'How to Get a Flat-Field Without a "Flat" Source'

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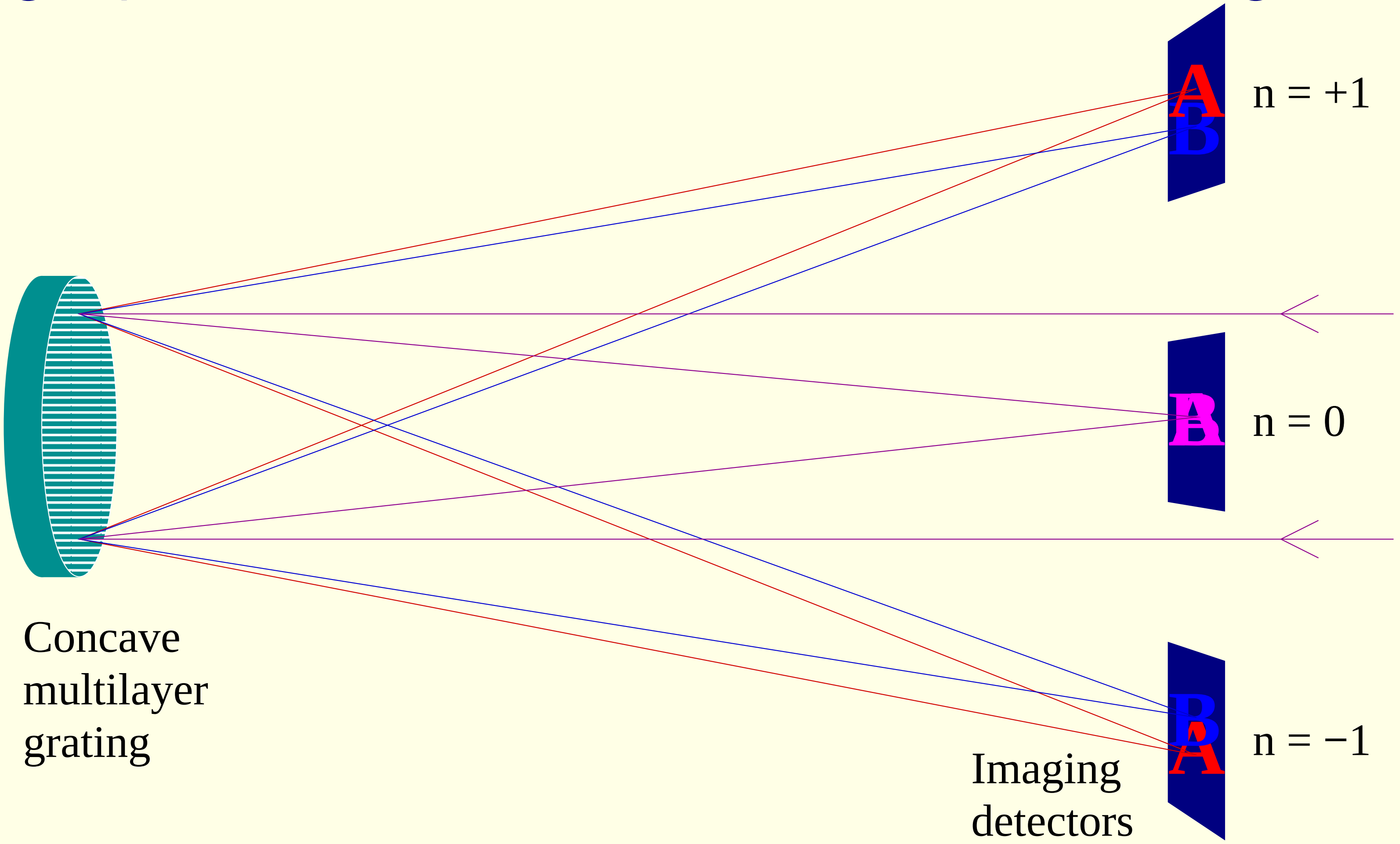
Abstract

Every scientific instrument must deal behind the scenes with instrumentation issues that affect the quality of the resulting data. For imaging instruments one of these concerns is the instrument's flat-field, which is a measure of the non-uniformity of instrument response across the field of view. This type of correction is normally assumed to be trivial. I will discuss how non-trivial it can be to flat-field a CCD detector in an unvignetted optical system in the Extreme UltraViolet (EUV) region of the spectrum, where no uniform sources of illumination exist.

MOSES

Haven't you heard enough about MOSES yet? It's an imaging spectrometer. The idea is something like this:



Flat-fielding

- Normally accomplished by shining a uniform intensity beam into the instrument.
  - A custom built white target; for example the Mayall Telescope at Kitt Peak.

Interior of the Mayall Telescope

  - A bedsheet.
  - Milk.
  - A Lambertian source purchased from an optics catalog.

In EUV

- Lucky to have a source of any kind.
- Synchrotron beamline or Hollow Cathode.
- Calibrated output intensity is a LOT of trouble.
- No uniform sources exist.

