MIT
Center for Space Research **Chandra X-Ray Center**

MEMORANDUM
November 15, 2004

To:	Dale Graessle, CALDB lead
From:	Bish K. Ishibashi (MIT/SDS) and D. Dewey (MIT/Cal)
Subject:	Update on ACIS-S detector corner positions; MEG period
Revision:	1.0
URL:	`http://space.mit.edu/CXC/docs/memo_geometry_acis_s_1.0.ps`
File:	`/nfs/cxc/h2/bish/CXC SDS/LETGROT/memo_geometry_acis_s_1.0.tex`

1 Justification for Geometry Update on ACIS-S

While attempting to examine the LETG+ACIS-S rotation issue, it was noted that some ACIS-S chips are slightly rotationally misaligned. Furthermore, inaccurate CCD chip gaps were noted when comparing ±1st order MEG line emission spectra of Capella while attempting to merge them together for analysis. In order to analyze HETG grating spectra to the extremes allowed by the hardware, these calibration issues at the sub-pixel level should be characterized and the calibration should be slightly adjusted.

This memorandum describes the methods to characterize these misalignments in the ACIS-S chip position, redefine new corner positions of these chips and then verify the accuracy of the new geometry product.

2 Measurements of ACIS-S Chip Geometry Alignments

The following describes our two-step approach to the misalignment issues: (1) quantify rotational misalignments (and positional offsets) of ACIS-S chips; and then (2) re-derive ACIS-S chip gap offsets with respect to the current CALDB geometry file (`telD1999-07-23geomN0004.fits`, or N0004). Throughout our analysis, we make the assumption that the changes in the focal point temperature (from -110 to -120°C) would not affect the physical layout of the detectors[1].

2.1 Rotational Alignments and Positional Offsets

In the process, we have chosen a bright X-ray source[2] – MKN 421 (ObsID 4148) – as the representative of LETG+ACIS-S observations. To characterize rotational misalignment of individual ACIS-S chips, first we take out the global rotational error of ≈0.088° associated with the LETG + ACIS-S configuration (see Drake and Ratzlaff at `http://hea-www.harvard.edu/~jdrake/memo/geomn0004/`). Since the 0.088° angle is not

[1] And we did not see any significant changes in our measurements between two temperature settings.

[2] MKN 421 is a bright power-law X-ray source that is used to study the scale of ACIS contamination by the Cal team. There are a number of observations with different SIM-Z offsets, which are useful to determine variation in misalignment at different chip positions.

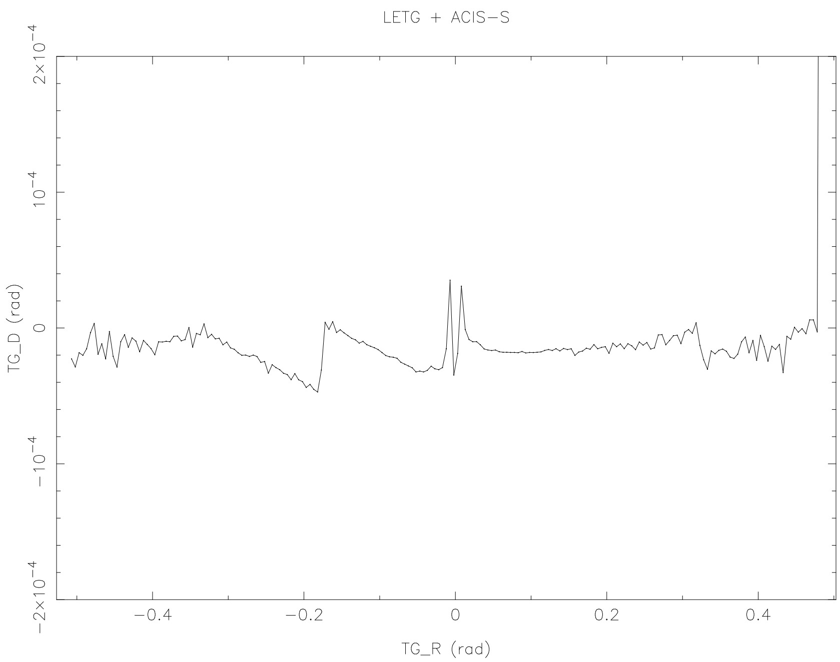

Figure 1: Misalignment in the geometry of ACIS-S chips. The effect of the misalignments are illustrated in the TG coordinate space. Spurious double-horn feature near TG_R =0° is due to the halo of the zeroth order emission structure.

