CHIRON: Commissioning tests and alignments

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In this document, we summarize the tests and alignment procedures that have been performed during commissioning.

1 CCD tilt

In order to check and correct the tilt of the CCD, we developed a few idl programs. The idea behind the programs is to find the surface of best focus. If there is no field curvature (actual field curvature or chromatic effect), this surface is a plane and this plane should be perpendicular to the optical axis to ensure optimal resolution at all wavelengths.

The way we find the surface of best focus is by scanning through the focal region (moving the APO lens along the optical axis). For each position of the lens, we record a ThAr spectrum, we divide the CCD into nine tiles and calculate the average FWHM of the ThAr lines for each part of the CCD. Going through the focal region, we can calculate the best focal position for each tile by fitting a parabola to the through-focus average FWHM (see Figure 1). The minimum of the parabola is the best focus for that specific part of the CCD.

The IDL programs used for these calculations are located in `/mir7/focus_ctio/` (either at CTIO on `ctimac1.ctio.noao.edu` or at Yale):

- `fwhm_thar.pro`: calculates the FWHM of ThAr spectral lines.
- `tilesfwhm.pro`: splits the CCD in nine regions and calculates the FWHM of the ThAr lines for each region (calls `fwhm_thar.pro`).
- `foctilt.pro`: given a list of filenames, it calculates the through-focus average FWHM and then computes the best focus position for all nine regions of the CCD. It needs a minimum of three files corresponding to different focus positions but more files give better results (typically 10 positions within 1mm before or after the focus).

Figure 1 represents the through-focus average FWHM for all nine parts of the CCD before we started adjusting the CCD tilt. Colors are representative of the wavelength, in such a way that the cross-dispersion direction is horizontal and the dispersion direction is vertical. We see that there is a large tilt in the CCD since the difference in best focus position is about 1 mm in the dispersion direction and 0.8 mm in the cross-dispersion direction.

Note that in some parts of the CCD, we have few data points due to the fact that not many spectral lines are present in these regions (mostly outside the free spectral range).

After a few iterations of CCD tilt adjustments, we have been able to get rid of most of the CCD tilt (see Figure 2). We see that the remaining shifts in the best focus positions are due to curvature rather than tilt, for both dispersion and cross-dispersion directions.

2 Best focus

Using `foctilt.pro`, we can directly know where the best focus position is. Once we moved the focus motor to that position, we took a ThAr spectrum and ran `fwhm_thar.pro` to evaluate the FWHM of the ThAr spectral lines. The results are depicted in Figure 3, Figure 4 and Figure 5.

Figure 3 represents the FWHM of all Th-Ar lines across the chip. We see on Figure 4 that the FWHM seems to be better on one side of the chip in the dispersion direction, which could be caused by a residual tilt. However, Figure 2 does not show any residual tilt. Additionally, a similar slope was observed for all implemented tilt adjustments, which might mean that the FWHM is simply not as good on one side of the chip as on the other (possibly because of the prism). If so, tilt can make the FWHM uniform along dispersion but only by deteriorating it on the side where it was good, which would decrease the overall

