Cross-calibration of the Chandra/ACIS and XMM/EPIC low-energy response using 1E0102-723

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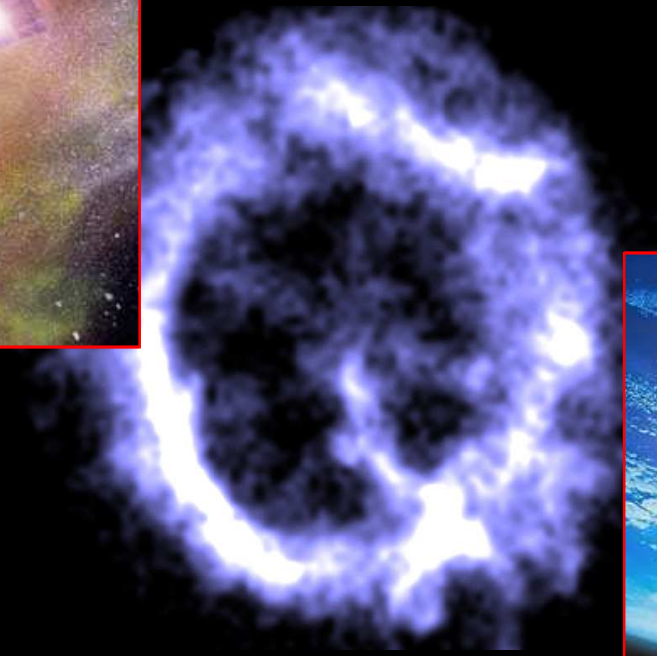
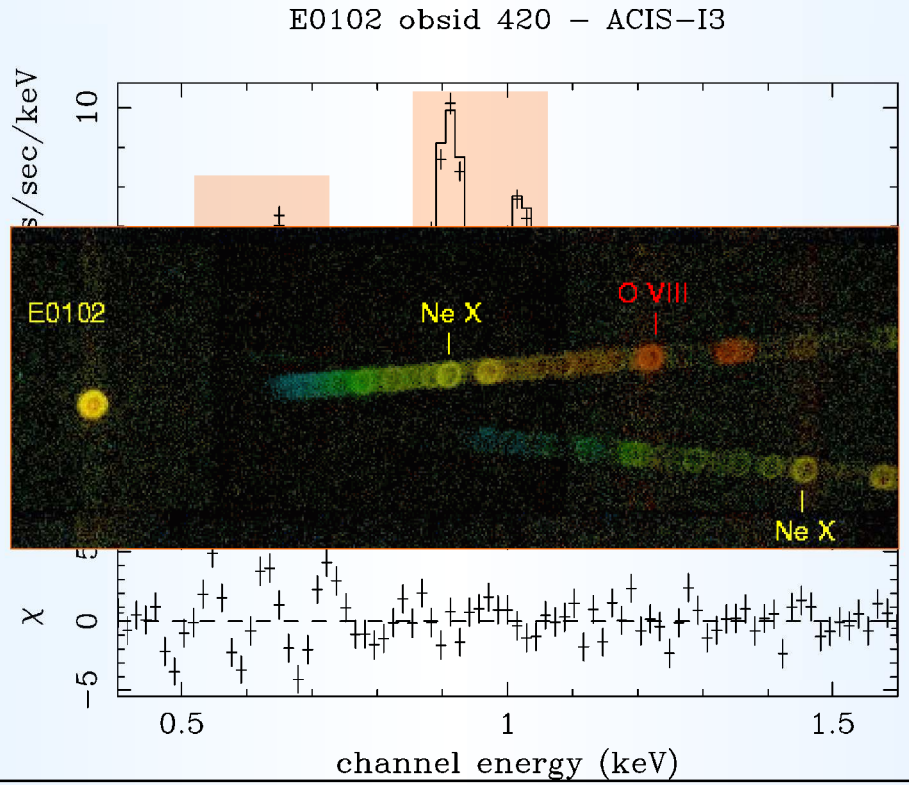


CXC Calibration Workshop 2005 Oct 31-Nov 2

Introduction

1E0102-723 – an ideal low-energy cal source

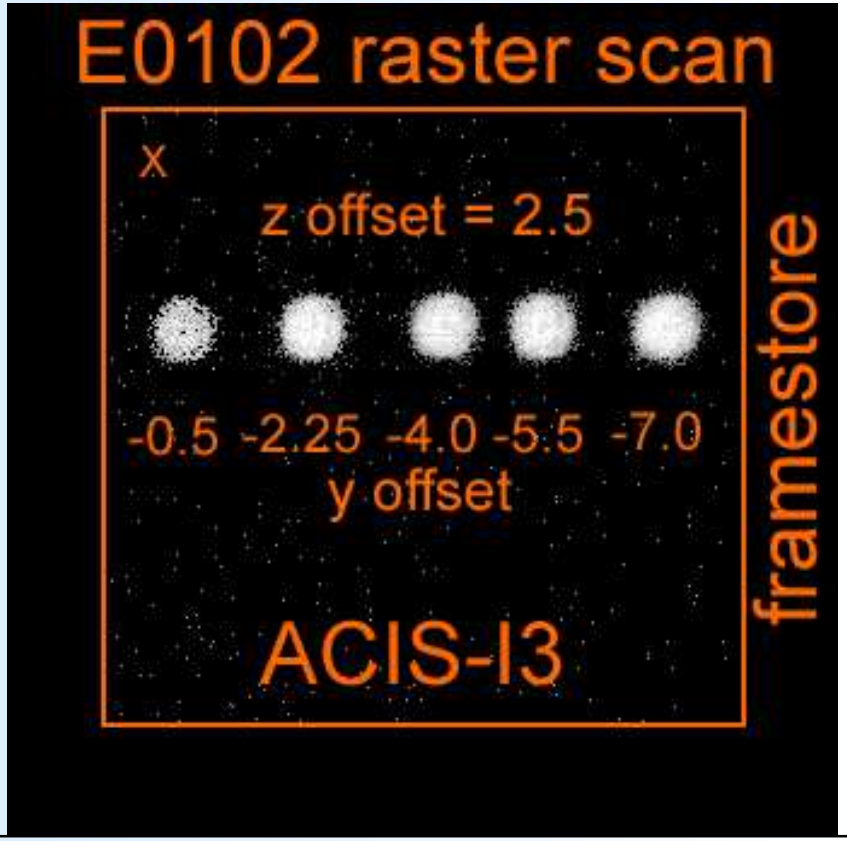
- Small angular size (~47” diameter); high surface brightness
- O, Ne, Mg rich, line dominated spectrum
- little to no Fe emission
- spectrum known to high precision (HETG/RGS)



