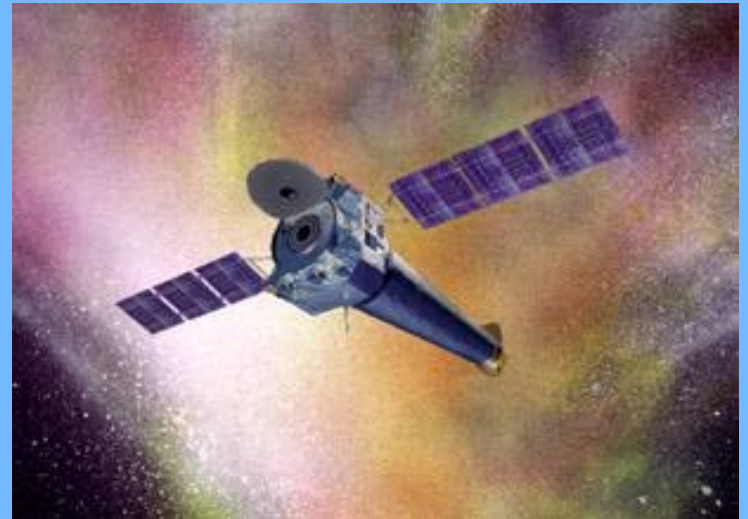


Non-linearities in the HRC-S detector

Strong emission lines in LETG/HRC-S Capella observations used to map irregularities

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Non-linearities in the HRC-S detector



Wavelength calibration



Capella:

optimally suited for the wavelength calibration of the Chandra Low Energy Transmission Grating Spectrometer (LETGS)

- spectrum has strong, separated emission lines.
- binary system at 12.9 pc
- G8 and G1 star with about equal X-ray flux
- angular distance (<57 mas) not resolved with Chandra
- known low radial velocity (30 km/s)

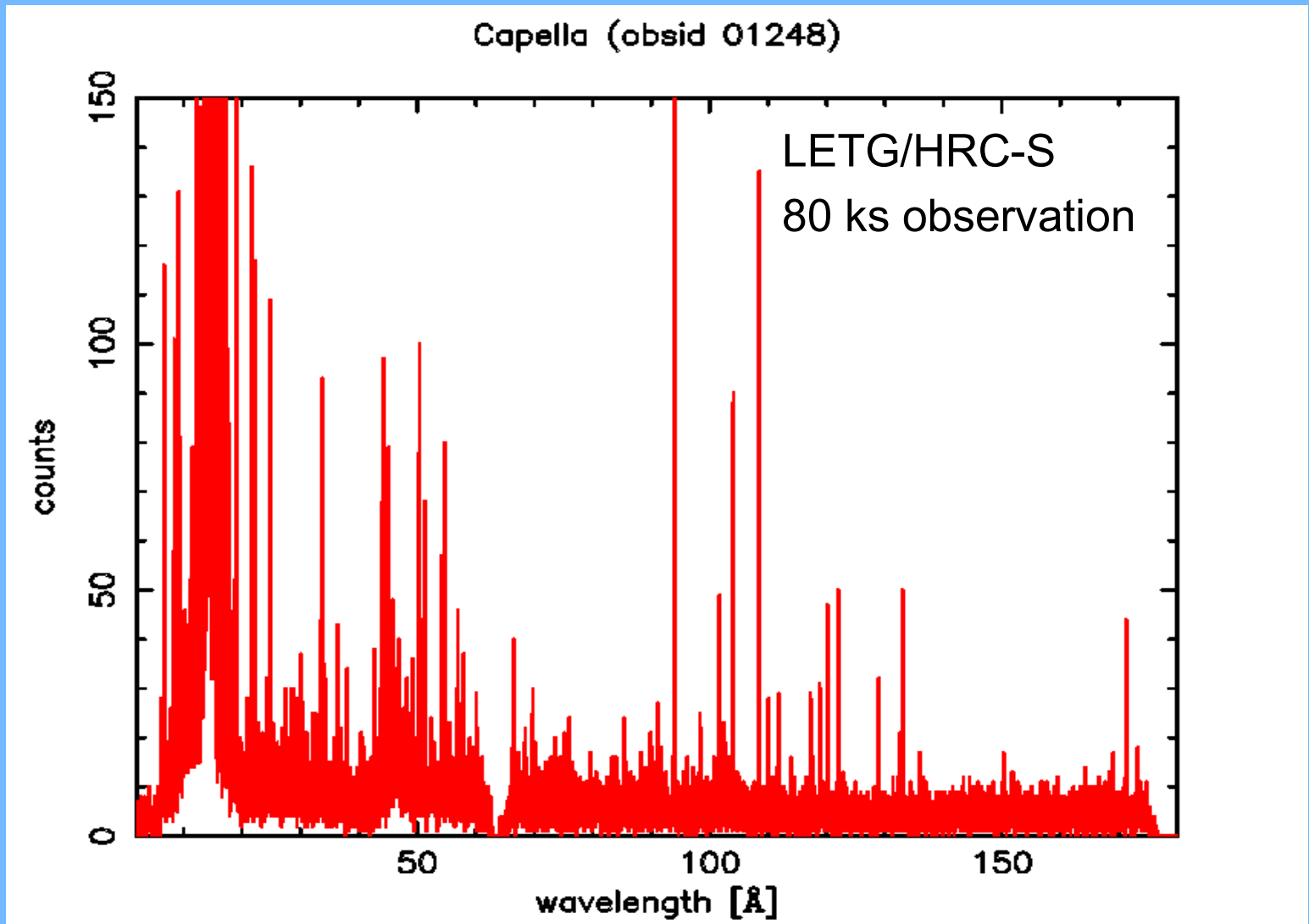
Non-linearities in the HRC-S detector



Wavelength calibration



This spectrum is only to show you what the spectrum looks like.



