Status of XMM-Newton instrument calibration

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on behalf of the whole EPIC & RGS Instrument Teams
Outline

• Status of EPIC calibration
  • 2-D PSF
  • Refinement of the pn redistribution
  • Improved modelling of the MOS redistribution
  • Rate-dependent CTI and quality of energy reconstruction in pn Timing Modes

• Status of RGS calibration
  • “Auditing the RGS effective area model”

• XMM-Newton internal cross-calibration
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2-D PSF: elliptical envelope

• Stack PA-corrected images of many sources in 2XMM for different energies and off-axis angles
• Fit the stacks with a beta- plus central Gaussian (MOS only) profiles
• Create new CCF (ELLBETA extension)
• Update CAL and arfgen

Available as of SASv8.0 via a switch (non-default)
“Spokes” (and sub-) with a source position-independent orientation

Azimuthally-dependent modulation
How SAS builds the 2-D PSF

[1] Elliptical PSF at a given E and θ
[2] Gaussian “core” (MOS only)
[3] Combine 1+2
[4] Rotate to correct source PA
[5] Azimuthal spoke filtering
pn redistribution: the problem

1E0102 - FF

Zeta Puppis - SW

Comet C/2000 WM1 - FF
Results

Zeta Puppis - SW
$\chi^2 = 1114$ (old) to 814 (new)

1E0102 – FF
$\chi^2 = 1495$ (old) to 859 (new)

1E0102 – LW
$\chi^2 = 1585$ (old) to 1236 (new)

1E0102 – SW
$\chi^2 = 1668$ (old) to 1112 (new)

Zeta Puppis - SW
$\chi^2 = 1114$ (old) to 814 (new)
MOS redistribution patch: the problem

Data excess below 0.5 keV (after \(\approx 2002\))

Effect due to not perfect calibration of the "MOS redistribution patch"
The new VRMF model

- Four parameters determine the overall shape: $E_{\text{peak}}$, $\sigma=a+b\sqrt{E}$, normalization
- $\sim30$ times faster than the current SAS method

Blue wing: triangular
Red wing: Gaussian
Blue wing: Gaussian
Red wing: Voigt function
Results: line normalizations (O)

SAS RMF

MOS1, 1E0102
MOS2, 1E0102

VRMF

(courtesy A. Tiengo)
As a bonus we gain the gain

SAS RMF

VRMF

(courtesy A.Tiengo)
Rate-dependent CTI for pn fast modes

- Count-rate dependent shift of the energy scale
- Supported as of SASv8.0 – CCF available as of December 2008
- Calibrated on a sample of non variable sources: 42 observations in Timing and 36 observations in Burst Mode

**Rate dependent CTI - pn timing mode**

- 1-σ confidence interval
- $y = a_0 x^{a_1} + a_2$
  - $a_0 = 0.9933$
  - $a_1 = 0.0029$
  - $a_2 = -0.0068$

**Rate-dependent CTI - pn burst mode**

- 1-σ confidence interval
- $y = a_0 x^{a_1} + a_2$
  - $a_0 = 0.047$
  - $a_1 = 0.121$
  - $a_2 = 0.854$
Post RDCTI spectral quality assessment

Timing Mode

- Difference to the laboratory energies:
  - $\lesssim 20$ eV ($E < 2$ keV), $\lesssim 50$ eV ($E \approx 6$ keV)

Burst Mode

- Obs.0155762501 – GROJ1655–40
  - CCF#19: $E = 6.93 \pm 0.02$ keV
  - CCF#20: $E = 6.982 \pm 0.017$ keV
  - Nominal: 6.969–6.983 keV

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EFFAREACORR CCF = absorption(C*(t-t0),λ)) × areaCorrection(λ)

- thickness of carbon contamination C*(t-t0) increasing linearly with time
  - RXJ1856-3754 constant
- areaCorrection(λ)
  - Mkn421 power-law spectrum
    - slope estimated from centre of the RGS waveband
  - Crab adjustment
- time-variable model parameters unchanged since last year
rgscombined RXJ1856-3754 compared to EPIC-pn model

This is the current contamination calibration
• consistent with XCal discrepancies but…
• contamination model not very well constrained
• 3990 ≤ N ≤ 16113 counts per spectrum
• linear carbon increase C-statistic=81523.8
• noisy individual carbon C-statistic=81510.4
• Vela PWN helps
• More contamination constraints required
• Is the model right?