Observations

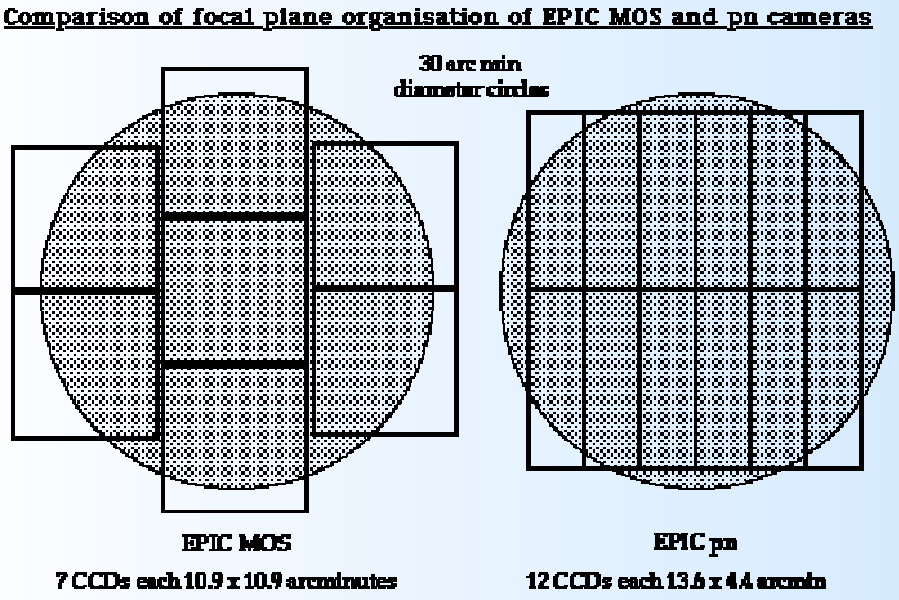
Chandra

- E0102 observed ~6 month intervals in raster scan
- 48 I3, 22 S3 observations
- Focus on subarray mode



XMM

- utilize MOS data taken before revolution 447 (pre “patch”)
- 5 Total observations; 3 MOS1, 1 MOS2, 3 PN



