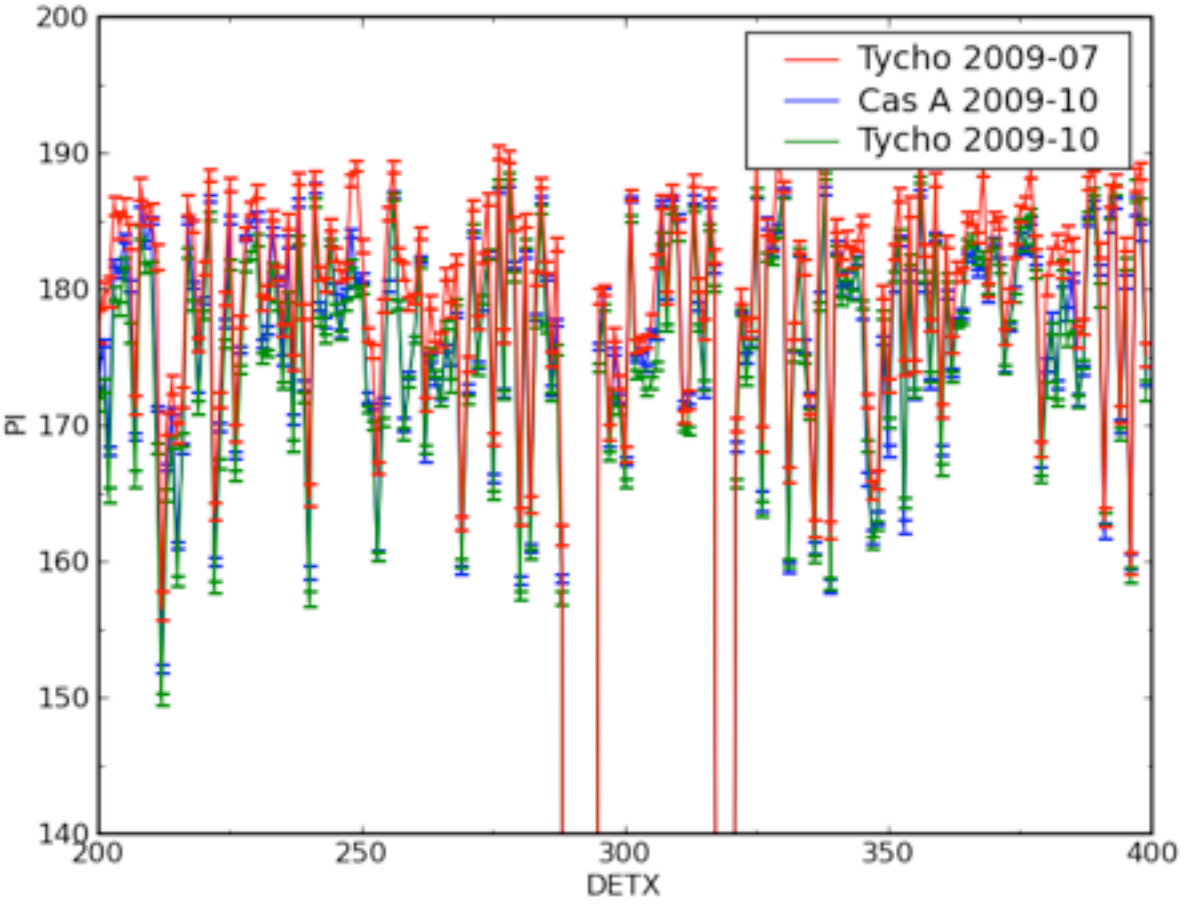


Tycho WT mode

15ks DETX=200-345 + 15ks DETX=200-399



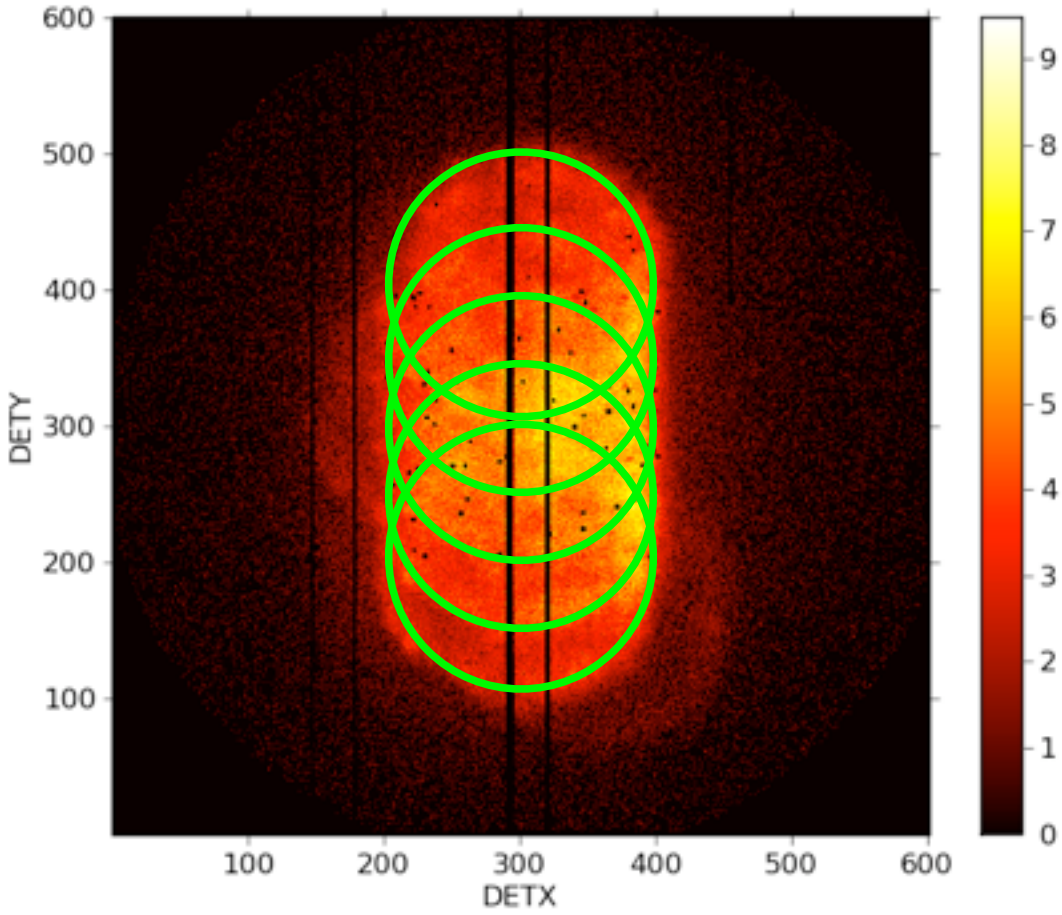
Comparison with Cas A



Trap evolution
In as little as
3 months

CasA & Tycho
give consistent
results

Tycho – PC mode