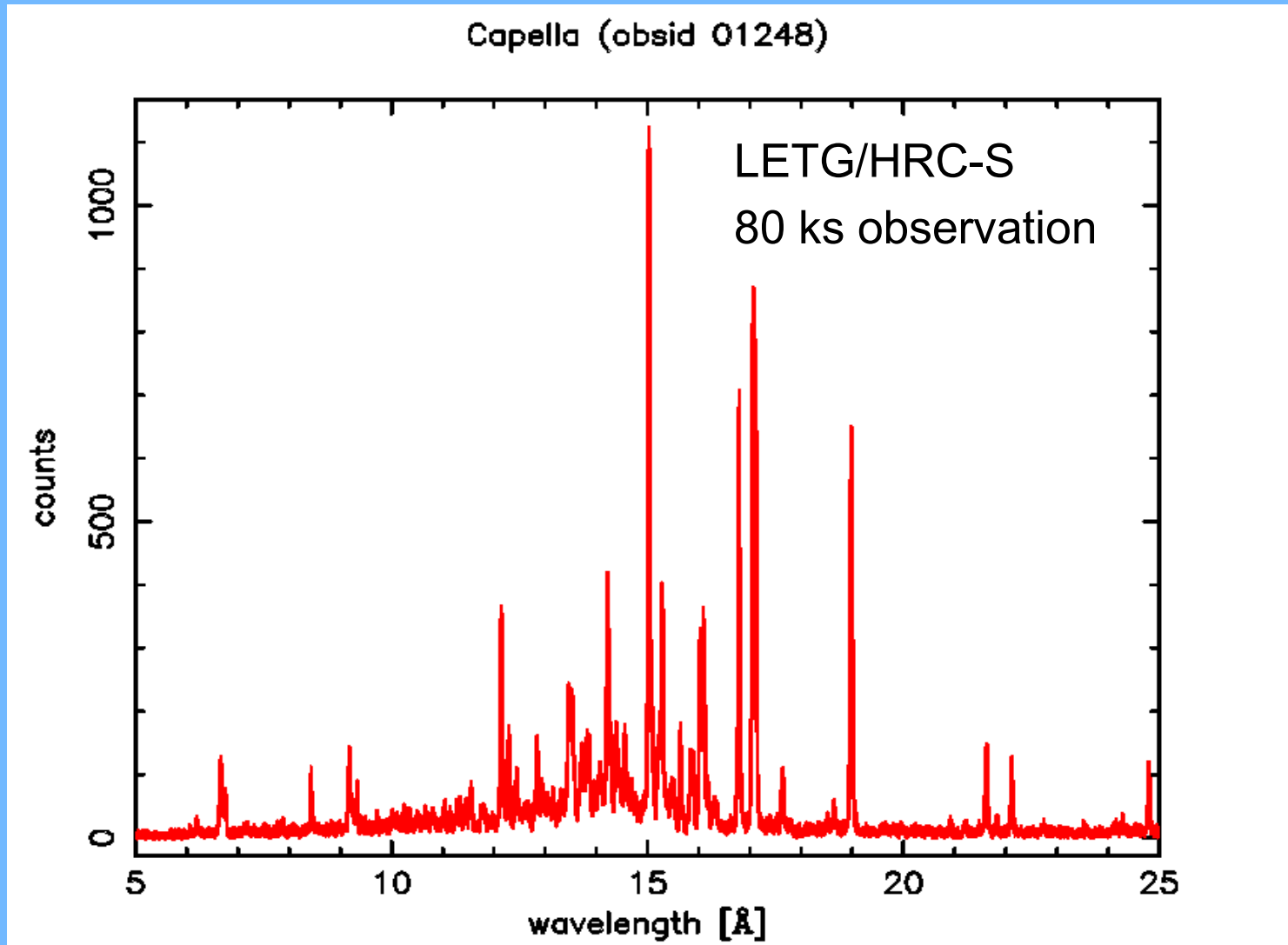
Non-linearities in the HRC-S detector



Wavelength calibration



This is a blow-up of the region with the strongest emission lines.



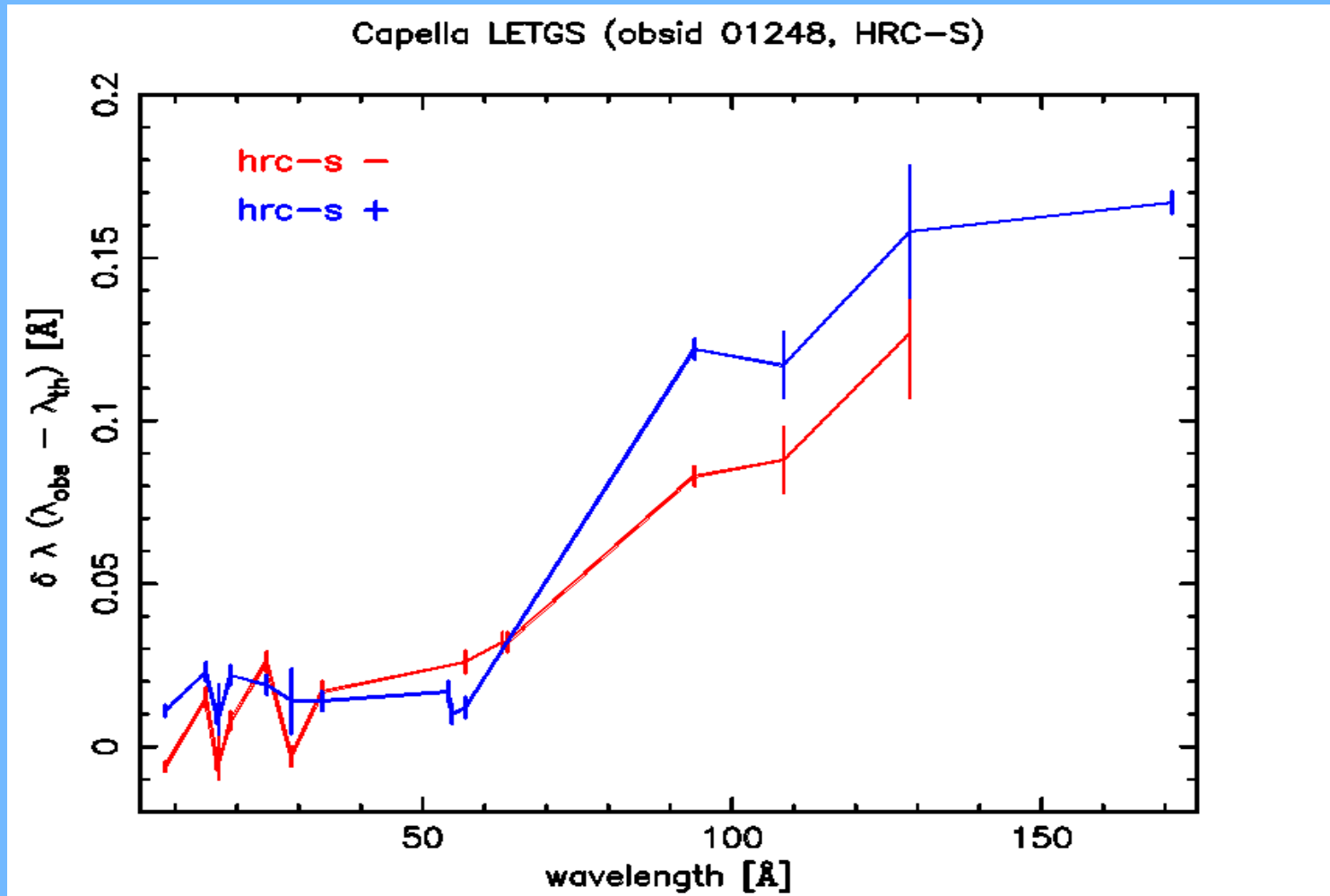
Non-linearities in the HRC-S detector



Wavelength calibration



This figure shows the observed line position minus the theoretical/laboratory wavelength



Non-linearities in the HRC-S detector

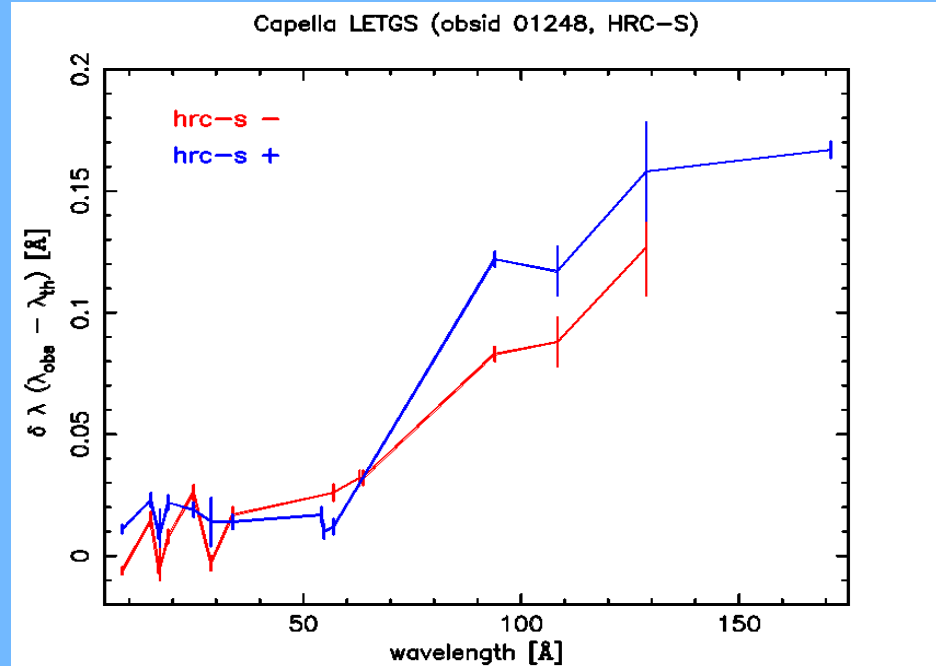


Wavelength calibration



Conclusions on the previous figure (also small below):

- above 55 Å, on the two outer detector plates, there is a linear trend in $\delta\lambda$ v.s. λ . This is caused partly by the wrong Rowland distance that is still in the reduction software and partly by an unknown bug in the software (Jeremy Drake at this conference).
- below 55 Å, the average $\delta\lambda$ is not 0 and the deviation is irregular.