Data Preparation

I. Chandra processing

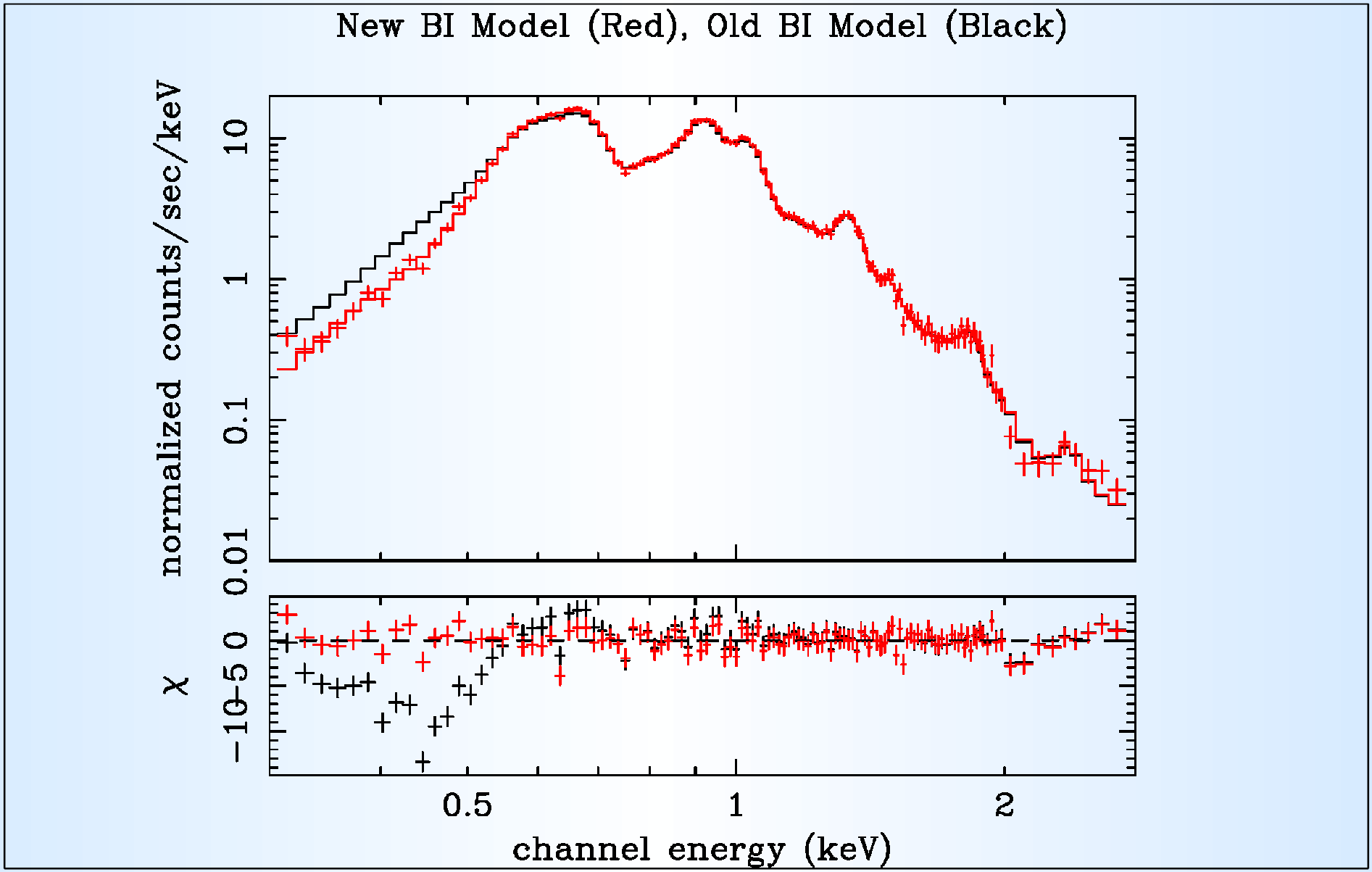
- *CIAO v3.2.2*
- CALDB 3.1.0*

  * - S3 rmfs made with test calibration file
- CTI correction applied to I3 data
- Time dependent gain correction
- Time and spatially dependent contamination correction

I. XMM processing

- *SAS v6.5.0*
- Current calibration database
- Calibration of photon event files using *empchain* and *epchain*
- Periods of enhanced soft proton activity are excluded
- S, S+D grades
- PN PrimeFullWindow, thin filter

New BI Model


New BI Model (Red), Old BI Model (Black)
normalized counts/sec/keV
10
1
0.1
0.01
χ
10
5
0
−5
0.5
1
2
channel energy (keV)

Analysis Methods

Spectral Fitting

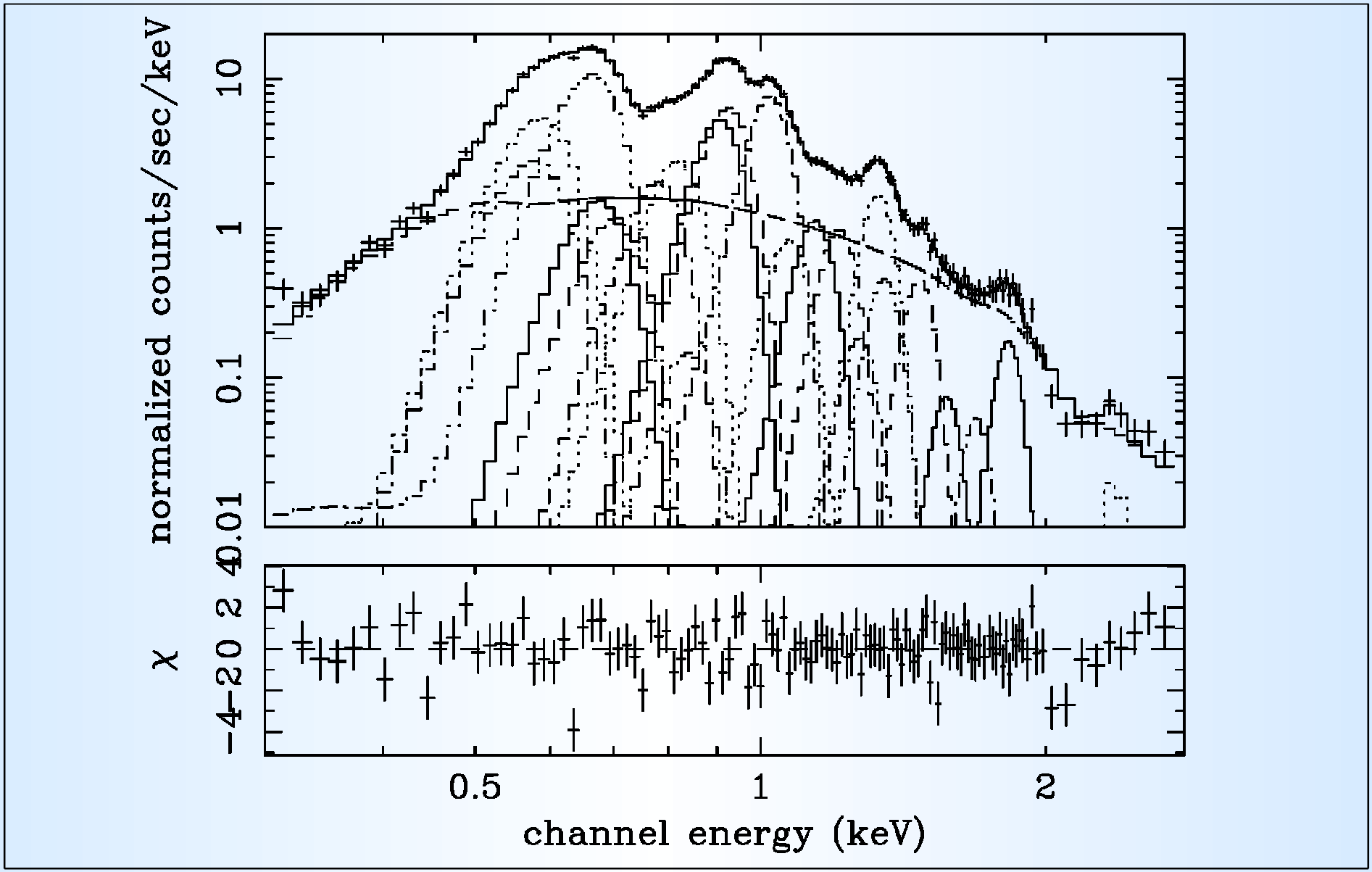
- all extracted spectra fit in *XSPEC V11.0*
- CXC-standard E0102 calibration model from HETG and RGS:
  - phabs – galactic absorption
  - vphabs – SMC absorption
  - thermal Bremmstrahlung for the continuum
  - 24 Gaussians for the brightest line emission
- galactic N_H frozen at 5.36×10^{20} cm^{-2}
- SMC N_H free
- Bremmstrahlung temperature and normalization free
- Line energies frozen; line widths frozen at 0
- Line normalizations free except:
  - OVII F and R lines restricted to values derived from HETG and OVII 665 eV line is 13.5% of the OVIII Ly-α line