definitive, the rotation error values are re-measured for each LETG+ACIS-S dataset[3]. Figure 1 shows the centroid positions of the projected LEG ±1st-order events in the TG coordinate after the gross rotational error has been taken out. A large saw-tooth pattern, seen in Figure 1 in the range of -0.3 < TG_R < -0.05, is the most clear demonstration of the chip misalignments (see an illustration in Figure 2). The slope of these rotational misalignments are measured per chip[4]. In addition, positional offsets of each chip with respect to the ACIS S3 chip in the TG_D direction (nearly corresponding to DETY) are measured as well (then converted to the pixel scale of the DET coordinate). These measured values are tabulated in Table 1 ("angle" and "δDETY" columns).

2.2 Measurement of Chip Gaps

Figures 3 and 4 demonstrate the problem with inaccurate chip gaps. To make these plots, Capella (ObsID 1103) dataset has been processed with `telD1999-07-23geomN0004.fits` using CIAOX 3.2[5]. MEG +1st order line spectrum of Capella (solid black) does not match well with that of MEG -1st order spectrum (red). A close visual inspection in Figure 4 shows that Fe XVII λ15.01Å is offset by ≈ 0.002Å, whereas Fe XVIII line at 14.208Å in both ±1st orders match reasonably well. Inspections of other emission lines short-ward of 14Åalso show no sign that the zero-order offset affects here significantly. These discrepancies, as it turns out, can be understood since there exists a chip gap between S2 and S1, i.e., there is a chip gap located between the Fe XVIII and Fe XVII lines.

To characterize the offset in chip gaps, we have chosen several Capella HETG+ACIS-S datasets. Using the newly derived geometry file (corrections based on the measurements in the last section), all of the bright Capella HETG datasets are reprocessed using CIAOX 3.2. The processed PHA, ARF and RMF files are used to derive accurate positions of selected bright emission lines in the HEG and MEG spectra using *ISIS*. Then

[3] Note that the rotational error values scattered around 0.089° by 0.003° or so. We suspect that the scale of the uncertainty may be tied to the uncertainty in determining the spacecraft roll angle.

[4] A positive rotation value implies that the corner positions are rotated clock-wisely in the DET coordinates.

[5] Not that it really mattered if I used CIAO 3.0 or 3.1.