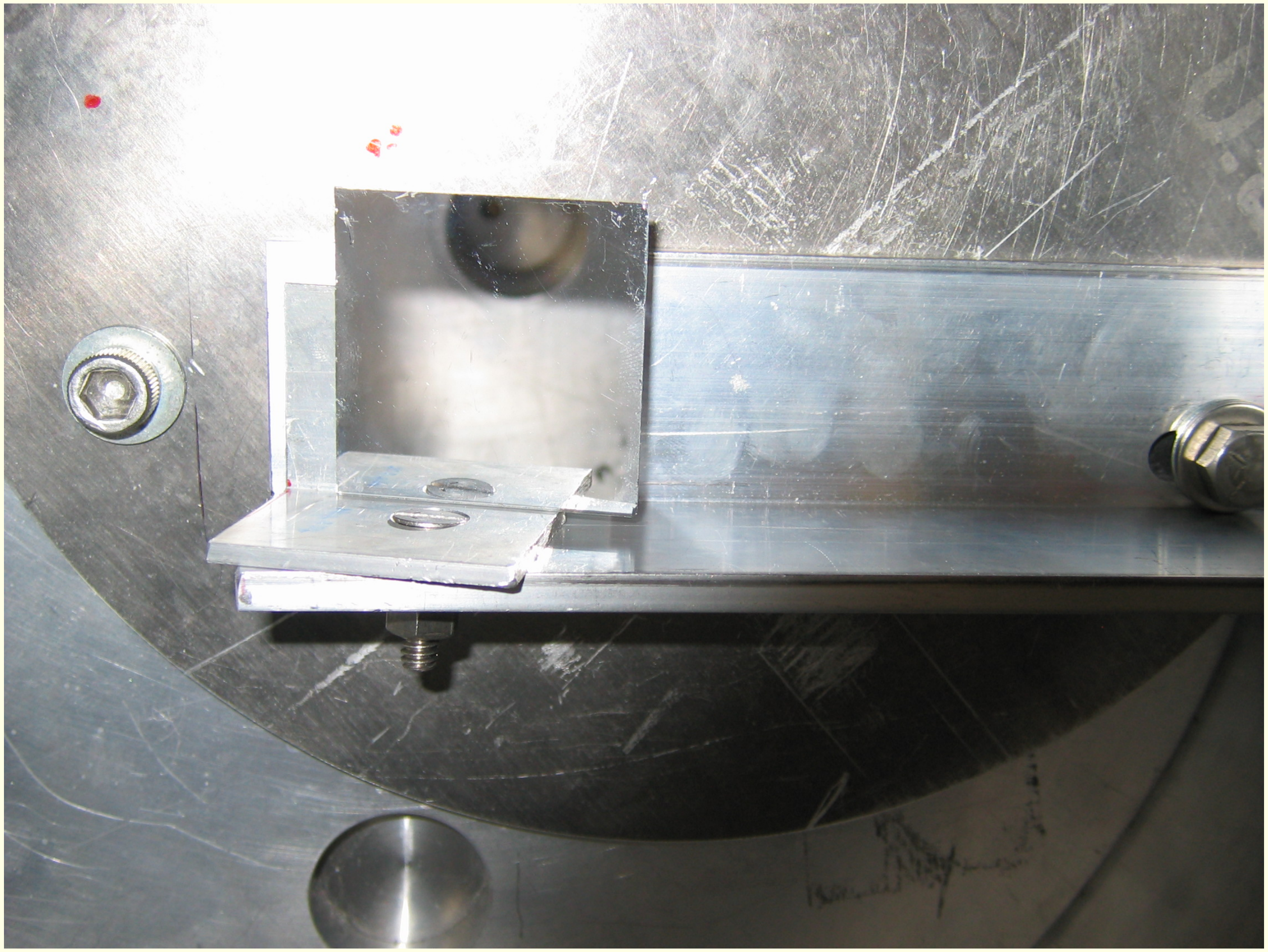
Our Source

- Goddard has a Hollow Cathode source with a chamber they use for this sort of thing in the Davila/Rabin rocket lab.
- It is uncalibrated. . .
- with an unknown beam structure. . .
- which is unlikely to remain constant from one experiment to the next anyway.
- But, it's a source (one of not so very many) that we can use, which produces light at the wavelength of the MOSES experiment.

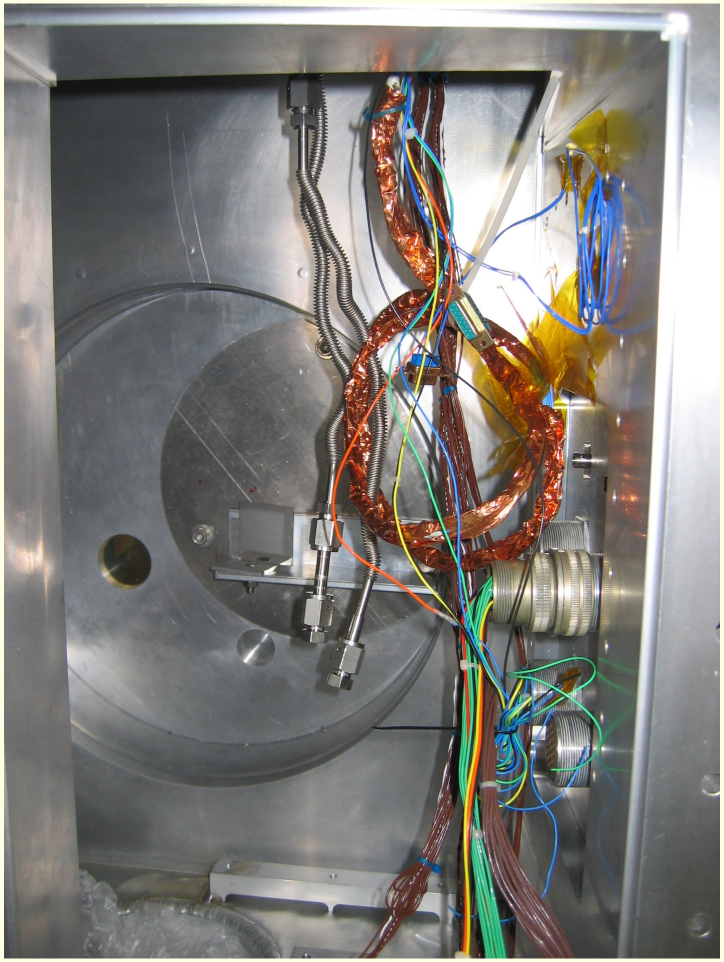
Our Strategy

- Put the detector and housing into the beam (this works because our instrument is unvignetted and unamplified. We calibrate the mirror response separately)
- Translate the detector within the beam horizontally and take exposures at several positions (we ended up using 7).
- The series of images will contain features that don't move (the flat-field) multiplied by features that do move (the beam).

