IACHEC standards

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On the in-flight calibration plans of modern x-ray observatories

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Outline

• Standards that are likely to remain adequate in the future

• Standards that we may need to revise
Standards likely to be adequate in the future

- Good standard candles to in-flight calibrate the LSF/energy scale at $\mu$-calorimeter resolution at $E \leq 2$ keV
High-resolution LSF and wavelength scale (soft)

RGS spectra of calibration targets (same y-scale)

Caveats:
- rotational broadening
- orbital broadening
- thermal broadening

Safe for Resolve (requirement 1 eV)

Unclear for X-IFU (requirement 0.15 eV)

Alternative: ADLeo, $v \sin(i) \leq 6$ km s$^{-1}$
Standards likely to be adequate in the future

- Good standard candles to in-flight calibrate the LSF/energy scale at $\mu$-calorimeter resolution at $E \leq 2$ keV

- Good standard candles to identify/monitor molecular contamination in-flight (1E0102-72, RXJ1856-3754, Abell1795 …)

- Good standard candles for timing
The “timing lot”

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Crab</th>
<th>PSR B1509-58</th>
<th>PSR B0540-69</th>
<th>Cen X-3</th>
<th>Vela X-1</th>
<th>PSR B1821-24</th>
<th>Burst phenomenon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 ks (PV) + 2 x 10 ks</td>
<td>40 ks (TBD)</td>
<td>50 ks</td>
<td>xx ks (PV Target)</td>
<td>xx ks (PV Target)</td>
<td>(80 ks) optional, not recommended</td>
<td>short bursts from any possible ToOs</td>
</tr>
<tr>
<td>Exposure</td>
<td>Absolute Time / Phase</td>
<td>Relative Time</td>
<td>Relative Time</td>
<td>Relative Time</td>
<td>Relative Time</td>
<td>Timing Jitter Each Event broadening of spiky peak is a good marker for the timing jitter</td>
<td>Relative precise time serendipitous bursts in ToO: relative timing phase among instruments</td>
</tr>
<tr>
<td></td>
<td>Sharp pulse peak is compared with the radio ephemeris</td>
<td>Pulse profile and period could be reproduced? (broad profile)</td>
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<td>Pulse profile and period could be reproduced?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A/I</td>
<td>- SXS grade, dead-time</td>
<td>- Exposure is TBD</td>
<td>- Coordination of SXI modes</td>
<td></td>
<td></td>
<td>(optional)</td>
<td>(optional)</td>
</tr>
<tr>
<td>Intensity</td>
<td>1 Crab (~10%)</td>
<td>~1 mCrab</td>
<td>~1 mCrab</td>
<td></td>
<td>~0.1 mCrab</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Period</td>
<td>33 ms</td>
<td>151 ms</td>
<td>50.5 ms</td>
<td>3 s</td>
<td>283 s</td>
<td>3 ms</td>
<td>N/A</td>
</tr>
<tr>
<td>SXS</td>
<td>△</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>SXI</td>
<td></td>
<td></td>
<td></td>
<td>△ (1/8 mode)</td>
<td>○ (any mode)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HXI</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGD</td>
<td>○ (100 ks)</td>
<td>△</td>
<td>△</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Proposed Targets**

Additionally proposed exposure for our timing calibration is shown in red
○: mainly used, ◯: used, △: used with an issue to be checked

Guainazzi et al., 2016, JAXA-ASTH-SOT-001. Main inputs by Y.Terada (Saitama University) & T.Enoto (Kyoto University)
Standards likely to be adequate in the future

- Good standard candles to in-flight calibrate the LSF/energy scale at $\mu$-calorimeter resolution at $E \leq 2$ keV

- Good standard candles to identify/monitor molecular contamination in-flight (1E0102-72, RXJ1856-3754, Abell 1795 ...)

- Good standard candles for timing

- “Fudges happen” (R.Petre) - we will continue making use of allegedly smooth continuum sources to correct areas
Latest examples of (area) “fudges happen”

Gonzalez-Riestra, 2017, XMM-CCF-REL-349

Based on an analysis of blazar spectra by the RGS/SRON Team

XMM-Newton/RGS

Hitomi/SXS

SXS Crab spectrum
Standards likely to be adequate in the future

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- Good standard candles to identify/monitor molecular contamination in-flight (1E0102-72, RXJ1856-3754, Abell 1795 …)

- Good standard candles for timing

- "Fudges happen" (R. Petre) - we will continue making use of allegedly smooth continuum sources to correct area

- Ground-based calibration will continue to be a key factor
Standards that we may need to revise

- LSF/energy scale at $\mu$-calorimeter resolution for $E \geq 2$ keV?
SXS LSF/energy scale

ABDor, HR1099

Alternatives?

- **XRB**: Ionisation status and broadening of Fe line uncertain
- **Highly-obscured Be binaries**? Uncertainties on the origin of the lines, poor constraints on the broadening by Chandra/HETG
- **Galaxy clusters cores**? Simple, but dynamical properties still poorly known

**HR1099**: rotational broadening 0.85 eV @FeXXV
**ABDor**: thermal broadening only (Drake et al. 2015)
Standards that we may need to revise

- LSF/energy scale at $\mu$-calorimeter resolution for $E \geq 2$ keV?

- How to calibrate 3800 $\mu$-calorimeter’s pixels?

In the SXS we planned a $\sim 260$ ks pixel-by-pixel scan of Capella
SNRs: energy scale and area

Guainazzi et al., 2015, JATIS, 1(4), 047001
Even larger structures considered for the SXS …

Guainazzi et al., 2016, JAXA-ASTH-SOT-001. Main inputs by K.Mori (Miyazaki University)

ROSAT/PSPC image of the Cygnus Loop
Ionisation and velocity structure

1E0201-72 - Chandra/ACIS

N132D - Hitomi/SXS

Si-K

Fe-K

Red (0.3-0.5 keV), Green (0.5-0.75 keV), Blue (0.75 – 7.0 keV)
Cool core clusters are relaxed and have isothermal structure at a radial range of 0.1 to 0.3 $r_{500}$. 

Guainazzi et al., 2015, JATIS, 1(4), 047001. Main inputs by J. Nevalainen (Tartu University)
On-board calibration sources on the *Hitomi*/SXS

- **Calibration pixel**: $^{55}$Fe
- **Filter Wheel**: $^{55}$Fe
- **Direct modulated X-ray source**: Cr-K, Cu-K
- **Indirect modulated X-ray source**: MXS+AL/Mg targets (unclear if it would be used)

Energy shift per pixel from the FW $^{55}$Fe (March 19)
Standards that we may need to revise

- LSF/energy scale at μ-calorimeter resolution for $E \geq 2$ keV?
- How to calibrate 3800 μ-calorimeter’s pixels?
- How to calibrate $R > 1000$ grating instruments?
Capella (lacking of better alternatives?)

Alternatives: σGem (longer orbital period), ISM?
Standards that we may need to revise

- LSF/energy scale at μ-calorimeter resolution for $E \geq 2$ keV?
- How to calibrate 3800 μ-calorimeter’s pixels?
- How to calibrate $R > 1000$ grating instruments?
- Which featureless sources do we need for the future?
Cross-talk area vs. PSF

2016 XMM-Newton PSF

2017 XMM-Newton PSF

Smith et al., 2017, XMM-CCF-REL-348
Secondary blazars

Sample of 104 BLLac observed by XMM-Newton

Systematic residuals $\pm 1\%$ ($E \leq 4$ keV) $\pm 3\%$ ($E > 4$ keV)

(in *Hitomi*: 1ES0033+595; see L.Brenneman’s talk)