Non-linearities in the HRC-S detector

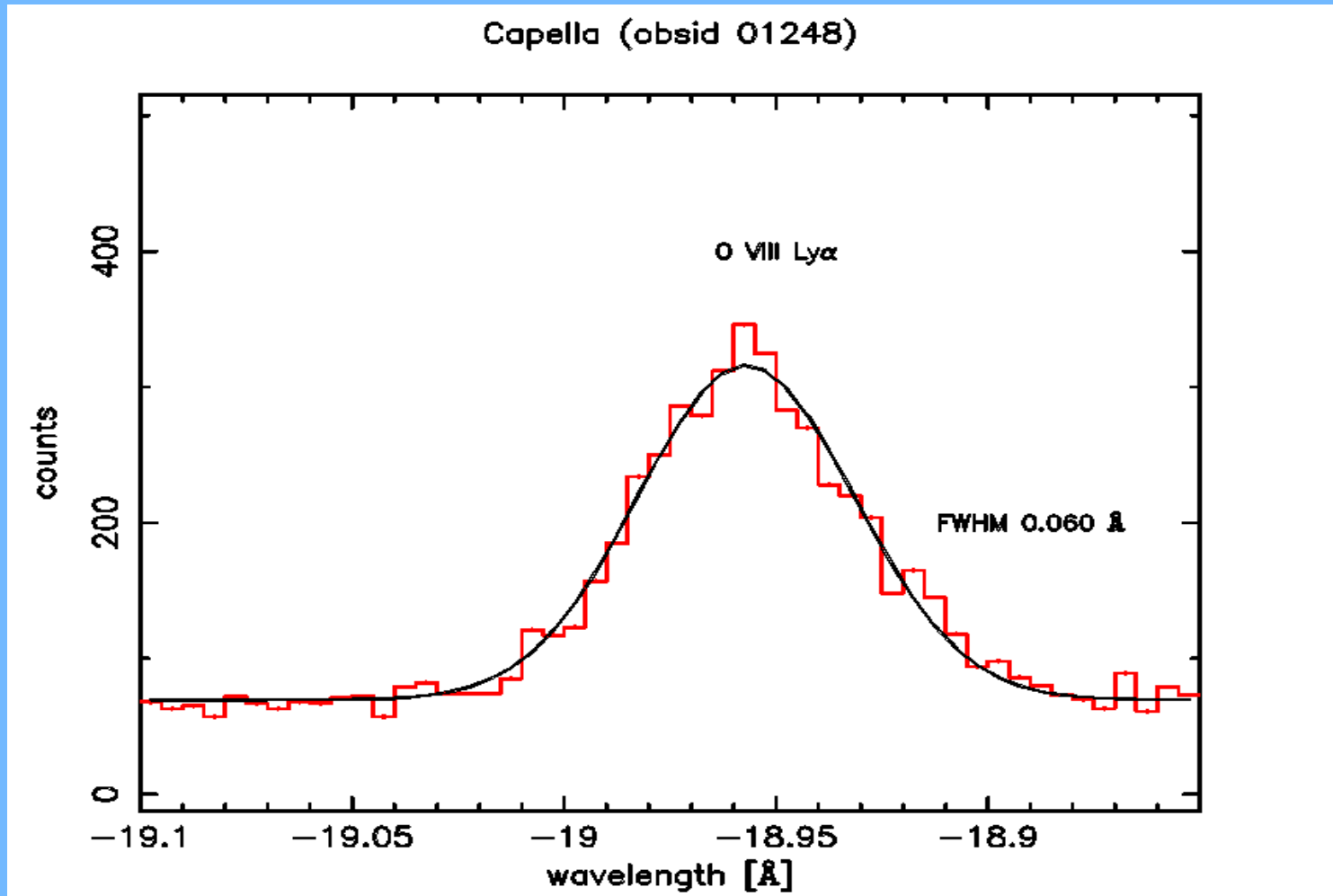


Line Spread Function

This is an example of a line that is too broad:

Isolated O VIII Ly α line: FWHM 0.06 Å.

Expected LSF FWHM < 0.05 Å



Non-linearities in the HRC-S detector



Line Spread Function



The wavelength in the previous figure was derived as 'tg_mlam' from the data with the data reduction software CIAO.

What might cause this widening?

- Mirror (HRMA)
- grating (LETG)
- detector (HRC-S)

We first looked at the detector (coordinates) to find clues for this widening.

- Chipy is the coordinate to look at.

Plot chipy versus tg_mlam:

What do you expect to see?

- On the large scale there should be a linear relation
- locally, for an emission line: tg_mlam should be 'independent' of chipy

Non-linearities in the HRC-S detector



Line Spread Function



The black dots represent the average value (with rms) in a small box around the emission line (box parameters explained later).

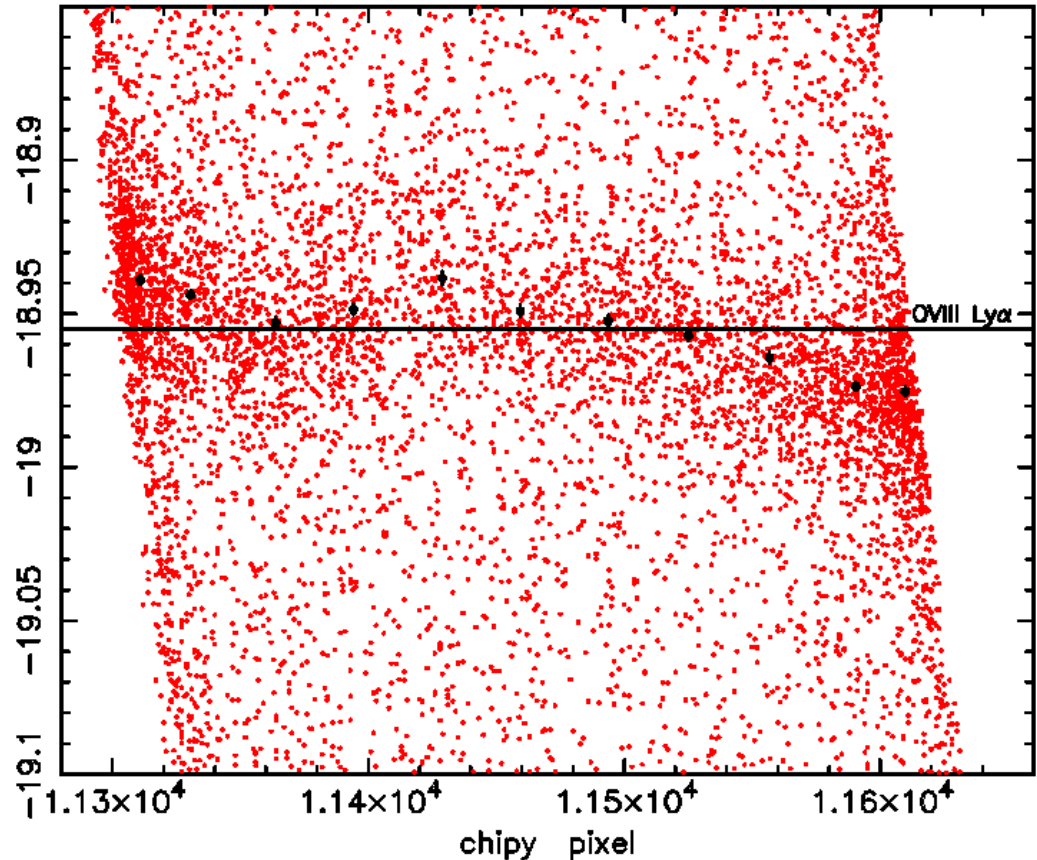
This is not what we expected to see.

The large scale linear relation is correct, but this emission line should look like a horizontal line in this plot.

The horizontal line is plotted to guide the eye.

How can this be explained?

Capella (obsid 01248)



Non-linearities in the HRC-S detector



Line Spread Function



It looks like the mapping from chipy coordinate to tg_mlam is not optimal due to irregularities in the chipy detector coordinates. The irregularities are consistent over a large area of the detector. The averages in the figure are taken over 32 chipy pixels.

Results from this previous figure:

- The averages show a spread of 35 mÅ in the OVIII Ly- α line.
- This 35 mÅ corresponds to ~ 5 HRC-S pixels.

