IACHEC: International Astronomical Consortium for High Energy Calibration

Defining High Energy Calibration Standards and Procedures

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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

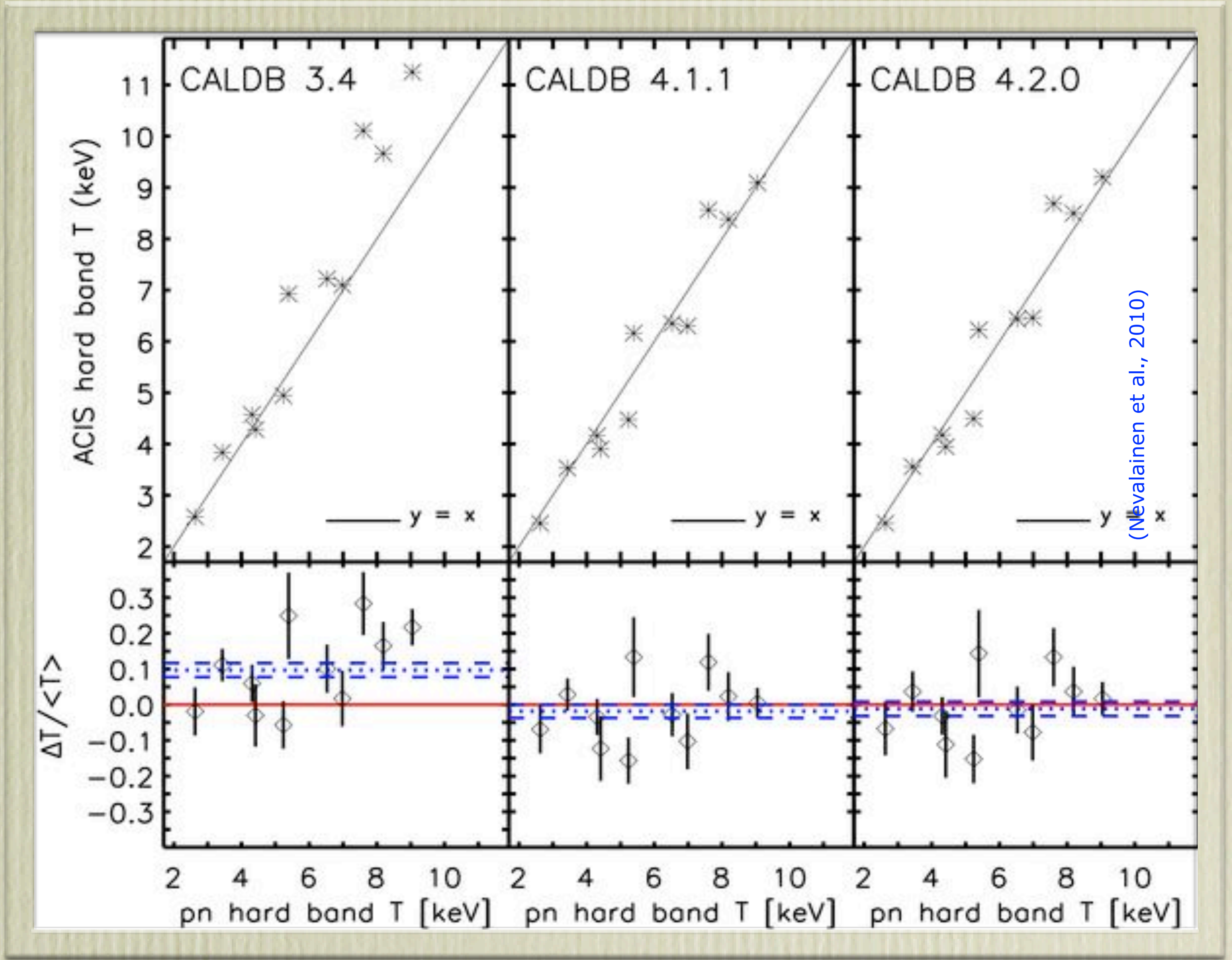
- Reviews ground calibration plans for new missions
  - Upcoming: IXPE, Athena
- Reviews flight calibration plans and results
  - Investigate optics and detector physics
  - Examine methods, systematic errors
- Define new calibration standards
  - Characterize sources physically
  - Compare results from 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

