Clocking angle and detector geometry inconsistencies 2: LETG with HRC-I and ACIS-I

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Summary

An earlier *memo* dated 2002-11-30 described inconsistencies in the apparent dispersion axes in LETG+HRC-S and LETG+ACIS-S data processed with the geometry file `telD1999-07-23geomN0004.fits`. This analysis suggested that the combination of the LETG clocking angle and the orientation of HRC-S and ACIS-S detectors in `telD1999-07-23geomN0004.fits` is inconsistent by about 8.8×10^{-2} deg. Based on the results reported in that *memo*, it was not possible to determine the cause of the problem, or which detector orientation might be in error. In this *memo*, we extend the analysis to LETG+HRC-I and LETG+ACIS-I observations. Even larger discrepencies are found in which the `tg_r,tg_d` coordinates differ in alignment compared to the HRC-S by -0.18 deg for HRC-I and 0.13 deg ACIS-I. The discrepency between HRC-I and ACIS-I is therefore about 0.3 deg.

Comparison with results of Maxim Markevitch's astrometry verification of `telD1999-07-23geomN0004.fits` indicates that the relative rotations seen in `tg_r,tg_d` coordinates are not consistent with those seen in sky coordinates. The problem in `tg_r,tg_d` relative rotations must then lie in software implementation of telescope, grating and detector geometry, and probably in the computation of `tg_r,tg_d` coordinates.

1 Data Processing and Analysis

Observations analysed were OBSIDs 3169,3172,3175 (PKS 2155-304 LETG+ACIS-I) and 87 (Cyg X2 LETG+HRC-I). Data analysis proceeded in an identical fashion to the analysis described in the earlier memo. Data were all uniformly reprocessed using the steps listed in the Appendix using the default CALDB geometry file

```
caldb-2.18/data/chandra/tel/bcf/geom/telD1999-07-23geomN0004.fits
```

Residual angles between the true dispersion axis and the `tg_r,tg_d(0)` axis were determined by fitting gaussians to the data in `tg_r,tg_d` coordinates in the `tg_d` direction. In order to obtain a useful signal-to-noise ratio for the fitting process, data were binned in `tg_r` by approximately 0.15 mm and in `tg_r` by approximately 0.02 mm. In the case of LETG+ACIS-I, three of the PKS 2155-304 observations were coadded to obtain sufficient S/N. This set of observations was carried out at different off-axis angles; we used only those data taken at the same small off-axis angle of +0.5 arcmin. The results for the default CALDB geometry file are illustrated in Figures 1 and 2.

The residual rotation of the HRC-I and ACIS-I in `tg_r,tg_d` coordinates is much larger than the rotations allowed by astrometry using the open cluster NGC 2516 and off-axis observations of LMC X1. Maxim Markevitch details astrometric analyses in two separate memos at urls

```
http://cxc.harvard.edu/cal/Hrma/optaxis/platescale/geom_public.html
http://icxc.harvard.edu/cal/oldcal/platescale/hrcs_scale.html
```

Based on these analyses, the uncertainties in detector rotations in sky coordinates amount to of order 0.2 deg (1σ). Here are the tables for HRC-I, ACIS-S and ACIS-I. The HRC-S analyses was less certain because slightly different results were obtained for NGC 2516 and LMC X1 analyses (based on 1σ errors). One might then expect a maximum error of order 0.05 deg in the relative rotation between HRC-I and ACIS-I (see below). This is to be compared with the observed discrepency in `tg_r,tg_d` coordinates of 0.3 deg.

