

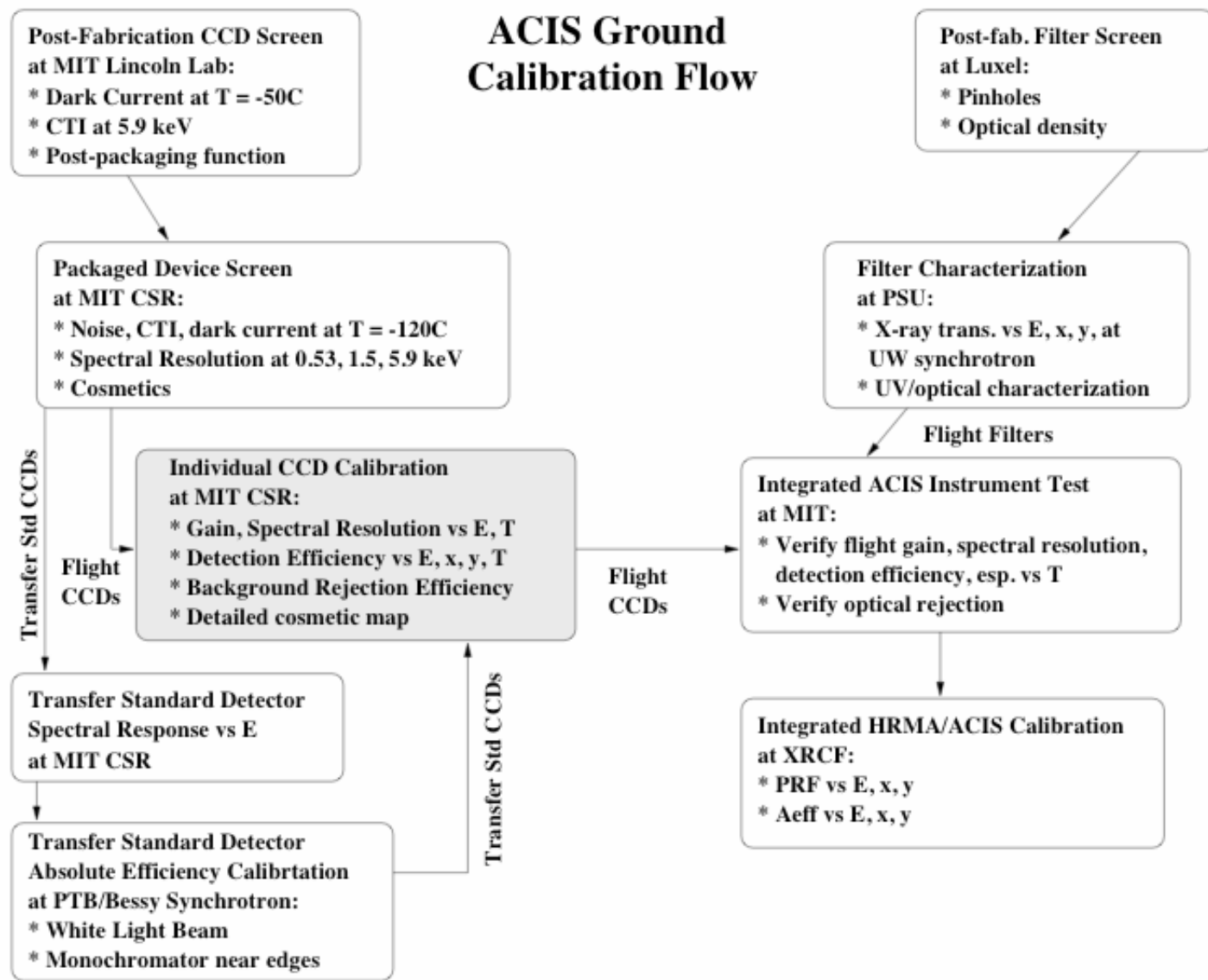


ACIS Calibration: Strategy, Implementation & Status

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**Bautz
etal
Fig 2
1998**





I: ACIS Pre-launch Calibration

Absolute QE: reference CCDs calibrated at BESSY (see Bautz *et al.* 2000)

- the parameters (thickness of gate structure components, depletion depth) of the CCD response model were varied until an acceptable fit to the BESSY “white light” spectrum was achieved
- reference CCDs returned to MIT lab to be used as transfer standard for flight CCDs

