IACHEC: International Astronomical Consortium for High Energy Calibration

Defining High Energy Calibration Standards and Procedures

Herman L. Marshall
(MIT Kavli Institute, Chandra Science Center)
IACHEC Overview

- Annual international meetings (since 2006)
  - Started by 2 largest X-ray groups (Chandra & XMM)
  - Support comes from projects (XMM, Suzaku, etc.)
  - Most recent meeting: Avigliano Umbro, Italy (April 2018)

- Meetings involve work!
  - Several half-days for working group sessions
  - Telecons between meetings maintain progress

- All major X- & gamma-ray missions represented

- 35-50 attendees/meeting, most give talks

- 12 papers published since 2008

- URL: http://web.mit.edu/iachec/ with Wiki
What IACHEC Does

- Reviews ground calibration plans for new missions
  - Upcoming: IXPE, Athena
- Reviews flight calibration plans and results
  - Investigate optics and detector physics
  - Examine methods, systematic errors
- Define new calibration standards
  - Characterize sources physically
  - Compare results from different missions
  - Publish results
- Arrange coordinated observations
- Consider infrastructure: statistics, archives
Working Groups

- **Methods**
  - Background (particles, “space weather”, cosmic sources)
  - Detectors (CCDs, calorimeters, proportional counters...)
  - Coordinated observations
  - Emission line identifications, wavelengths
  - Statistics

- **Sources**
  - Clusters of galaxies
  - Nonthermal SNR (e.g. Crab)
  - Thermal SNR
  - WDs and isolated neutron stars
Examples — 1

- Galaxy clusters = hot gas balls
- Measured kT with 2 telescopes
- Validated XMM (pn) kTs with Fe line flux ratios
- Fixed Chandra optics model
- Project started at 2nd IACHEC meeting

See also Schellenberger+ 2015, A&A, 575, 30
Examples — 2

- Joint observations of an AGN
- Technical issues:
  - only joint times
  - fluxes from PL fits in narrow bands
  - relative to joint fit
- Published as an IACHEC project
- Elucidated instrument differences

Ishida et al. 2011, PASJ, 63, S657.
Examples — 2

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Examples — 3

- Thermal SNR group: results for iE0102-7219
- Spectrum is simple, stable
- Set reference fluxes
- Provides comparison of instruments

Examples — 4

- Fluxes in bands compared
- XMM (top) and Chandra (bottom)
- Simultaneous observations used
- IACHEC paper in progress

Smith, Stuhlinger, Guainazzi, Marshall, in prep.
Examples — 5

- Encode systematic error estimates in ensemble of cal files
- Fit model to data using each cal file set
  - Markov Chain Monte Carlo enables process
  - Populate parameter space with viable solutions
- Examine distributions of parameters
- Implemented for Chandra: pyBloCXs

See http://hea-www.harvard.edu/AstroStat/pyBLoCXS/
Examples — 6+

- For NICER: coordinating new observations of 3C 273 with Chandra, XMM, NuSTAR, AstroSat
- Study of N132D, an SNR in LMC
- Use of HZ 43, Sirius B, & PKS 2155-304 to correct QE of spectrometer on Chandra
- Use of RX J1856, 1E0102, and Mk 421 to measure contamination, compared to Suzaku
- Switch over to ML statistics (e.g. cstat from $\chi^2$)
- Posting and maintaining wiki pages for data, results
- Concordance: suggesting changes to EAs
New Work on Coordinated Data

- Generally:
  - One person leads, collects GTIs, computes overlaps
  - Rest use overlap GTIs and provide spectra

- 2015, ’16, ’17 3C 273 with NuSTAR+; KKM will coordinate
- 2018 3C 273 with NICER+; CM will coordinate

- Others (with analysis lead):
  - GX 13+1: NSS
  - MAXI J1820: EJ
  - Capella: VK & JeKa from many years
  - Her X-1: PK (XMM) lead
Concordance

- Answer to “How to change effective areas given many observations by different instruments differ?”
- Method: Multiplicative Shrinkage (Chen+ 2019)
  - uses all data to find best true fluxes, then correct EAs
  - needs \( \tau \) values, fractional uncertainties on prior EA
  - if ground-cal is poor (large \( \tau \)), observations drive new EA
  - if observations are poor (large \( \sigma \)), prior dominates
- Developed jointly with statistics academicians
- IACHEC scientists set \( \tau \) values
- Working on new cross-cal data sets (Marshall+ 2019)
## The Matrix (excerpt)

<table>
<thead>
<tr>
<th>Energy Range (keV)</th>
<th>Chandra ACIS</th>
<th>Chandra HETGS</th>
<th>Chandra LETGS</th>
<th>XMM pn</th>
<th>XMM MOS1,2</th>
<th>ROSAT PSPC</th>
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<td>2</td>
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<td>10</td>
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<td>7</td>
<td>2</td>
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</table>
Supporting Cross Calibration

1. Publish ground-cal data; acknowledge model deviations
2. Observe non-varying ‘standards’ (e.g. 1E0102, A1795)
3. Coordinate observations of simple targets (e.g. 3C 273)
4. Facilitate coordinated observations by users
5. Take in-flight cal observations more often than needed
6. Estimate ground-cal uncertainties (τ values) on EA
   a. Try physical uncertainties first (in edge depths, geom. area...)
   b. Determine τ in different energy bands (see τ table)
7. Adopt IACHEC ‘best practices’ (e.g. Cstat, BG model)
8. Send representatives to IACHEC meetings!

H. L. Marshall — Cross-Cal  May 17, 2019