# The LETGS Dispersion Relation and the Accuracy of Chandra Velocity Studies


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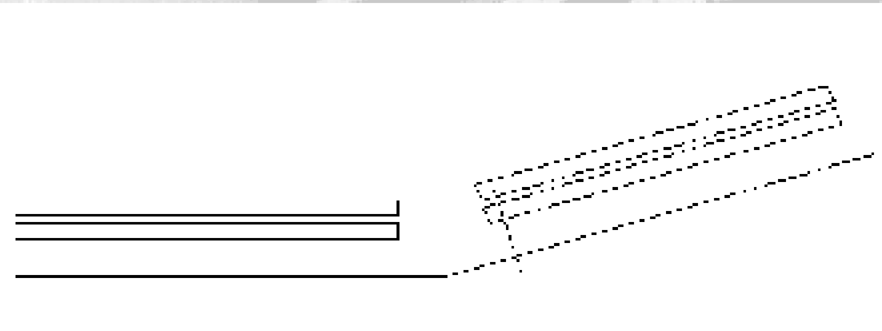
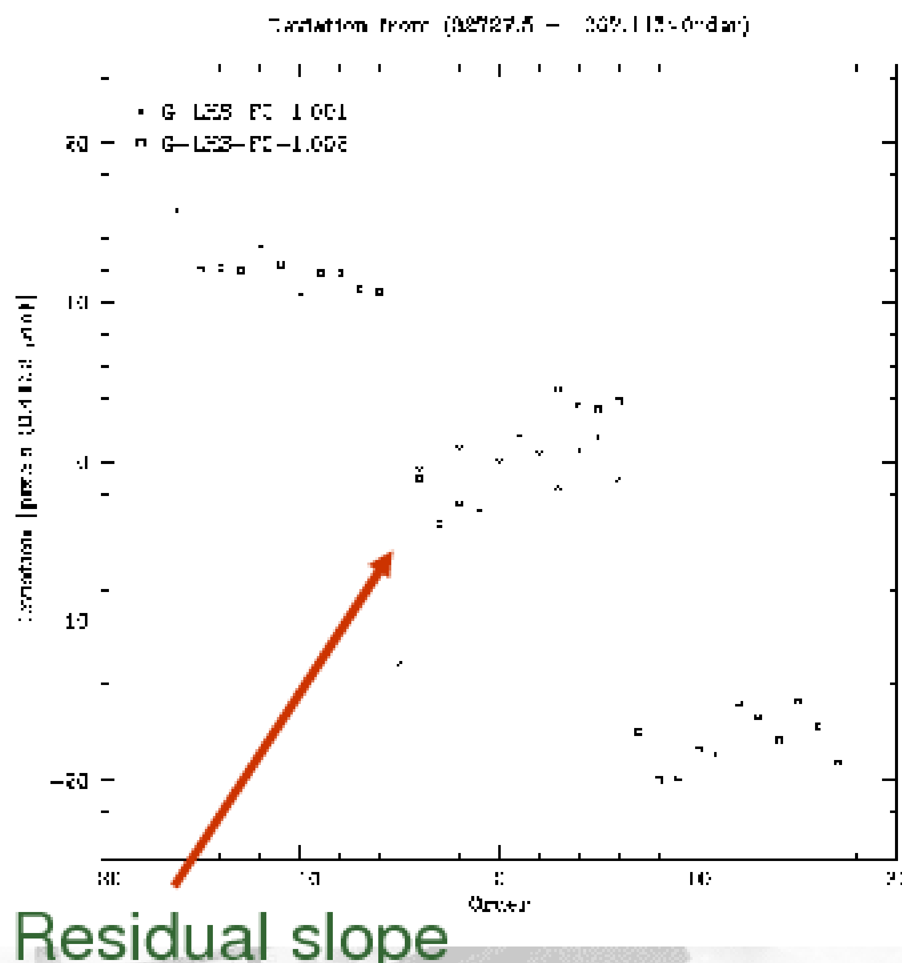
1. New plate gap calibration
2. Impact of empirical HRC-S degap on dispersion relation non-linearities
3. How accurately can we measure velocities with Chandra gratings?
   - HETGS examples