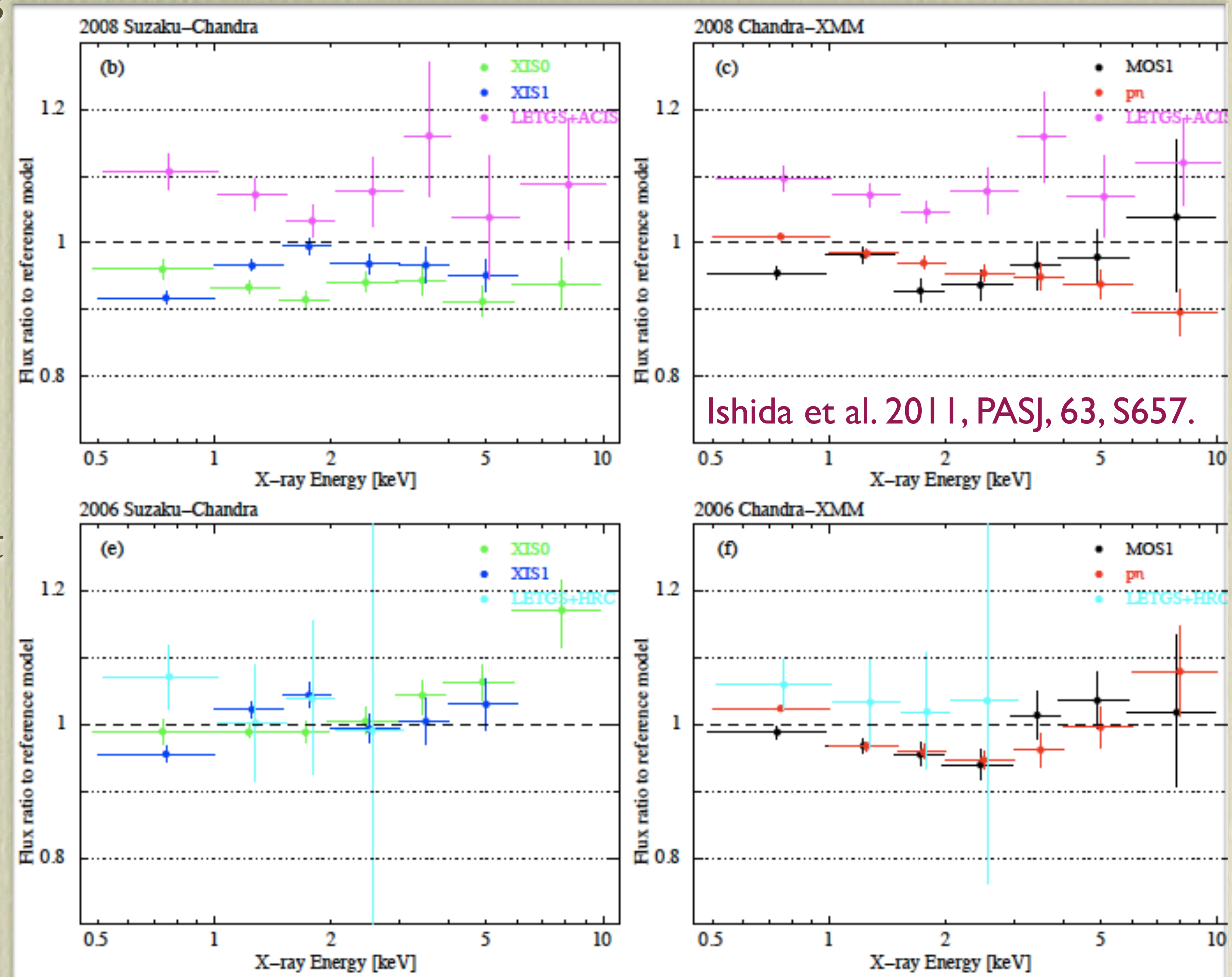
- Galaxy clusters = hot gas balls
- Measured kT with 2 telescopes
- Validated XMM (pn) kTs with Fe line flux ratios
- Fixed Chandra optics model
- Project started at 2nd IACHEC meeting