Non-linearities in the HRC-S detector



Dithering pattern

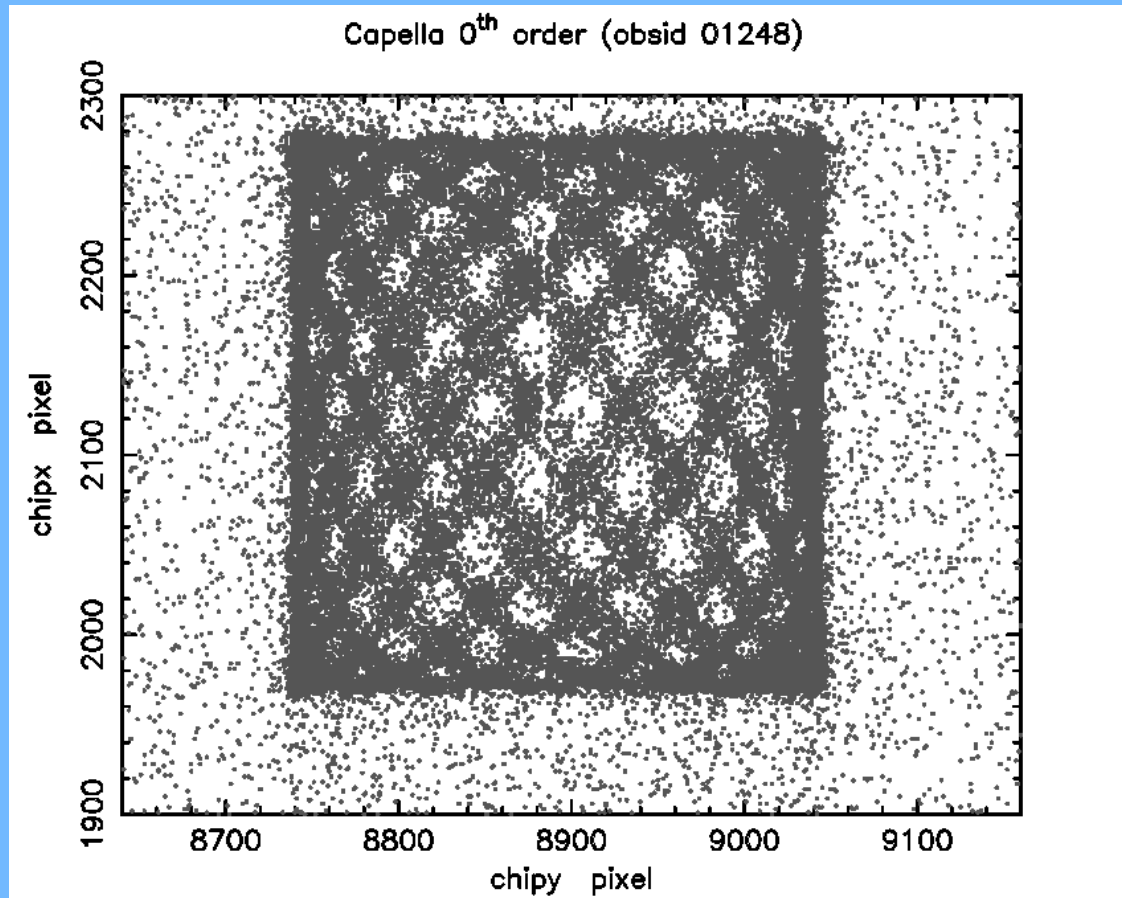


Given:

- The satellite is dithering over ~ 350 pixels in chipy coordinate.
- This is equivalent to about 2.5 \AA in wavelength.

Satellite dithering allows us to sample different parts of the detector.

In this way we can determine the correction to the conversion from chipy to tg_mlam.



Non-linearities in the HRC-S detector

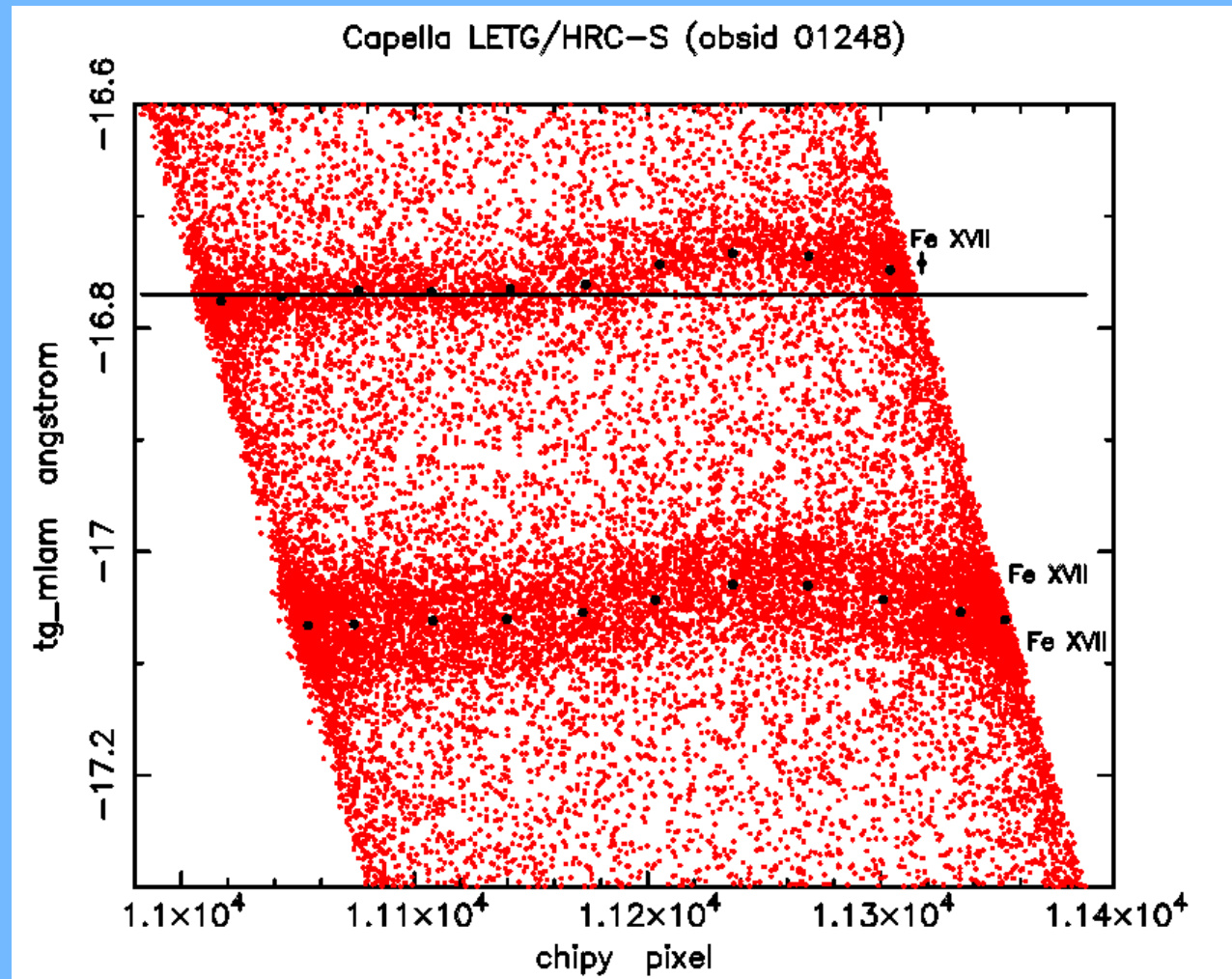
Chipy relation to wavelength



Overlapping lines help map the detector as well.

The correction should be the same for equal chipy bins.

Blended lines can be used as well.