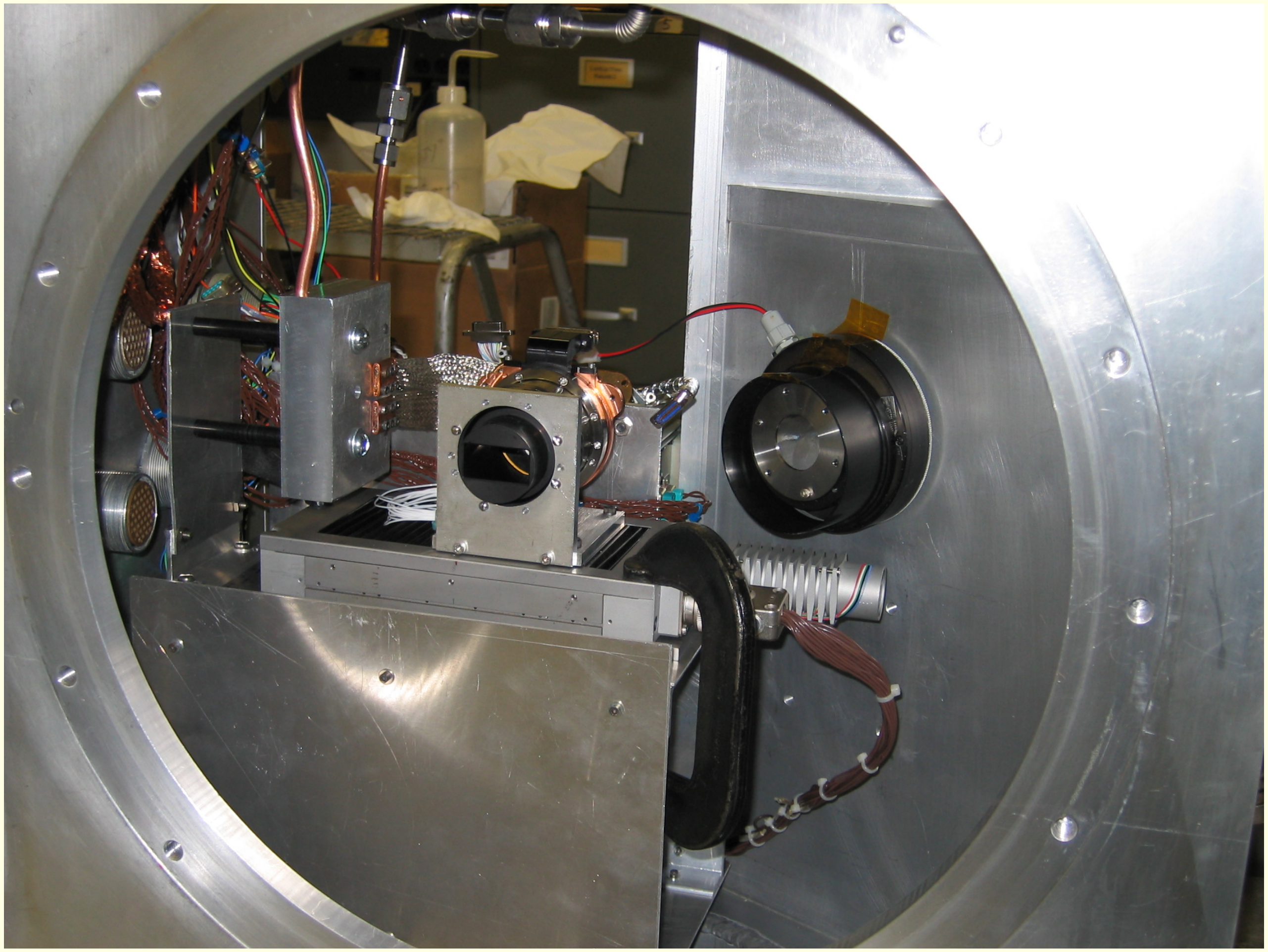
The Setup



The Setup



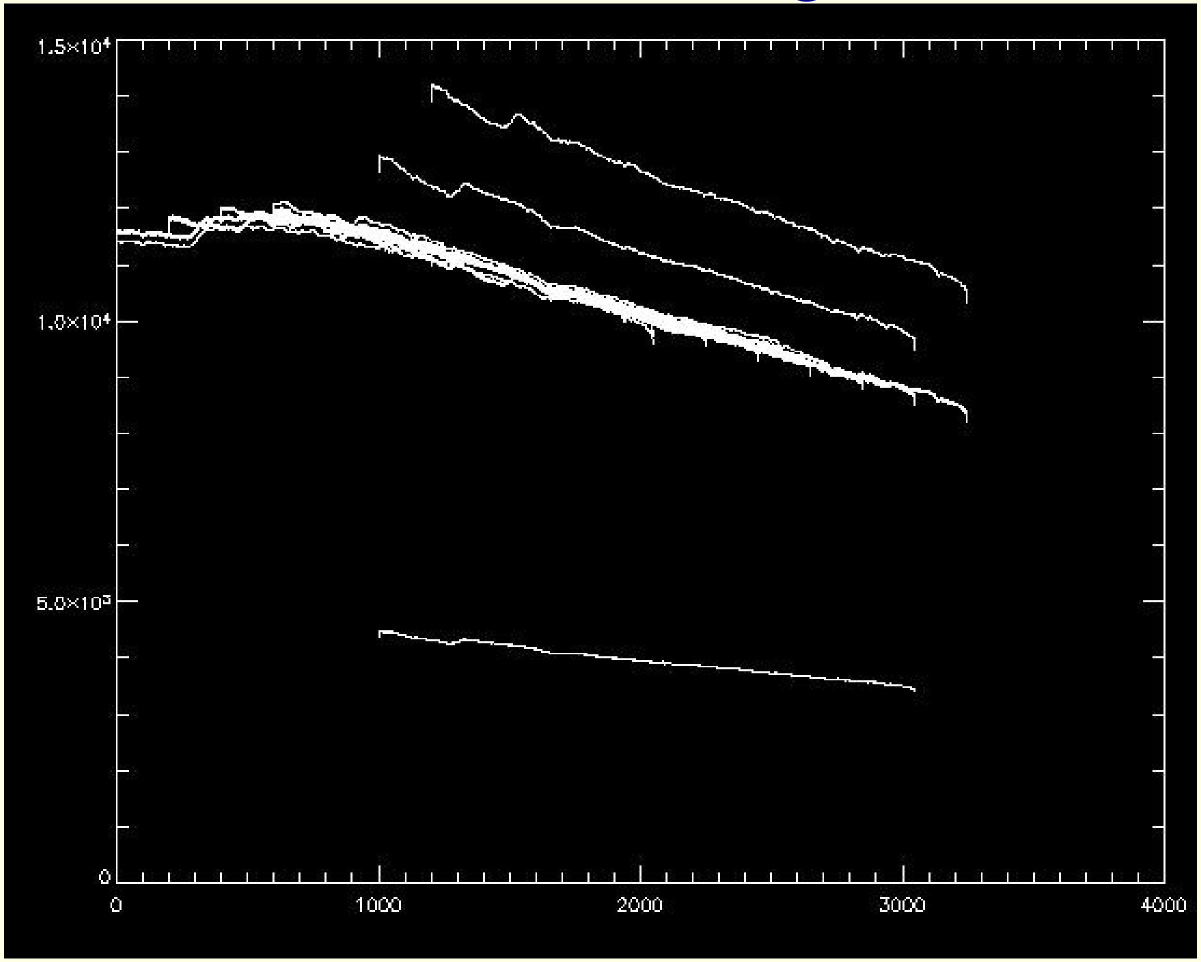
The Setup



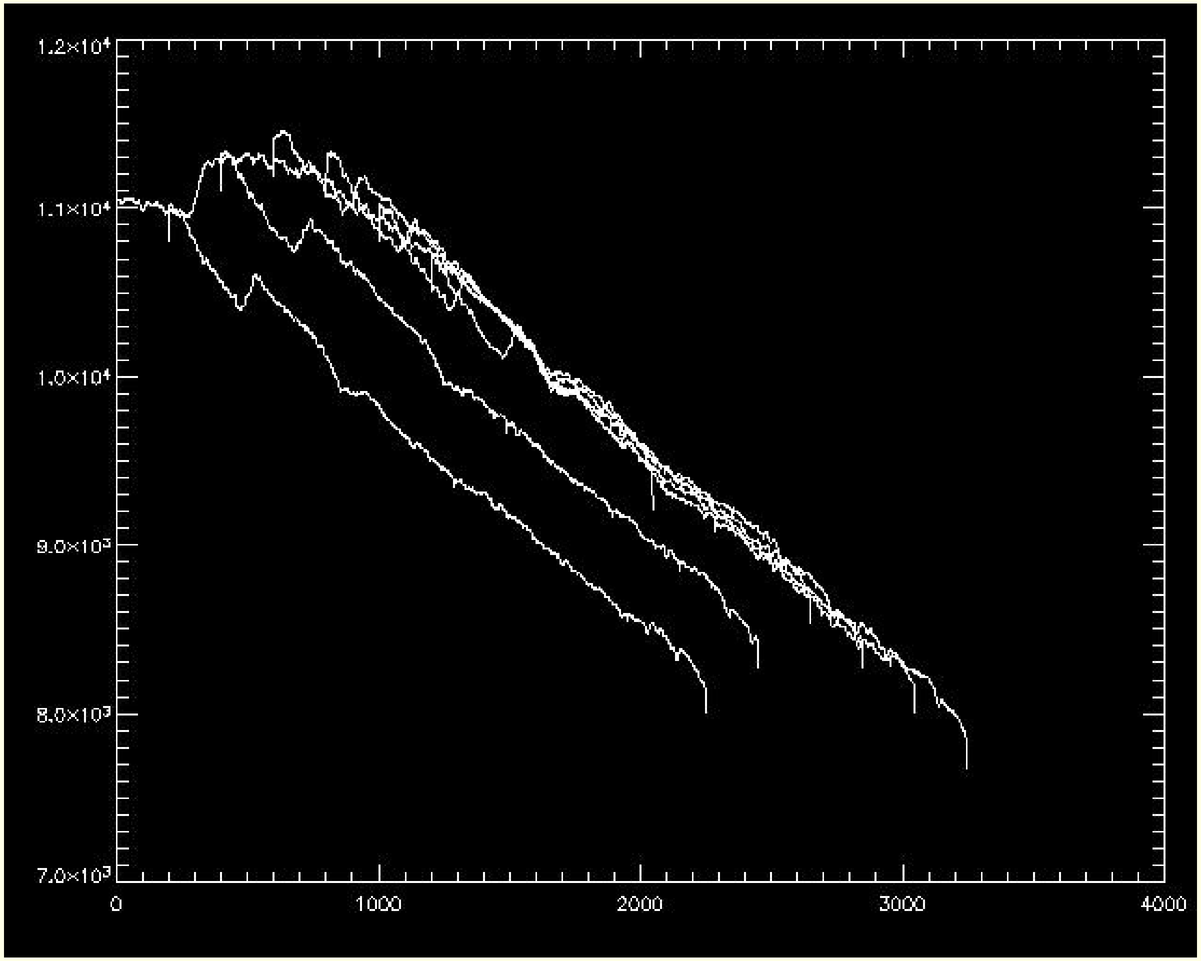
The Setup

The Data

Data often leaves something to be desired. . .