ACIS Calibration Report Table 4.28

Chip	CCD Parameters (in μm)							(0.3-4 keV) RMS Deviation of Fit	Best Fit Normalization
	Free			Fixed					
	Si†	SiO ₂ ‡	Si ₃ N ₄	CS Si	CS SiO ₂	CS Width	Depletion Depth		
w190c3	0.259	0.354	0.031	0.35	0.45	4.1	71.3	2.54%	1.000 ± .003
w190c1	0.261	0.358	0.029	0.35	0.45	4.1	70.6	2.24%	0.994 ± .003
w103c4	0.291	0.202	0.030	0.35	0.45	4.1	57.9	3.88%	0.956 ± .003

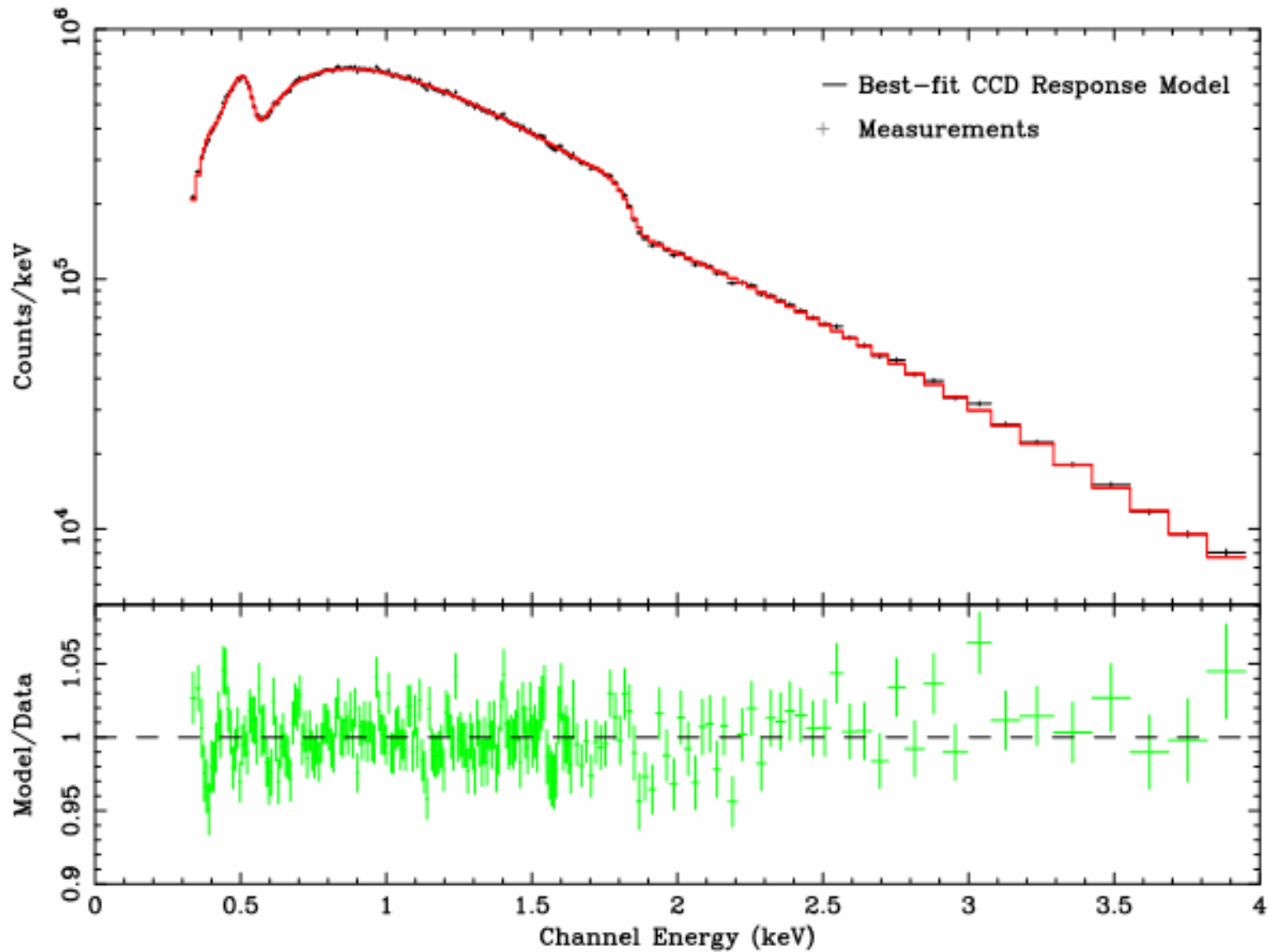
†: typical 90% confidence error is ±0.008 μm

‡: typical 90% confidence error is ±0.011 μm



Measured and Modelled Response of MIT CCD to PTB/BESSY White Light Beam

Bautz et al
1998
Fig 7





I: ACIS Pre-launch Calibration

Spectral Redistribution Function: Prigozhin 1998, Bautz *etal* 2000, Prigozhin 2000

