LETG

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Calibration Vortex

I write while blasted this winter by another encroachment of the cliched, nouveau-famed polar vortex that we are all completely fed up with hearing about from the media. This brings me to the LETGS calibration. It is a sort of vortex of iteration itself, though has of course nothing to do with the polar vortex. That goes aimlessly around and around in circles leaving people completely cold and gets joked about on late-night television, while the LETGS has never even been mentioned on late-night television. Yet.

The calibration vortex currently gripping the LETGS revolves around the chilling circular task of maintaining consistency with the slippery calibrations of the other *Chandra* instruments, all under the constraint that the absolute calibration based on hot white dwarfs should not thaw out. In *Chandra* Newsletter 20, I described a fairly successful operation to re-calibrate the HRC-S quantum efficiency following an increase in the detector high voltage. The voltage change was implemented to mitigate gain droop that had steadily sapped the quantum efficiency at an average rate of about 1.6% per year. We observed the hot—despite the polar vortex—white dwarf HZ43 and the still blazing blazar Mkn 421 at both new and old voltage settings to determine that the QE jumped back up by about 6% at the longest wavelengths covered by the instrument (100–170 Å) and about 4% or so at shorter wavelengths. This calibration was built into a subsequent CALDB release.

A perennial problem for the LETGS, however, is the lack of a bright absolute calibrator in the 30–60 Å range, where extragalactic sources tend to become too absorbed and uncertain in terms of spectral energy distribution, and hot white dwarfs like HZ43 lose signal to the precipitous downward slope of the Wien tail. We therefore returned to a slightly fainter old friend, RX J1856.5−3754. Touted as a possible quark star candidate, this intriguing isolated neutron star was observed extensively using the LETG under a 500 ks Director's Discretionary program back in 2001. It has a black-body-like spectrum with a temperature of about 60 keV (Burwitz et al. 2003; Drake et al. 2002). It rotates, just like a polar vortex except a bit quicker, every 7 seconds, modulating its X-ray emission on this period by about 1% (Tiengo & Mereghetti 2007). Monitoring over the years by *XMM-Newton* confirms the source is impervious to the polar vortex and remains essentially constant on the decade timescales we are concerned with (Sartore et al. 2012)—the key characteristic for a calibration monitoring source.

Recently, the MPE and SRON teams teamed up with the LETG calibration group to observe the target again for a more modest 120 ks. Observations were completed last October—well before all this polar vortex business started—and we have been comparing the data obtained at the two different epochs. Cozy optimism that our recalibration of the HRC-S QE using the Mkn 421 and HZ43 data would be vindicated was soon chilled by the impertinent polar vortex-like intrusion of the actual results that indicated a flux discrepancy of a few percent in the troublesome 30–60 Å range. It seems the QE correction we applied to this range was too large, suggesting that the relevant areas of the detector for those wavelengths did not respond