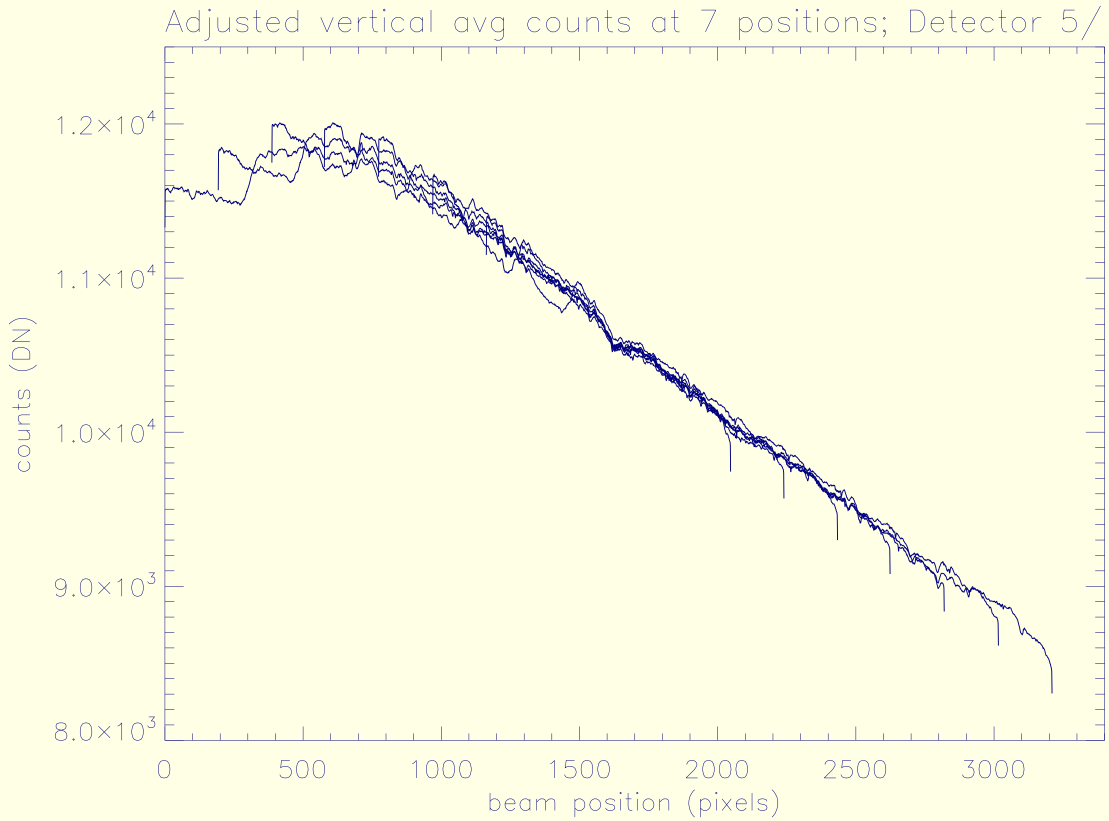


The Data



The Data

Adjust the total intensity of each image to scale with the first and each succeeding image in regions where they overlap.