Non-linearities in the HRC-S detector

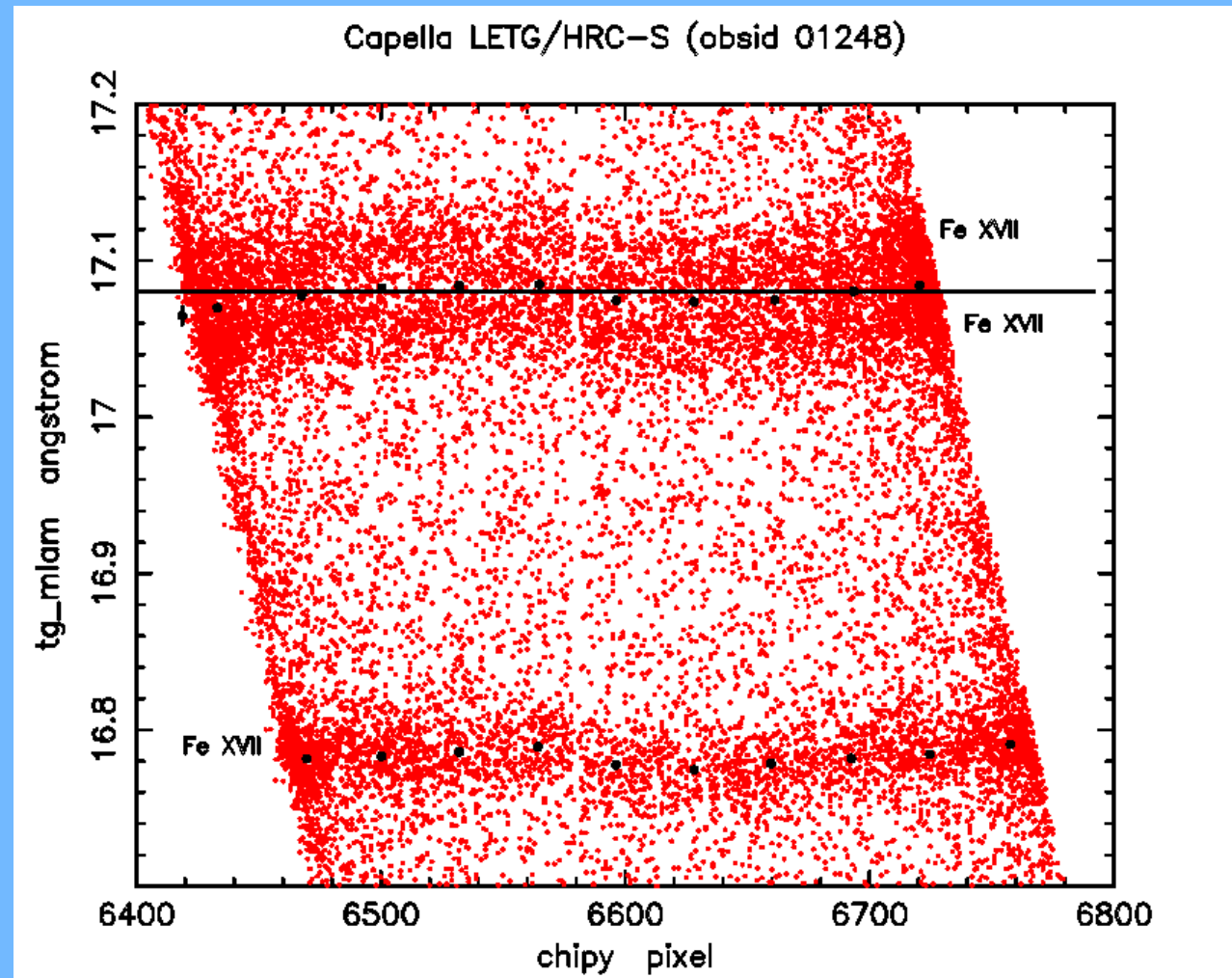


Chipy relation to wavelength



Another example with the positive orders

It looks like there is some connection with the tap position.



Non-linearities in the HRC-S detector



Chipy relation to wavelength



Analysis:

- Lines are not independent of chipy
- correction \sim equal in both lines

So what is causing this?

- Mirror (HRMA)
- grating (LETG)
- detector (HRC-S)

We do have a LETG/ACIS-S observation (obsid 00055)

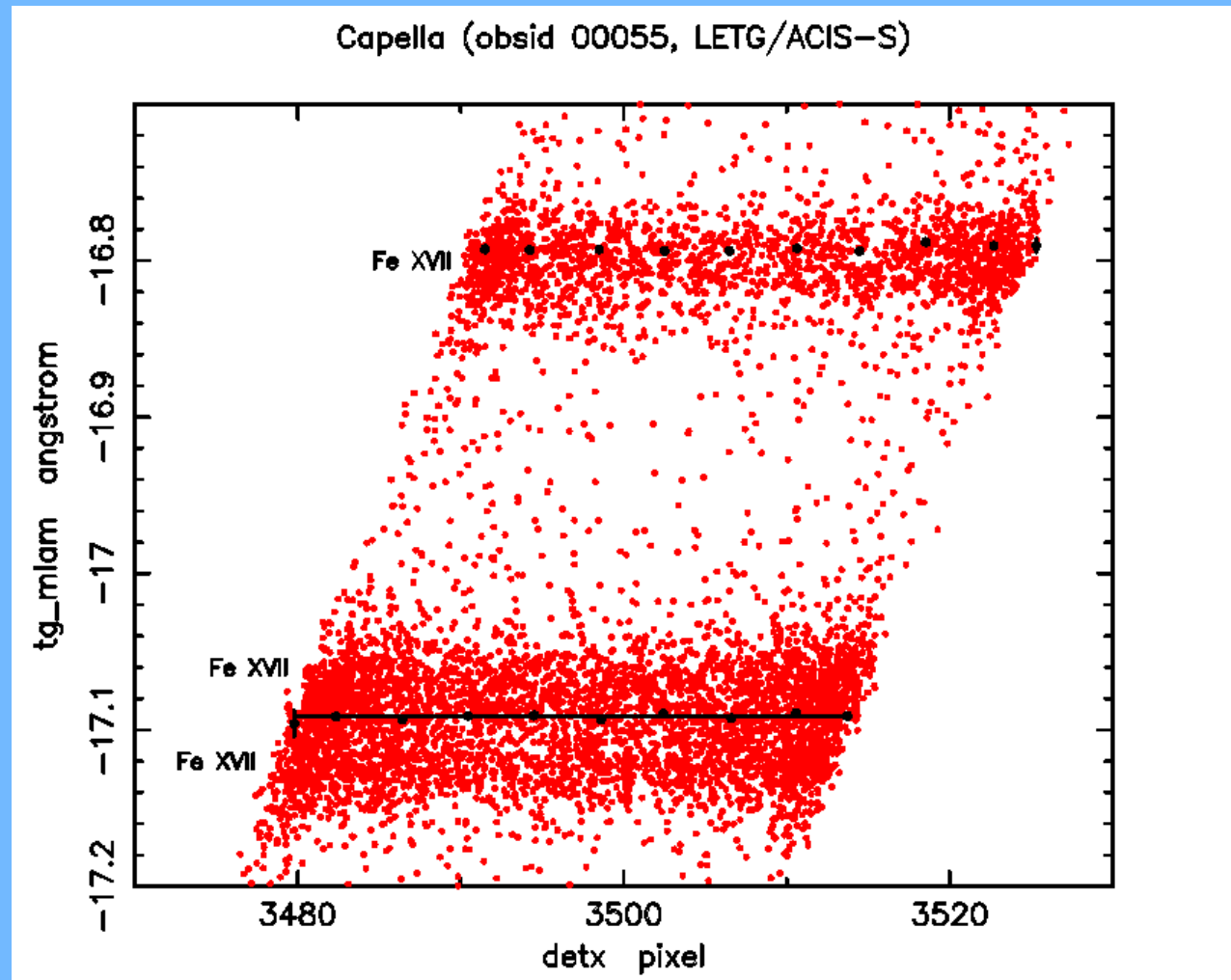
Non-linearities in the HRC-S detector

Chipy relation to wavelength



No significant effect in ACIS-S

Conclusion: The effect is caused by the HRC-S detector



Non-linearities in the HRC-S detector



Chipy correction method



Determining the correction

- take small region around emission line
- divide region in chipy bins
- locally correct skewness of bin (see next figure)
- determine average wavelength for each chipy bin
- solve complete set of equations with:
 - same line, same average wavelength
 - same chipy, same correction
 - some lines are well known wavelength, so fixed average
 - some lines free average wavelength (e.g. blends)