# XRCF Plate Gap Calibration (M.Juda)

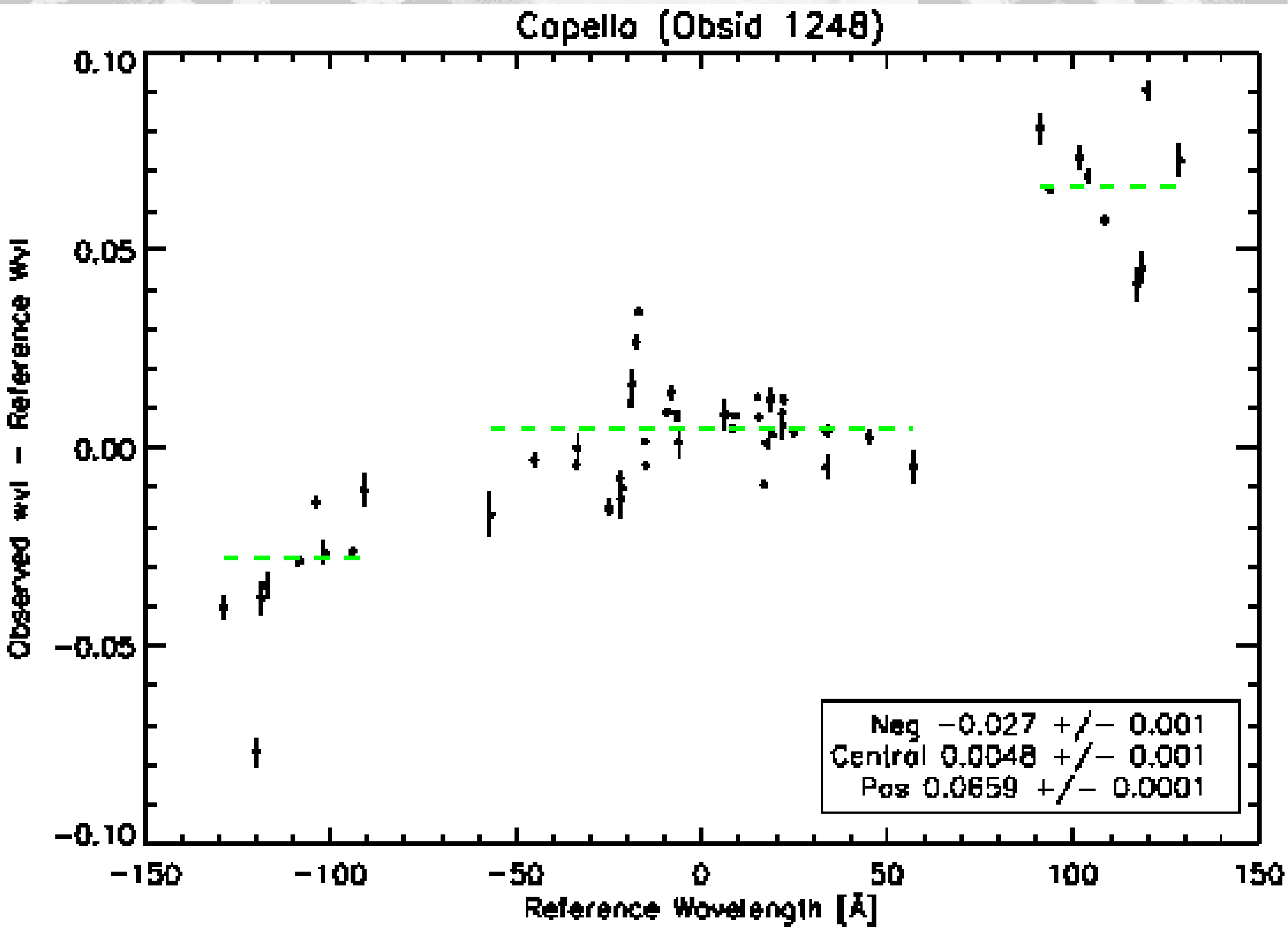


- Geometry of finite thickness HRC-S plates --> position error
- Additional correction arises from different LETG+HRC-S disp rel cf that known at XRCF