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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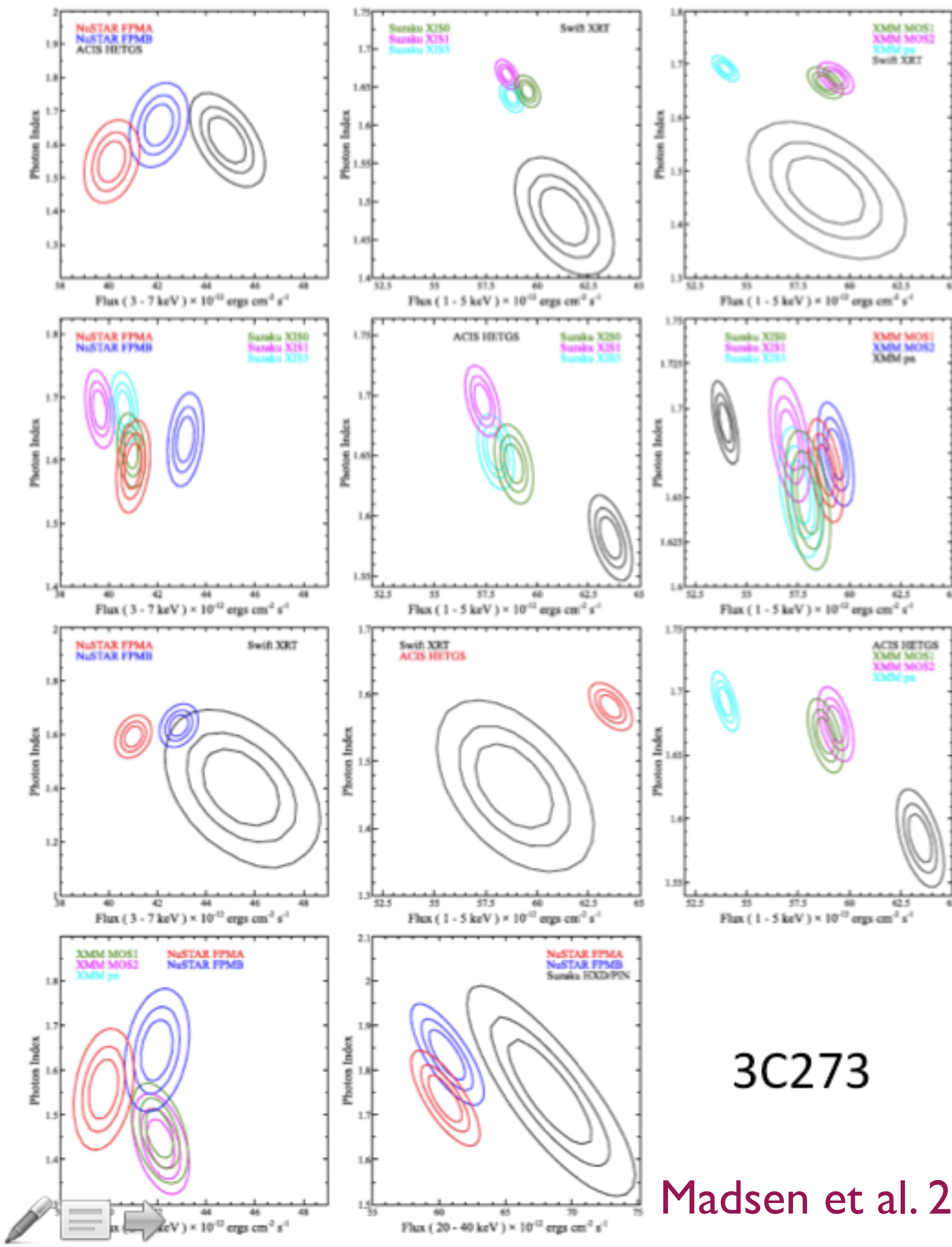
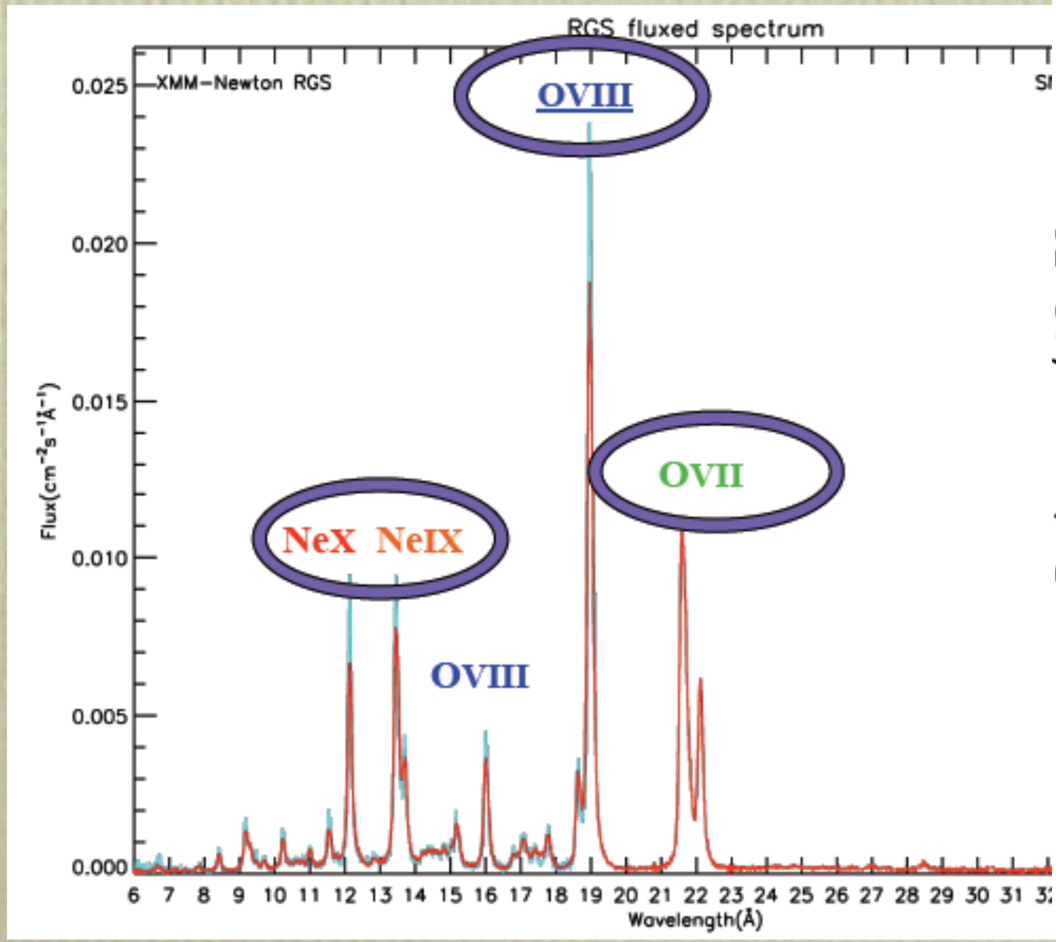