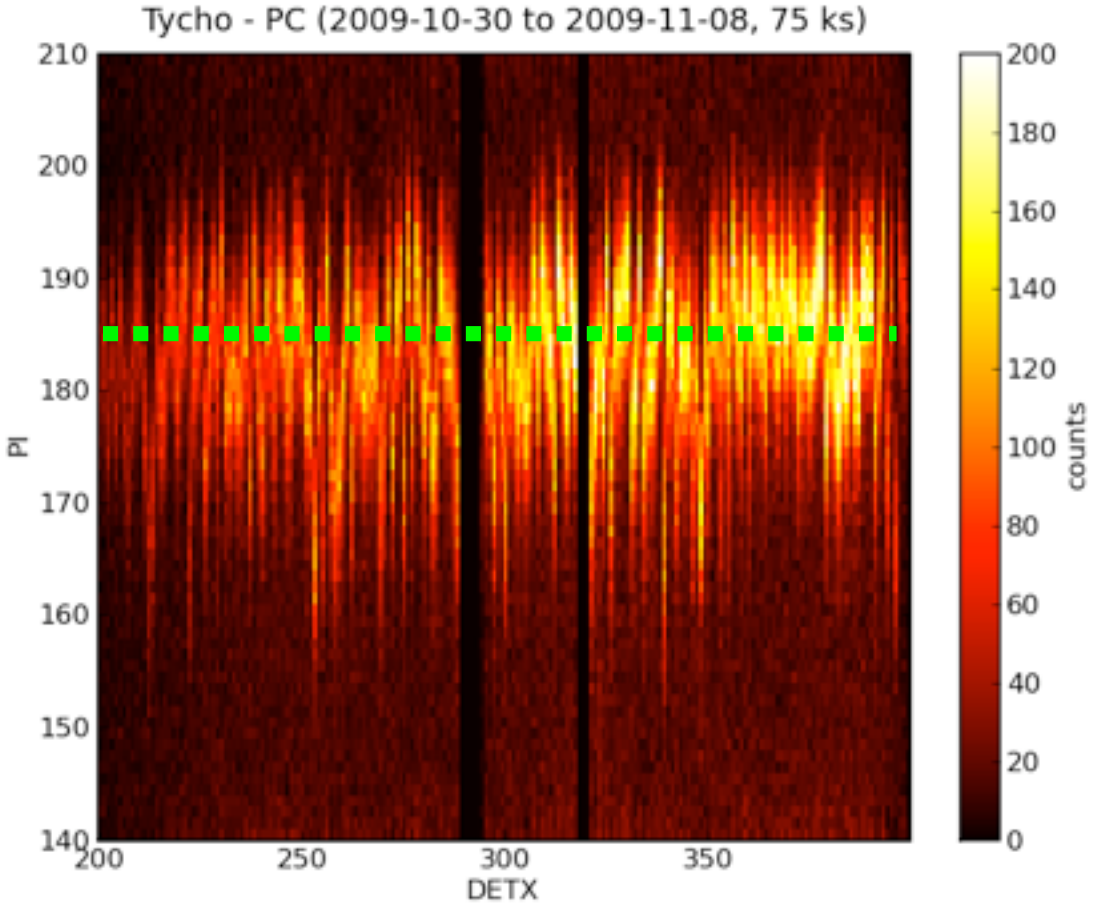


15ks per pointing →

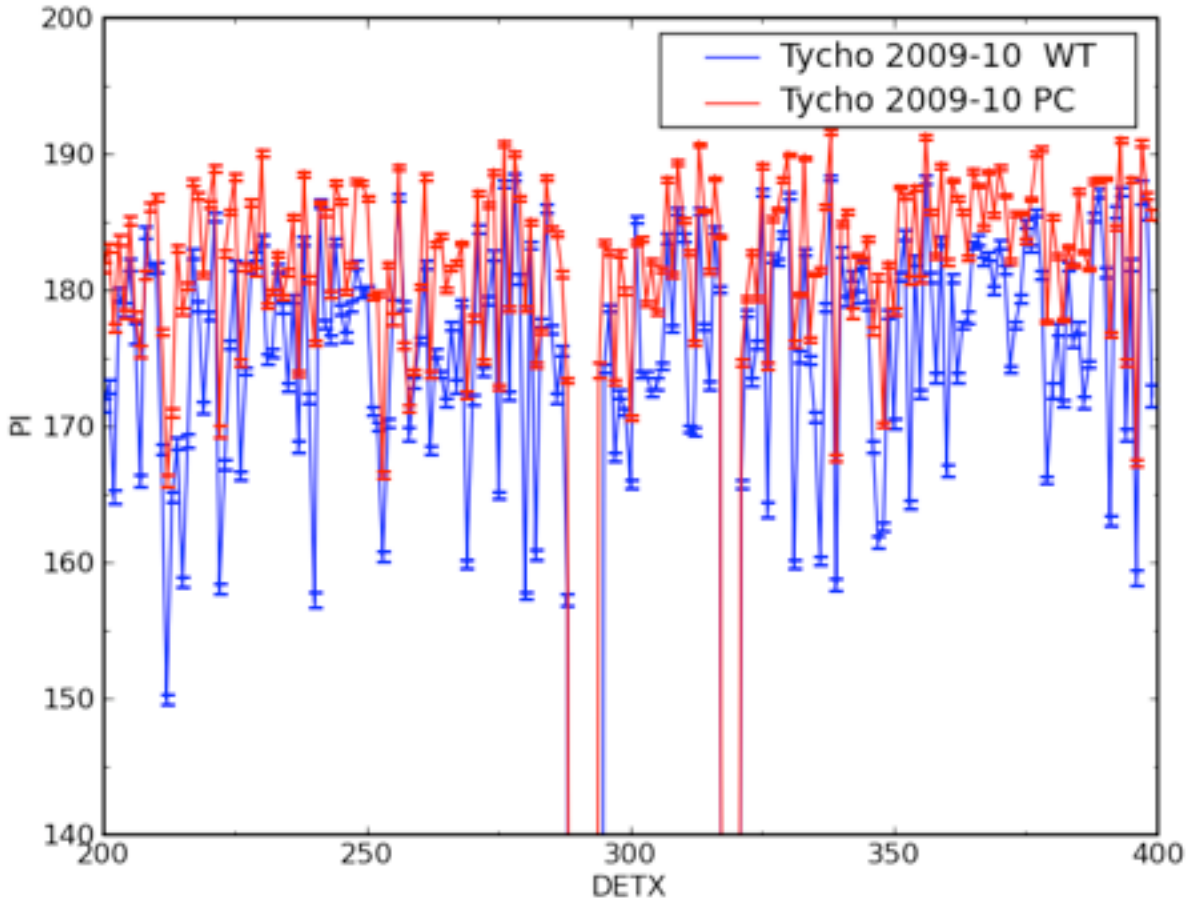
30-45ks in centre of CCD

Tycho - PC mode

Spectra accumulated from DETY 100 - 500.



WT – PC comparison



- Similar column-to-column variation apparent in both modes