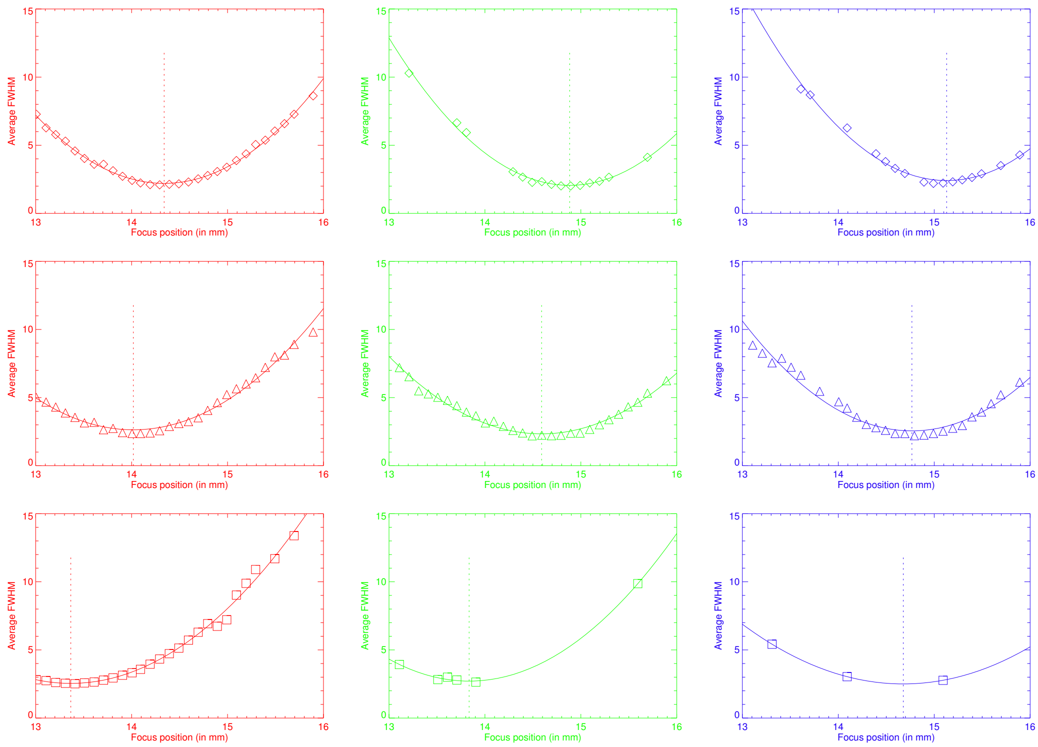

Figure 1: Through-focus average FWHM of ThAr lines per region of the CCD before adjusting the CCD tilt.

