X-calibration of NuSTAR and Swift

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Cross-calibration: Normal operations

- Require as stable target or strict simultaneity
  - Stable source are extended and faint
- The goldilocks source: 3C 273
  - Hard spectrum:
    - Not too bright for soft instruments
    - Bright enough for hard instruments
  - Fairly stable
    - Low Earth Orbit observatories can’t always be simultaneous
  - Fairly featureless
    - Between 1 – 20 keV a power-law
    - Below soft excess
    - Above curvature
Cross normalization
WT “Good fit” v. Not a “good fit”

TABLE 6
CROSS Normalization Constants (3-7 keV & 20-40 keV)

<table>
<thead>
<tr>
<th>Top/Bottom</th>
<th>LETGS</th>
<th>HETGS</th>
<th>FPMA &amp; FPMB</th>
<th>XIS0</th>
<th>XIS1</th>
<th>XIS2</th>
<th>HXDab</th>
<th>XRT</th>
<th>MOS1</th>
<th>MOS2</th>
<th>pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPMA &amp; FPMB</td>
<td>1.09(3)</td>
<td>1.10(7)</td>
<td>1</td>
<td>0.91(4) – 0.97(1)</td>
<td>0.87(4) – 0.94(1)</td>
<td>0.95(4) – 0.97(1)</td>
<td>1.12(5)</td>
<td>1.01(7) – 1.08(4)</td>
<td>1.01(5) – 1.03(2)</td>
<td>0.97(4) – 1.03(2)</td>
<td>0.88(2) – 0.90(4)</td>
</tr>
</tbody>
</table>

Note - Cross-normalization constants from Table 3 and 4. Where a range is given the instrument observed both sources, and the range are directly the lower and higher ratio.

*Energy range: 20-40 keV

Swift(WT) N=1.07

Her X-1

Swift J1728.9–3613

cons*tbabs*(pow+diskbb)

XRT: 0.97
FPMA: 1.66
FPMB: 1.04
Cross calibration: The issue

• Relevant for galactic high NH sources taken with
  • NuSTAR
  • Swift WT mode
  • Nicer
  • XMM
    • piled up sources
    • timing mode
    • Pn burst mode
Typical Analysis Cycle

Ignore NuSTAR above 20 keV
Ignore Swift above 7 keV

Ignore NuSTAR between 3 - 5 keV

Nustar = 0.95
Swift = 1.09
Xmm= 0.99
Is it the right thing to do?

• We all do it (me too... sometimes)

• We prune until the fit statistic is good because reviewers will otherwise question the result

• But
  • We do not know WHICH instrument is right
  • Pruning and chopping off parts of the spectrum will give you a “result”, but not necessarily the right one
  • We attempt to compare apples to apples, but we are really dealing with apples and oranges...
Dust scattering
Energy dependency

The problem


NuSTAR
Swift WT
XRT WT Profiles

• Example XRT WT mode 1D profiles from low NH source (MAXIJ1820+70, top) and high NH source (MAXIJ1535-571, bottom)

• latter has extended profile (black) compared with expected profile (red dashed), indicative of halo

• `xrtmkarf` applies EEF correction to ARF for a nominal point source PSF
  • Underestimates corrections for an extended source
  • Gives const factor > 1 when fitting
### Pilot project

<table>
<thead>
<tr>
<th>Source Name</th>
<th>NuSTAR OBSID</th>
<th>Swift OBSID</th>
<th>NH (litt.)</th>
<th>Halo Metric</th>
<th>Swift Count Rate (cts/s)</th>
<th>NuSTAR Count Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRS_1716m249</td>
<td>90301007002</td>
<td>00034924051</td>
<td>0.01</td>
<td>85.67</td>
<td>47.3</td>
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<tr>
<td>4U_1957p11</td>
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<td>00088692001</td>
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<td>00081425002</td>
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<tr>
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<td>00088245004</td>
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<tr>
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<tr>
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<td>00810300002</td>
<td>0.14</td>
<td>5.744</td>
<td>31.4</td>
<td></td>
</tr>
</tbody>
</table>

*Summer student project started by Isaiah Curtis, Caltech*
Halo metric: NuSTAR
NuSTAR and Swift
Halo and ‘discrepancy’ correlation
Conclusion and Recommendation

• Conclusion
  • Cross-normalization offsets are expected since the source is ‘extended’ in WT and the PSF correction assumes a point source
  • Clear correlation of ‘discrepancy’ with increasing halo size
  • Shape of ‘discrepancy’ is overall the same and gets worse with larger halos
  • Do we understand it? No...

• Recommendation
  • Allow for large cross-normalization constants between NuSTAR and Swift – that is alright
  • The fit won’t be good in the overlapping region, but DON’T attempt to fix it by adding unphysical components
  • Pruning and chopping can make the fit look pretty, but it won’t be more correct