International Astronomical Consortium for High-Energy Calibration

IACHEC Report 2016

Summary of the 11th IACHEC Meeting

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The International Astronomical Consortium for High Energy Calibration (IACHEC)[1] is a group dedicated to supporting the cross-calibration of the scientific payload of high energy astrophysics missions with the ultimate goal of maximizing their scientific return. Its members are drawn from instrument teams, international and national space agencies and other scientists with an interest in calibration in this area. Representatives of over a dozen current and future missions regularly contribute to the IACHEC activities. Support for the IACHEC in the form of travel costs for the participating members is generously provided by the relevant funding agencies.

IACHEC members cooperate within Working Groups (WGs) to define calibration standards and procedures. The scope of these groups is primarily a practical one: a set of data and results (eventually published in refereed journals) will be the outcome of a coordinated and standardized analysis of reference sources ("high-energy standard candles"). Past, present and future high-energy missions can use these results as a calibration reference.

The 11th IACHEC meeting was successfully hosted by the Inter-University Center for Astronomy and Astrophysics (IUCAA) in Pune (India). About 60 people attended the meeting. The scientific program[2] included a special session on the first scientific highlight and calibration results from Astrosat, successfully launched on September 28 2015. Its scientific payload includes:

- Three units of Large Area Xenon Proportional Counters (LAXPC) covering medium energy X-rays from 3 to 80 keV with an effective area of 8000 cm^2 at 10 keV.
- A Soft X-ray Telescope (SXT) with conical foil mirrors and X-ray CCD detector, covering the energy range 0.3-8 keV, with an effective of about 120 cm^2 at 1 keV.

[1] `http://web.mit.edu/iachec/`
[2] The presentations held at the meeting are available at: `http://web.mit.edu/iachec/meetings/2016/index.html`

- A Cadmium-Zinc-Telluride coded-mask imager (CZTI), covering hard X-rays from 10 to 150 keV, with a field-of-view of about 6° and an effective area of 480 cm^2
- A Scanning Sky Monitor (SSM) consisting of three one-dimensional position-sensitive proportional counters with coded masks. The assembly is placed on a rotating platform to scan the available sky once every six hours in order to locate transient X-ray sources.

1 Working Group reports

1.1 CCD

The CCD and Backgrounds WG provides a forum for cross-mission discussion and comparison of CCD-specific modeling and calibration issues, and for measuring and modeling instrument backgrounds in the spatial, spectral and temporal dimensions. At IACHEC 2016, we heard presentations about Suzaku/XIS, Chandra/ACIS, Swift/XRT, and CCDs under development in the United Kingdom. The WG was also happy to welcome members of the instrument teams from Astrosat and look forward to many years of fruitful collaboration. The WG would also like to expand in the future to include other devices that share similar physics to CCDs, such as the Silicon Drift Detectors that will fly on NICER next year.

Steve Sembay gave a brief overview of developing CCDs for the SMILE SXI, which could potentially see much higher particle fluence than XMM-Newton or Chandra, and CTI mitigation techniques. Eric Miller reviewed the complicated Suzaku/XIS experience with micro-meteoroid impacts, power cycling, and charge leakage. Jamie Kennea gave an update on Swift XRT gain/CTI/trap calibration, including an improved trap localization and mapping strategy, and an early comparison of an observation of Tycho with the XRT and the Astrosat SXT.

Finally, Catherine Grant discussed the evolution of the temperature-dependent CTI correction for Chandra CCDs. She is re-examining the energy scale calibration on ACIS in light of continuing radiation damage and changing spacecraft thermal environment. The calibration is still good for many regions of the focal plane, but there are some areas for improvement (see Grant et al. 2016 for a more extensive discussion).

1.2 Galaxy Clusters

The discussion in this WG continued along the lines discussed in prior reports (see, e.g., Li et al., 2015).

The WG continued planning the Multi Mission Study project aiming at comparing X-ray spectroscopic results of a sample of clusters obtained with on-going and past X-ray missions/instruments. In particular, the WG discussed in detail the criteria for suitable clusters with feasible exposure times to achieve our desired statistical precision of $\simeq$1% in about 10 spectral bins in the 0.5–7 keV band. Given the large variability of the effective areas of different instruments, it is very difficult to build a common cluster sample with statistically meaningful number of members, with observations reaching our pre-defined precision level. Furthermore, our requirement that the background must stay below 10% of the source signal in the 0.5-7 keV band limits the extraction region size and thus enhances the problem of accumulating enough counts with the instruments with lower effective area.