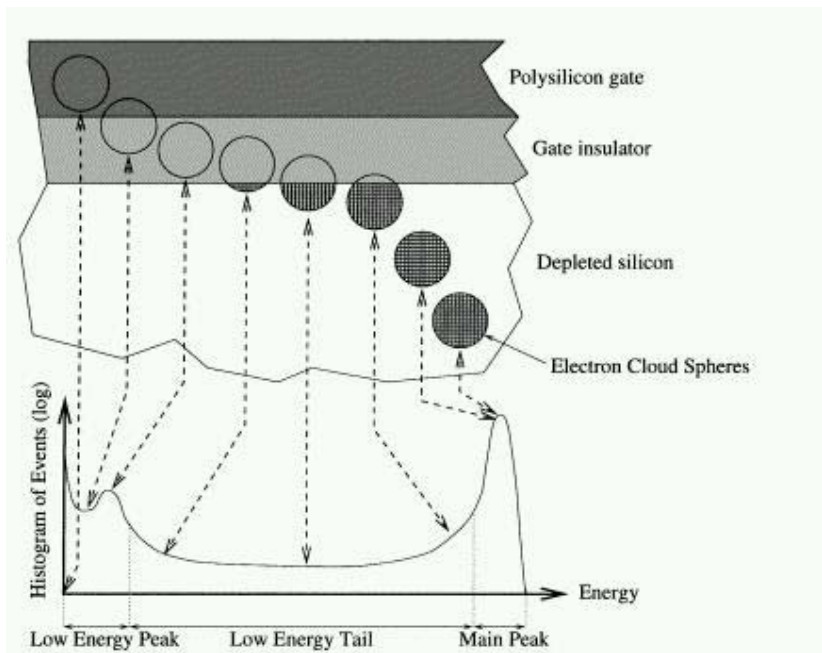


Fig. 7. Schematic illustration of the model of the low-energy peak and tail.

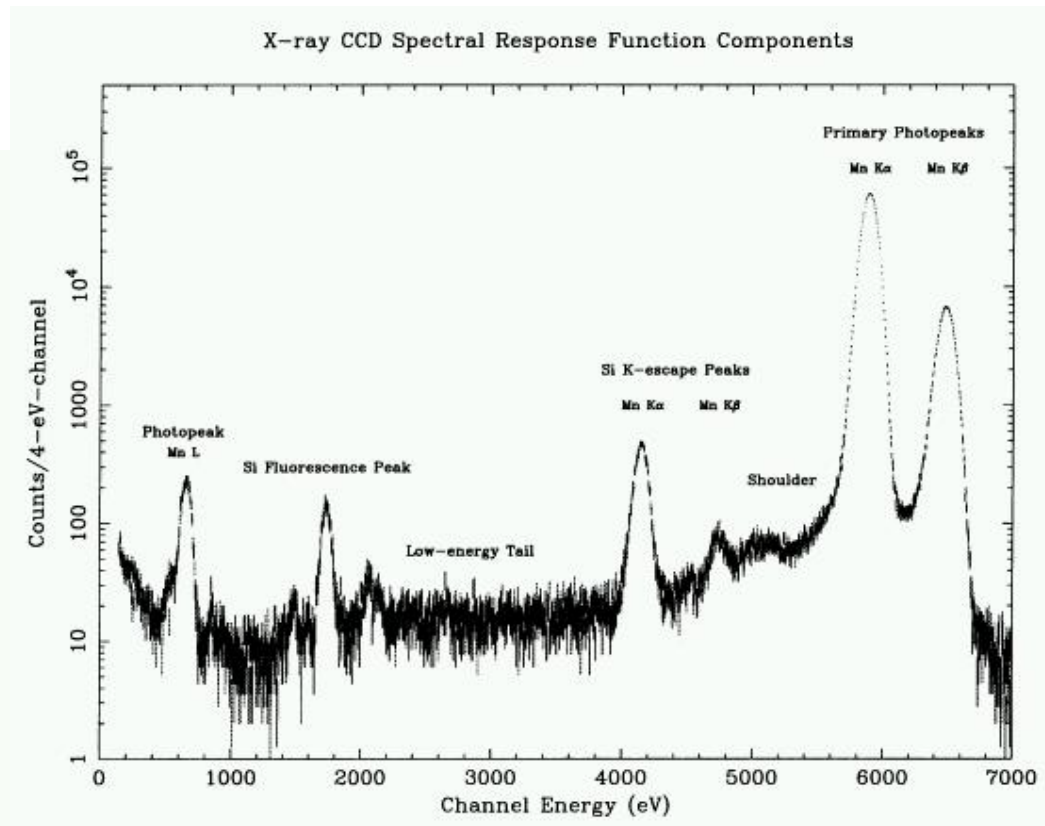


Fig. 1. X-ray CCD spectral redistribution function at 5.9 keV.