1st order 2nd order

XMM launch today

RXJ1856-3754's unvarnished rgslccorr history
Mkn421's RGS history in 1ks shots
Audit of the RGS effective-area model

- RXJ1856+3754
  - constant enough
  - complementary contamination information required
    - contamination build-up more complex than assumed?
  - model inconsistencies
    - IACHEC’s job
- Mkn421
  - far from constant in flux or slope within XMM exposures
  - spectral curvature argued in the literature
    - cf SRON Crab nebula analysis
- Small background issues
What now?

• Joint XMM calibration issues
  • EPIC pile-up
    • selection regions extensively assessed
• New RGS constraint
  • RXJ1856-3754 model constant
• continuum sources ⊕ line-rich sources
  • RGS ⇔ EPIC
  • Better constrained contamination history
    • NVI lines near 29 Å in ζ Pup
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Cross-calibration XMM-Newton database

Database of ~150 observation of different sources, optimally reduced, fit with spectral models defined on a source-by-source basis

Public interface available at:
http://xmm2.esac.esa.int/external/xmm_sw_cal/calib/cross_cal/index.php
Statistical flux evaluation for SASv8.0

Relative flux in different bands [Joint fit=1] (100 observations)

\[ \begin{align*}
\mu &= 0.99 \quad (\sigma = 0.15) \\
\mu &= 1.01 \quad (\sigma = 0.22) \\
\mu &= 1.04 \quad (\sigma = 0.16)
\end{align*} \]

\[ \begin{align*}
\mu &= 1.00 \quad (\sigma = 0.05) \\
\mu &= 1.00 \quad (\sigma = 0.13) \\
\mu &= 1.05 \quad (\sigma = 0.06) \\
\mu &= 1.03 \quad (\sigma = 0.17) \\
\mu &= 1.02 \quad (\sigma = 0.15)
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\mu &= 1.04 \quad (\sigma = 0.11) \\
\mu &= 1.02 \quad (\sigma = 0.16)
\end{align*} \]

\[ \begin{align*}
\mu &= 1.05 \quad (\sigma = 0.37) \\
\mu &= 1.05 \quad (\sigma = 0.31) \\
\mu &= 1.13 \quad (\sigma = 0.46)
\end{align*} \]

\[ \begin{align*}
\mu &= 0.99 \quad (\sigma = 0.05) \\
\mu &= 1.05 \quad (\sigma = 0.22) \\
\mu &= 1.06 \quad (\sigma = 0.09)
\end{align*} \]

\[ \begin{align*}
\mu &= 1.00 \quad (\sigma = 0.05) \\
\mu &= 1.01 \quad (\sigma = 0.13) \\
\mu &= 1.01 \quad (\sigma = 0.08) \\
\mu &= 1.04 \quad (\sigma = 0.18) \\
\mu &= 1.04 \quad (\sigma = 0.15)
\end{align*} \]
Summary of XMM-Newton XCAL

- Above ~0.8 keV, MOS fluxes are higher by on average 5-8% than pn.
- Several MOS flux ratios show decrease, dependent on energy band.
- High deviations for MOS/pn flux ratios below 0.3 keV.
- RGS flux ratios are stable for all energy bands.
- Above O-edge RGS (up to 1.5 keV) and EPIC-pn agree to 2% on average.
- Below O-edge RGS fluxes are on average 5-10% higher than EPIC-pn.

**EPIC and RGS are consistent on average within 10%**.