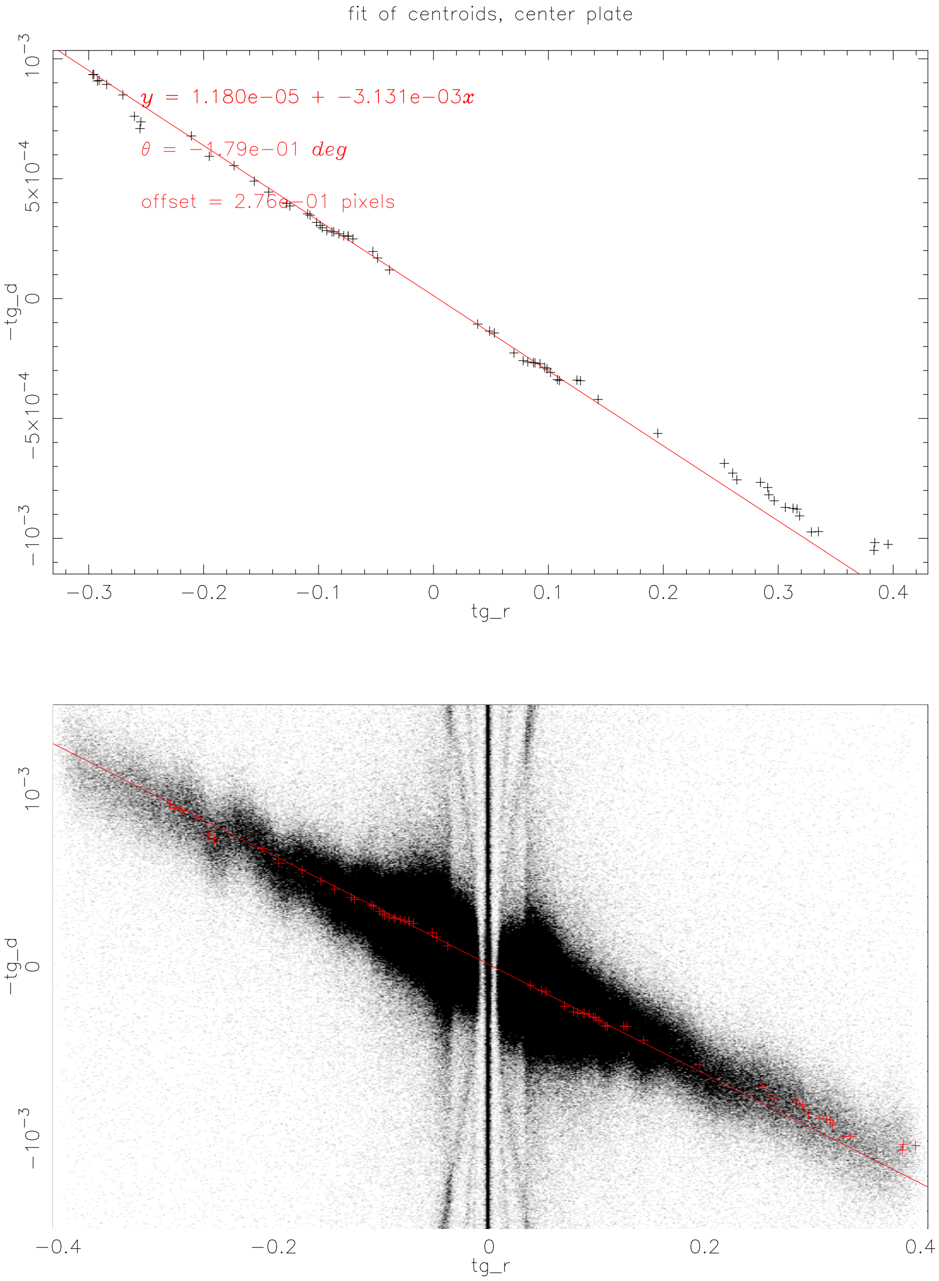
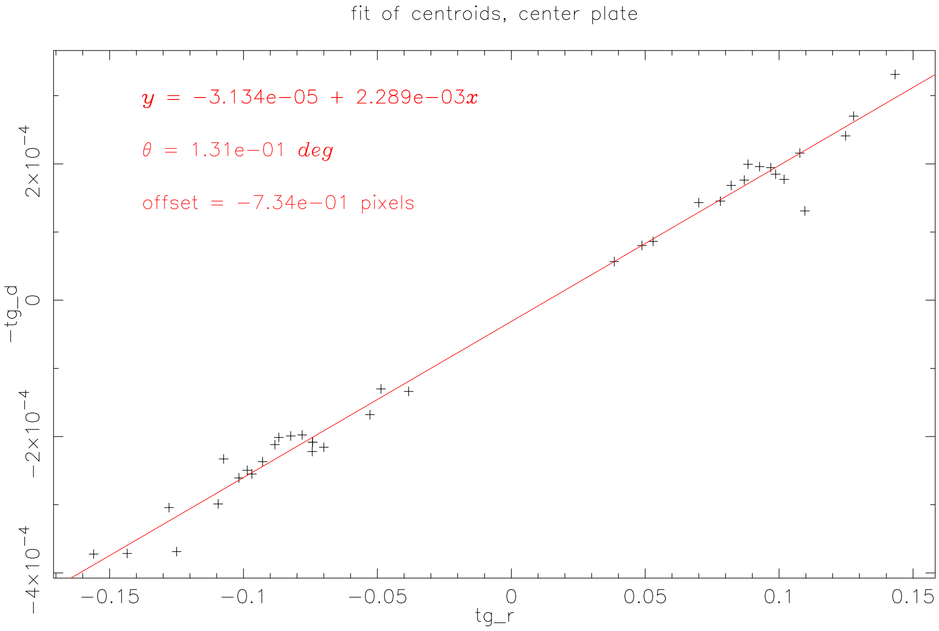


Figure 1: Illustration of the determination of the residual angle between LETG+HRC-I dispersion and tg_r,tg_d axes. The top panel shows the error-weighted linear fit to the dispersed data. The lower panel illustrates this linear fit superimposed on a scatter plot of the photon events in tg_r,tg_d coordinates. The residual angle is -0.18 deg.