The XMM-Newton/Chandra.ROSAT sample of 25 clusters does satisfy our criteria and will form the basis of the analysis. It may be feasible to cover the same sample with similar statistical quality with the eROSITA. Work to extend the sample to a smaller number of high-quality deep exposures in on-going.

1.3 Heritage

The "Heritage Working Group" started its activities at the 10^{th} IACHEC meeting in 2015. It aims at: a) providing a platform for the discussion of experiences coming from operational missions; b) facilitating the usage of good practices for the management of pre- and post-flight calibration data and procedures; c) documenting the best practices in analyzing high-energy astronomical data as a reference for the whole scientific community; d) ensuring the usage of homogeneous data analysis procedures across the IACHEC calibration and cross-calibration activities; e) consolidating and disseminate the experience of operational missions on the optimal calibration sources for each specific calibration goal.

The main activities of this WG in the last 12 months can be summarized as follows:

- A paper summarizing the in-flight calibration plans of modern X-ray observatories was published in the Journal of Astronomical Telescope, Instrument and Systems (SPIE) (Guainazzi et al. 2015)
- A list of ground- and in-flight calibration papers and documents has been compiled, and is being continuously maintained, under the IACHEC Wiki[3]
- The recent paper on the multi-instrument IACHEC cross-calibration campaign on 3C273 and PKS 2155-304 (Madsen et al., 2017) discusses the (negligible) impact on cross-calibration results of using different photo-electric absorption and associated cross-section, and abundance tables. This study will be extended to all future IACHEC cross-calibration papers. The different prescriptions therein discussed were selected following a consultation with a small group of community experts

1.4 Thermal SNR

The main topic of discussion was finalizing the IACHEC paper on the cross-calibration efforts using the Small Magellanic Cloud supernova remnant (SNR) 1E0102-72.3 (hereafter E0102). Since the meeting, the paper has been accepted for publication to Astronomy and Astrophysics (Plucinsky et al. 2017). The paper describes in detail how the IACHEC model was developed based on data from the XMM-Newton(RGS) and the *Chandra* (HETG). The IACHEC standard model has been used

[3] Available at `https://wikis.mit.edu/confluence/display/iachec/IACHEC+Heritage+Working+Group`

for several years now to test and improve the response models for the CCD instruments, specifically the *Advanced CCD Imaging Spectrometer* (ACIS) on *Chandra* the *European Photon Imaging Camera* (EPIC) *Metal-Oxide Semiconductor* (EPIC-MOS) and the EPIC p-n junction (EPIC-pn) on XMM-Newton the *X-ray Imaging Spectrometer* (XIS) on *Suzaku*, and the *X-ray Telescope* (XRT) on *Swift*. The paper includes a comparison of the effective areas of the five CCD instruments, using the latest calibration files available at the time of preparation of the paper. The standard IACHEC model is used to derive the normalizations of the four major line complexes in the E0102 spectrum, specifically the OVII triplet ($\sim$ 570 eV), the OVIII Lyα line (654 eV), the NeIX triplet ($\sim$ 915 eV), and the NeX Lyα (1022 eV). Figure 1 displays a comparison of the fitted line normalizations with respect to the standard IACHEC model. We do not claim that the normalizations in the standard IACHEC model for these four lines/line complexes are correct. Rather the standard IACHEC model values are useful for comparing the differences between the instruments.

The data sets used for this comparison were acquired early in the respective missions when the effects of radiation damage and any possible contamination layer on the response were at a minimum. The one exception to this is the XMM-Newtonn instrument, which is the most stable of all of the instruments included in the study. For the XMM-Newton pn, all observations taken close to the standard aimpoint in *Small Window* mode were included in this comparison (for details of the modes used for the other instruments please refer to the paper).

Figure 1 shows that the instruments generally agree to within $\pm$10% for the four line normalizations, but there are significant differences. The MOS1 and MOS2 appear $\sim$ 10% high compared to the IACHEC values and as much as 15% higher than the pn. The ACIS data appear $\sim$ 10% low compared to the IACHEC values at the OVII triplet and the OVIII Lyα line, but more consistent at the NeIX triplet and the NeX Lyα line. The XIS0, XIS1, and XIS2 are within 10% of the IACHEC value (except for the NeIX triplet for XIS1), but the O lines disagree with the IACHEC values by as much as 20% for XIS3. This apparent discrepancy is most likely due to the correction for the contamination layer on the XIS3. The XRT *Windowed Timing* (WT) agree significantly better with the IACHEC values than the *Photon Counting* (PC) mode data. It is believed that pile-up is depressing the line fluxes in PC mode compared to WT mode.

