HETG

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Performance, Calibration, and Software

In Cycle 14 there were 13 HETG programs comprised of exposures ranging from 15 ks to 656 ks, for a total of 2689 ks.

There were no major calibration updates in the past year. The CXC Calibration Group continues to monitor and update the ACIS contamination model as necessary, the grating spectra being key in this regard. A major effort to understand the continuous-clocking (CC) mode response has been completed. Good news: there is no significantly different response of the CCDs in CC-mode. Bad news: certain anomalies are due to source science and will require some effort on the analyst's part to disentangle them. The fundamental issue is that many of the very bright sources observed in CC-mode have large, bright, and soft dust-scattering haloes. When these are dispersed and then collapsed to a one-dimensional spectrum, they produce a "background" under the point-source's spectrum, with a complicated spatial-spectral morphology which will weaken and blur absorption edges. This is explained in detail in http://cxc.harvard.edu/cal/projects/index.html.

In CIAO 4.6, a new grating tool was released, `tgdetect2`, which completes the source detection improvements for CIAO reported here last year. The new tool uses empirical source rate statistics to determine whether to run the bright-source detection mode appropriate for distorted (or absent) zeroth orders (`tg_findzo`, which finds the CCD frame-shift streak and grating spectrum intersection), or the faint-source program (`tgdetect`) thus saving the user having to know which method to use.

Several enhancements to the *Chandra* grating spectral catalog, TGCat[1] were implemented. Source searches by name are now more forgiving, return-

1 http://tgcat.mit.edu/

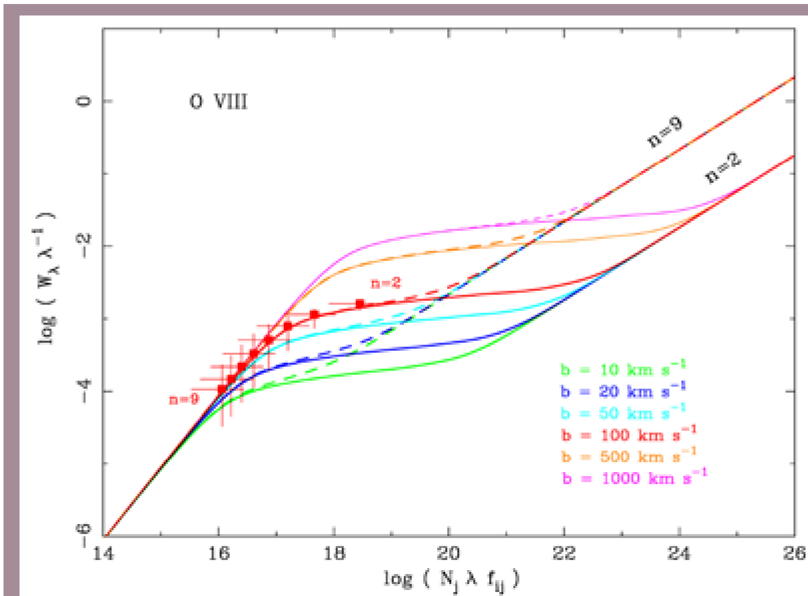

Fig.1 — The curve of growth in O VIII in IRAS 13349+2438 from a simultaneous fit to the the absorption lines in the HETG spectrum from upper levels n = 2 *to 9. With only the first two lines in the series, there would be an order-of-magnitude uncertainty in the column density. (From Lee et al. 2013).*