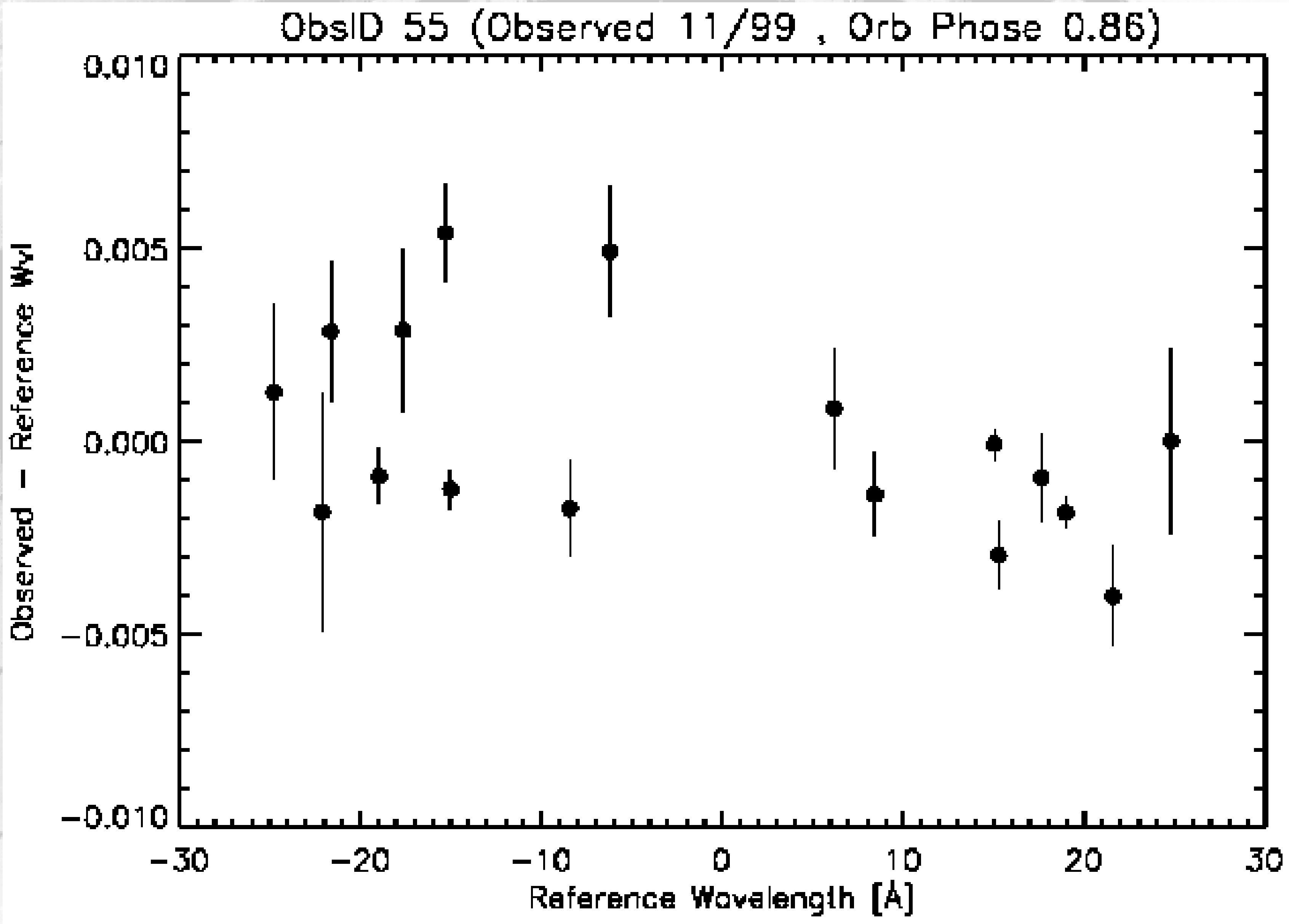


# Dispersion Relation Post-Bug Fix

- Clarified apparent plate gap problem