The Algorithm

- The data is a product of the flat-field and a section of the beam: $I_n = B_n Q + \eta$ with $B_n = B(\tau_n : \Delta + \tau_n)$

1. start with a uniform flat-field Q
2. Let $B_n = \frac{I_n}{Q}$
3. Combine the B_n into one continuous beam by averaging over the overlapping regions.
4. Smooth B with a Gaussian fourier domain windowing function of width $\sigma' = \sigma\chi^2$

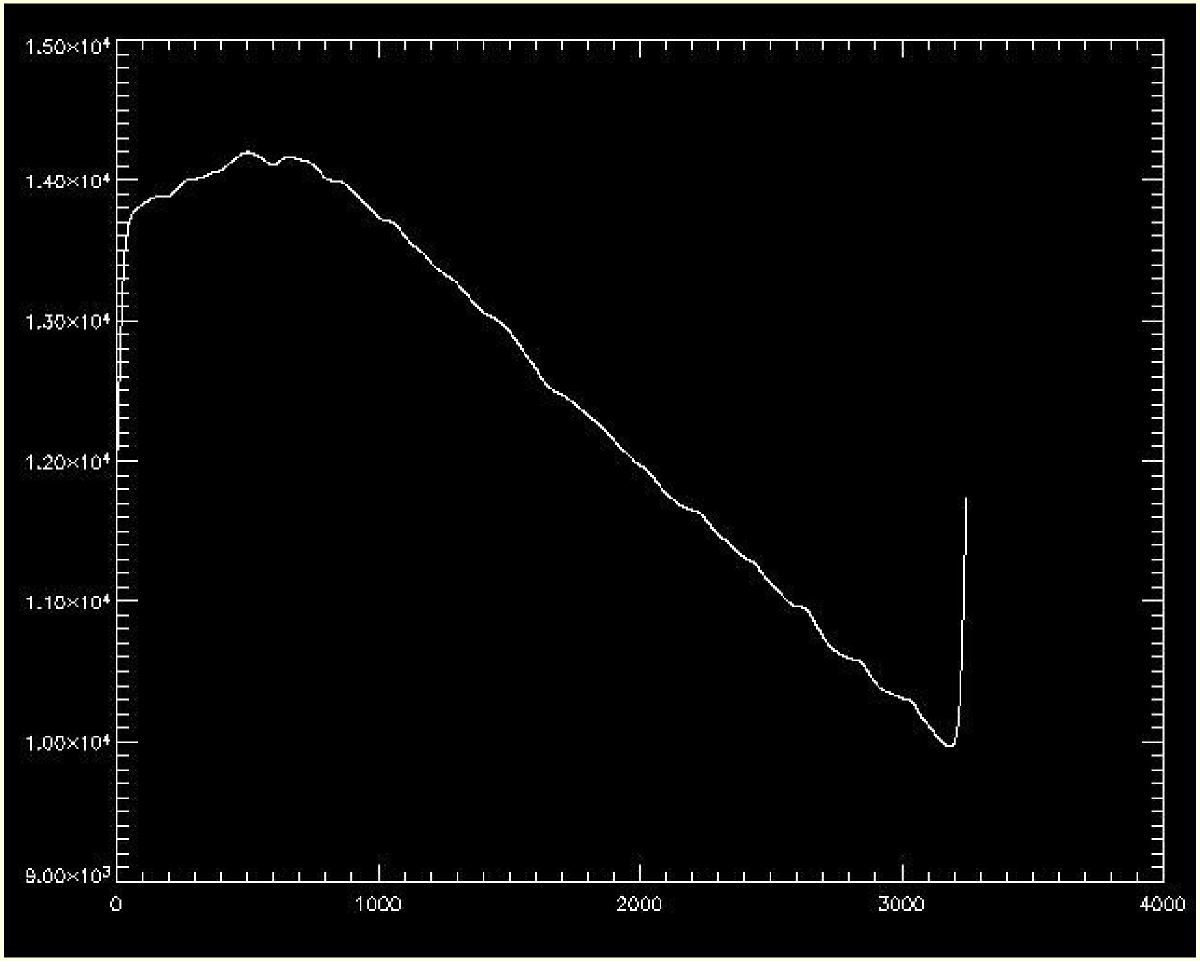
The Algorithm

5. Let $Q_n = \frac{I_n}{B_n}$. This will give multiple incompatible flat-fields.

6. $Q = < Q_n >$

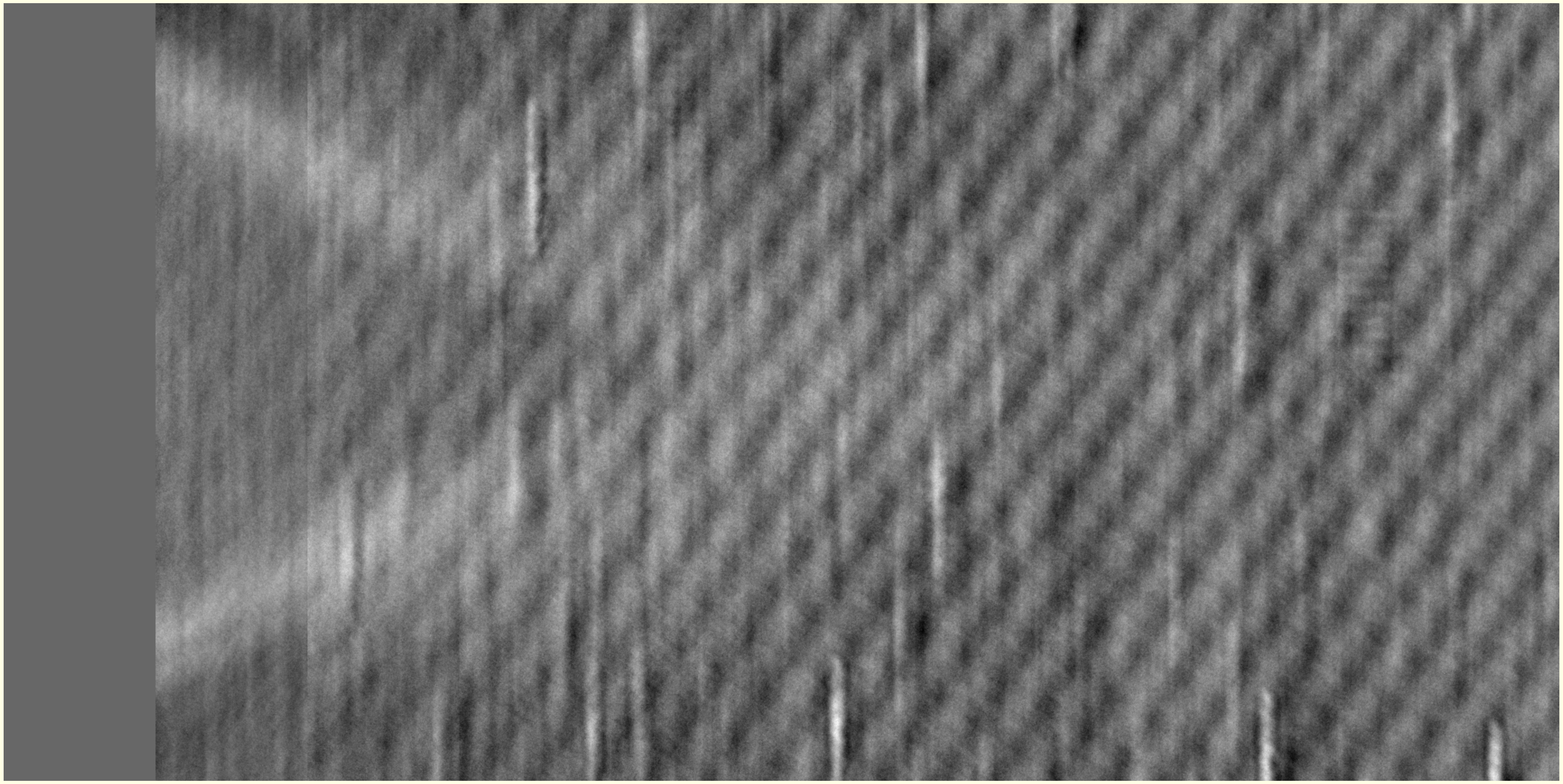
7. Repeat until χ^2 converges to something.