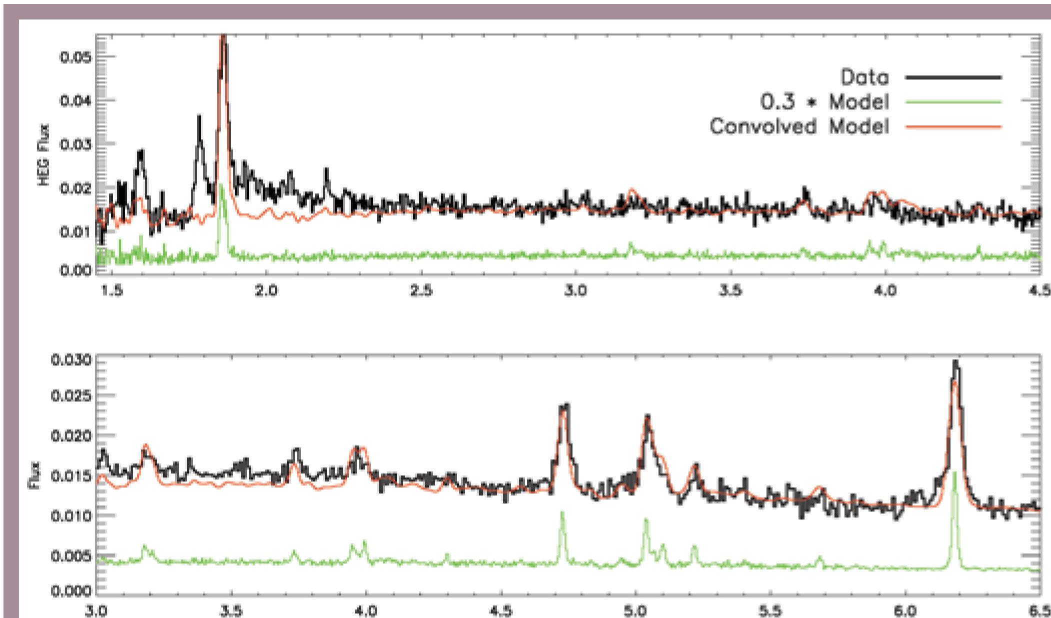

Fig. 2 — SS 433 spectrum (black) from 1.5–4.5 Å (top) and 3.0–6.5 Å (bottom). Red is the scaled and broadened θ[1]Ori C spectrum, and green a scaled, unbroadened version. (From Marshall et al. 2013.)

ing close matches if an exact sub-string match is not found. In the interactive plotter, you can now save the parameters and apply them to one or more plots, you can generate multiple plots for a selection of multiple extractions, and you can mark the positions of major spectral features. TGCat users who find a serendipitous spectrum in an image can send in a request for processing using a form on the main page, and the result will be run and posted to the catalog within a day or two.

Selected Scientific Highlights

About a dozen papers using HETG data went into press in the past year, many using archival data, and some using observations going back to *Chandra*'s first cycle, a testament to the value of the archive and the richness of the data. While we know that astronomical objects are not comprised of spherical homogeneous plasmas, we often have difficulty resolving detailed structure. Several of the works in the past year have made use of the high-resolution of HETG (in conjunction with spatial and temporal resolution) to probe the source geometry.

A Quasar

Lee et al. (2013 MNRAS 430, 2650) undertook a large, multi-band coordinated attack on the quasar IRAS 13349+2438, from the infrared to X-rays. With spectra, they probed the outflow: all X-ray absorption lines were blue-shifted, and by similar amounts as in the UV emission lines. Their simultaneous fits to X-ray, H-, or He-like absorption line series clearly demonstrated their value in curve-of-growth analysis, providing data on the linear part of the curve which constrains measurement of the absorbing column to a much higher degree than can be done with the low-n transitions alone (see Fig. 1). From their comprehensive analysis, they were able to conclude that the X-ray-UV ionizing spectrum implies a continuous distribution of ionization states in a smooth flow rather than discrete clouds in pressure equilibrium as claimed previously.

A Micro-Quasar

> *They call it SS-433, and they found out it's-a coming toward Earth at 30,000 miles a second. But.. it's also going away from Earth at 30,000 miles a second. (1979, Father Guido Sarducci, a.k.a Don Novello[2])*

Zooming in from the extragalactic macro-quasar to a Galactic micro-quasar, SS 433, we have another multi-band study by Marshall, et al. (2013 ApJ, 775, 75), comprised of contemporaneous radio to X-ray observations. The source is quite variable, both in flux (it is an eclipsing system) and—of course—in its signature Doppler shifts from the "it's-a coming and a going" jets. By summing spectra aligned on the blue-shifted jet, they found the spectrum to be thermal, not photoionized, and in fact empirically very similar to the broadened spectrum of θ^1 Ori C, a stellar wind-shocked thermal plasma (see Fig. 2). Given the