Spectral Model

Table 1: Included Lines

λ (A)	Energy (keV)	Line Description	T of Peak Emissivity (K)	Peak Emissivity photons cm^3 s^{-1}
22.100	0.561	O7 $1s^2(^1S_0) - 1s2s(^3S_1)$[For]	2.00×10^6	2.31×10^{-15}
21.600	0.574	O7 $1s^2(^1S_0) - 1s2p(^1P_1)$[Res]	2.00×10^6	3.52×10^{-15}
18.970	0.654	O8 $1s(^2S_{1/2}) - 2p(^2P_{n/2})$ [Ly α]	3.16×10^6	3.54×10^{-15}
18.627	0.665	O7 $1s^2(^1S_0) - 1s3p(^1P_1)$	2.00×10^6	3.74×10^{-16}
17.770	0.698	O7 $1s^2(^1S_0) - 1s4p(^1P_1)$	2.51×10^6	9.82×10^{-17}
16.010	0.774	O8 $1s(^2S_{1/2}) - 3p(^2P_{n/2})$ [Ly β]	3.16×10^6	4.00×10^{-16}
15.180	0.817	O8 $1s\ (^2S_{1/2}) - 4p\ (^2P_{n/2})$ [Ly γ]	3.16×10^6	1.20×10^{-16}
14.821	0.837	O8 $1s\ (^2S_{1/2}) - 5p\ (^2P_{n/2})$ [Ly δ]	3.16×10^6	5.24×10^{-17}
13.700	0.905	Ne9 $1s^2(^1S_0) - 1s2s(^3S_1)$[For]	3.98×10^6	2.10×10^{-16}
13.447	0.923	Ne9 $1s^2(^1S_0) - 1s2p(^1P_1)$[Res]	3.98×10^6	4.11×10^{-16}
12.135	1.022	Ne10 $1s\ (^2S_{1/2}) - 2p\ (^2P_{n/2})$ [Ly α]	5.01×10^6	3.36×10^{-16}
11.560	1.073	Ne9 $1s^2\ (^1S_0) - 1s3p\ (^1P_1)$	3.98×10^6	4.79×10^{-17}
11.000	1.127	Ne9 $1s^2\ (^1S_0) - 1s4p\ (^1P_1)$	3.98×10^6	1.25×10^{-17}
10.765	1.150	Ne9 $1s\ 2(^1S_0) - 1s5p\ (^1P_1)$	3.98×10^6	5.05×10^{-18}
10.239	1.212	Ne10 $1s\ (^2S_{1/2}) - 3p\ (^2P_{n/2})$ [Ly β]	6.31×10^6	4.27×10^{-17}
9.709	1.277	Ne10 $1s\ (^2S_{1/2}) - 4p\ (^2P_{n/2})$ [Ly γ]	6.31×10^6	1.33×10^{-17}
9.314	1.331	Mg11 $1s^2\ (^1S_0) - 1s2s\ (^3S_1)$ [For]	6.31×10^6	5.28×10^{-17}
9.169	1.352	Mg11 $1s^2\ (^1S_0) - 1s2p\ (^1P_1)$ [Res]	6.31×10^6	1.12×10^{-16}
8.422	1.473	Mg12 $1s\ ^2S_{1/2} - 2p\ ^2P_{n/2}$ [Ly α]	7.94×10^6	7.04×10^{-17}
7.850	1.579	Mg11 $1s^2\ (^1S_0) - 1s3p\ (^1P_1)$	6.31×10^6	1.31×10^{-17}
7.310	1.696	Mg11 $1s^2\ (^1S_0) - 1s5p\ (^1P_1)$	6.31×10^6	1.38×10^{-18}
6.740	1.840	Si13 $1s^2\ (^1S_0) - 1s2s\ (^3S_1)$ [For]	1.00×10^7	3.54×10^{-17}
6.183	2.006	Si14 $1s\ ^2S_{1/2} - 2p\ (^2P_{n/2})$ [Ly α]	1.58×10^7	4.95×10^{-17}
5.218	2.375	Si14 $1s\ ^2S_{1/2} - 3p\ (^2P_{n/2})$ [Ly β]	1.58×10^7	6.80×10^{-18}