- WT traps much deeper than PC

Correcting for Traps.

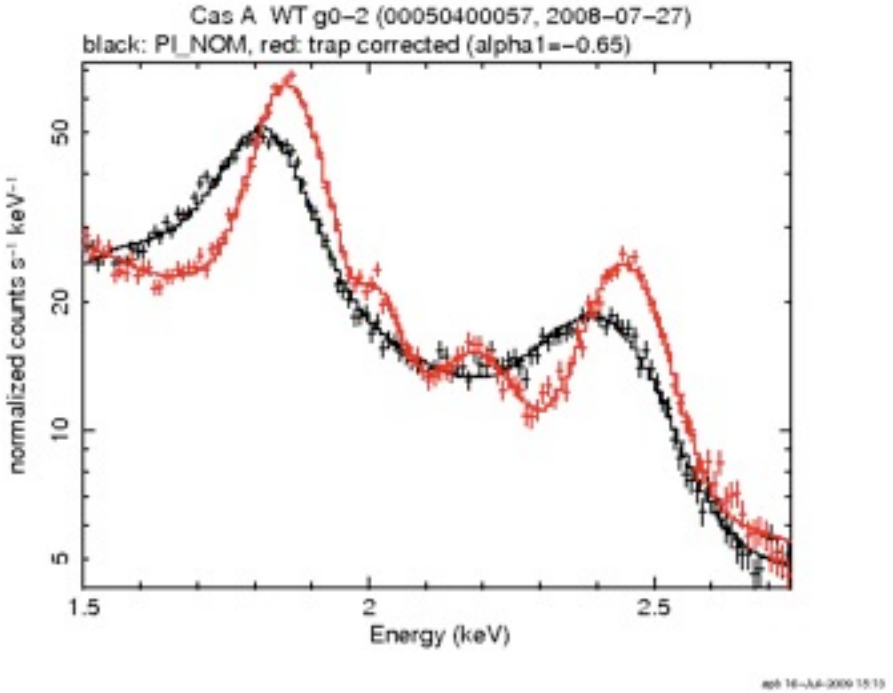
- Swift software release 3.2 (20090407) and later has a revised version of xrtcalcpi which implements a charge trap correction algorithm (but disabled by default)
- Gain file format modified to accommodate traps:
  - RAWX, RAWY, YEXTENT, OFFSET
- Using best non-trapped gain file, measure column-by-column offsets at Si (1.86 keV) on Cas A. Then
  - Offset(E) = Offset(Si) * (E/1.86) **(-alpha1) E < 1.86 keV