Watch out for Fourier



Detector 5

Detector 5



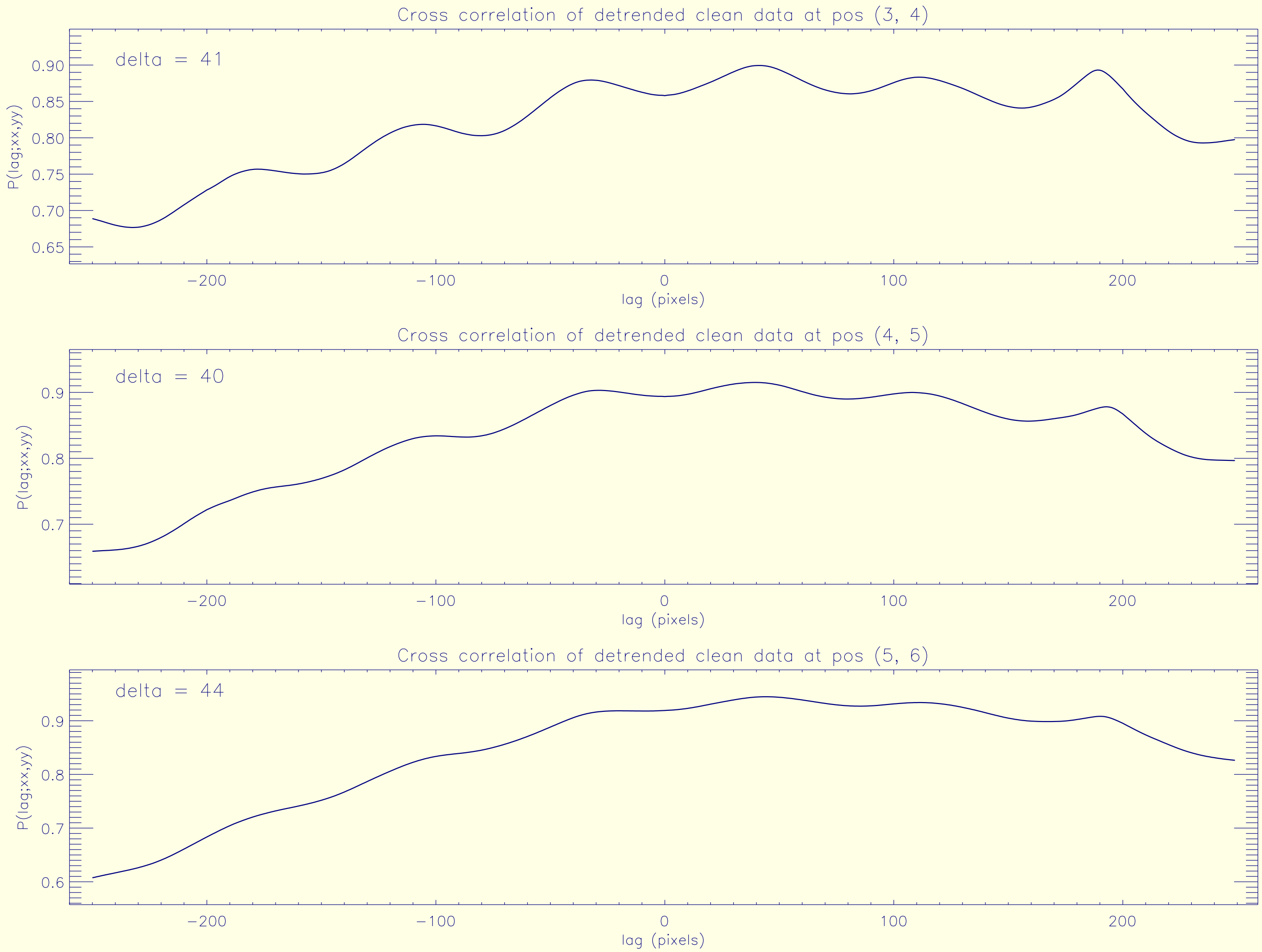
What's going on?

Take a close look and you see that the shift is not the constant 200 pixels it was supposed to be.

Try this:

- Cross-correlate one image with the next one and see where the peaks are.
- First flat-field the data with what we already have, then detrend it.