I: ACIS Pre-launch Calibration

OBF Calibration: transmission maps at Wisconsin synchrotron (Townesley *etal.* 1996) and detailed transmission at Brookhaven (see Chartas *etal.* 1996)

Instrument Thermal Vac: at MIT Lincoln Laboratories

- flight CCDs integrated with flight electronics (noise, gain)
- verify performance of flight SW
- verify instrument performance at cold operating temperatures and after several thermal cycles

X-ray Calibration Facility (XRCF) at NASA MSFC

- measurements with HRMA and gratings, first experience with sharply focused images and the effects of pileup
- after HRMA left, flat-field measurements with XRCF source system

Integrated Science Instrument Module (ISIM) Thermal Vac at Ball:

- verify instrument after integration on ISIM
- first measurements of external calibration source at -120 C



I: ACIS Pre-launch Calibration

Highlights of Results

Absolute QE of CCDs - known to better than 5.0% in the 0.3-4.0 keV band

QE Uniformity - FI CCDs uniform to 2% on 32X32 pixel regions

Energy Scale - FI CCDs known to better than < 0.1 %

Spectral redistribution - FWHM of FI CCDs known to better than < 5.0%

OBF transmission - known to better than 1.0% in the 0.3-3.0 keV band except around EXAFS

OBF uniformity - uniform to 2% at 0.273, 0.522, and 0.775 keV

HRMA/ACIS Effective Area - XRCF measurements consistent with the model to within 12% in the 0.5-9.0 keV range in the absence of pileup

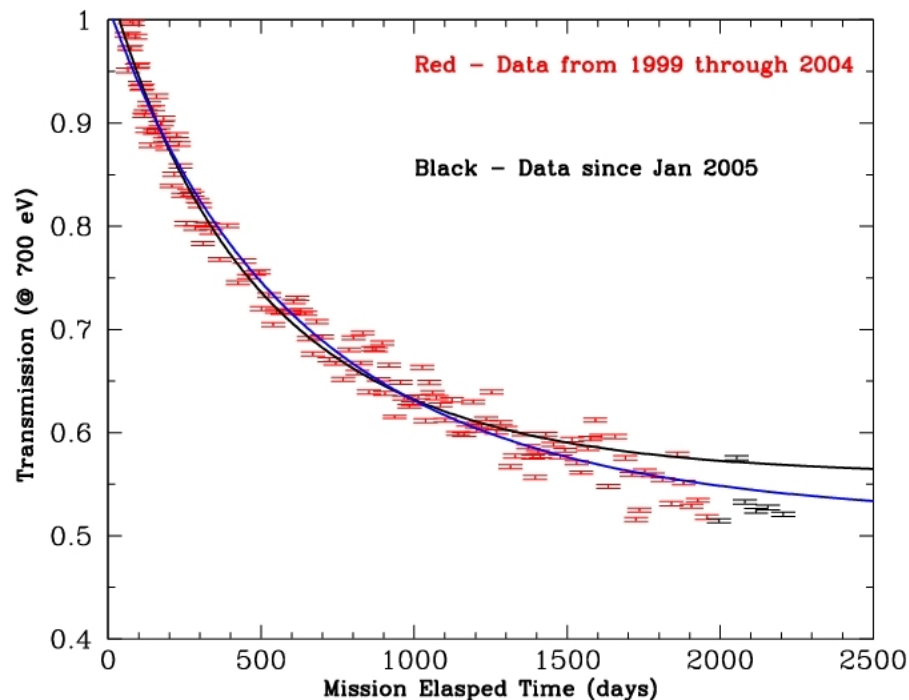
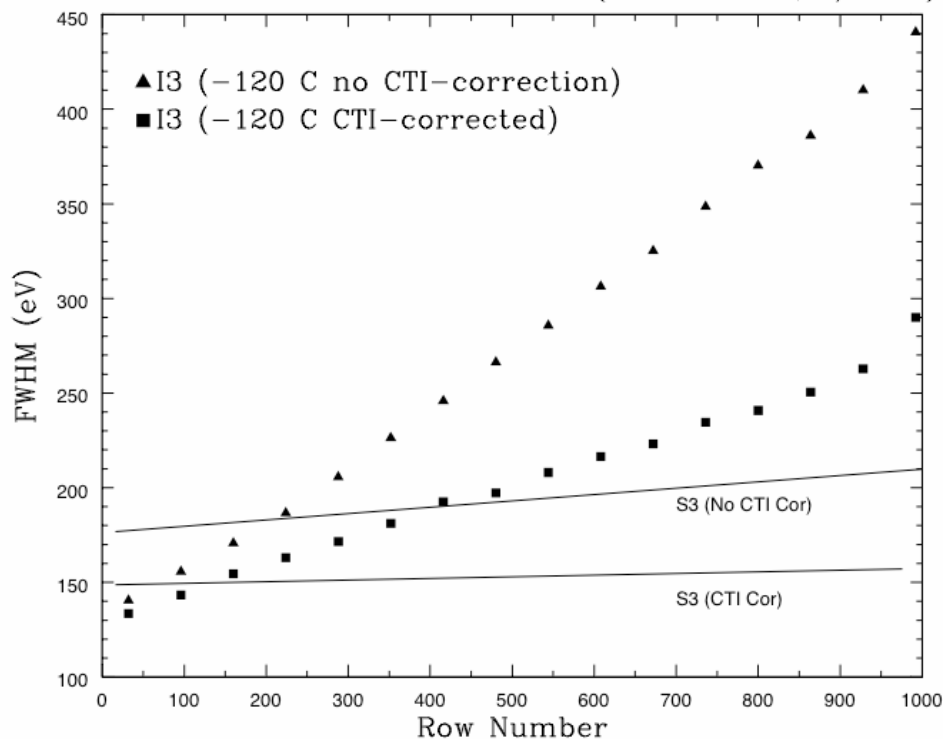


