LETG

Jeremy J. Drake for the LETG Team

Item 7

It's like painting the Forth Bridge. At least it used to be, until 2011 when the Forth Bridge painting was unsportingly declared finished for at least another 20 years. Completed in 1890, the Forth Railway Bridge near Edinburgh is a marvelous cantilever design spanning the estuary of the River Forth (the "Firth of Forth"). To stave off the ravages of the somewhat corrosive combination of the North Sea and Scottish weather on its steel structure, it needed, or so the myth went, continuous painting—by the time you finished at one end it was time to go back to the other and start again.

With an inconvenient moratorium on Forth Bridge painting, there is then a clear need in the popular lexicon for a new idiom to represent such unceasing toil. The rather similar Myth of Sisyphus might suffice. Having been a bit naughty, Sisyphus was condemned by the gods to pushing a boulder up to the top of a mountain only for it then to tumble back to the bottom, leaving him to repeat the cycle ad infinitum—a bit reminiscent of trying to teach a small child how to ski. "Like calibrating the LETGS!" has a much better ring to it though, and besides, Sisyphus must have had moments of considerable satisfaction watching his boulder crashing back down the mountain, especially if it was like Mount Washington on a holiday weekend. I would hazard that painters of the Forth Bridge, just like calibrators of the LETGS, did not typically glean such regular wild enjoyment from their travail. "Like calibrating the LETGS!" it is then.

Previous issues of the Newsletter have detailed some of the secular changes in the detectors deployed with the LETG—primarily the HRC-S but also ACIS-S—that necessitate continuous reappraisal of performance and regular calibration updates. In addition to this pre-2011 Forth Bridge painting exercise, there is also a top secret list of calibrations that still need to be performed, but which are deemed of lower priority than the continual tasks of ensuring we understand the effective area and dispersion relation over the full wavelength range. The papyrus scroll on which the secret list is inscribed is solemnly examined in a ritualistic ceremony by the LETG calibration group once or twice a year. Whilst strict ceremonial protocol forbids disclosure of the full details of the list, excerpts read as follows:

> *7. Fix the LETG/HRC-S spectrum/gARF wavelength mismatches.*
>
> ...
>
> *22. Verify that the malleable logarithmic casing surmounting the prefabulated amulite base-plate does in fact ensure that the two spurving bearings are in a direct line with the pentametric fan, as suggested by Quick (1944).*

After weeks of cloistered deliberation and metaphorical black smoke (meeting rooms here having already been designed shortsightedly without chimneys), a candidate rises to the top and is studied and dealt with by the crack calibration team.

At first sight, Item 7 sounds quite grave and meritorious of higher ranking. It actually refers to the problem that the observed spectrum at the very ends of each microchannel plate segment did not match expectations very well (recall there is a central plate flanked by two outer plates, each 10 cm long making up the 30 cm long detector). The extreme ends of the detector show the most ugly departures from the modelled response, but there are few spectra that have used data at the longest wavelengths. The worst case from a scientific perspective is the plate gap region of the negative order shown in Figure 1. The model of the plate gap is poor over the regions ±3 Å from the gap affected by the spacecraft dither.

There are reasons other than dither that might also render data near the plate gaps poor. The plates sit in a strong electric field that accelerates photoelectrons within the pores of the plates much like in a photomultiplier tube. The field in the vicinity of the plate gaps is likely not to be completely uniform, leading to distortion in the inferred positions of photon events. This is seen in fact in the spikes containing such misplaced events at the shoulders of the gap dither region in Figure 1.

All this was not deemed too important because plate gap regions affected by dither have been considered "bad data", retained in level 2 files in case they might be useful but not to be included in formal analyses without very careful treatment. There are no really important spectral diagnostics at the affected wavelengths and, besides, the detector was also designed so that positive and negative orders have gaps at different wavelengths and so coverage with "good" data is still continuous.

With items 1–6 either being long-term analysis problems or having been solved by brilliant strokes of calibration, item 7 then emerged in a billow of white smoke. Our top expert scientists Brad Wargelin and Dave Huenemoerder dug around the roots of the issue and discovered that most of the problem originates because the HRC-S Quantum Efficiency Uniformity (QEU) file had incorrect spatial limits set that did not exactly match the actual detector. This explains the dither-related problems, but what of the spikes of events whose positions have been determined incorrectly? One approach would be to reassess the "degap" map in those regions of the detector. Degap refers to the algorithms and parameters that are applied to fine-tune the positions of photon events, making use of, among other things, the fact that there should be no gaps in data that otherwise appear in raw detector images. This would be a considerable undertaking, requiring a fully two-dimensional degap map instead of the combination of one-dimensional maps we currently use, and a complete rewrite of the degapping software within the data system, and all with no guarantee that event positions could be reconstructed with sufficient accuracy to make them useful: one for the papyrus, perhaps at number 23.