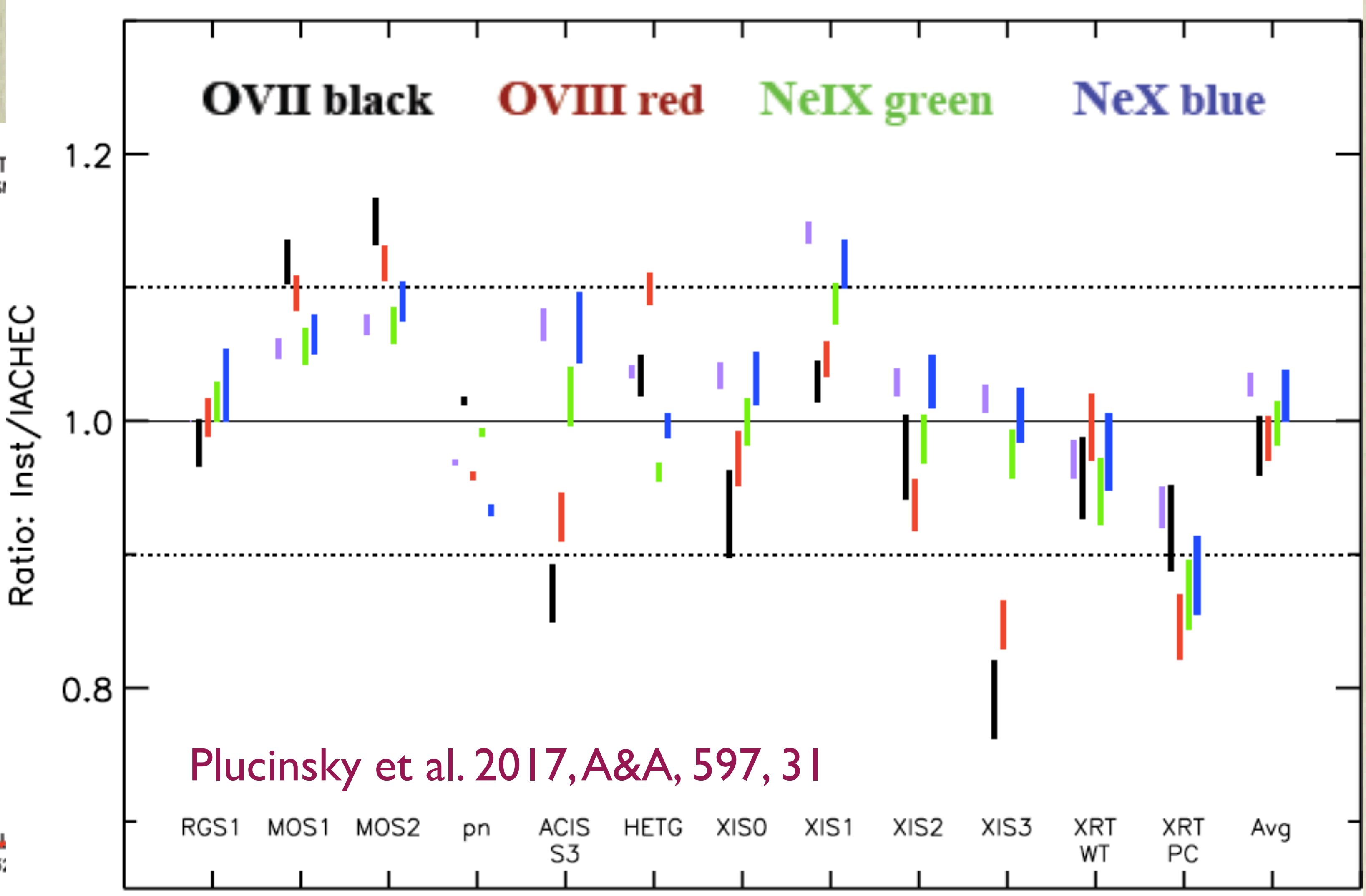
3C273

Madsen et al. 2017, AJ, 153, 2.