II: ACIS Post-launch Calibration

Two Major Changes to the Instrument:

- radiation damage of the FI CCDs produced a large increase in CTI (Prigozhin *etal.* 2000, Townsley *etal.* 2000, Townsley *etal.* 2002, Grant *etal.* 2004)
- contamination layer on the OBF (Vikhlinin 2004, Marshall *etal.* 2004, Plucinsky *etal.* 2003, 2004)

S3 & I3 FWHM vs Row at Mn-K (OBSID 62895, 2/2000)

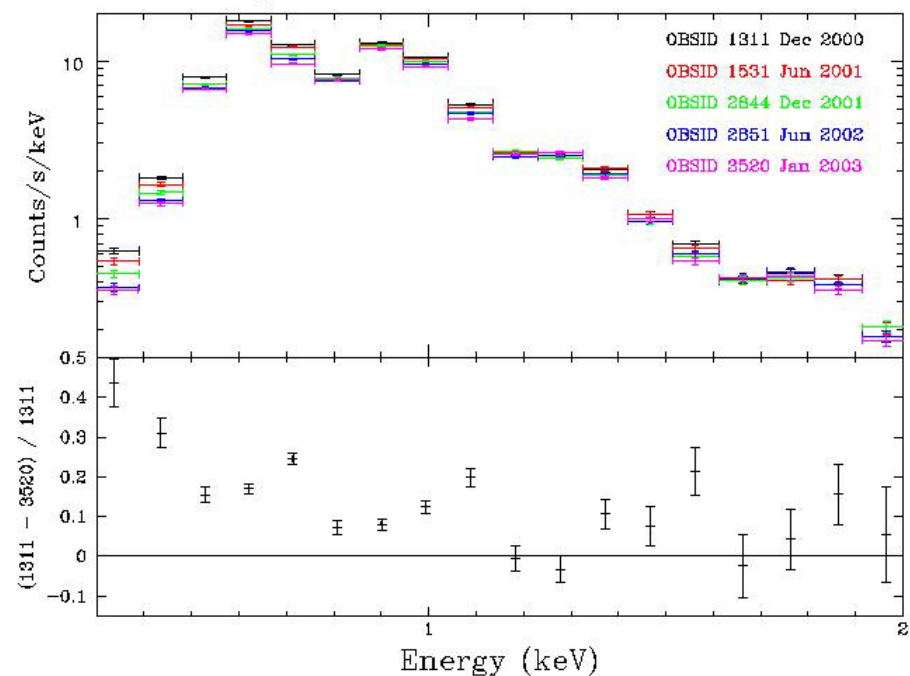