There, a convincing and bullet-proof argument not to embark on doing a lot of hard work. So, what else can we do with these bothersome events? Another approach, and a much more efficient one, is to, well, sweep them under the rug, so to speak. A suitable rug is in fact already built into the software system in the form of a "bad pixel map".

The badpix file contains in essence a list of the regions of the detector that are considered problematic for one reason or another. These regions are excised from Level 2 event files and the resulting holes in the detector response are noted and included when the effective area of the instrument is computed within CIAO. Brad worked out which regions of the plate ends were indeed problematic and swept them under the badpix rug. A comparison between an effective area computed using the combination of the new badpix file and QEU file corrected for the plate ends error and an observed spectrum is illustrated in Figure 2. Note that this is not a model fit, but just an arbitrary scaling of data and effective area. It yields a rather good match.

Item 7 having been dispensed with, several other items have sprung up to take their place in the list, one or two having surprisingly leapfrogged the verification of the spurving bearing alignment in priority ranking. Its never ending really, just like calibrating the LETGS.

On a whim

If Λ Cold Dark Matter Cosmology (ΛCDM) bears any semblance to reality, there must be quite a lot of matter around that is cold and dark, supposedly making up about a quarter of the mass-energy density of the universe. It sounds like lots and lots of pints of Guinness, but it's not. It's peculiar stuff that doesn't really do anything but sit there, like a free-floating mass of untold numbers of teenage boys. But not to worry because there is some warm normal stuff out there too, and maybe even hot, according to hydrodynamical simulations of structure formation.

The simulations predict a filamentary web of dark matter within which this warm-hot stuff at temperatures of 100,000 to 10,000,000 K should be embedded, in between the galaxies, making up about half of the baryons in the universe. Since we can't see most of the bits and bobs in the ΛCDM model—95% of them if about 70% is Dark Energy—one might imagine there is considerable interest in trying to see the things we can. The Warm Hot Intergalactic Medium is so diffuse though, at only about one atom per cubic meter, that we can't really see it either. At least not until shining some light on it.

Chandra has been studying the WHIM by shining the light of distant quasars on it, and looking for its shadows in absorption lines due to metals that come from things we can see and know are really there—stars in galaxies. University of Alabama in Huntsville astronomer Max Bonamente and colleagues (Bonamente et al. 2016) reported the possible detection of the WHIM in the line of sight toward the quasar PG 1116+215. Earlier *Hubble* Space Telescope observations had detected several O VI and broad H I Lyman α absorption lines that might be associated with the WHIM. The redshifts measured from those features enabled the search for lines in LETG+HRC-S spectra to be narrowed down to specific wavelengths. Bonamente et al. detected an absorption line in the LETG spectra corresponding to O VIII Kα at a redshift z = 0.0911. Sloan Digital Sky Survey spectroscopic galaxy survey data toward PG 1116+215 also revealed telling evidence for a galaxy filament in the sightline together with other galaxy structures within a few Mpc of the inferred O VIII Kα absorption that support the presence of the inferred WHIM.

While Bonamente et al. note that the LETG detection could benefit from further verification, they point out that combining H I broad line absorption measurements with X-ray data for larger samples has the potential to locate large reservoirs of warm-hot baryons and possibly solve the missing baryons problem (see, e.g., Shull et al. 2012).

It's just the small issue of the dark matter and dark energy left after that. JJD thanks the LETG team for useful comments, information and discussion. ■

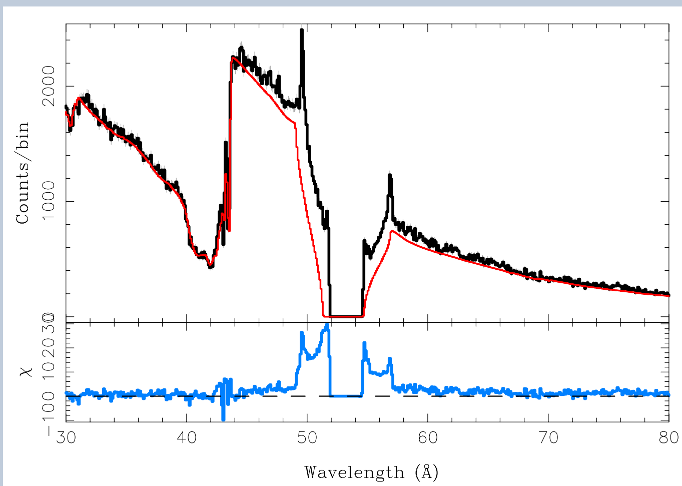

Figure 1: Illustration of residuals around the negative order plate gap in single power law fits to observed spectra of the blazar Mkn 421 ObsID 4149 (Figure courtesy David Huenemoerder).