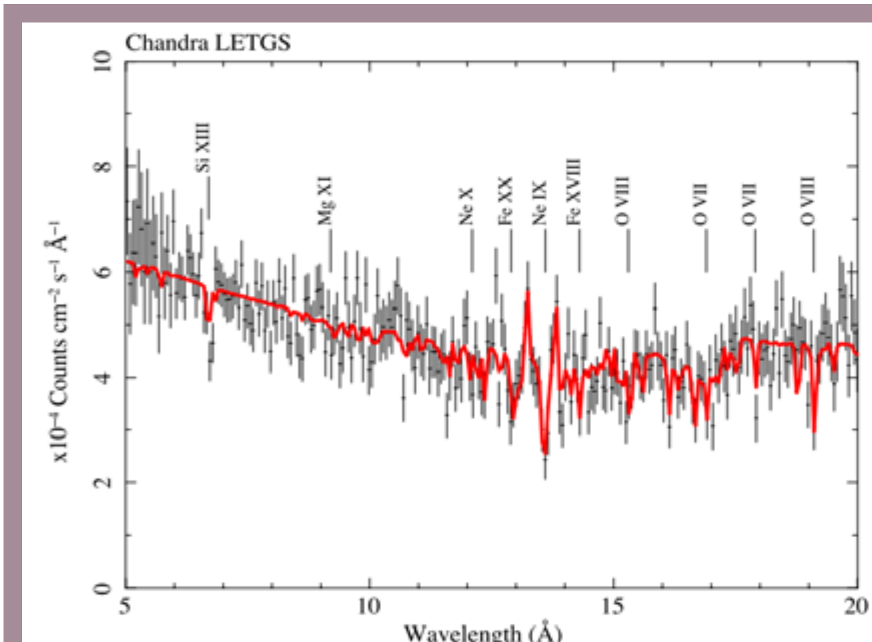

Fig. 1 — LETG+HRC-S spectrum of the Seyfert galaxy NGC 4593 in the 5–20 Å region, showing prominent absorption lines due to Si XIII, Ne IX and O VIII, as well as several other weaker features, that betray the warm absorber outflow. The absorption lines are formed within 30 pc from the central accretion vortex. From Ebrero et al. (2013).

to the voltage increase as much as the areas serving the shorter and longer wavelengths. This is probably nothing to do with the polar vortex, but more likely the spatial gain variation over the plates themselves.

While all the work following the voltage change to re-calibrate the HRC QE was underway, the other instrument teams did not sit politely by and wait for us to finish. Oh no. Rather, progress was brashly flaunted in a whirlwind of activity, like a polar vortex except a bit warmer, with updated HETG grating diffraction efficiencies, and a revised ACIS contamination model that reflects the more accurate emerging picture of the spatial and temporal evolution of the layer. The LETG+HRC-S has only been absolutely calibrated in-flight, and then only at wavelengths longward of 50 Å or so where our white dwarf calibrators remain bright. At shorter wavelengths, the calibration has been tied to that of the MEG+ACIS-S combination. When any aspect of the calibration of this combination is changed, there is a knock-on effect through to the LETGS and any pleasant cordial concord between instruments, with their different colorful flux symbols overlapping nicely on plots, can be blown away, like colorful flux symbols on plots being blasted by an icy polar vortex. Current assessment of the flux symbols suggest the LETG+HRC-S ones are riding a little bit low at wavelengths shortward of 30 Å—perhaps about 10% lower than the ones in other colors representing the different instrument combinations. Reconciliation likely then requires a slight decrease in the higher energy HRC-S QE.

The two main components of the LETGS calibration are the detector quantum efficiencies and the diffraction efficiencies of the LETG itself. The latter are currently described by a diffraction model in first order, and empirically-derived corrections to the model for the higher orders. Convincing evidence indicating that the model for first order diffraction needs significant revision has so far been lacking, the matter being complicated by uncertainties in the time-dependent transmittance of the ACIS contamination layer, the lack of constant point-like calibration sources at higher energies, and earlier evidence that MEG and HEG diffraction efficiencies needed reconciling. With those elements now in place, for this iteration at least, we will soon be in a position to make a judgment on whether the first order efficiency requires correction. And so the cycle of calibration continues—just like a polar vortex, except different.