Cross-correlation

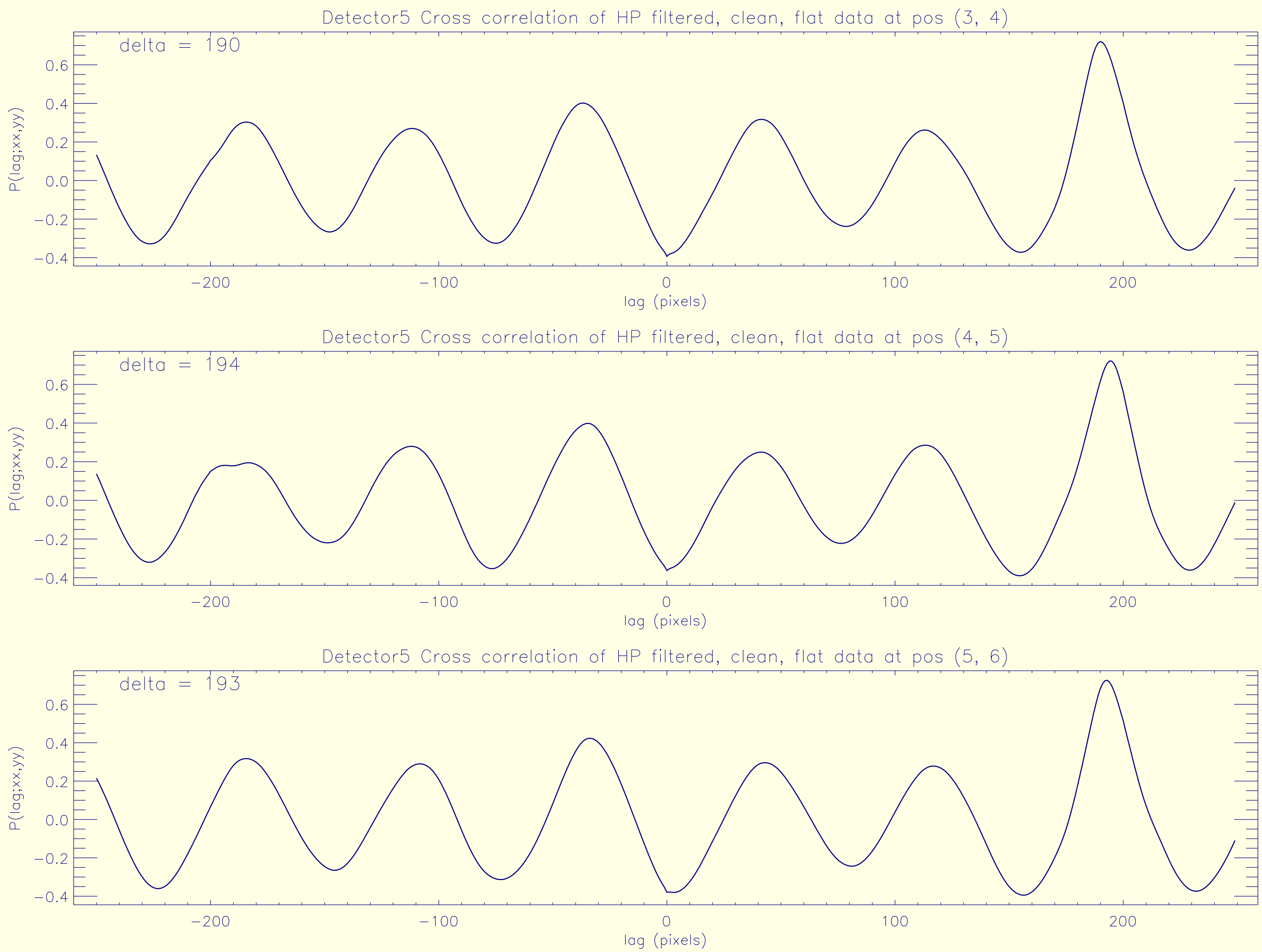


Cross-correlation

Not quite. . .

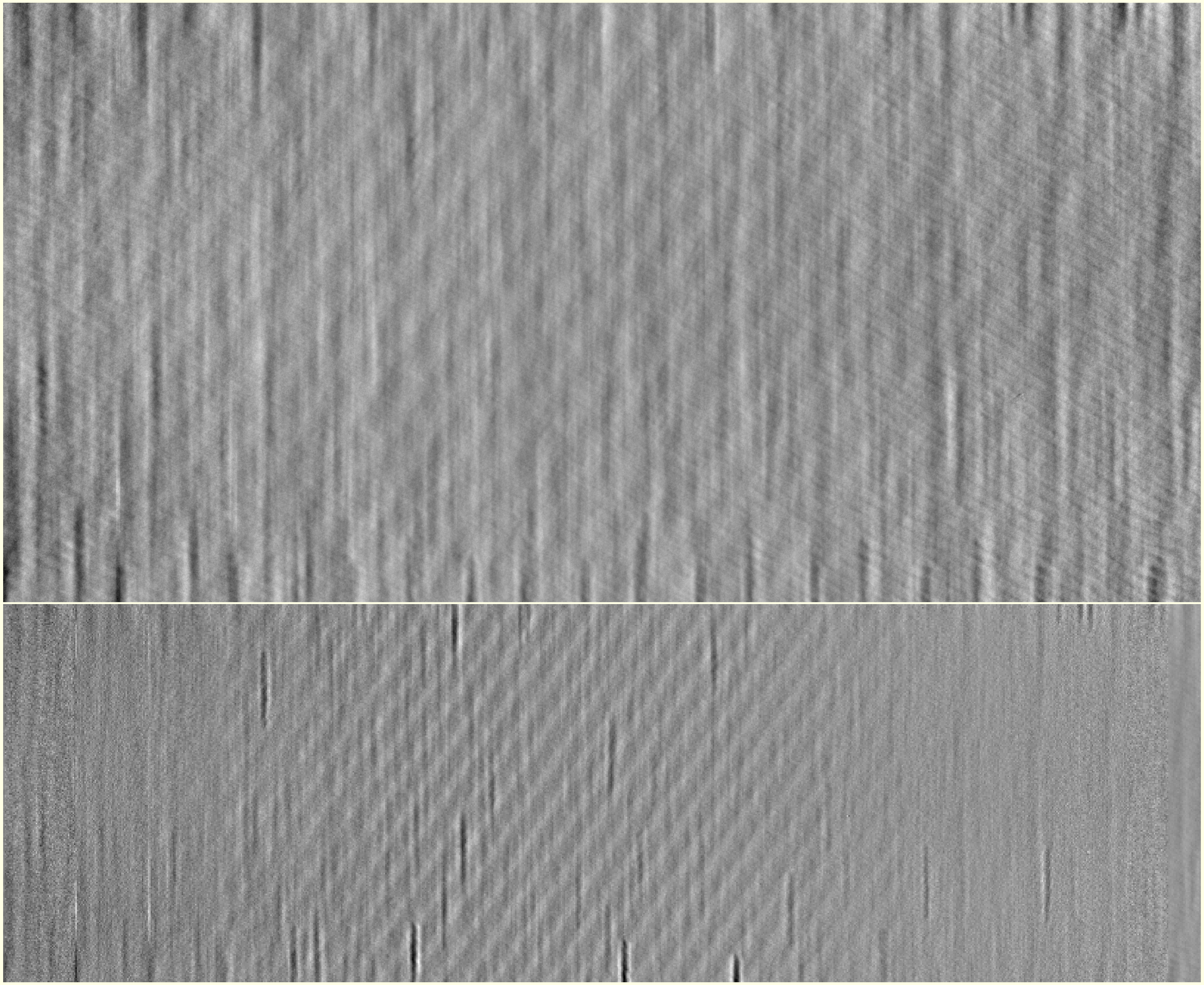
Use our fourier filtering technique but make it a high pass filter to remove the large scale beam features.