Trap mapping – WT mode

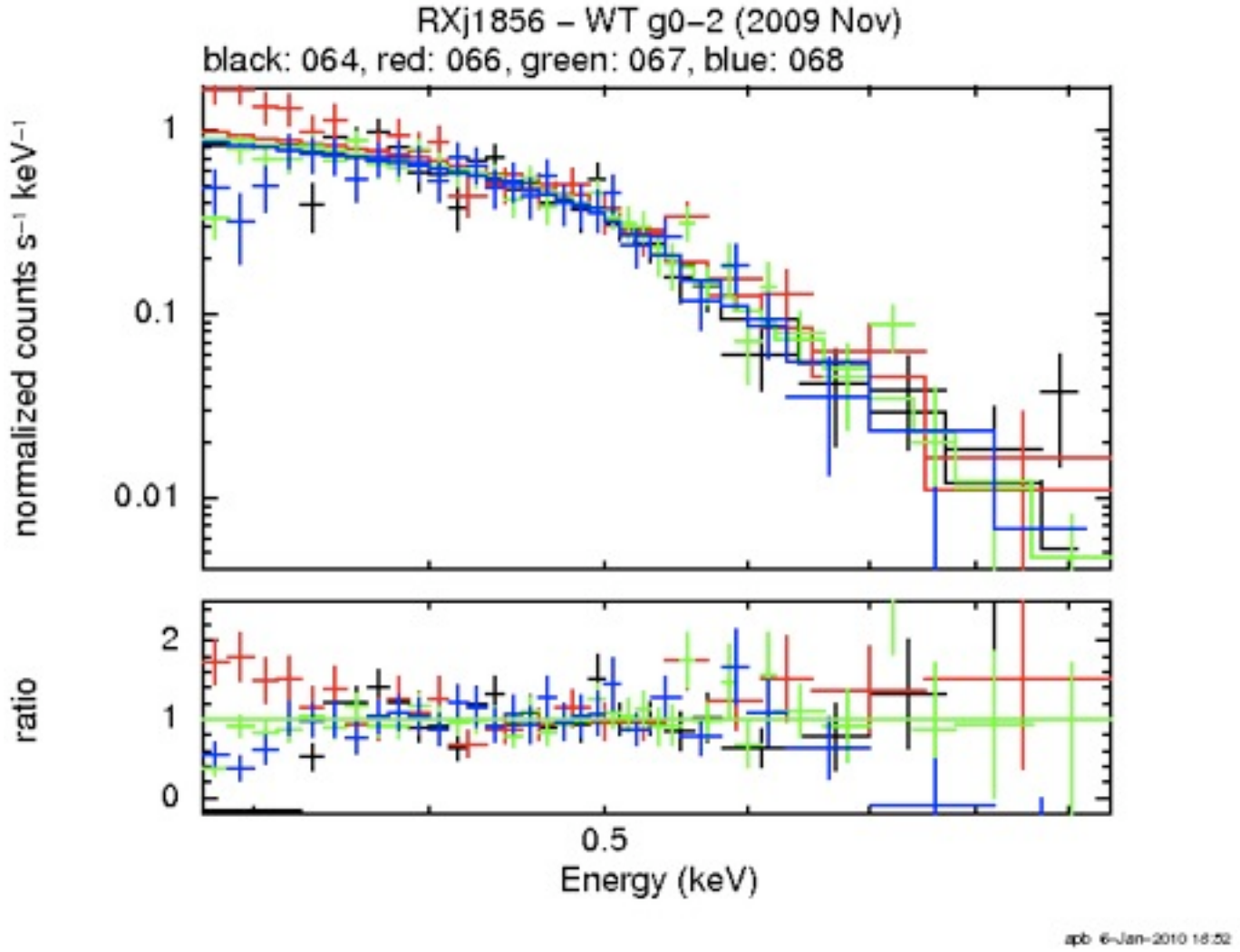
- Olivier produced a list of traps in both WT mode from Cas A trap mapping observations taken in 2007 July and 2008 August.
  - Traps defined as those (segments of) columns showing a measured Si shift > 30eV. (Limited by statistics and velocity shifts across Cas A)
  - WT 2007-July (central 100 pixels only): 47 traps
  - 2008-August (all 200 pixels): 130 traps
- Inserted offsets into gain file, assuming RAWY=0 and YEXTENT=600.