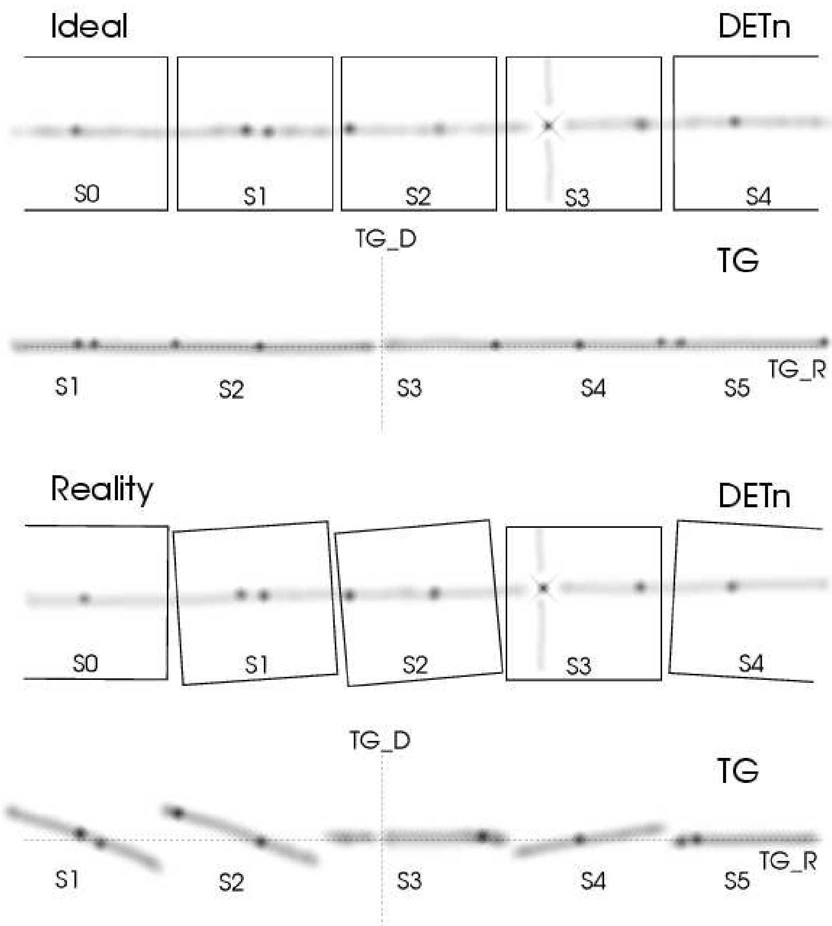

Figure 2: Illustration of inaccurate chip corner positions and its side effect. The top two panels illustrate the ideal condition of chip alignments. The bottom two, on the other hand, illustrates a case of chip misalignments that may explain what we see in Figure 1.

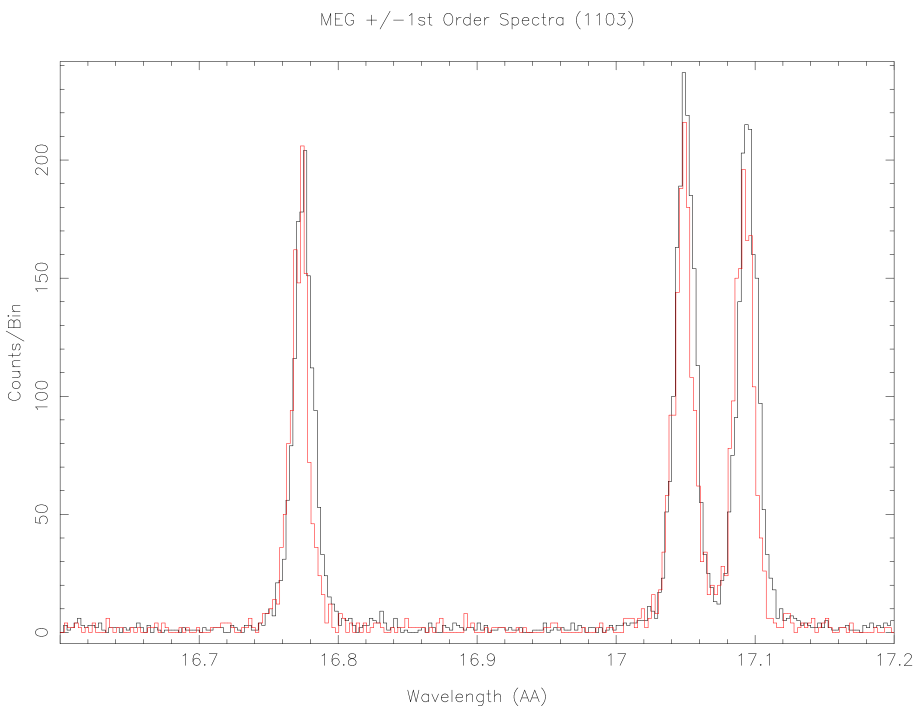

Figure 3: Example I: Spurious instrumental line shift due to inaccurate chip gap. (solid black) MEG +1st order spectrum; (red) MEG -1st order spectrum. The MEG -1st spectrum appears to be shifted by 0.002Å.