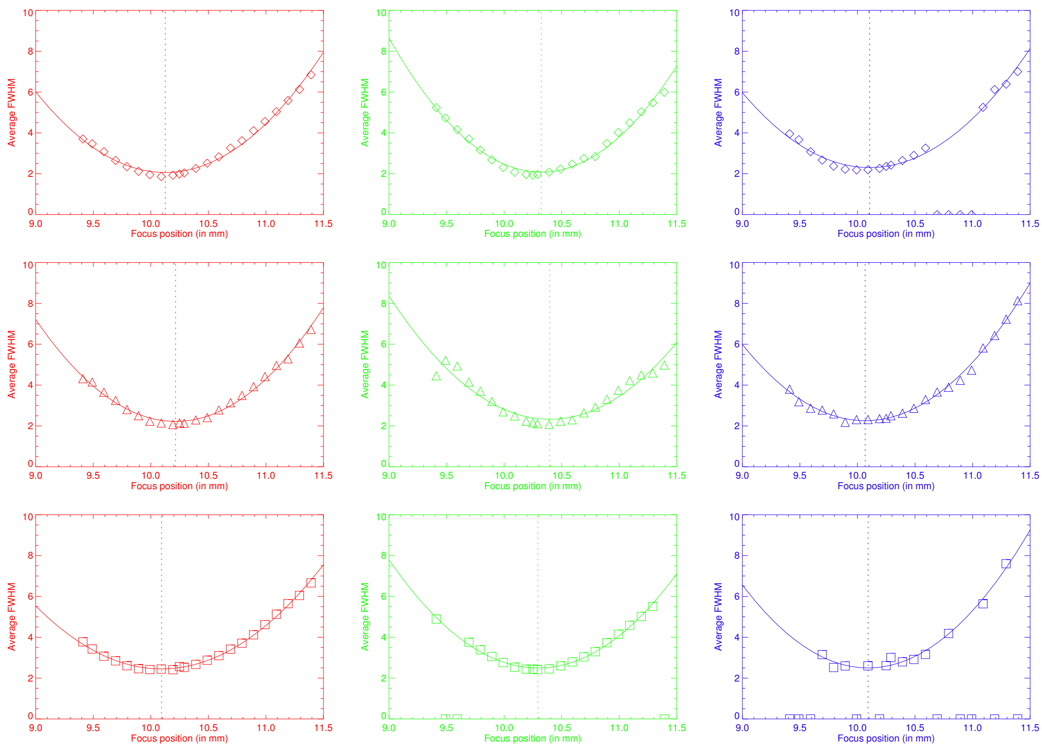

Figure 2: Through-focus average FWHM of ThAr lines per region of the CCD after adjusting the CCD tilt.

resolution. Note that we have not tried to tilt the CCD even further to compensate for that slope. As we see on Figure 5, very little tilt remains in the cross-dispersion.

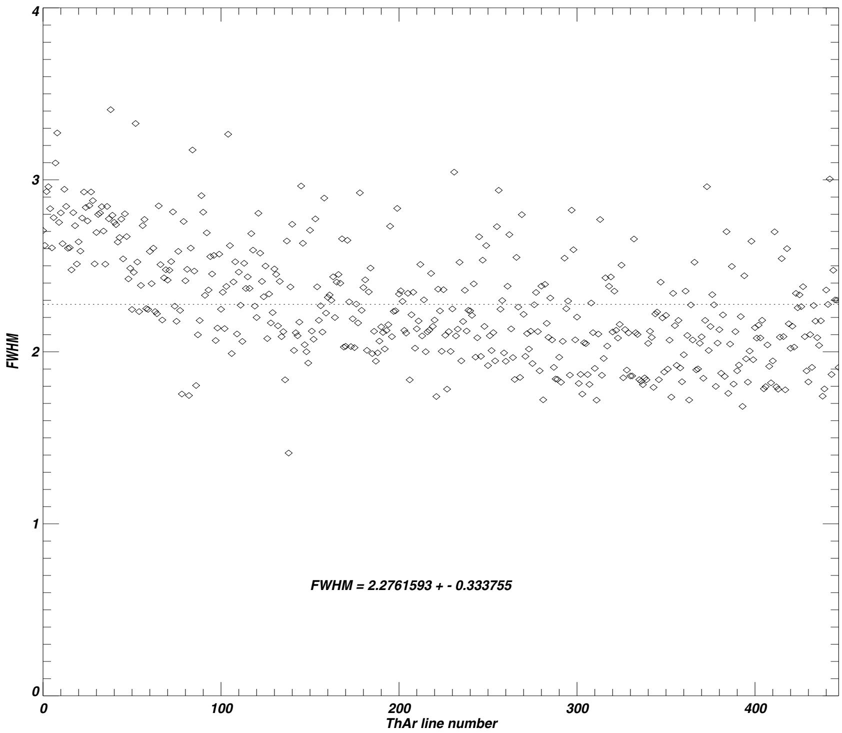

Figure 3: FWHM of ThAr across the CCD.

3 CCD rotation

Once the CCD tilt was corrected, we needed to check the CCD rotation. Since we want to use binning in the cross-dispersion direction, we need to align the CCD so that the rows are in the dispersion direction.

This is done by looking at a chosen Th-Ar line on two adjacent orders Figure 6. Since the line corresponds to the same wavelength, the CCD must be oriented in such a way that these lines hit the detector on the same row. We chose a line that for which both representations (on two adjacent orders) are at equal distances from the center of the CCD. We then adjusted the CCD rotation until these lines fall on the same row.

4 Slit tilt

The program that we have developed to measure the FWHM of Th-Ar spectral lines (`fwhm_thar.pro`) can also be used for checking the slit tilt (using the keyword `slittilt`). To check the slit orientation, we fit a two-dimensional gaussian to each identified line. The orientation is a direct result of `gauss2d.pro`.