Cross-correlation

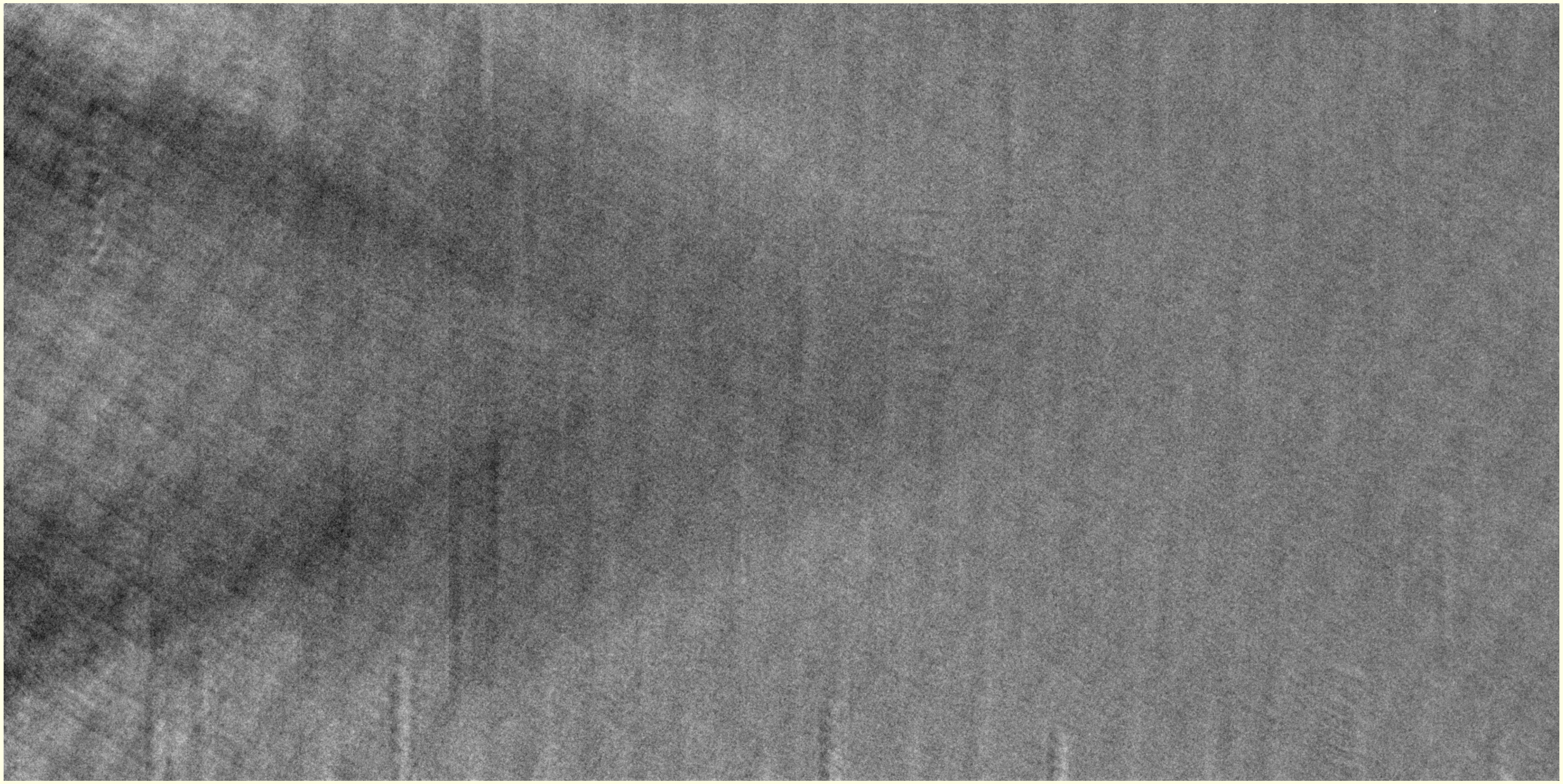


Now redo the analysis

The difference



Now the residuals. . .



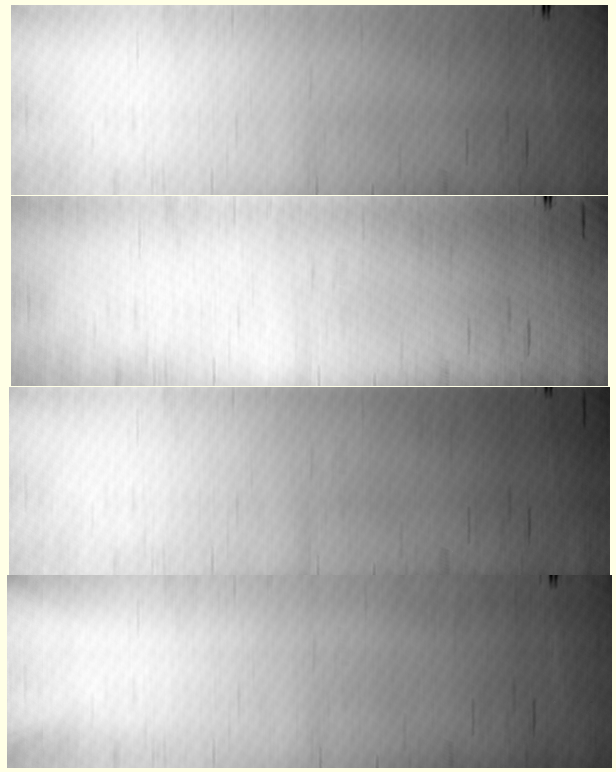
The end result

Detector 1

Detector 2

Detector 4

Detector 5



Acknowledgements

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