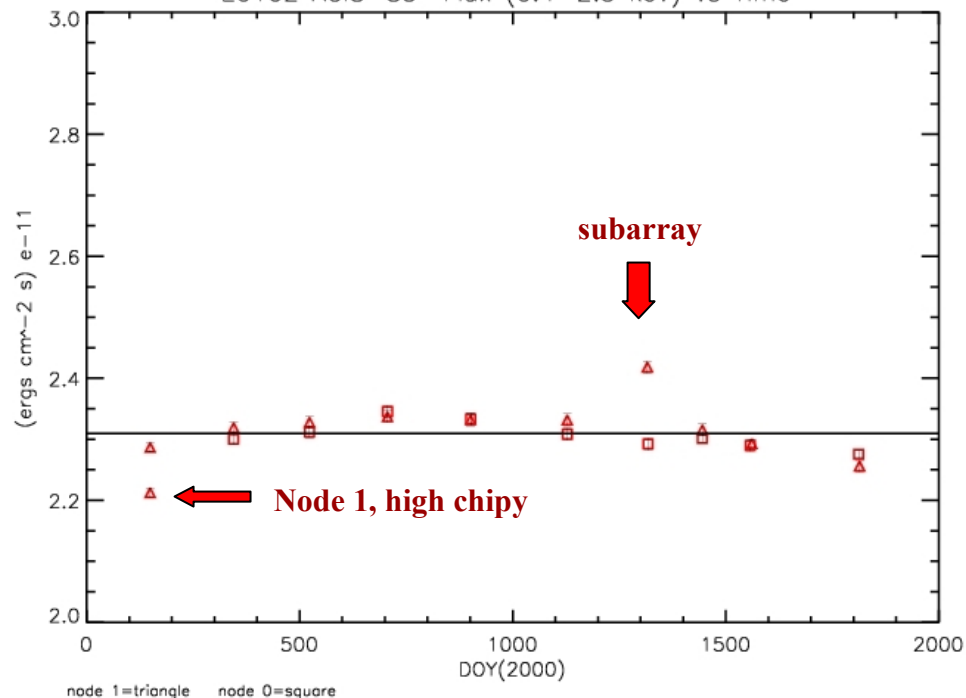
II: ACIS Post-launch Calibration

- CTI correction recovers some of the lost spectral resolution
- contamination correction has a temporal and spatial dependence
- weighted responses for both BI and FI CCDs

Comparison of E0102 Observations on S3



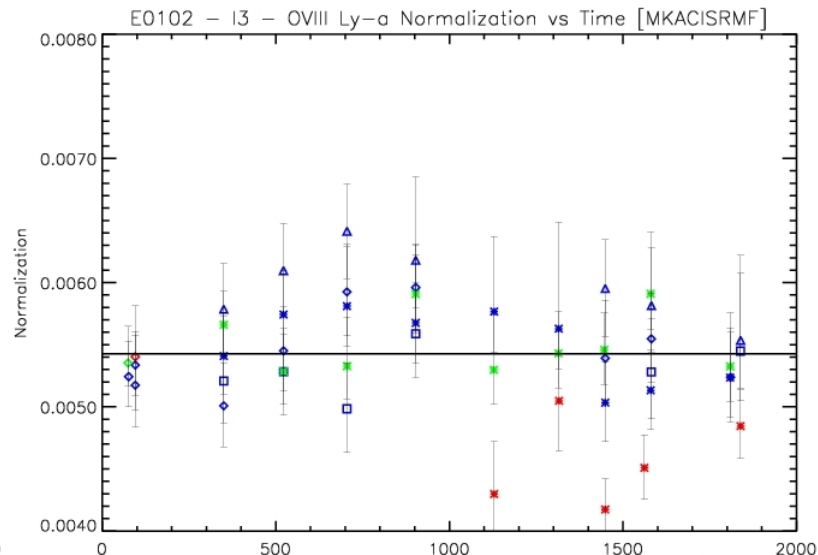
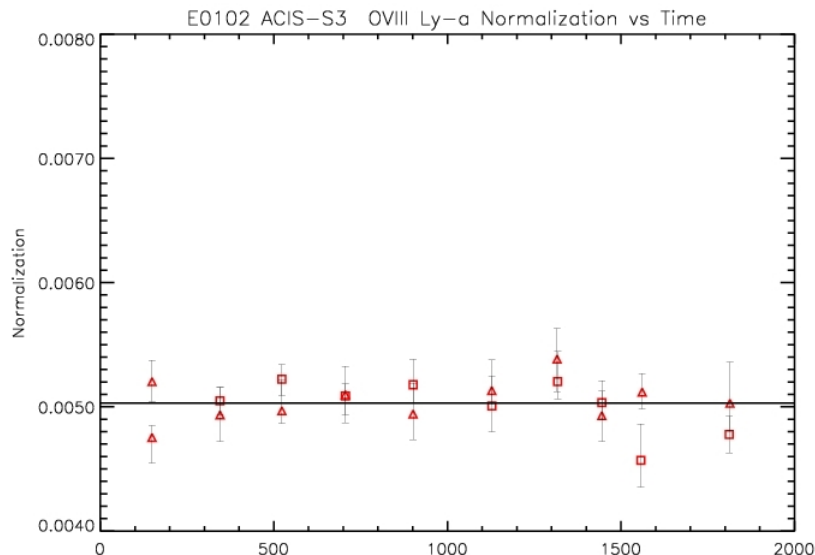
E0102 ACIS-S3 Flux (0.4-2.5 keV) vs Time