WT trap mapping 1st tests

- Trap correction recovers FWHM and "missing" lines



Effect of traps on soft sources

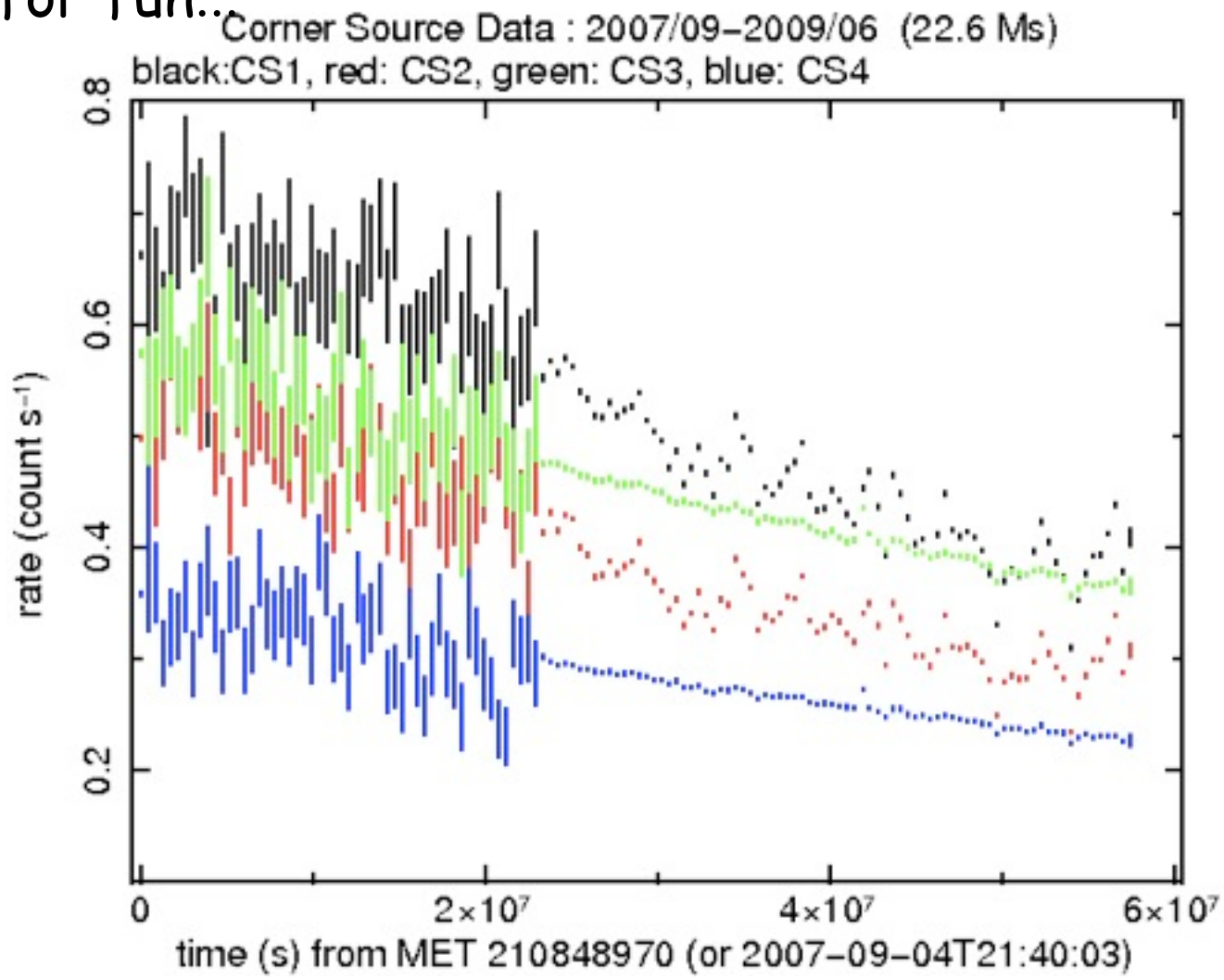


Trap mapping summary

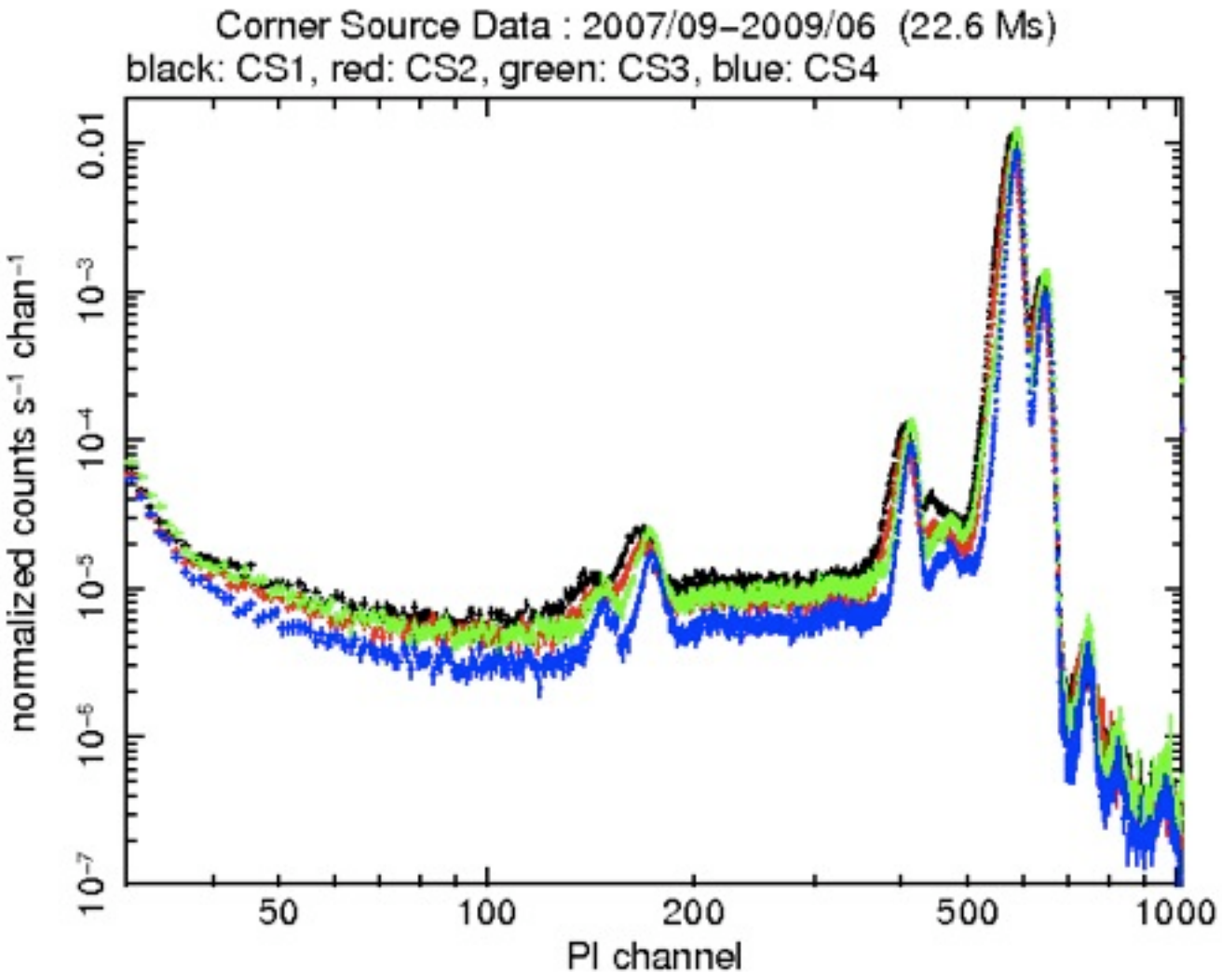
- Initial analysis performed shows
  - Clear evolution in WT trap depths with time
  - PC traps occupy same columns but with reduced depth
- Todo
  - Finalise the trap depth estimates as a function of time
  - Calibrate the trap depth energy dependence

CS Vss=6V data

Just for fun..



CS 'fun'


Corner Source Data : 2007/09–2009/06 (22.6 Ms)
black: CS1, red: CS2, green: CS3, blue: CS4
normalized counts s⁻¹ chan⁻¹
0.01
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
50
100
200
500
1000
PI channel