The ACIS, MOS, XIS, and XRT teams also presented the line normalizations as a function of time for their instruments. Each of these instruments has a significant time-dependent response over their respective missions. We assume that E0102 is constant over the time span of these missions and we test the time-dependent calibration of each instrument by determining the E0102 line fluxes as a function time. Line fluxes in the 0.5–1.0 keV range are strongly affected by the contamination layers on some of the instruments and therefore provide a stringent constraint on the models of those contamination layers. Each instrument has a section in the paper in which the time-dependent response is discussed and the E0102 line normalizations as a function of time are presented. It is hoped that the Guest Observers of these missions can use these results to estimate uncertainties on their measurements acquired at different times in the mission.

The ASTROSAT *Soft X-ray Telescope* (SXT) team starting using the IACHEC model for E0102 for the first time during the meeting. The SXT team showed results for the bright galactic SNR Cas A and the data were well-fitted by the model. The SXT data for E0102 were not well-fitted by the IACHEC model, there were clear residuals at low energies. Soon after the meeting, the SXT calibration team improved the low energy calibration for the SXT and achieved a significantly improved fit with the IACHEC model. Figure 2 shows the SXT data with the latest calibration

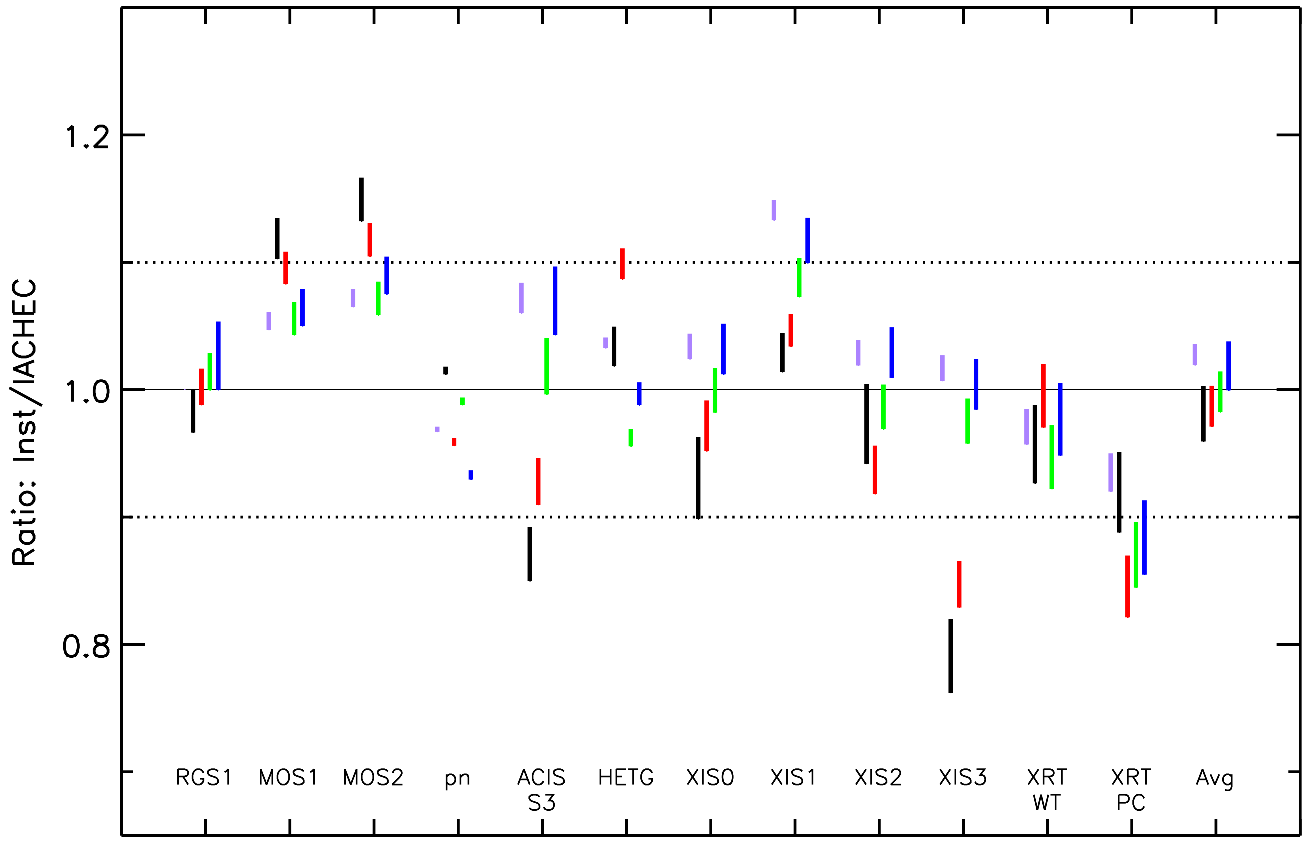

Figure 1: Comparison of the scaled normalizations for each instrument to the IACHEC model values and the average. There are four or five points for each instrument which are from left to right, global normalization (purple), VII Heα r (BLACK), VIII Lyα (RED), IX Heα r (GREEN), AND X Lyα (BLUE). THE LENGTH OF THE LINE INDICATES THE 1.0σ CL FOR THE SCALED NORMALIZATION.

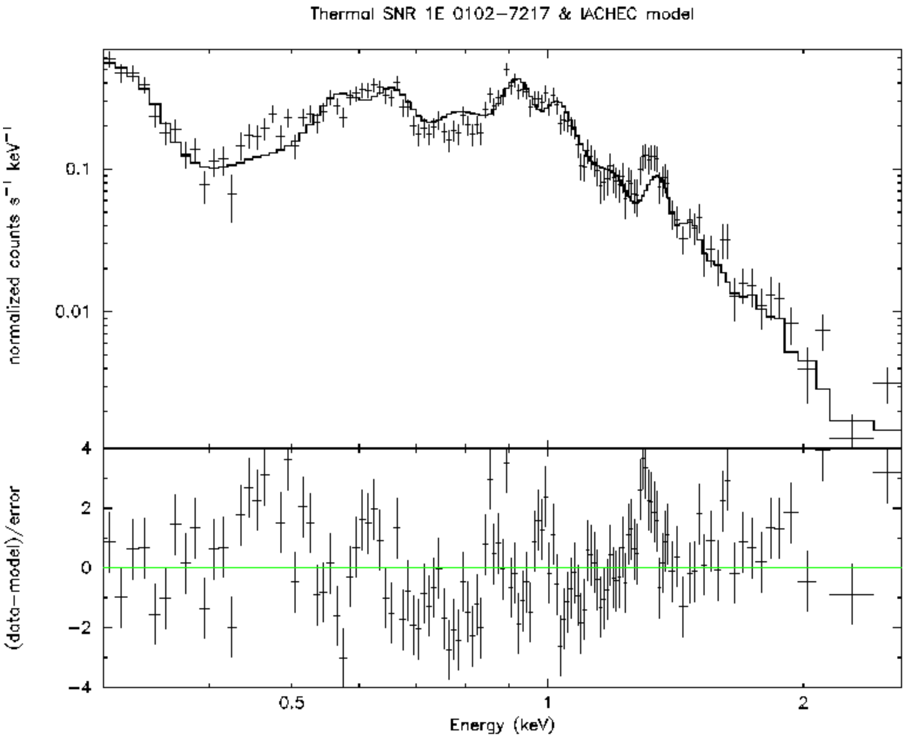

Figure 2: ASTROSAT SXT spectrum of 1E0102-72.3itted with the IACHEC model.

files and fit with the IACHEC model for E0102 (provided by Sunil Chandra of the SXT team). The fit is significantly improved although there appear to be some significant patterns in the residuals. Now that the calibration has been refined to the point that a fit of this quality can be achieved with the IACHEC model, the model can be used for more subtle adjustments to the SXT response. The thermal SNR working group is delighted to welcome the SXT calibration team to the group and looks forward to working with them in the future.

References[4]

Grant C., et al., 2016, Proc. SPIE 9905, 990545
Guainazzi M., et al., 2015, JATIS, 1(4), 047001
Li X., et al., 2015, 10^{th} IACHEC Report, arXiv:1512.08585
Madsen K., et al., 2017, AJ, 153, 2
Plucinsky P, et al., 2017, A&A, 597, 35

[4]see http://web.mit.edu/iachec/papers/index.html for a complete list of IACHEC papers