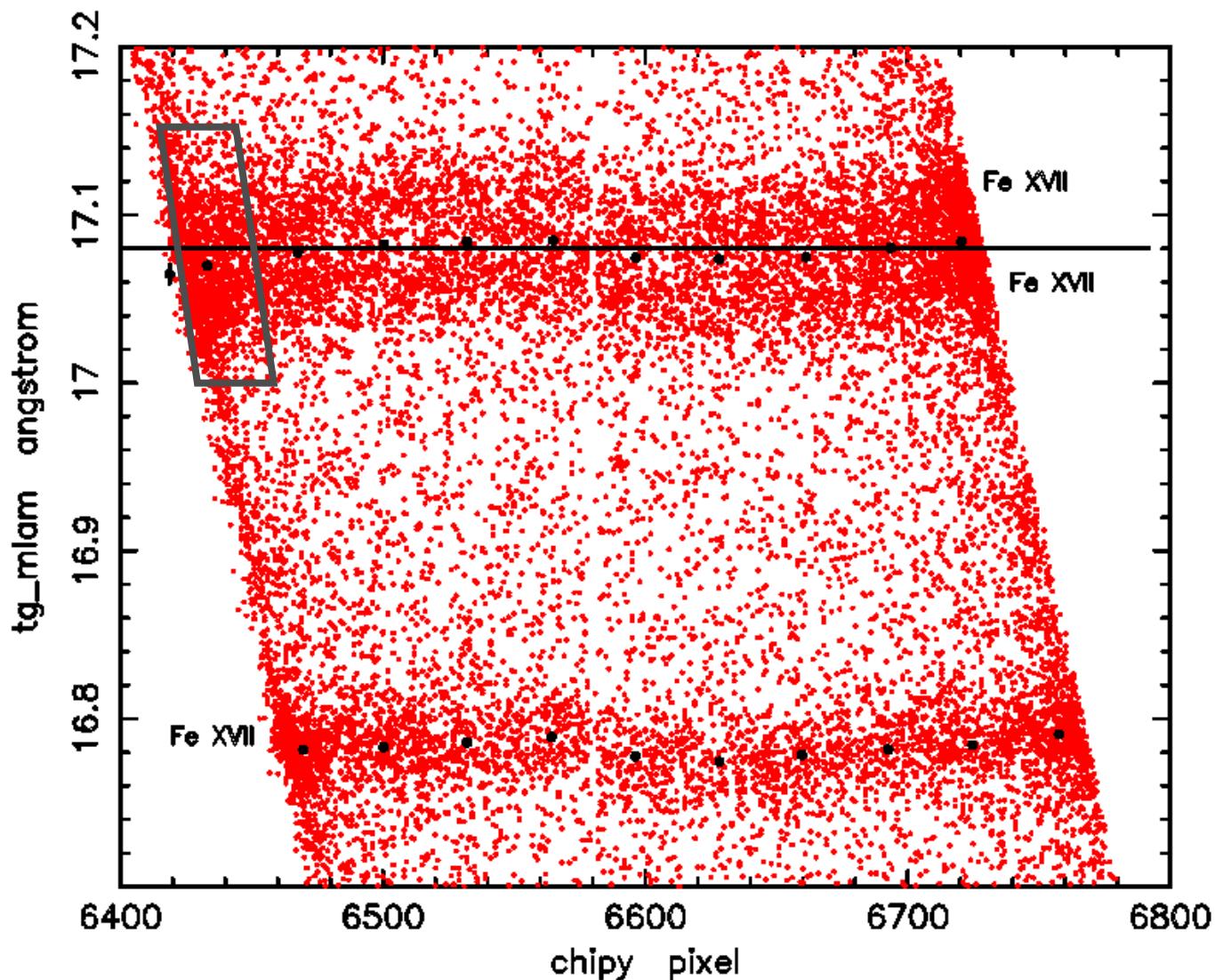


Non-linearities in the HRC-S detector

Chipy correction method



Capella LETG/HRC-S (obsid 01248)



Non-linearities in the HRC-S detector



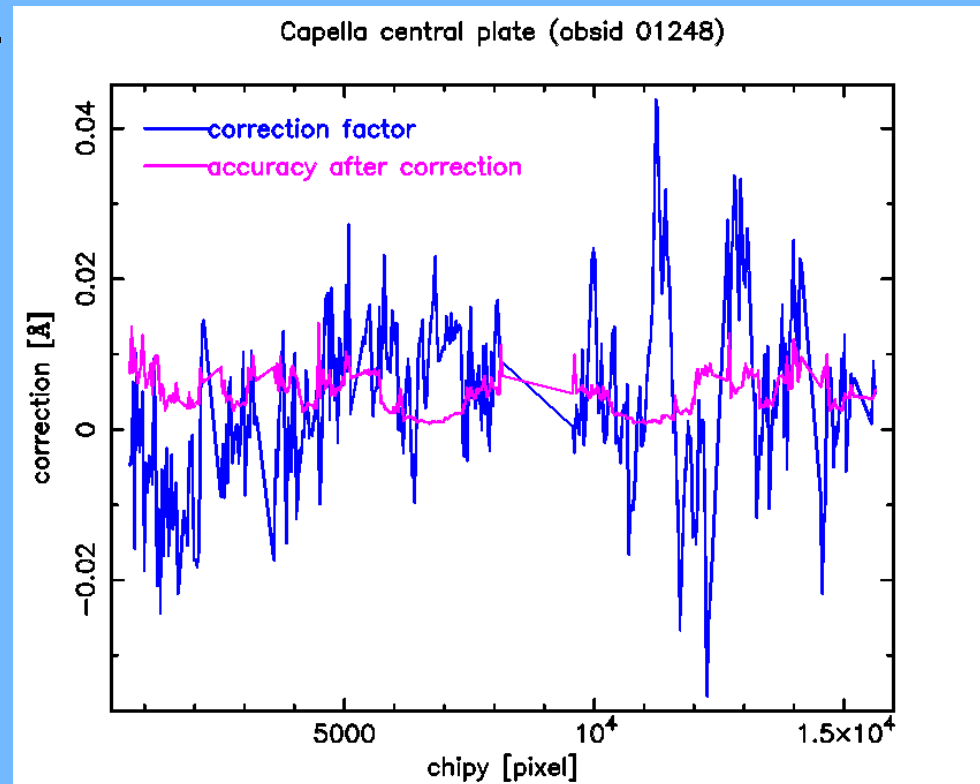
Chipy correction



The correction factor and the accuracy are given in this figure. This is based on all the lines on the central detector plate, so from -55 to $+55$ Å.

The corrections go up to 40 mÅ.

The accuracy after correction is given only by the statistical error on the correction.



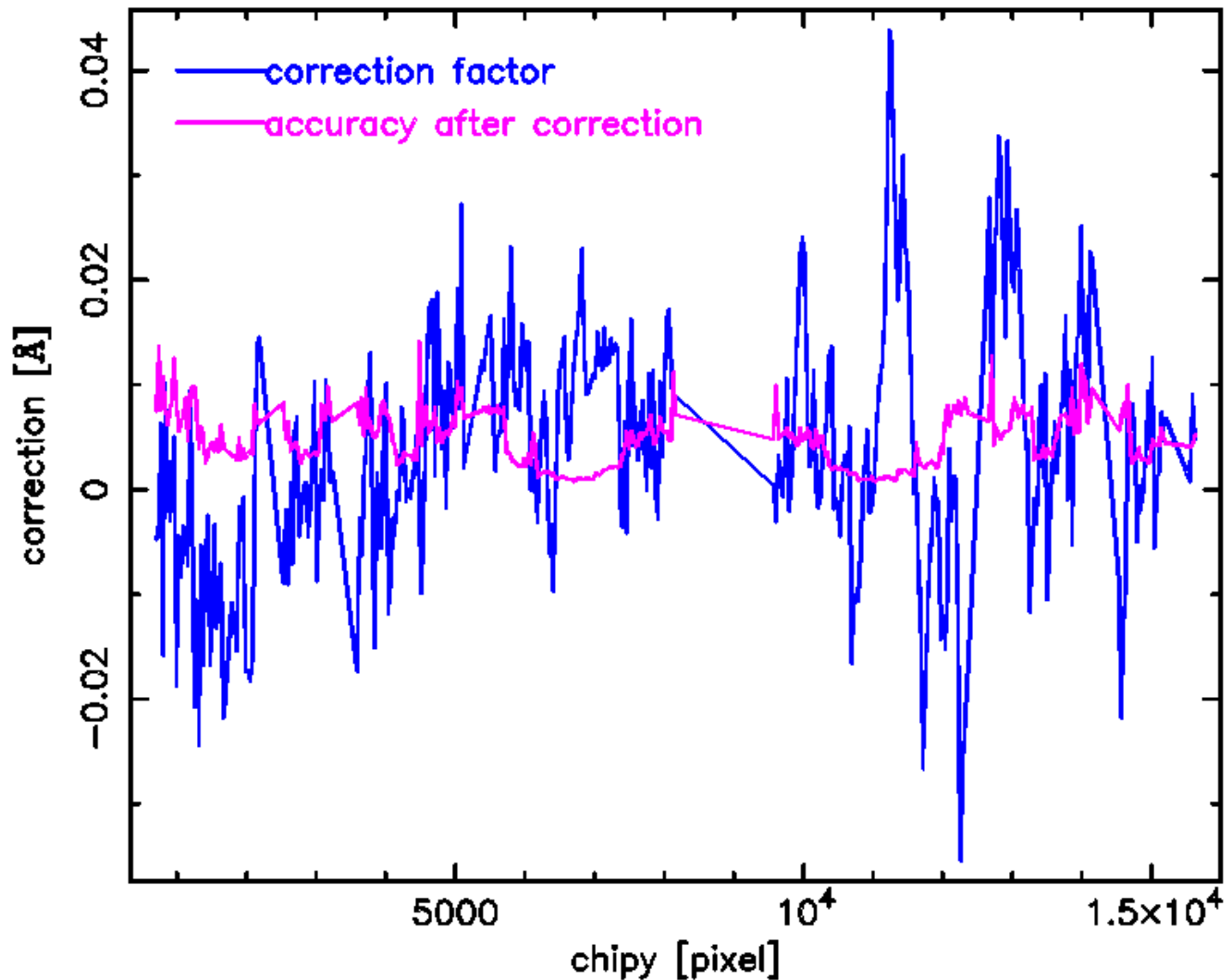
Larger figure on next page

Non-linearities in the HRC-S detector

Chipy correction



Capella central plate (obsid 01248)