For easier correction, we used the image slicer (making the slit effectively three times longer). Figure 7 and Figure 8 respectively represent the slit tilt across the CCD before and after correction.

5 PSF

Using a single-mode fiber, we have measured CHIRON's Point Spread Function (PSF) by taking Th-Ar spectra.

We then wrote a couple of IDL programs that calculate the average PSF in a given region of the CCD. We first subdivide the CCD into nine tiles. For each spectral line in the considered region of the CCD, we fit a gaussian to the mashed rows and columns and derive the centroid of the line. We

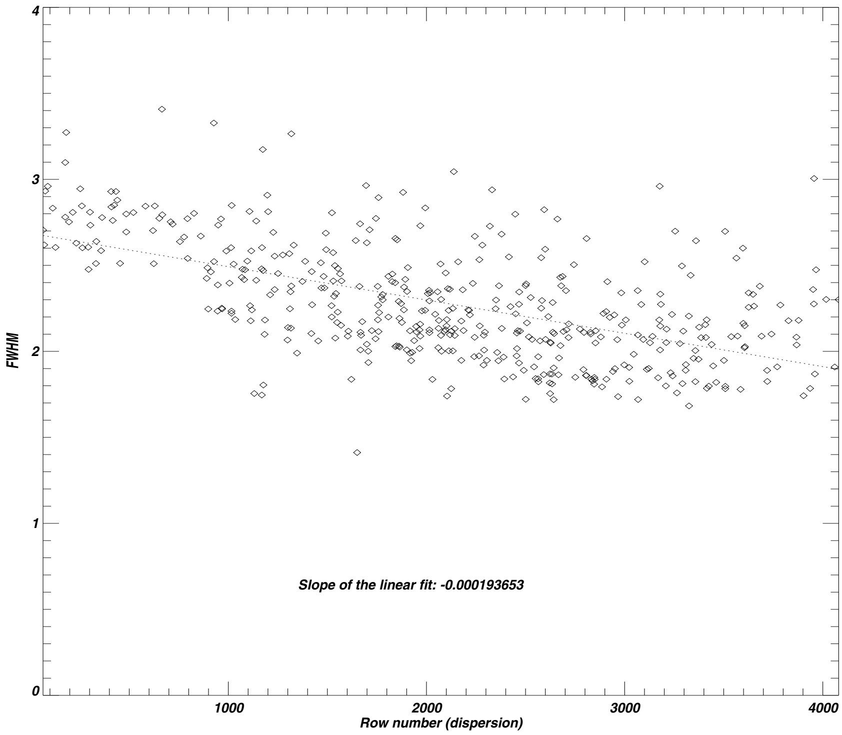

Figure 4: FWHM of ThAr as a function of row number (dispersion direction).

