Comparison of XMM-Newton EPIC, Chandra ACIS-S3, ASCA SIS and GIS, and ROSAT PSPC results for G21.5-0.9, 1ES0102-72.3, and MS1054.4-0321

A “Man on the street” view of the current status of the cross calibration.

- Publicly available software (SAS 5.2, mostly CIAO 2.1) and current calibration data bases (well almost)
- Will not address “Truth” but “Beauty” is a relative concept

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Richard Mushotzky – GSFC

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Ian George, Kip Kuntz – UMBC

ESTEC:NVS – WA2 XMM Instrument Calibration - 1
Caveats

Calibration and software as current in the last month or two

The calibration and software are moving quantities which are improving with time, i.e., in the last 8 months these results have changed for the better.

Fudge for the ACIS-S3 fits: a carbon Kalpha edge of optical depth 1.0 has been added which improves the fits.

There are sensitivities to the energy range, background selection, spectral model, which data are being fit, what parameters are being fit simultaneously, etc.

ACIS results are for the S3 CCD only.
G21.5-0.9

Crab-like SNR with an extended X-ray halo

In order to compare XMM and Chandra results with those from ASCA, full remnant extracted (XMM/Chandra 165” radius, ASCA 240” radius)

Power-law spectrum dominates

PN, MOS1, MOS2, ACIS-S3, SIS0, SIS1, GIS2, GIS3
G21.5-0.9 Spectra - All

G21.5–0.9 Spectral Fits
Black: MOS1, Red: MOS2, Green: PN, Dark Blue: ACIS–S
Blue: SIS0, Magenta: SIS1, Yellow: GIS2, Orange: GIS3

Flux (2–10 keV, $10^{-11}$ ergs cm$^{-2}$ s$^{-1}$)
(Flux Ratio)

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Flux</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOS1</td>
<td>6.34</td>
<td>1.08</td>
</tr>
<tr>
<td>MOS2</td>
<td>6.36</td>
<td>1.07</td>
</tr>
<tr>
<td>PN</td>
<td>5.95</td>
<td>1.00</td>
</tr>
<tr>
<td>ACIS–S</td>
<td>5.68</td>
<td>0.95</td>
</tr>
<tr>
<td>SIS0</td>
<td>5.68</td>
<td>0.95</td>
</tr>
<tr>
<td>SIS1</td>
<td>5.68</td>
<td>0.95</td>
</tr>
<tr>
<td>GIS2</td>
<td>5.53</td>
<td>0.93</td>
</tr>
<tr>
<td>GIS3</td>
<td>5.68</td>
<td>0.95</td>
</tr>
</tbody>
</table>
G21.5-0.9 Confidence Contours - All

G21.5–0.9 Confidence Contours

Black: EPIC, Red: ACIS–S, Green: SIS

Dark Blue: GIS

N_H (10^{22} cm^{-2})

Photon Index

1.8 1.9 2
G21.5-0.9 Spectra – EPIC/ACIS

G21.5–0.9 Spectral Fits
Black: MOS1, Red: MOS2, Green: PN, Dark Blue: ACIS–S

Flux (2–10 keV, $10^{-14}$ ergs cm$^{-2}$ s$^{-1}$)
(Flux Ratio)
MOS1: 6.43 (1.02)
MOS2: 6.45 (1.03)
PN: 6.02 (0.96)
ACIS–S: 6.22 (0.99)
G21.5-0.9 Confidence Contours – EPIC/ACIS

G21.5–0.9 Confidence Contours
Black: MOS1, Red: MOS2, Green: PN
Dark Blue: ACIS-S

Photon Index

N_{\text{H}} \times 10^{22} \text{ cm}^{-2}
1ES0102-72.3

SMC SNR

Very line rich

MOS1, MOS2, ACIS-S3, SIS0, SIS1, GIS2, GIS3, PSPC, RGS1, RGS2

Spectrum: 2 absorbed APEC thermal spectra with variable abundances

Terrible fit in terms of $\chi^2/\nu$ but good enough for fitted flux comparison
1ES0102-72.3 Spectra - All