Examples — 3

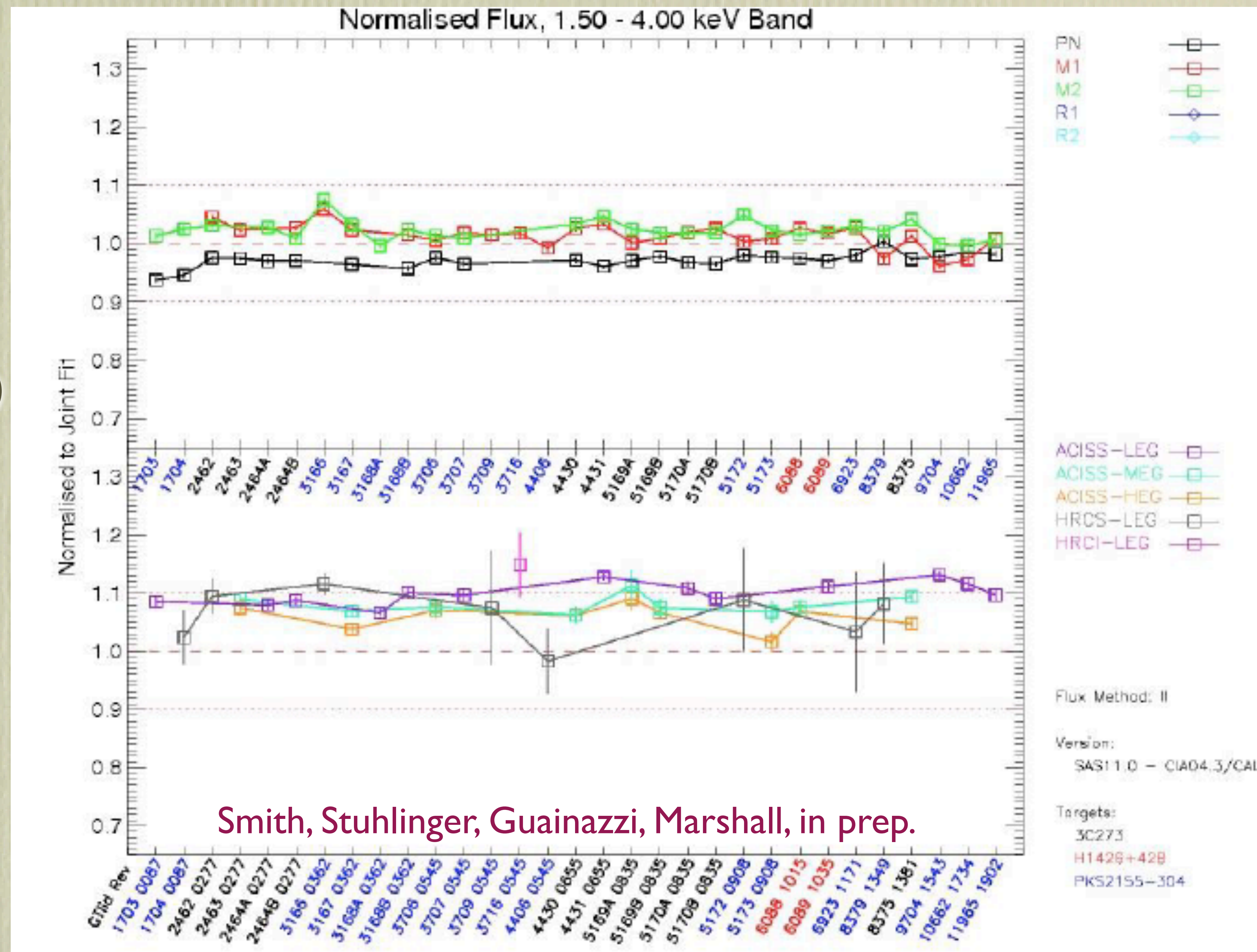
- Thermal SNR group: results for 1E0102-7219
- Spectrum is simple, stable
- Set reference fluxes
- Provides comparison of instruments