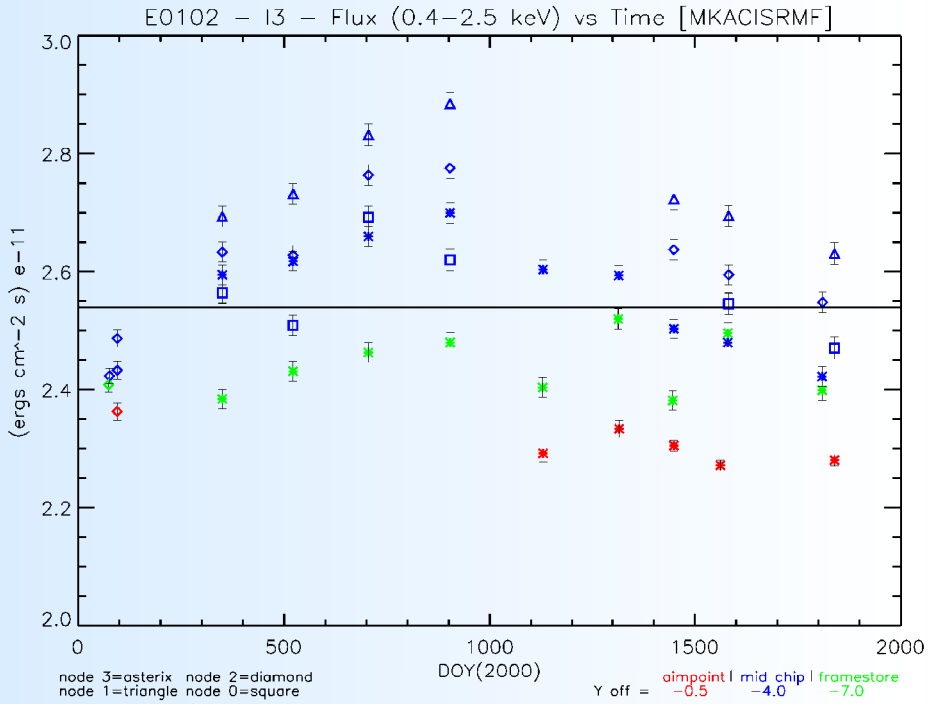
Spectral Model

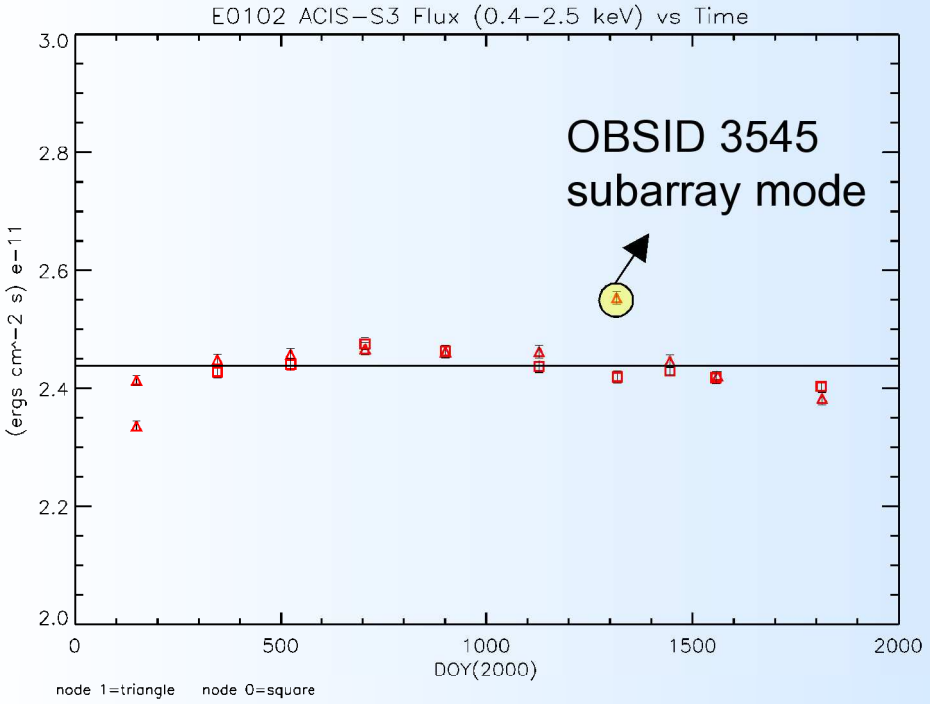


Results

Chandra calibration

- E0102 source flux vs Time for I3 and S3

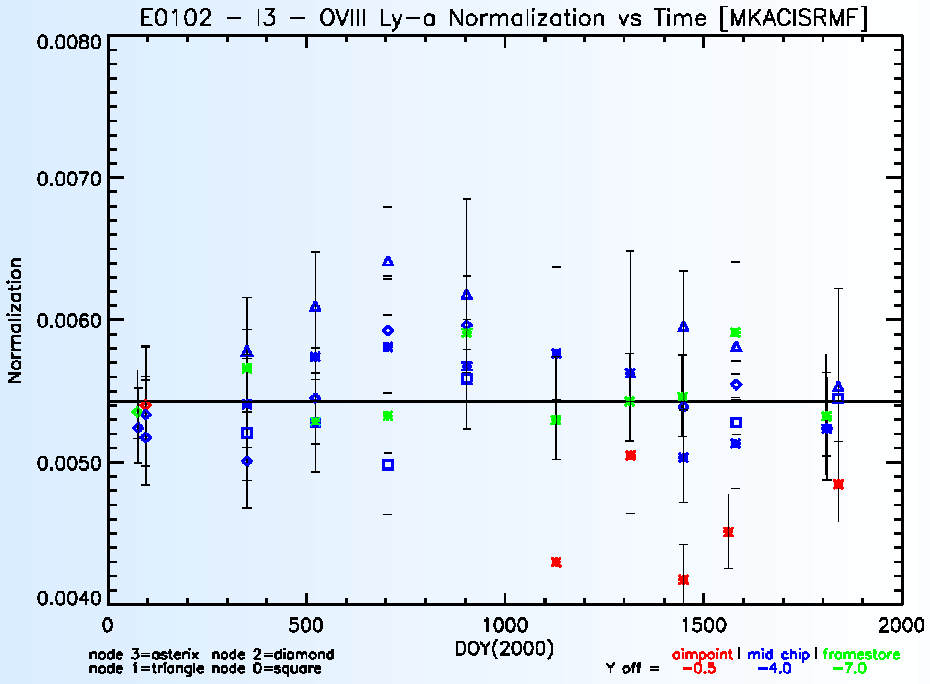


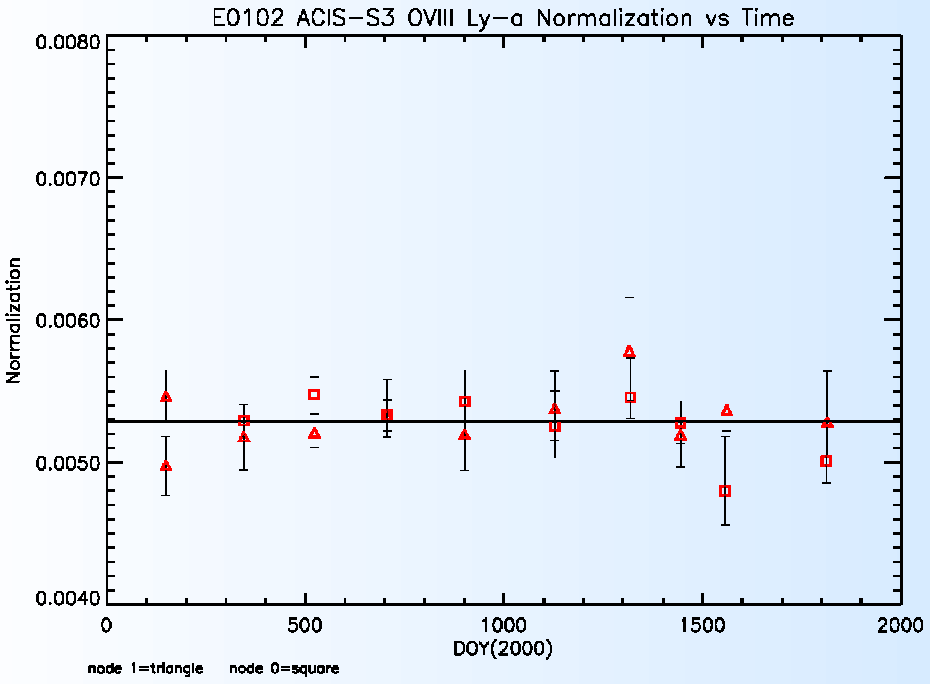


Results

Chandra calibration

- E0102 OVIII Lyα Norm vs Time for I3 and S3

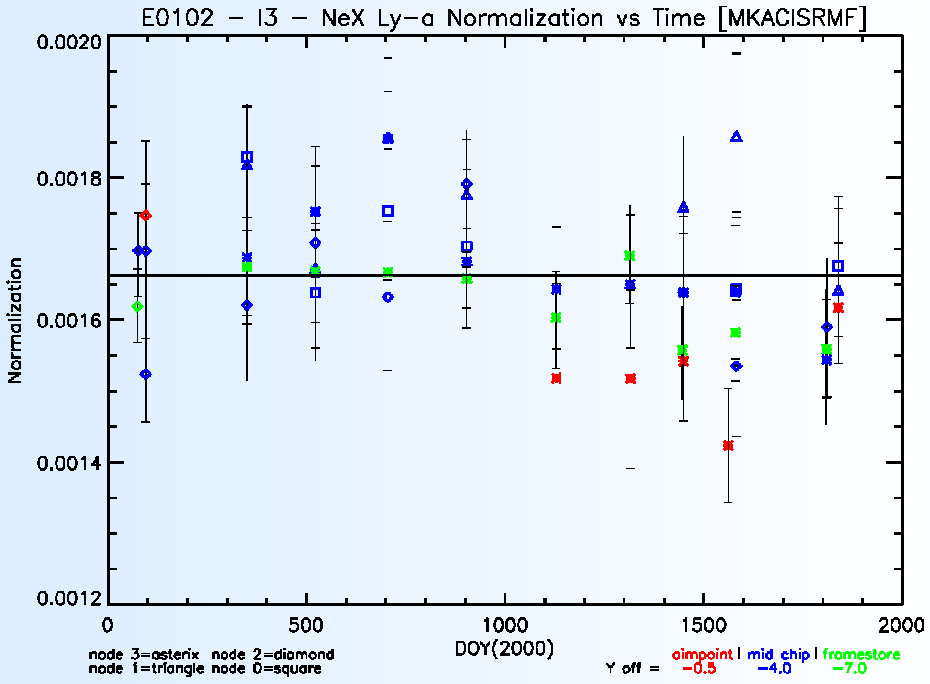


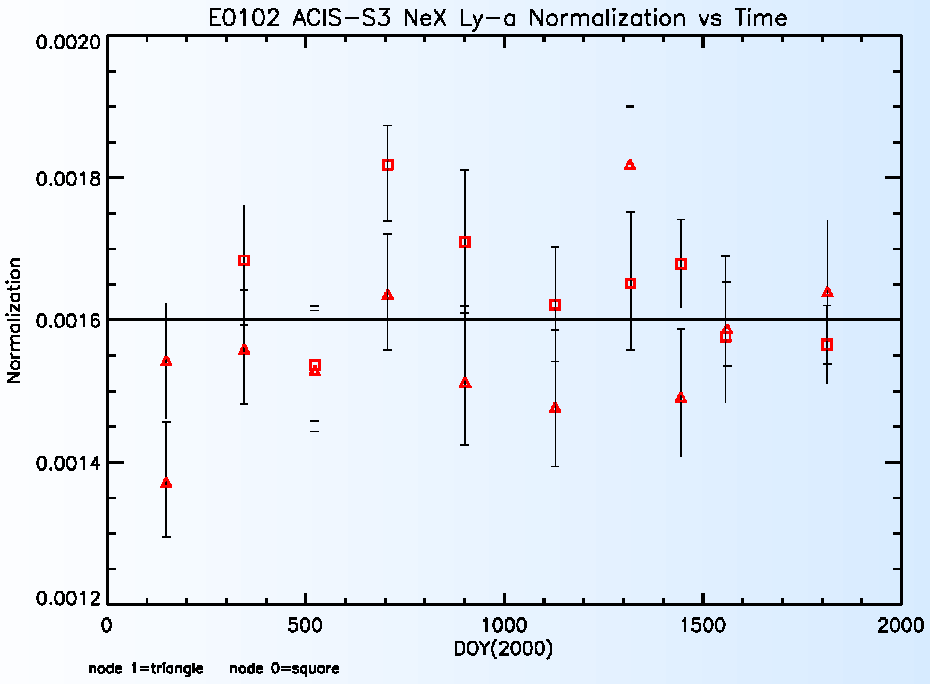