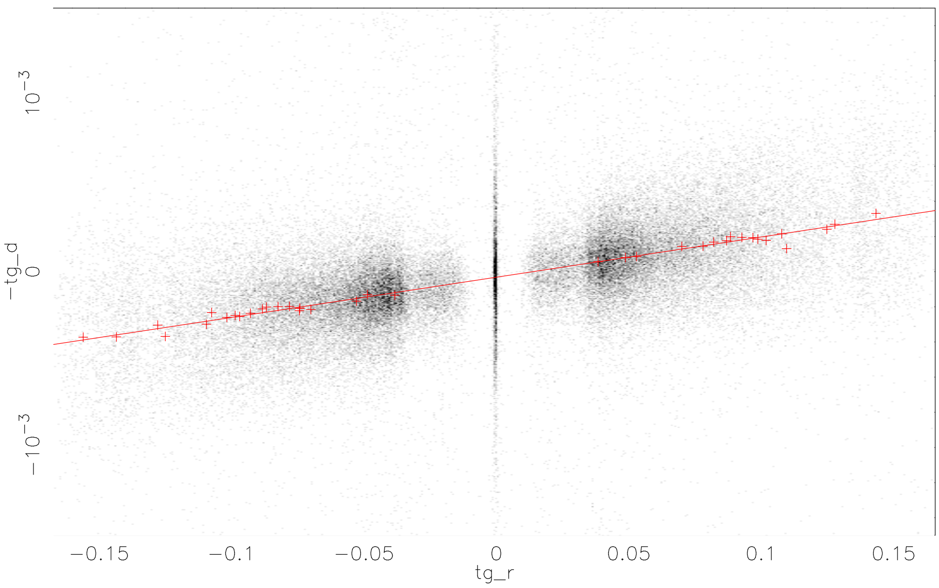


Figure 2: Similar to Figure 1 except for the ACIS-I detector. The residual angle is 0.13 deg; note the opposite sign of this rotation compared to that in Figure 1.

HRC-I

	old	new
rotation, deg	-0.04	-0.04 (-0.06 -0.02)

The possibly significant rotation in HRC-I was not corrected for in the geometry file. Maxim noted the following.

> The marginally significant detector rotation shown in the table was not seen in the four LMC X-1 pointings (15' offsets), so it is ignored in the new GEOM file, possibly causing a negligible absolute displacement at the useful off-axis angles.

ACIS-I

	old rot, deg	new rot (68%)
I0	-0.08	-0.05 (-0.07 -0.03)
I1	-0.03	0.02 (-0.04 0.07)
I2	-0.01	-0.01 (-0.01 0.02)
I3	-0.01	0.00 (-0.02 0.02)

ACIS-S

	old	new
S3 rotation, deg	0.04 (0.04 0.05)	0.00 (-0.01 0.01)
S2 rotation, deg	0.06 (0.05 0.07)	0.04 (0.01 0.05)

2 Conclusions

Following on from our analysis of discrepencies between HRC-S and ACIS-S rotation angles seen in `tg_r,tg_d` coordinates reported in a memo dated 2002-11-30, we have applied similar analyses to HRC-I and ACIS-I data. These analyses reveal even larger problems, with a difference in apparent dispersion axes alignments for HRC-I and ACIS-I of about 0.3 deg. These differences cannot be reconciled with astrometric calibration of the detector rotations, that indicate consistency within a 1σ uncertainty of about 0.05 deg. We do not have a physical explanation for this. It appears, then, that the detector alignment discrepencies uncovered here occur through errors in the software implementation of the Chandra instrument geometry.

We note that the LETG dispersion axis presents a measure of the *relative* orientations of the *Chandra* detectors that is much more sensitive than astrometric observations analysed to date. Once the software problems outlined in this *memo* have been resolved, it would be worthwhile re-examining this problem in order to further refine our knowledge of the instrument geometry.

Appendix: Data processing steps

For explicit listing of the processing steps see earlier *memo*, or .log files in working directories listed below. For a period of at least 1 month after the date of this *memo*, the data and results can be found in the following directories

```
~rpete/rpete7/flight/data/obsid87 HRC-I
~rpete/rpete7/flight/data/obsid3169 ACIS-I
~rpete/rpete7/flight/data/obsid3172 ACIS-I
~rpete/rpete7/flight/data/obsid3175 ACIS-I
```