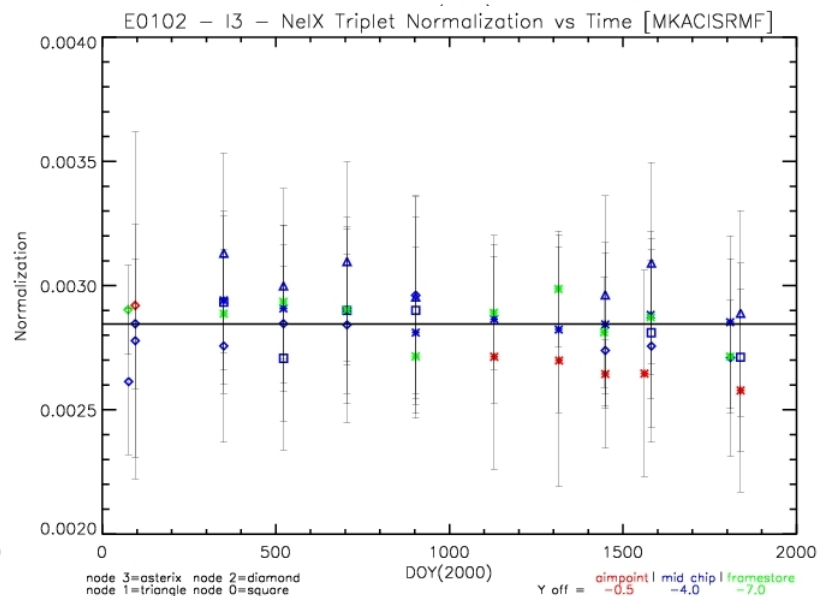
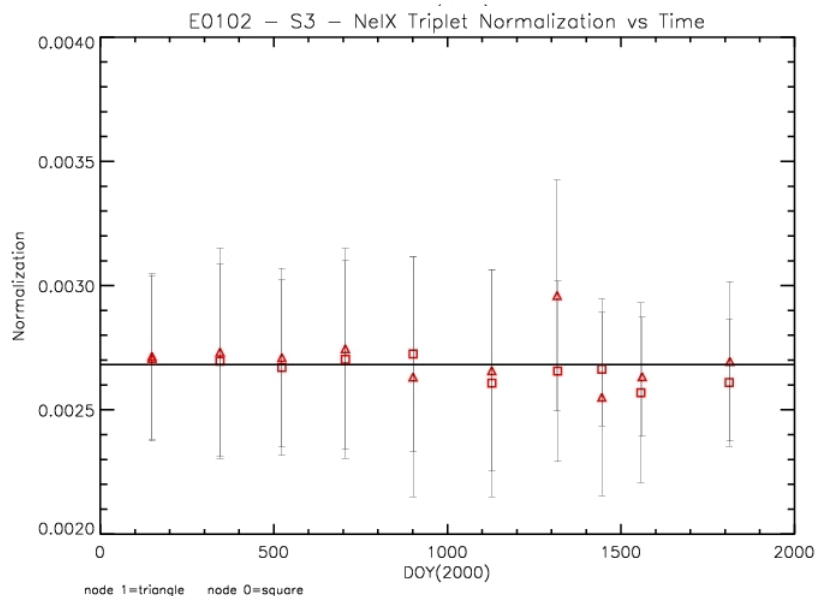
II: ACIS Post-launch Calibration

S3



I3

S3

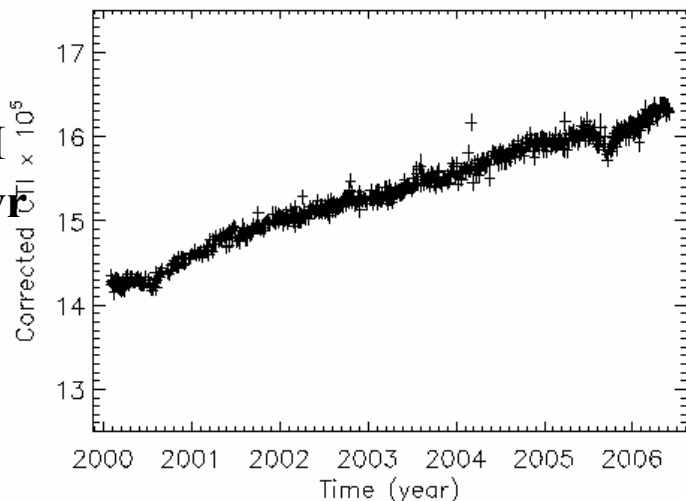


I3



Monitoring with the ECS (Grant *et al.* 2005)