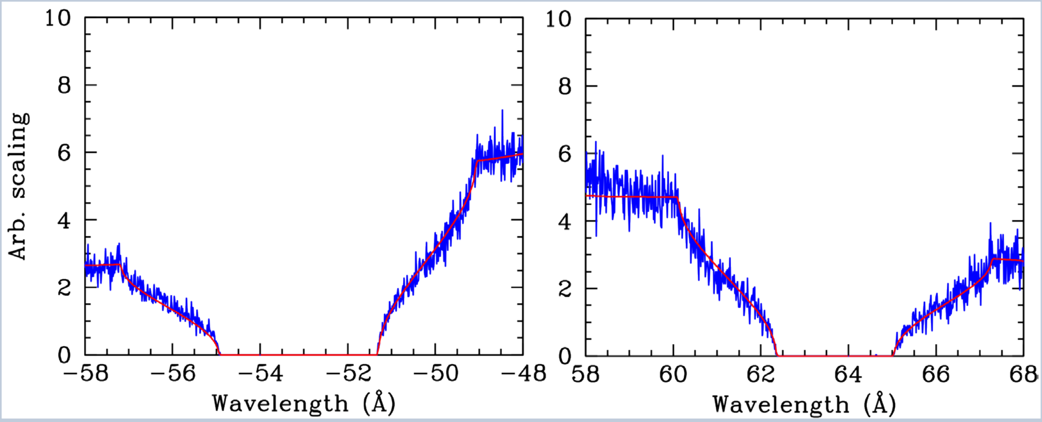

Figure 2: Comparison of data in the vicinity of the negative order plate gap with an effective area computed using revised QEU and badpix files. No spectral model is included and data have been arbitrarily scaled to match the count rate levels in the vicinity of the gap (Figure courtesy Brad Wargelin).

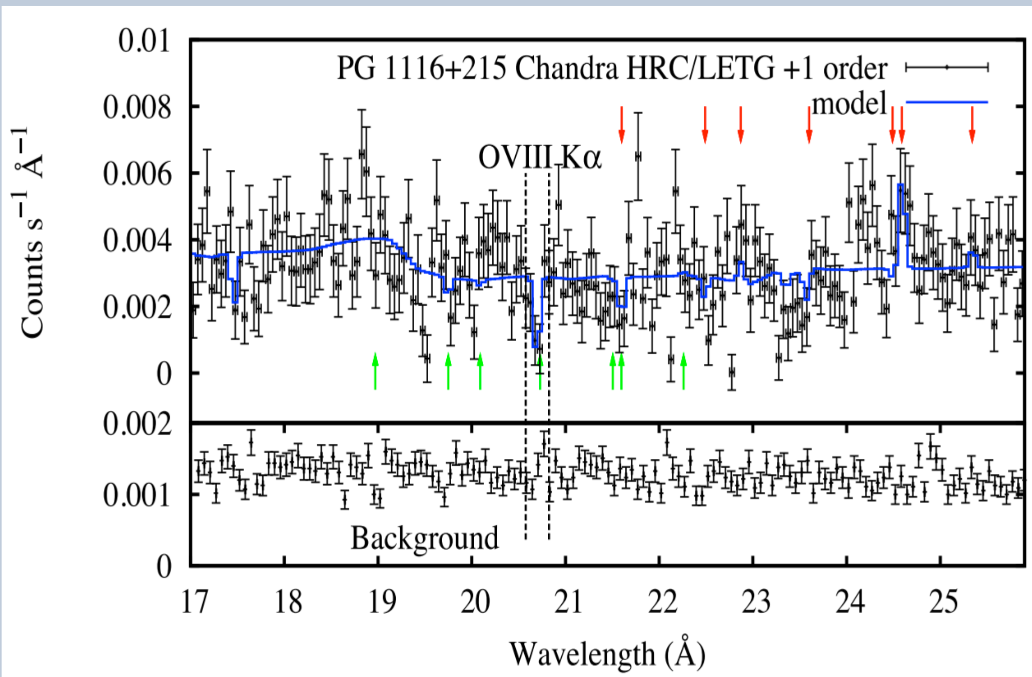

Figure 3: LETG+HRC-S positive order spectrum of PG 1116+215 from Bonamente et al. (2016) together with the fitted model. Arrows mark expected positions of O VII and O VIII Kα lines at redshifts of z = 0, 0.041, 0.059, 0.0928, 0.1337, 0.1385 and 0.1734. The feature at 17.5 Å is possibly O VIII Kβ.

References

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