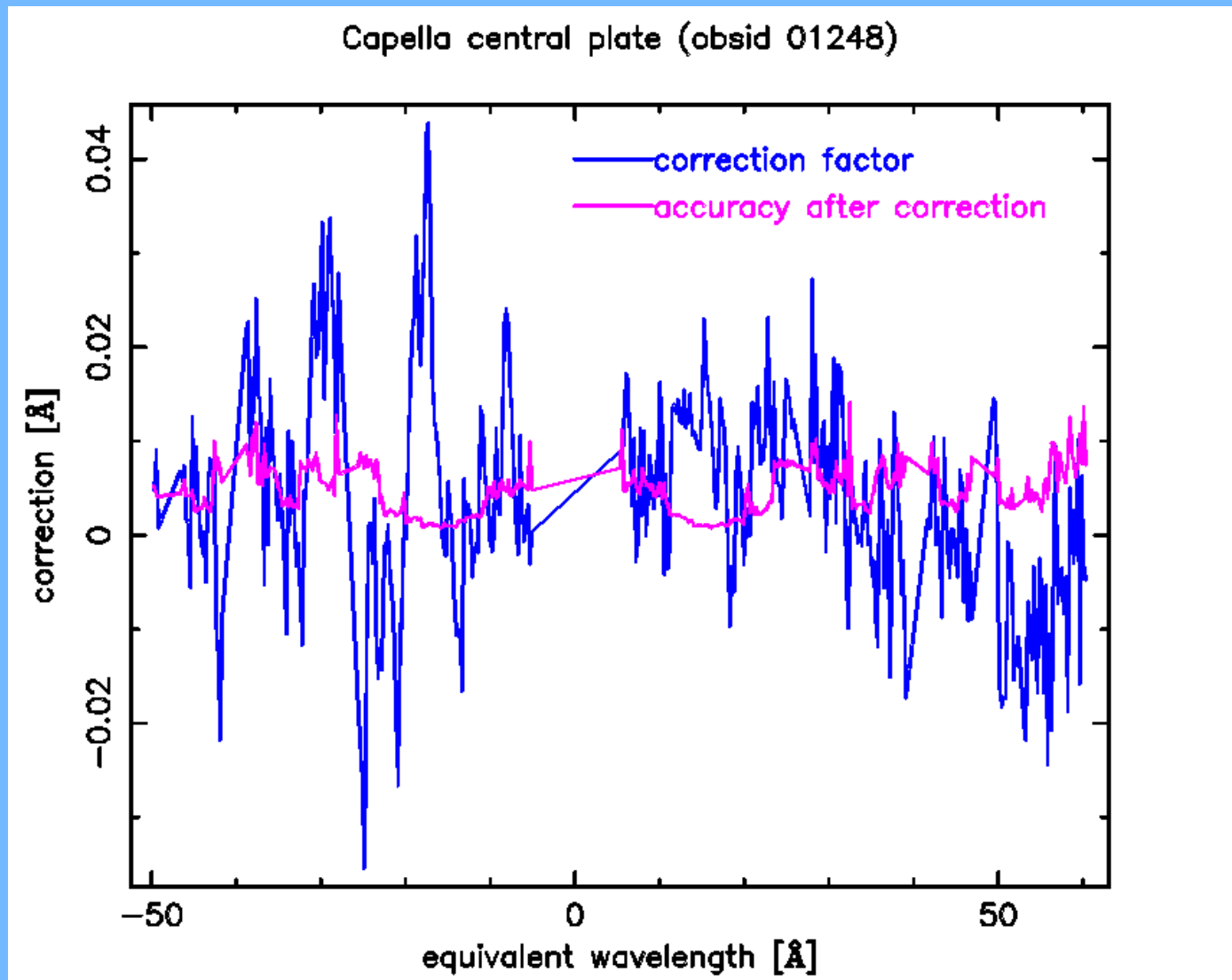


Non-linearities in the HRC-S detector



Chipy correction

The correction factor here versus wavelength.



Non-linearities in the HRC-S detector



Chipy correction



Correction based on one observation, one pointing of 80 ks.

Multiple pointings would enlarge coverage:

October 4 and 6 2002 two observations with offset pointing (obsid 02585 and 03479) on either side of first observation of 30 ks each.

Assumption:

The corrections similar for equal chipy.

Non-linearities in the HRC-S detector

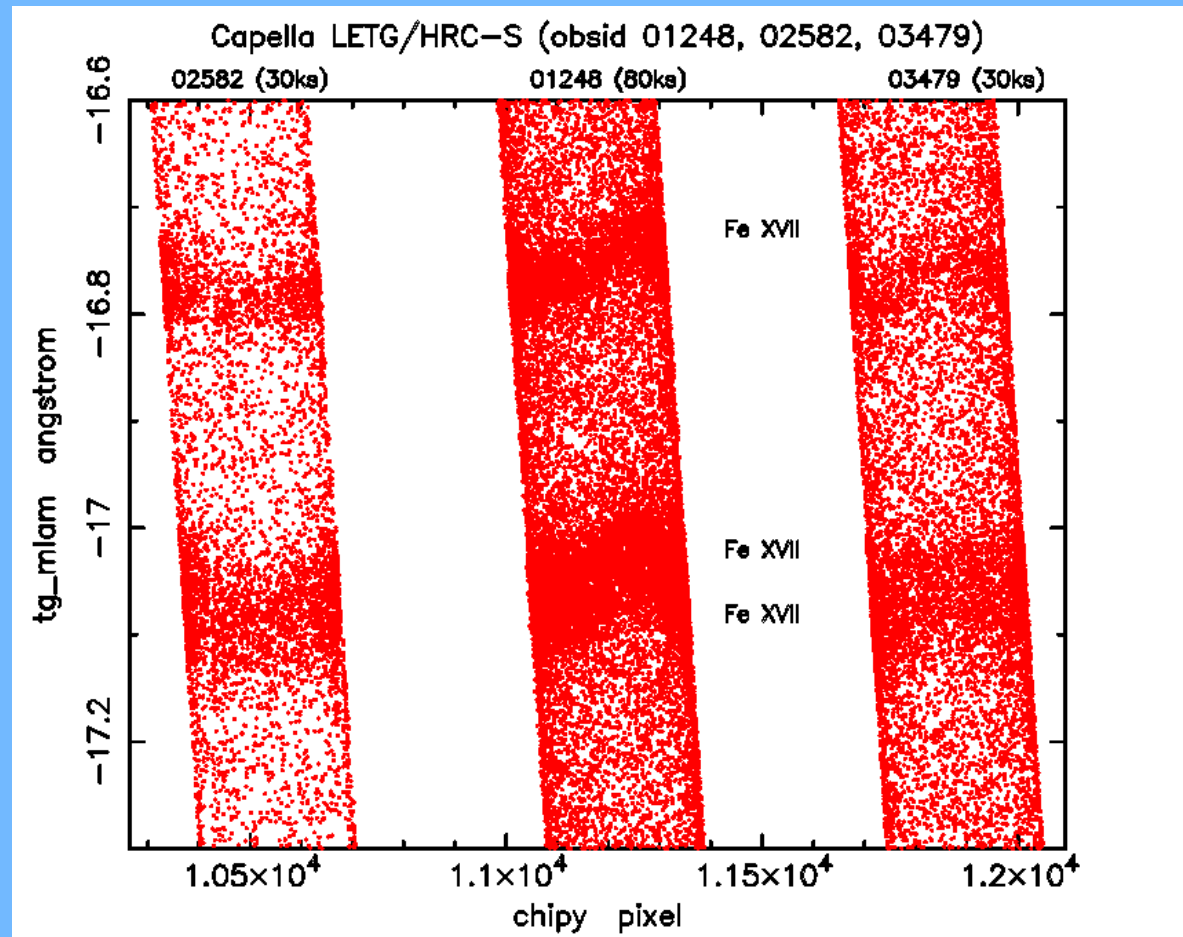


Chipy correction



Three pointings combined in one figure. One line now maps larger range in chipy.