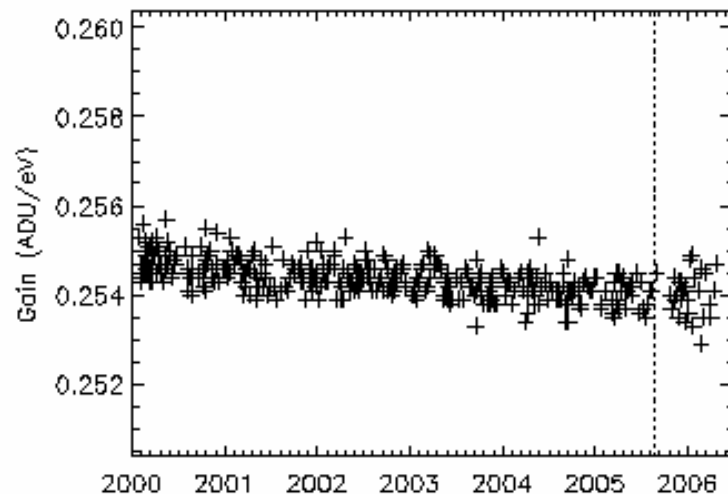
FI CCDs Corrected Parallel CTI Mon Jun 5 14:34:38 2006



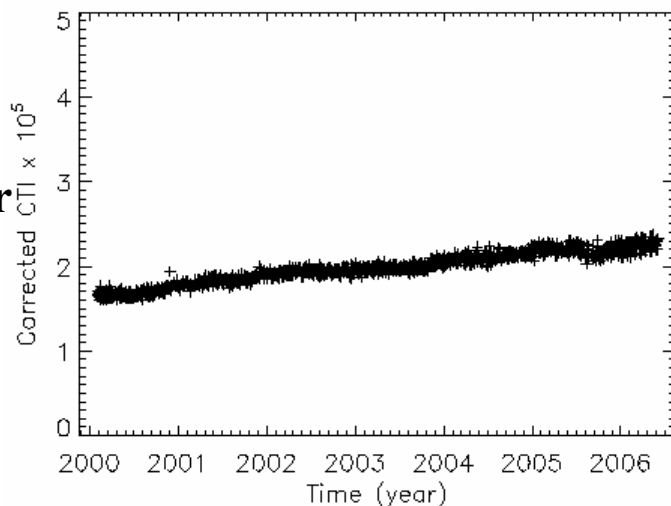
FI CTI
2.5%/yr

I3 Gain

CCD i3 Node 0



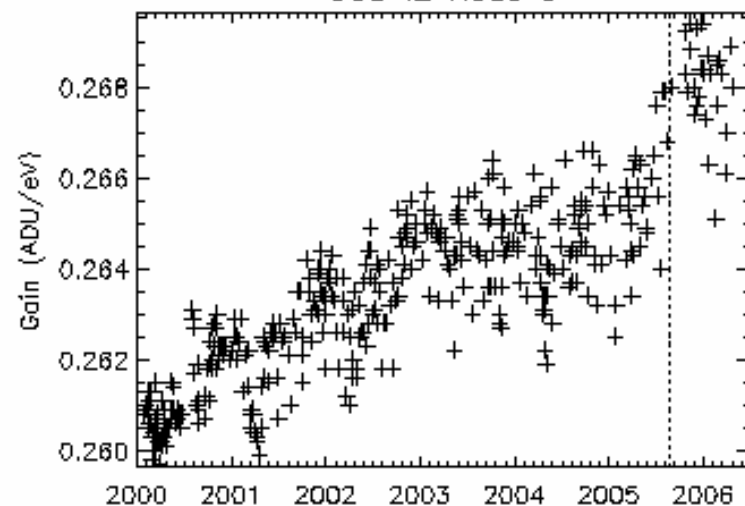
BI CCD Corrected Parallel CTI Mon Jun 5 14:34:38 2006



BI CTI
0.5%/yr

I2 Gain

CCD i2 Node 0





II: ACIS Post-launch Calibration

Current Status:

Energy Scale - I array and S2, S3 CCDs known to better than $< 0.3\%$ for most regions from 1.5-6.0 keV

Spectral redistribution - FWHM of CCDs known to better than $< 10.0\%$

QE uniformity - uncertainty less than 1.0% in a 1 arcminute region, less than 5.0% across the detectors

HRMA/ACIS Effective Area - uncertainties are less than 10% in the 1.5-6.0 keV band

III: Lessons Learned

- 1) **need immediate, simple on-orbit verification of instrument performance**
- 2) **contamination control and mitigation**
- 3) **ground calibration needs to be as close to the on-orbit conditions as possible**