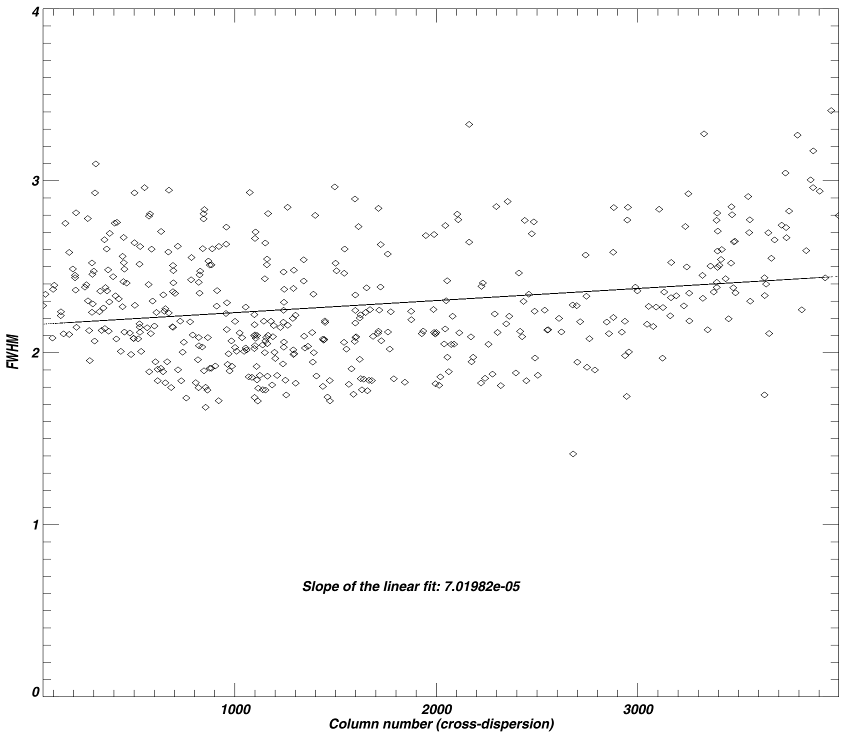

Figure 5: FWHM of ThAr as a function of column number (cross-dispersion direction).

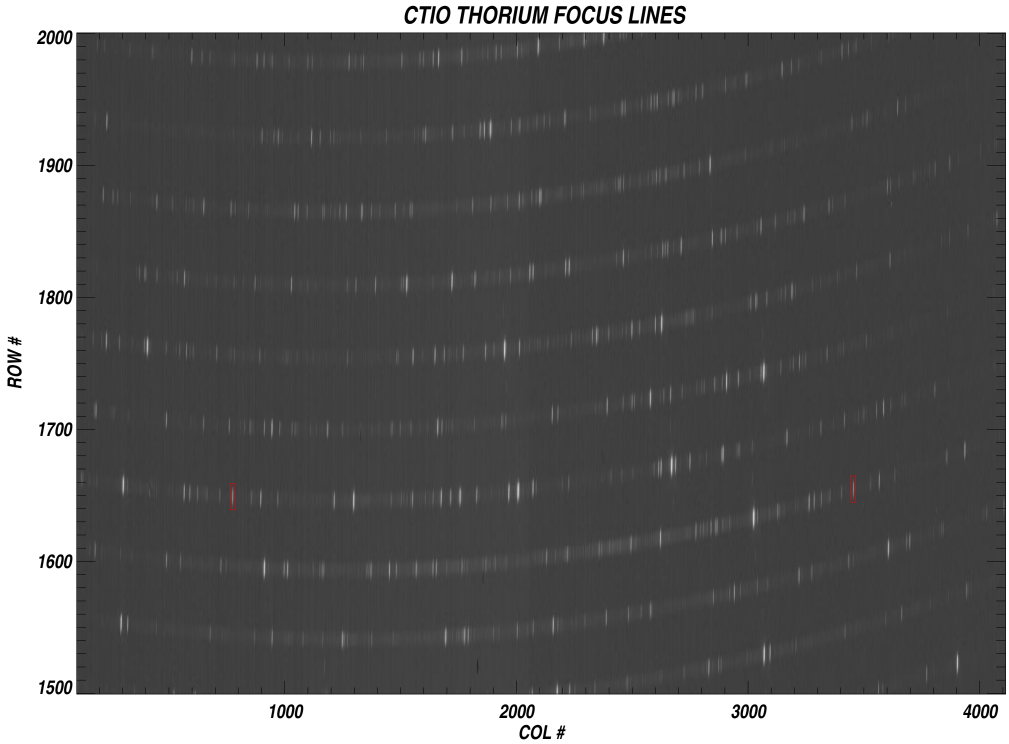

Figure 6: This figure illustrates how we have corrected the CCD rotation. Two spectral lines, on two adjacent orders, symmetric with respect to the center of the CCD and corresponding to the same wavelength must fall on the same row.