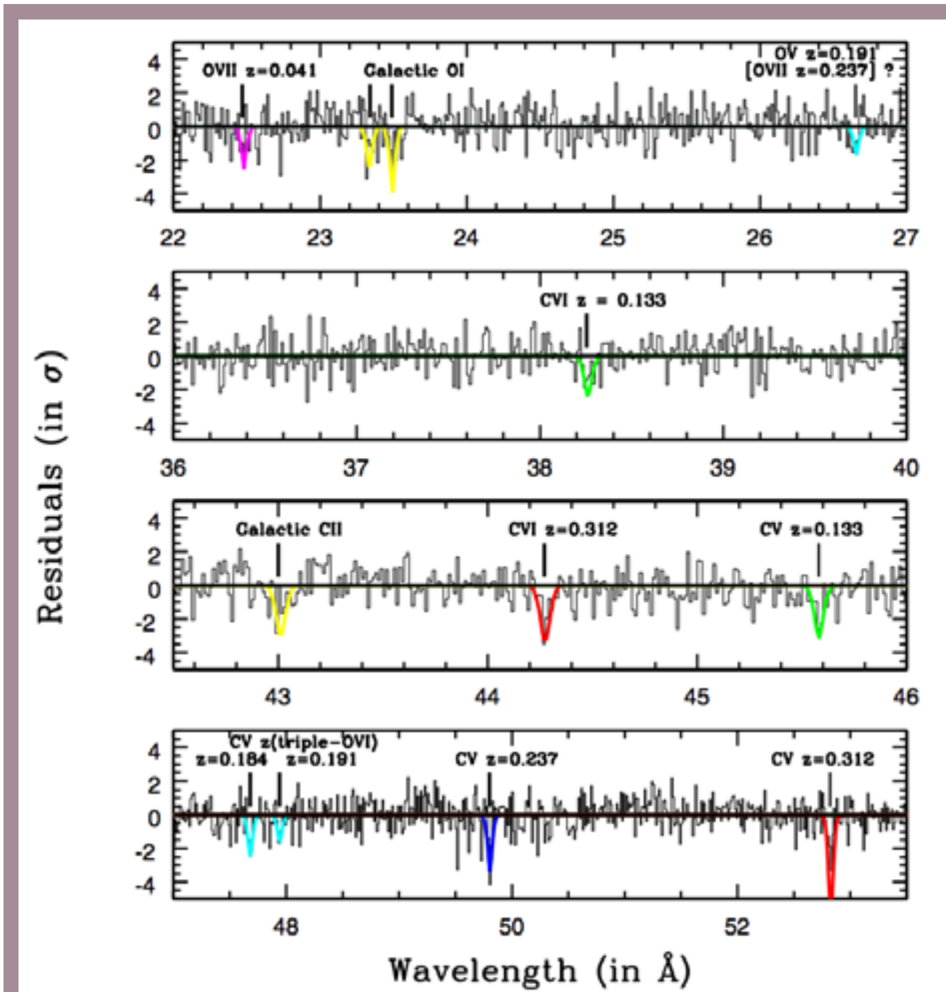

Fig. 2 — Residuals from a fit of the 500 ks LETG+HRC-S spectrum of the blazar 1ES 1553+113 to a continuum model. Galactic O I and C II are detected, as well as lines due to C V and C VI in different filaments of the WHIM. From Nicastro et al. (2013).

Still Warm

The LETGS has continued to defy the polar vortex by observing the absorbers in Seyfert galaxies, that remain warm, and the positively toasty warm-hot intergalactic medium. The warm absorbers in active galaxies are thought to originate as the wind driven from the hot central accreting vortex (some stubborn people still say "disk") around a supermassive black hole source. The outflows inject mass and energy into the host galaxy's interstellar medium at rates that might be sufficiently powerful to impact the evolution of the galaxy itself.

Combining LETG spectra from *Chandra* with data from *XMM-Newton* and HST on the Seyfert NGC 4593, Ebrero et al. (2013) found four distinct ionized plasma components, all outflowing at velocities of several hundreds of km per second. Fig. 1 shows the LETG spectrum in the 5–20 Å range in which absorption lines due to highly ionized Si, Ne, O and Fe are prominent. The outflowing gas responsible for this absorption was found to lie within 6–29 pc of the central ionizing source. Ebrero et al. (2013) were able to combine the velocity and absorption measurements to probe the total energy in the outflow. In this case, the kinetic energy of the outflows injected into the surroundings of the host galaxy were found to account for only a very small fraction of the total bolometric luminosity of the central source. The authors conclude that it is unlikely that the outflow has a significant impact on the interstellar medium of NGC 4593 in a single given episode of activity. Now, if it only had a polar vortex…

Instead of polar vortices, though, galaxies are thought only to have much more mundane "superwinds." These superwinds arise from supernova explosions and the outflows from active galactic nuclei, and perhaps contribute significant gas and metals to the warm-hot intergalactic medium (WHIM) that is predicted to host all those baryons that seem to have gone missing in the present epoch compared with the high-redshift universe (e.g. Cen & Ostriker 2006). Nicastro et al. (2013) have been looking for the baryons with *Chandra* again, trying to spot a few of them in the line-of-sight toward the blazar 1ES 1553+113. The experiment is simple enough—the blazar acts like a background continuum source against which the baryons should be seen in absorption, bathed in the blazar light and with their hands raised meekly in surrender. Nicastro et al. (2013) observed 1ES 1553+113 for 500 ks using the LETG+HRC-S and identified a total of 11 possible absorption lines, illustrated in residual form in Fig. 2. Three were from friendly Galactic baryons in the form of O I and C II, but five of the remaining eight appear to arise from C V and C VI Kα absorption in three distinct WHIM systems at redshifts between 0.133 and 0.312. These systems have also been detected in the far ultraviolet in H I and O VI absorption, and the authors suggest that the intergalactic medium structure could be more rich in ionization phase than typically predicted by cosmological hydrodynamic simulations (that, it must be pointed out, currently do not include the effect of the polar vortex).

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