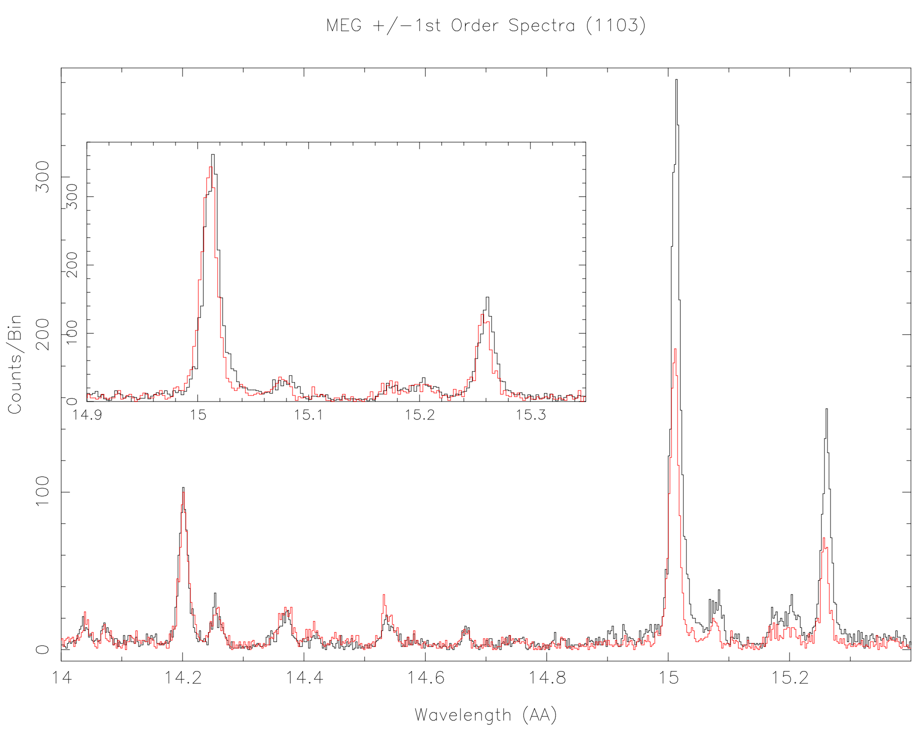

Figure 4: Example II: Spurious instrumental line shift due to inaccurate chip gap. The inset figure shows the same datasets, except the MEG +1st order spectrum is scaled by 1.8 for better visual comparison.

Table 1. Correction terms to the ACIS-S corner positions

CHIP	Angle (radian)	δ DETX (pixel)	δ DETY (pixel)
S0	-3.33358×10^{-5}	0.243385	0.10005
S1	3.05485×10^{-4}	0.10882	6.11667×10^{-3}
S2	3.02989×10^{-4}	-0.113739	1.58333×10^{-2}
S3	6.98132×10^{-7}	0.0	0.0
S4	-4.45059×10^{-5}	-0.025713	1.49333×10^{-2}
S5	-1.23046×10^{-4}	-0.254467	-1.40000×10^{-3}

the measured line positions are processed with the simple IDL routine `chip_gap_resolve.pro` to determine offsets to the assumed ACIS chip gaps (see `http://space.mit.edu/HETG/technotes/chip_gaps/chip_gaps_2583.html` for the detail of the IDL code). Note that the offset size of the gaps are measured with respect to whatever geometry file was used to process to datasets. The measured offset values are also tabulated in Table 1 (δDETX column).

3 New ACIS-S Chip Corner Positions

The measured values in Table 1 are the offset parameters to adjust the chip corner positions listed in the current CALDB geometry file `telD1999-07-23geomN0004.fits`. Since these values are measured in the TG frame and then scaled to the DET coordinate frame, the corner position values in the CALDB geom file (specified in local science instrument coordinate, or LSI) need to be converted first to the DET values, apply corrections, and then convert them back to the LSI frame. We utilized Glenn Allen's and my own S-Lang codes to perform Chandra coordinate transformations[6]. Note that all the offset adjustments are made with respect to the chip center (at CHIP coordinates of `[512.5, 512.5]`).

The corrected four corner positions (LL, LR, UR, and UL) of the ACIS-S chips are tabulated in Table 2. Appropriate columns in the FITS extension `INSTGEOM1` of the CALDB geometry file will be updated with the tabulated values.

[6]Relevant S-Lang codes are: `coords.sl` and `det_to_lsi.sl` & `lsi_to_det.sl`.

Table 2. New ACIS-S Chip Corner Positions (in LSI)

CHIP	LSI_X (mm)	LSI_Y (mm)	LSI_Z (mm)
LL	(Lower Left Corner)		
S0	0.7439136	-81.11357	-59.20799
S1	0.3479355	-56.08963	-59.19590
S2	0.09599568	-31.07601	-59.18310
S3	-0.01100000	-6.02599	-59.16601
S4	0.02599138	18.96284	-59.15281
S5	0.2079007	43.95838	-59.13846
LR	(Lower Right Corner)		
S0	0.3529136	-56.55457	-59.19581
S1	0.09893549	-31.52964	-59.17639
S2	-0.01100432	-6.51401	-59.16366
S3	0.02400001	18.53501	-59.15299
S4	0.2079914	43.52384	-59.14091
S5	0.5279008	68.51838	-59.12848
UR	(Upper Right Corner)		
S0	0.3529005	-56.56675	-34.63281
S1	0.09901156	-31.55014	-34.61340
S2	-0.01097190	-6.53445	-34.60066
S3	0.0240000	18.52199	-34.59099
S4	0.2079995	43.51193	-34.57890
S5	0.5279401	68.50841	-34.56648
UL	(Upper Left Corner)		
S0	0.7439005	-81.12575	-34.64499
S1	0.3480116	-56.11014	-34.63390
S2	0.09602810	-31.09645	-34.62110
S3	-0.01100001	-6.03900	-34.60401
S4	0.02599948	18.95093	-34.59081
S5	0.2079401	43.94840	-34.57545