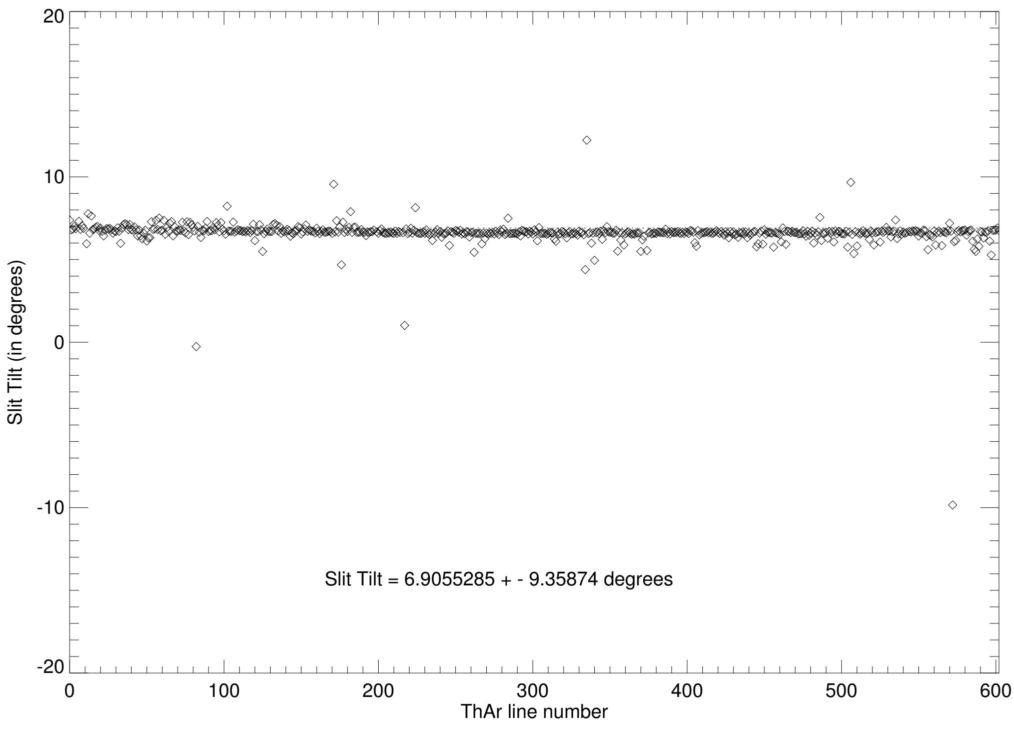

Figure 7: Measured slit tilt for all identified Th-Ar spectral lines before correction.