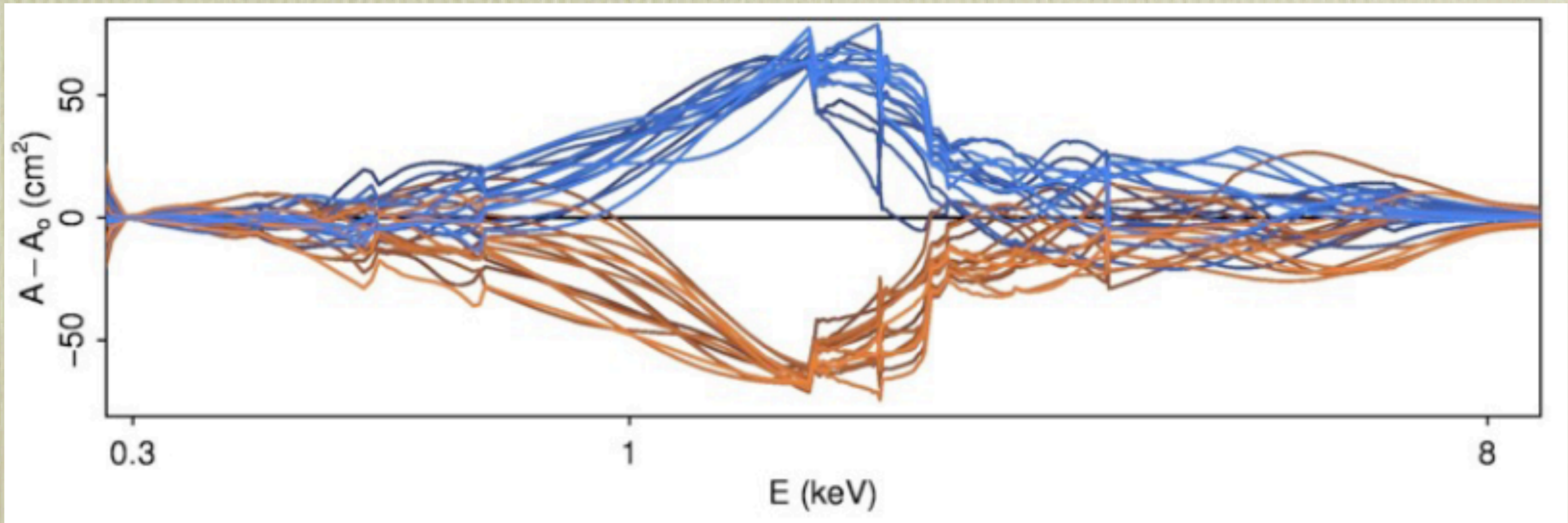
Examples — 4

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



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 χ^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
  - Contacts: Chandra: HLM, SPI: EJ, IBIS: LN, XMM: MS, Swift: AB/JaKe, NuSTAR: KKM/KF, NICER: CM, HXMT: LS
- 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 τ values, fractional uncertainties on prior EA
  - if ground-cal is poor (large τ), observations drive new EA
  - if observations are poor (large σ), prior dominates
- Developed jointly with statistics academicians
- IACHEC scientists set τ values
- Working on new cross-cal data sets (Marshall+ 2019)

The Matrix (excerpt)

	Chandra ACIS	Chandra HETGS	Chandra LETGS	XMM pn	XMM MOS1,2	ROSAT PSPC
.15-.33	3	-	5	2	20	10
.33-.54	3	-	7	2	10	10
.54-.8	3	10	7	2	6	10
.8-1.2	3	5	7	2	6	10
1.2-1.8	2.6	4	7	2	6	10
1.8-2.2	3.3	4	7	2	6	10
2.2-3.5	3.3	4	7	2	6	-
3.5-5.5	4.9	5	10	2	6	-
5.5-10	5	7	10	3	10	-

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!