One range in chipy is now covered by more lines.

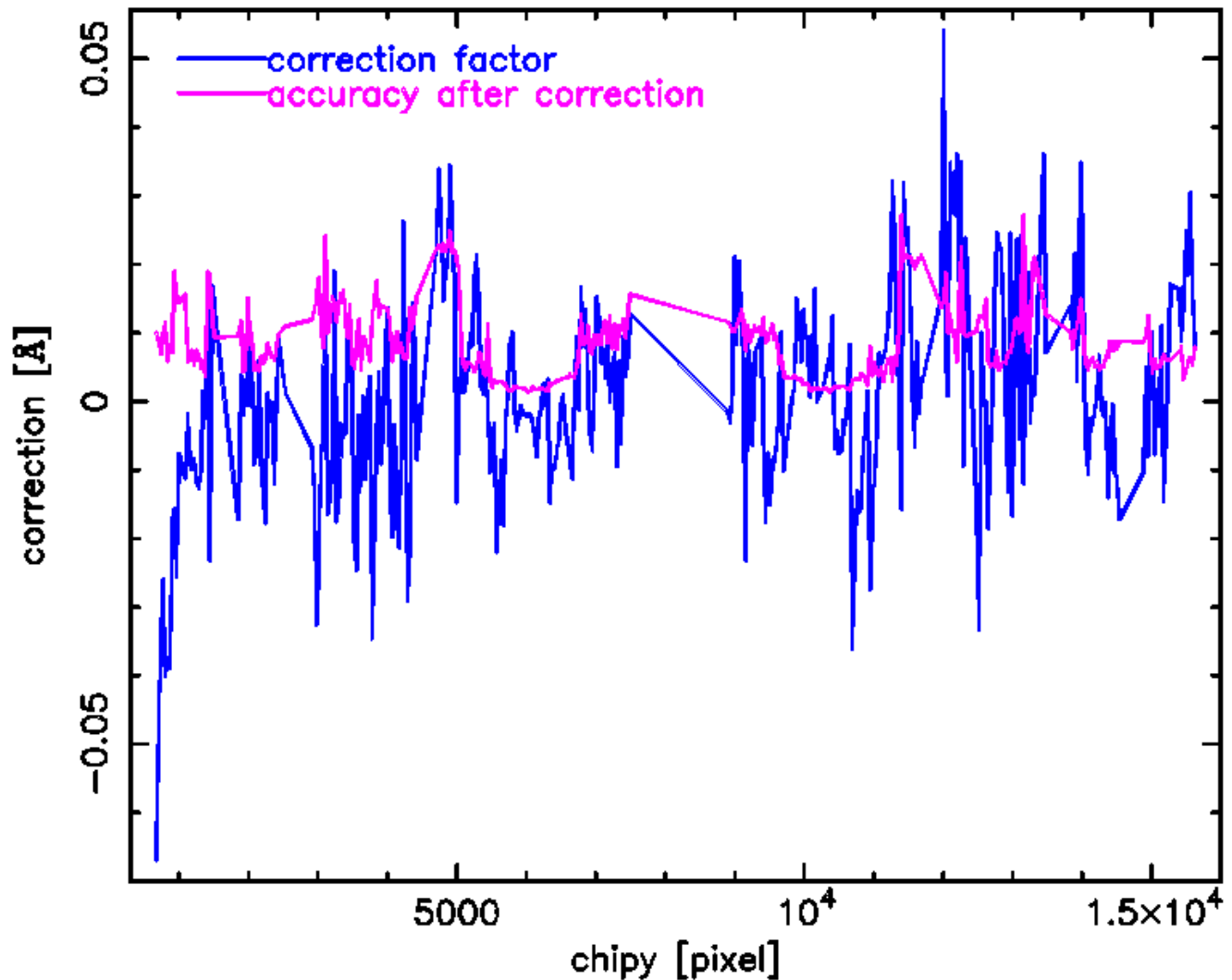


Non-linearities in the HRC-S detector

Chipy correction



Capella central plate (obsid 02582)

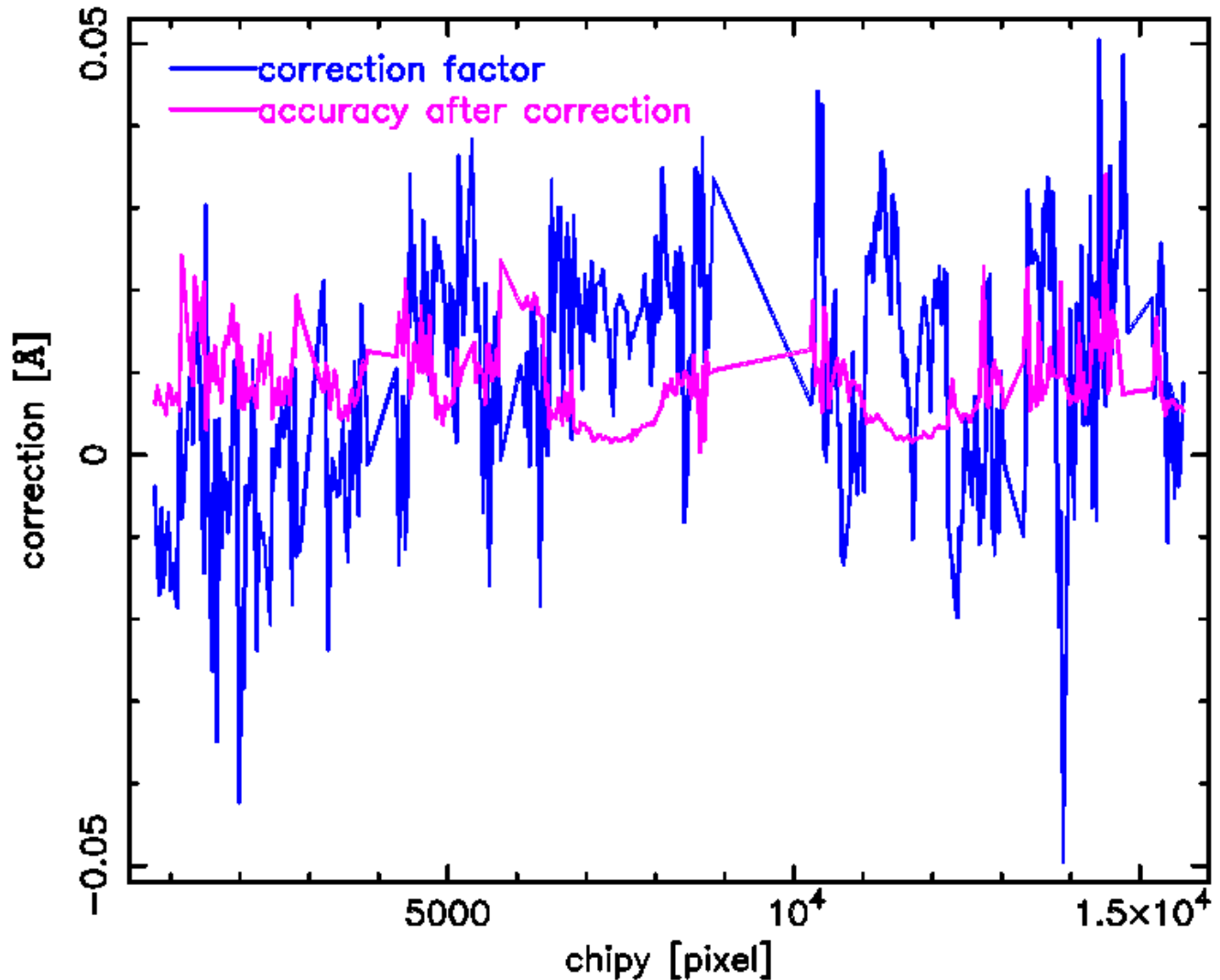


Non-linearities in the HRC-S detector

Chipy correction



Capella central plate (obsid 03479)



Non-linearities in the HRC-S detector



Conclusions

- We found that the plot of chipy versus tg_mlam shows irregularities.
- These irregularities seem to be caused by detector non-linearities.
- A correction for each observation is possible.
- We double checked with recent observations, but the investigation is still ongoing.
- wavelength accuracy improves to 0.003 Å around strong lines and 0.010 Å around weaker lines.
- Can we repeat and find the same corrections?
We do not have enough information to tell.