The Multi-Mission Cross-Calibration Campaign on 3C 273

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3C 273

• Unabsorbed radio loud QSO, \( z = 0.1583 \)

• X-ray spectrum is jet dominated >2 keV, synchrotron bump at >MeV energies

  => Bright, hard X-ray spectrum well represented with a simple powerlaw

• Long term flux and mild spectral variability

  => Simultaneity potentially important
2012 X-ray Observations

NuSTAR

INTEGRAL

Swift

Chandra

Suzaku

XMM-Newton

MJD - 55000 (days)
NuSTAR: Current CALDB ARFs

Powerlaw model results in residuals at high energies
**NuSTAR** and **INTEGRAL**

- **NuSTAR** data simultaneous with **INTEGRAL** observation

- ISGRI spectrum provided by **INTEGRAL** (although may be missing majority of data)

- Spectra modeled simultaneously

**INTEGRAL** spectrum continues to high energies

=> **NuSTAR** turnover not astrophysical
**NuSTAR: Crab Corrected**

**FPMA**
\[
\Gamma = 1.683 \pm 0.005 \\
N = (2.38 \pm 0.01) \times 10^{-2}
\]

(90% errors, 1 param)

\[\chi^2/\text{DoF} = 1781/1639\]

**FPMB**
\[
\Gamma = 1.689 \pm 0.006 \\
N = (2.42 \pm 0.03) \times 10^{-2}
\]

(90% errors, 1 param)

=> Excellent agreement between FPMA and FPMB
Photon Index Energy Dependence?

Comparison of *NuSTAR* photon indices from various energy bands (FPMA,B linked):

- Full band (4-79 keV): \( \Gamma = 1.683 \pm 0.003 \)
- 4-10 keV: \( \Gamma = 1.676 \pm 0.009 \)
- 10-25 keV: \( \Gamma = 1.70 \pm 0.02 \)
- 25-79 keV: \( \Gamma = 1.68 \pm 0.04 \)

\[ \Rightarrow \text{Photon indices are consistent, although constraint naturally degrades at higher energies} \]
~10% variability around the mean count rate during the NuSTAR observation.
Comparison of *NuSTAR* photon indices from various intervals (FPMA,B linked):

- Full observation: $\Gamma = 1.683 \pm 0.003$
- Simultaneous with *INTEGRAL*: $\Gamma = 1.690 \pm 0.004$
- Simultaneous with *Suzaku*: $\Gamma = 1.706 \pm 0.009$
- Simultaneous with *XMM*: $\Gamma = 1.69 \pm 0.02$

=> Perhaps, but if so, not very much.
Observed in small window mode, 18 ks exposure

Mild pile-up in pn, more severe pileup in MOS, so spectra extracted from annular regions
**Suzaku**

**Individual**
- XIS0: $\Gamma = 1.62 \pm 0.02$
- XIS1: $\Gamma = 1.65 \pm 0.02$
- XIS3: $\Gamma = 1.64 \pm 0.02$
- PIN: $\Gamma = 1.7 \pm 0.1$

(XIS: 2-10; PIN: 15-70 keV)

**Combined**
- $\Gamma = 1.642 \pm 0.009$

(2-70 keV)

$\chi^2$/DoF = 1768/1768

$C_{\text{PIN/XIS}} = 1.08 \pm 0.04$

**Simultaneous with XMM**
- $\Gamma = 1.65 \pm 0.02$
More Photon Indices

<table>
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<tr>
<th>INSTRUMENT</th>
<th>EN. RANGE (keV)</th>
<th>PHOTON INDEX</th>
<th>NOTES</th>
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<td><em>NuSTAR</em> (FPMA,B)</td>
<td>4-79</td>
<td>1.683 +/- 0.003</td>
<td>Crab-corrected</td>
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<td><em>XMM</em>-pn</td>
<td>2-10</td>
<td>1.59 +/- 0.01</td>
<td>Mild pile-up, annulus</td>
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<td><em>XMM</em>-MOS1</td>
<td>2-10</td>
<td>1.56 +/- 0.02</td>
<td>Piled-up, annulus</td>
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<td><em>XMM</em>-MOS2</td>
<td>2-10</td>
<td>1.56 +/- 0.02</td>
<td>Piled-up, annulus</td>
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<td><em>Swift</em>-XRT</td>
<td>2-9</td>
<td>1.60 +/- 0.06</td>
<td>Piled up, annulus</td>
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<tr>
<td><em>Suzaku</em> (combined)</td>
<td>2-70</td>
<td>1.642 +/- 0.009</td>
<td>Tuned PIN background</td>
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<td><em>INTEGRAL</em>-ISGRI</td>
<td>~18-350</td>
<td>1.6 +/- 0.1</td>
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<td><em>Chandra</em>-HEG (ord. -1,1)</td>
<td>2-8</td>
<td>1.55 +/- 0.05</td>
<td></td>
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</tbody>
</table>

Generally good agreement between most of the missions

*But*

*NuSTAR* looks a little soft, as does *Suzaku* (to a lesser extent)
NuSTAR Offaxis Distribution

- Mast motion results in a distribution of offaxis angles throughout an observation
- This distribution is unique for each FPM, and for each observation
- Damn (although not surprising)
- More complex correction procedure probably required
Future Plans

• Do more stuff.
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• Examples of more stuffs to be done:
  
  ➢ Confirm *NuSTAR* optical axis alignment
  
  ➢ Improve corrections based on the crab, with more specific treatment of different offaxis-angles
  
  ➢ In parallel, improve ray-traced ARFs (rather time consuming)
  
  ➢ Take a more strict approach to simultaneity with the other missions (but this may not change much)