1ES0102-72 Spectral Fits

Black: MOS1, Red: MOS2, Green: ACIS-S, Orange: PSPC

Blues: SIS, Yellow/Purple: GIS, Light/Blue Green: RGS

Flux (0.5–2.0 keV) and flux ratio

- MOS1: 2.34 (1.06)
- MOS2: 2.30 (1.03)
- ACIS-S: 2.14 (0.96)
- PSPC: 2.20 (0.96)
- SIS: 2.22 (1.00)
- GIS: 2.06 (0.92)
- GIS: 2.19 (0.98)
- RGS1: 1.35 (0.61)
- RGS2: 1.35 (0.61)

Flux (counts s^{-1} keV^{-1})

Ratio

Energy (keV)
1ES0102-72.3 Spectra – MOS/ACIS

1ES0102-72 Spectral Fits

Black: MOS1, Red: MOS2, Green: ACIS-S, Orange: PSPC

Flux (0.5–2.0 keV) and flux ratio
MOS1  2.35 (1.04)
MOS2  2.31 (1.02)
ACIS-S 2.14 (0.94)
MS1054.4-0321

High redshift cluster
Low absorption
MOS1, MOS2, ACIS-S3
One absorbed high-temperature spectrum
Relatively poor statistics
XMM proprietary data
courtesy of Mike Watson
MS1054.4-0321 Spectra

MS1054.4–0321 Spectral Fits
Black: MOS1, Red: MOS2, Green: PN, Blue: ACIS–S

Flux (counts s\(^{-1}\) keV\(^{-1}\))

Ratio

Energy (keV)
MS1054.4-0321 Confidence Contours

Black: EPIC, Blue: ACIS-S3

Flux (1–5 keV, x 10^{-13} ergs cm^{-2} s^{-1}) and (Flux Ratio)
MOS1 4.39 (0.98)
MOS2 4.43 (0.99)
PN 4.19 (0.94)
ACIS-S3 4.57 (1.02)
Relative Flux Summary

Simultaneous Fits, normalized to the MOS1, MOS2, ACIS-S3 average

<table>
<thead>
<tr>
<th>Source</th>
<th>G21.5-0.9</th>
<th>1ES0102-72.3</th>
<th>MS1054.4-0321</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 – 10 keV</td>
<td>0.5 - 2.0 keV</td>
<td>1 – 5 keV</td>
</tr>
<tr>
<td>PN</td>
<td>0.95</td>
<td>----</td>
<td>0.94</td>
</tr>
<tr>
<td>MOS1</td>
<td>1.01</td>
<td>1.04</td>
<td>0.98</td>
</tr>
<tr>
<td>MOS2</td>
<td>1.01</td>
<td>1.02</td>
<td>0.99</td>
</tr>
<tr>
<td>ACIS-S3</td>
<td>0.98</td>
<td>0.95</td>
<td>1.02</td>
</tr>
<tr>
<td>SIS0</td>
<td>0.91</td>
<td>1.06</td>
<td>----</td>
</tr>
<tr>
<td>SIS1</td>
<td>0.96</td>
<td>0.99</td>
<td>----</td>
</tr>
<tr>
<td>GIS2</td>
<td>0.88</td>
<td>0.91</td>
<td>----</td>
</tr>
<tr>
<td>GIS3</td>
<td>0.91</td>
<td>0.97</td>
<td>----</td>
</tr>
<tr>
<td>PSPC</td>
<td>0.85*</td>
<td>0.97</td>
<td>----</td>
</tr>
</tbody>
</table>

* Flux compared over the 0.5-2.5 keV band
Conclusions

Pretty good, but work left to do.

- EPIC/ACIS flux calibration good to +/- 5%
- Power law indices good to < 0.1
- EPIC MOS/PN inconsistency must be resolved
- ACIS-S3 low energy response must be fixed

- And, of course, more comparisons need to be done
  - Different spectra
  - EPIC vs ACIS-I