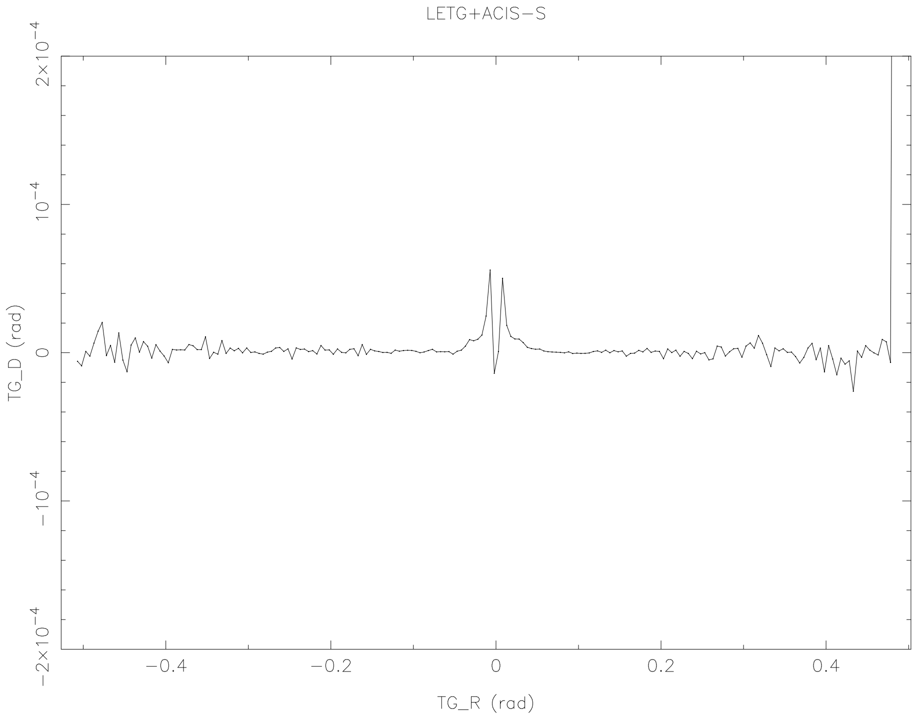

Figure 5: Corrected alignment in the geometry of ACIS-S chips

4 Validation of New ACIS-S Geometry

Using these new CCD corner positions, we repeat the procedures illustrated in Section 2 in order to verify the improvement made on the geometry file.

4.1 Chip Alignments

Figure 5 shows the plot of the event centroid positions vs. TG_R. Compared to Figure 1, the centroid distribution is flat and free of saw-tooth like feature.

4.2 Chip Gap

Figures 6 and 7 demonstrate the improvement in the determination of relative wavelengths in MEG ±1st orders. A small wavelength offset of ≈0.002Å is eliminated, hence making it simpler to merge these two spectra (should the users desire such action).

5 A Corollary: Adjustment to the MEG period

With the ACIS-S geometry "nailed down", we are in a position to determine (1) relative HEG–MEG wavelength calibration and (2) absolute wavelength calibration. The accuracy of the absolute wavelength depends directly on the accuracy of the grating period and Rowland spacing. By inter-comparing HEG and MEG wavelength scales (where Rowland spacing is the same), we have demonstrated that the MEG grating period may need to be adjusted from 4001.41 to 4001.95 (in the extension `GRATINGS` of the N0004 geometry file). Please see the summary of this particular analysis at Dan's web page:

`http://space.mit.edu/HETG/technotes/chip_gaps04/chip_gaps04.html`

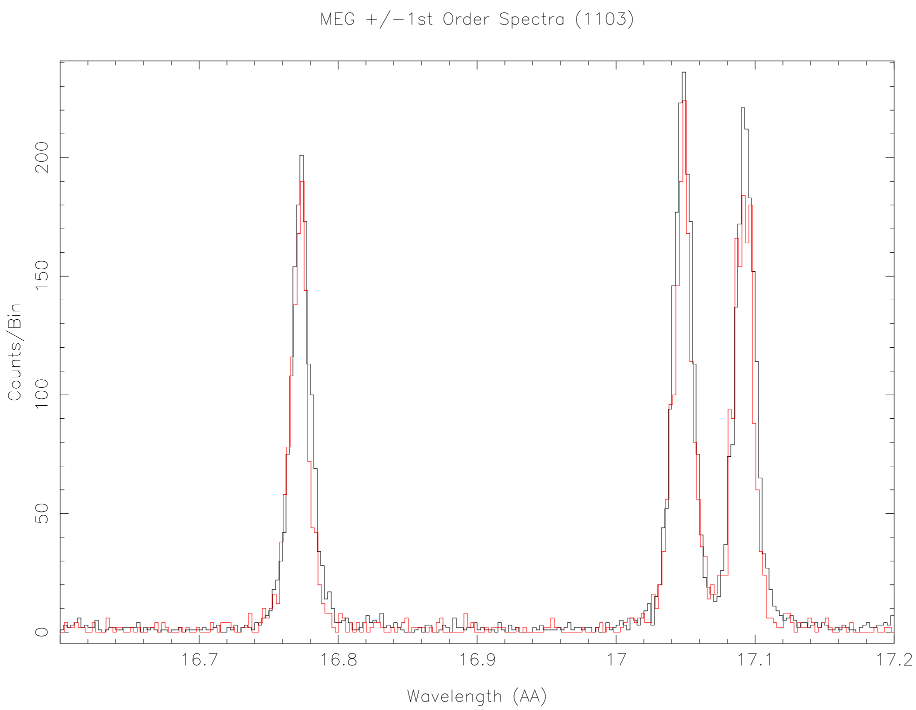

Figure 6: Example I: Emission line positions after chip gap corrections (c.f., Figure 3).

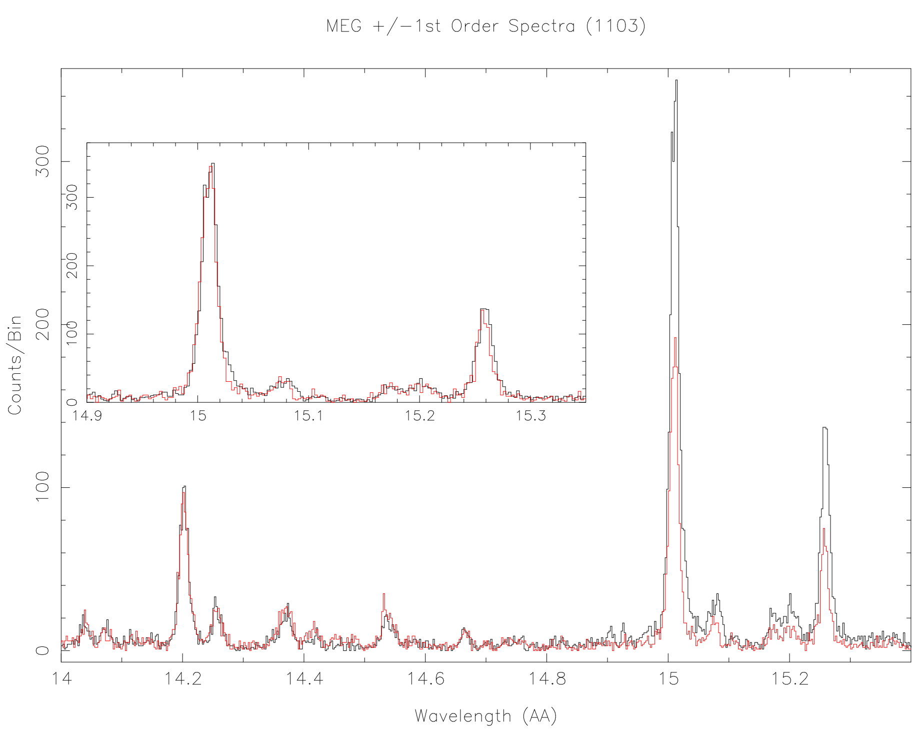

Figure 7: Example II: Emission line positions after chip gap corrections (c.f., Figure 4). The inset figure shows the same datasets, except the MEG +1st order spectrum is scaled by 1.8 for better visual comparison.