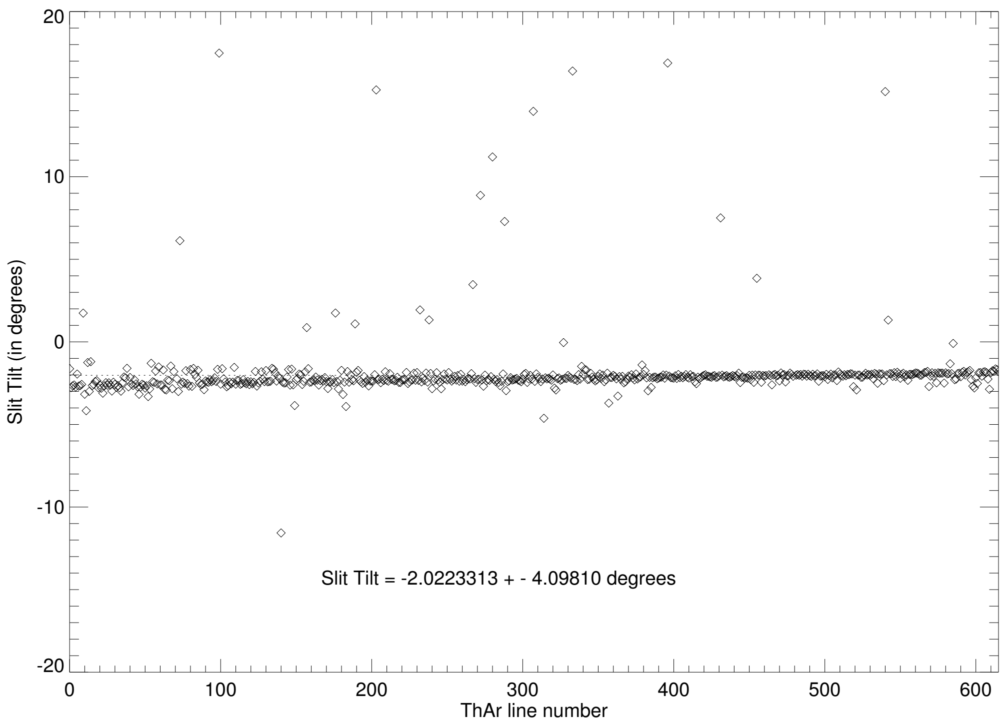

Figure 8: Measured slit tilt for all identified Th-Ar spectral lines after correction.

oversample the PSF by a factor 10 and re-center the PSF to have the centroid of the PSF in the center of the re-sampled box. We then average the PSF of all lines in the considered region of the CCD.

The IDL programs used for these calculations are located in `/mir7/focus_ctio/` (either at CTIO on `ctimac1.ctio.noao.edu` or at Yale):

- `smpsf.pro`: calculates the average PSF across the CCD (or the region of interest) using ThAr spectral lines.

- `tilessmpsf.pro`: splits the CCD in nine regions and calculates the average PSF for each region (calls `smpsf.pro`).

Figure 9 represents the average PSF in the nine regions of the chip in the best focus position. We see that the PSF is rather constant in the dispersion direction. In the green (center tiles), the PSF is nice and symmetric, while it is a little bit more elongated in the red (left tiles) and even more so in the blue (right tiles), which is expected from the Zemax model.

Figure 10 and Figure 11 respectively depict the PSF 0.5 mm intra- and extra-focus. We see that the PSF is elongated in one direction for the intra-focal image (see Figure 10) and the perpendicular direction for the extra-focal image (see Figure 11). This is a clear indication of astigmatism, which is expected from the grating mount. Indeed, the grating is only held by the bottom and the top and bends under its own weight, which causes astigmatism as we have seen during integration.

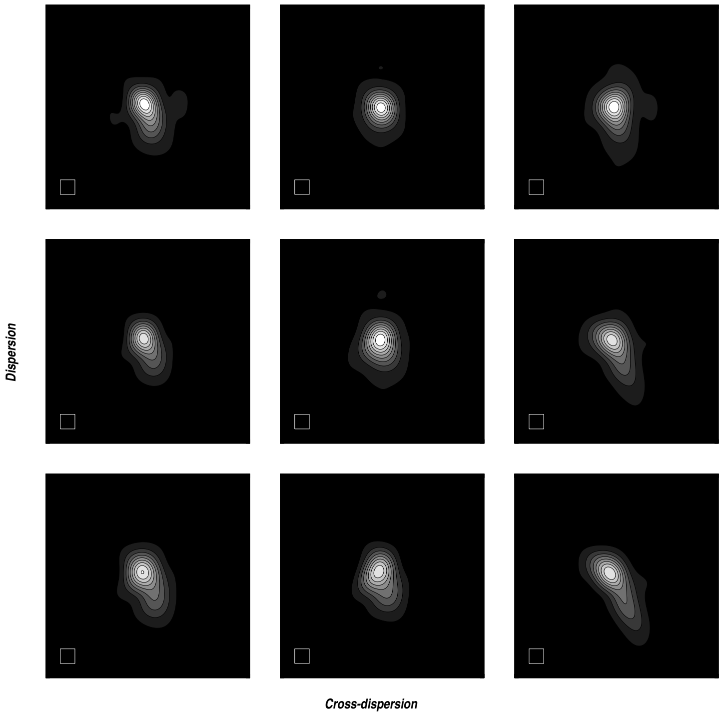

Figure 9: Average PSF per CCD region when the detector is in focus.