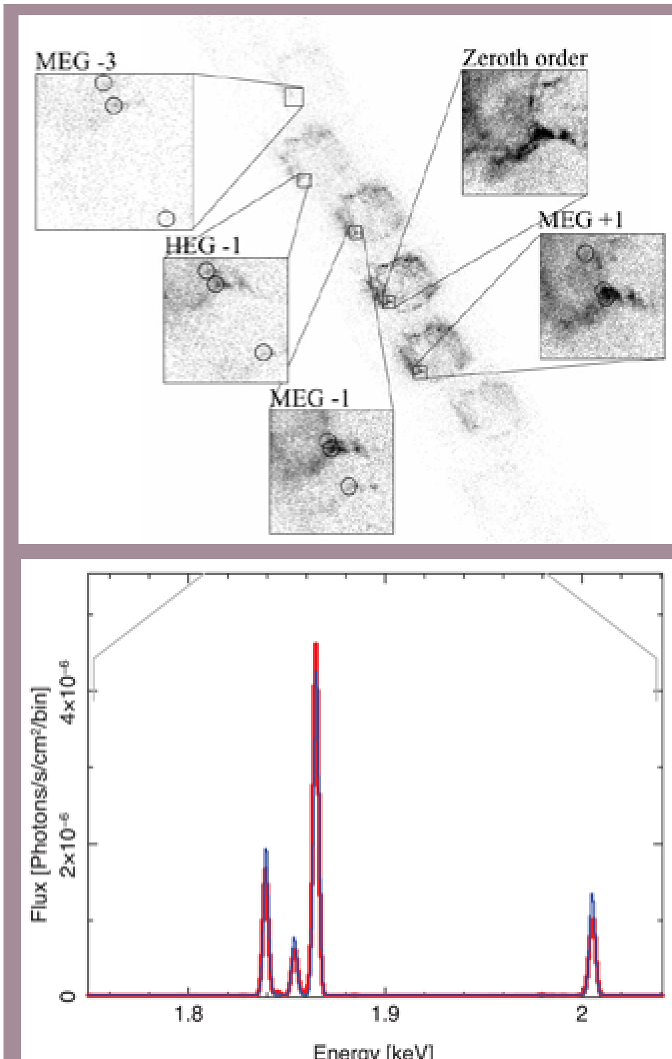

Fig. 3 — Cas A dispersed; top: diagonally on the left we see the -1, zeroth, and +1 orders, with a zoom in the labeled boxes to the right. Circles in the MEG+1 box show the positions of the H-like and He-like Si lines; these are shown in histogram form in the bottom panel, with nearly indistinguishable models and data in different colors. From left-to-right these are the forbidden, intercombination and resonance lines of the Si XIII triplet, and then the Si XIV H-Lyα-like line. (See the original publication for un-cropped figures; from Rutherford et al. 2013.)

2 http://snltranscripts.jt.org/78/78rupdate.phtml

thermal nature, the jet base density was determined from the spectrum to be about 10^{10}–10^{13} cm^{-3}. Abundances seem unusual (assuming typical or plausible supernovae progenitors for the compact object) with Ni enhanced by about a factor of 15. They found that the jet flow starts as a continuous plasma, then forms clumps.

A Micro-Blazar?

Vilhu and Hannikainen (2013 A&Ap, 550, A48) have suggested that Cyg X-3, a high-mass X-ray binary, is a "micro-blazar," since it is probable that its jet is directed nearly at Earth. Its jet shock, they hypothesize, enhances or creates clumps in the massive embedding wind of the companion Wolf-Rayet star. In their model, the jet paints a transient trail in the wind, and then the X-ray-binary can be observed through this disturbance, with a specific phase dependence. Their clumpy scenario gave a better fit to HETGS emission line variations than did a smooth model.

A Supernova Remnant

Rutherford et al. (2013 ApJ, 769, 64) have used a decade-long baseline of Cas A observations to study the kinematics and structure of this photogenic supernova remnant. In this work, they performed sophisticated spatial-spectral analysis of the dispersed image, fitting the two-dimensional distribution, to study individual knots in the remnant, achieving superb consistency between the high-resolution grating and ACIS imaging spectra. The grating spectra provided such useful diagnostics as resolved Si XIII triplets which were fit with non-equilibrium models (see Fig. 3). From the spectra and lack of significant variability over the past decade, they concluded that there are two distinct plasmas present, one high of metallicity, and one low metallicity, which are unmixed at small spatial scales.

It has been a good year for the High Energy Transmission Grating ("*where all the sources are strong, all the spectra are good looking, and all the results are above average*").