Results

Chandra calibration

- E0102 NeX Lyα Norm vs Time for I3 and S3

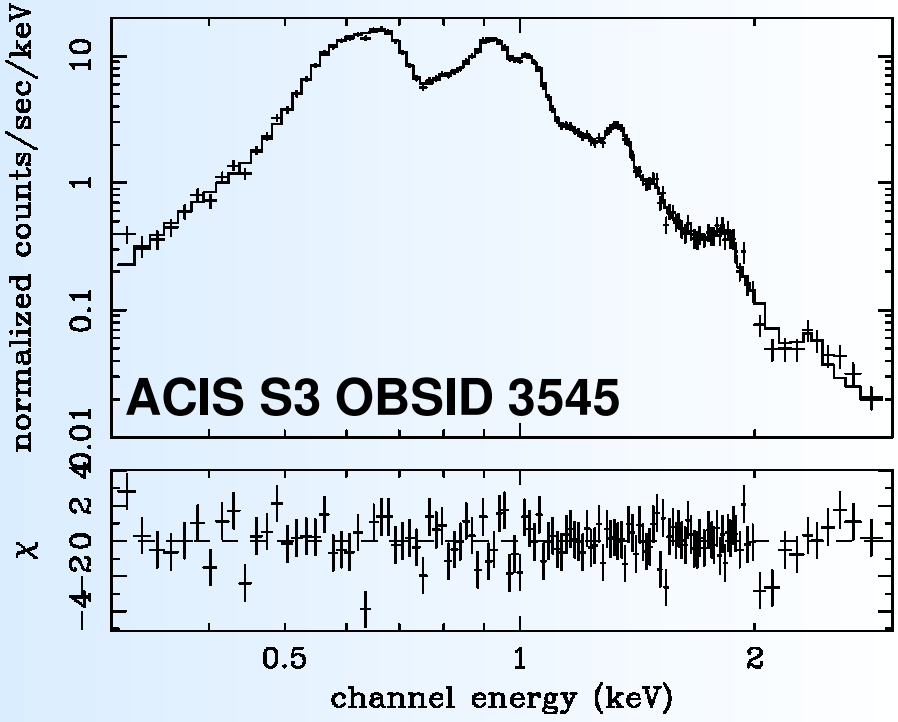




Results

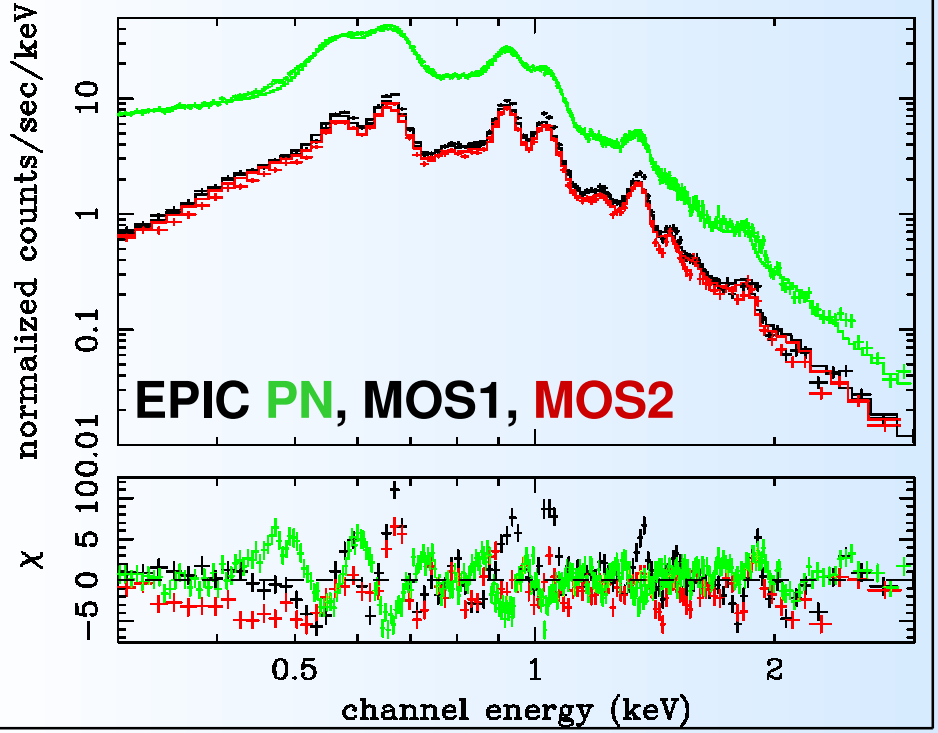
I. Chandra

- Red ChiSq: ~2.1
- SMC N_H: 0
- Brems Temp: ~0.75
- some gain residuals
- FI/BI consistency



I. XMM

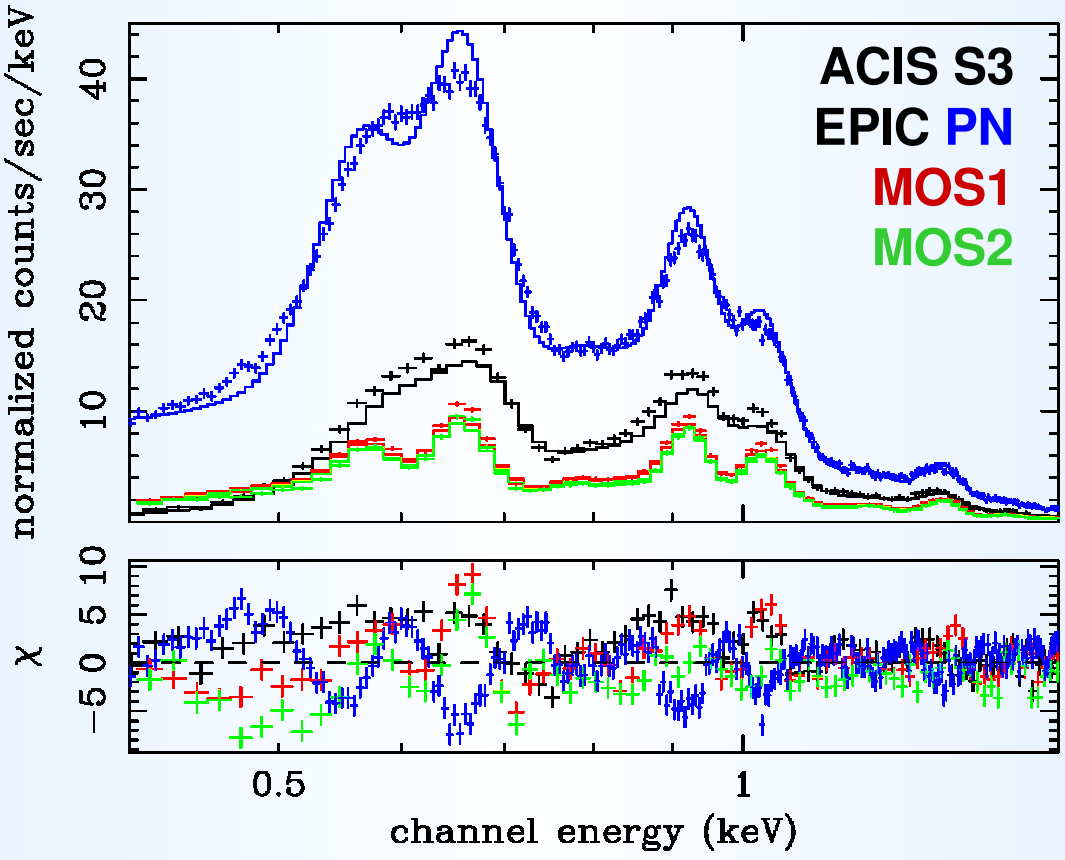
- Red ChiSq: ~2.3(MOS), 2.5 (PN)
- SMC N_H: 7e19 – 9e20
- Brems Temp: 0.5 - 0.7
- some gain residuals
- discrepancy in PN normalizations



Results

Cross Calibration

- Good agreement between MOS and ACIS S3 and I3 detectors
- Possible discrepancy in normalizations from the PN detector



Conclusions

- E0102 provides a great estimate for the low energy performance of these detectors
- EPIC MOS detectors appear to be in good agreement with Chandra ACIS S3 and I3 detectors
- EPIC PN detector shows possible discrepancy in normalizations; may be due to presence of bad columns in the data

Future Work

- We plan to continue this collaborative effort and continue to convene monthly telecons
- We continue to seek out the best possible calibration for both observatories
- We would like to further explore the effect of pileup on the ACIS spectra
  - compare subarray to full-frame observations

The End