Brainstorming The Universe in High-resolution X-ray Spectra

Randall Smith

From August 19-21st, 2015 a group of ~100 X-ray astronomers met in Cambridge, MA to present recent results from X-ray grating spectroscopy with *Chandra* and *XMM-Newton*, as well as to discuss possibilities for the future (*http://cxc.harvard.edu/cdo/hrxs2015/)*. During the meeting, approximately 60 astronomers, separated into 9 tables with 6-8 people per table, took part in a 'brainstorming' session. A series of questions were addressed and participants switched tables after each question. Discussion leaders, who stayed fixed at each table, compiled the results - thanks to Elisa Costantini, Martin Elvis, Dave Huenemoerder, Delphine Porquet, Tim Kallman, Takayuki Yuasa, Nancy Brickhouse, David Cohen, and Lia Corrales. Four questions were addressed and the conclusions for each are summarised below; the complete document is available at *http://cxc.harvard.edu/cdo/hrxs2015/brainstorming.pdf*.

What important science questions could data from the existing or near-term X-ray high-resolution spectrometers answer? Would data from other existing observatories be needed as well? A recurring theme in the responses was the need for high-resolution spectroscopic monitoring and variability studies of a range of sources, including stars, X-ray binaries (XRB), stellar mass black holes, novae, and young supernovae. Winds from stars, XRB, and Active Galactic Nuclei (AGN) were also mentioned in the timing/monitoring context but also generally as an area that could be productive with more observations. Finally, abundance studies were highlighted in a range of contexts such as iron-peak element studies in supernova remnants and galaxy clusters, either with the *XMM-Newton* RGS or Hitomi, as well as absorption studies in the Galaxy using bright XRB or beyond using flaring AGN. Another topic frequently mentioned was the need to better exploit the archives of all of these missions.

What improvements in calibration, lab astrophysics data, or analysis tools are needed to enable us to answer these questions? The two topics most frequently mentioned (at seven out of the nine tables) were improvements in atomic data and analysis tools. In regards to the atomic data, the participants argued for improvements for some Fe-peak ions (e.g. Mn, Cr, Ni) as well as inner-shell K lines (and for AGN warm absorbers, the M-shell and L-shell inner shell lines), along with better charge exchange rates and diagnostics. A key need was to make it easier for users to access/assess the physics in the models. Another request was a more thorough cross-calibration of optically thin X-ray plasma codes (both collisional and photoionization) to better understand when and where differences arise from various codes. Analysis tools were also held up as needing improvement, starting with the idea that such tools work best if they are constructed collaboratively, not "owned" by one person. General requests were made for better extended-source modeling as well as more flexible photoionization models. Participants expressed the need for IRAF-like automatic tools that could extract intensities of temperature/density diagnostic lines and then search a spectral database to find similar spectral shape/lines. Similarly, participants noted that spectral-timing tools were underdeveloped and that calibration facilities could use improvement. Calibration in general was frequently mentioned, with a number of specific issues such as wavelength calibration accurate to < 100 km/s for wind studies, line profiles in 1st and higher order, and easier-to-use background models.

What future observations (or new archives with different processing) are needed to answer these questions? This question provided mixed results – possibly because of the difficulty of determining what precisely would answer the issues raised so far, and possibly because participants were already planning out new proposals to submit. However, there were a number of monitoring proposals described, matching the focus on timing and monitoring raised in the first issue. In this context, it was noted that time allocation committees should be explicitly told that re-observing sources is allowable when the purpose is monitoring. A number of groups also described the benefits from simplifying proposals for coordinated observations with other facilities, especially if ways to increase the available time for such proposals could be found.

What observations could *Chandra* or *XMM-Newton* do today that would complement future Hitomi or act as pathfinders for *Athena* or *X-ray Surveyor* observations? Nearly all the tables identified deep observations of crowded/complex fields such as M82, Galactic SNR, and galaxy clusters as a key need, especially for *Chandra* as similar angular resolution will not be available until *X-ray Surveyor* launches. Similarly, the participants highlighted the need for grating spectra on

point sources, since even the *Athena* calorimeter will have lower resolution below 1.5 keV than the *Chandra* and *XMM-Newton* gratings. Deep imaging observations of nearby galaxies and especially the LMC and SMC were mentioned, along with the Galactic center region, in order to spatially-resolve sources that might be confused in Hitomi or *Athena* observations. Finally, it was noted that *Chandra*'s angular resolution would be needed to separate the nuclear regions of AGN from the surrounding gas.

Thanks to all the workshop attendees for making this an excellent conference, and to the participants in the brainstorming exercise for your time and thoughtful suggestions! ■