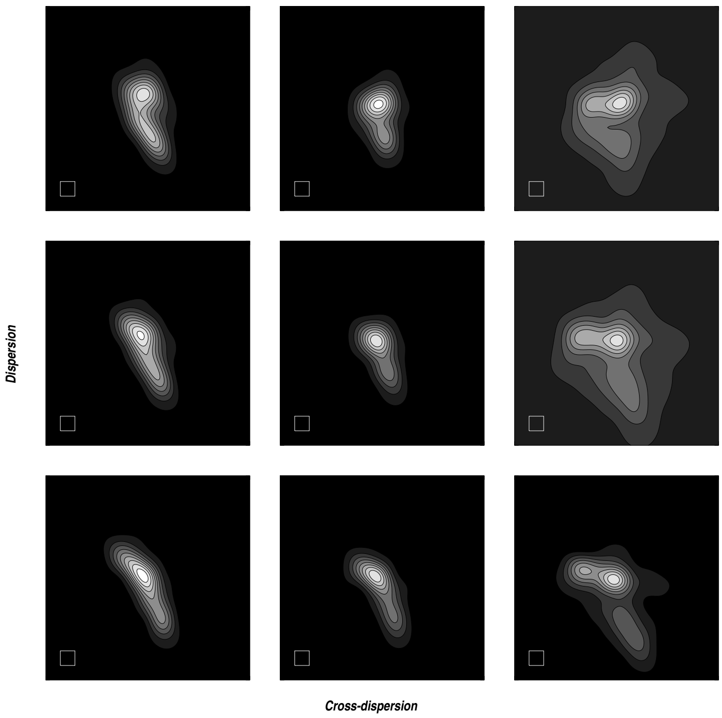

Figure 10: Average PSF per CCD region when the detector is 0.5 mm intra-focus.

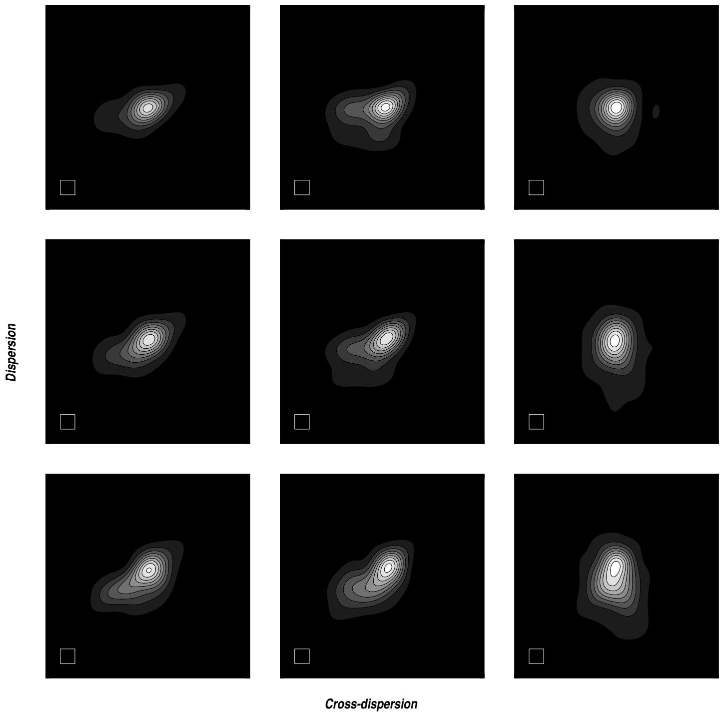

Figure 11: Average PSF per CCD region when the detector is 0.5 mm extra-focus.