  - Non-linearities not affected

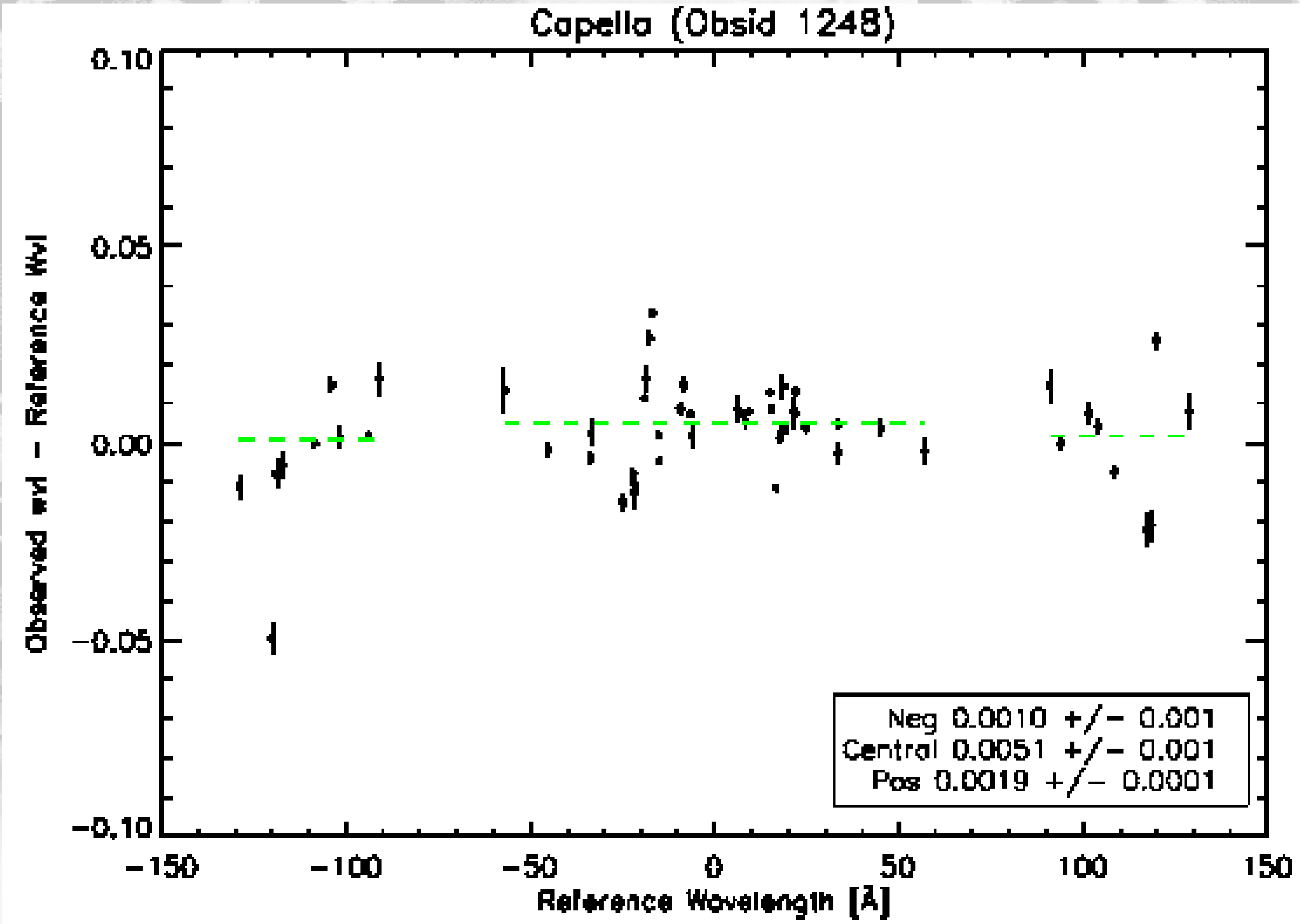


# Verification with ACIS-S



# New Plate Gap Calibration

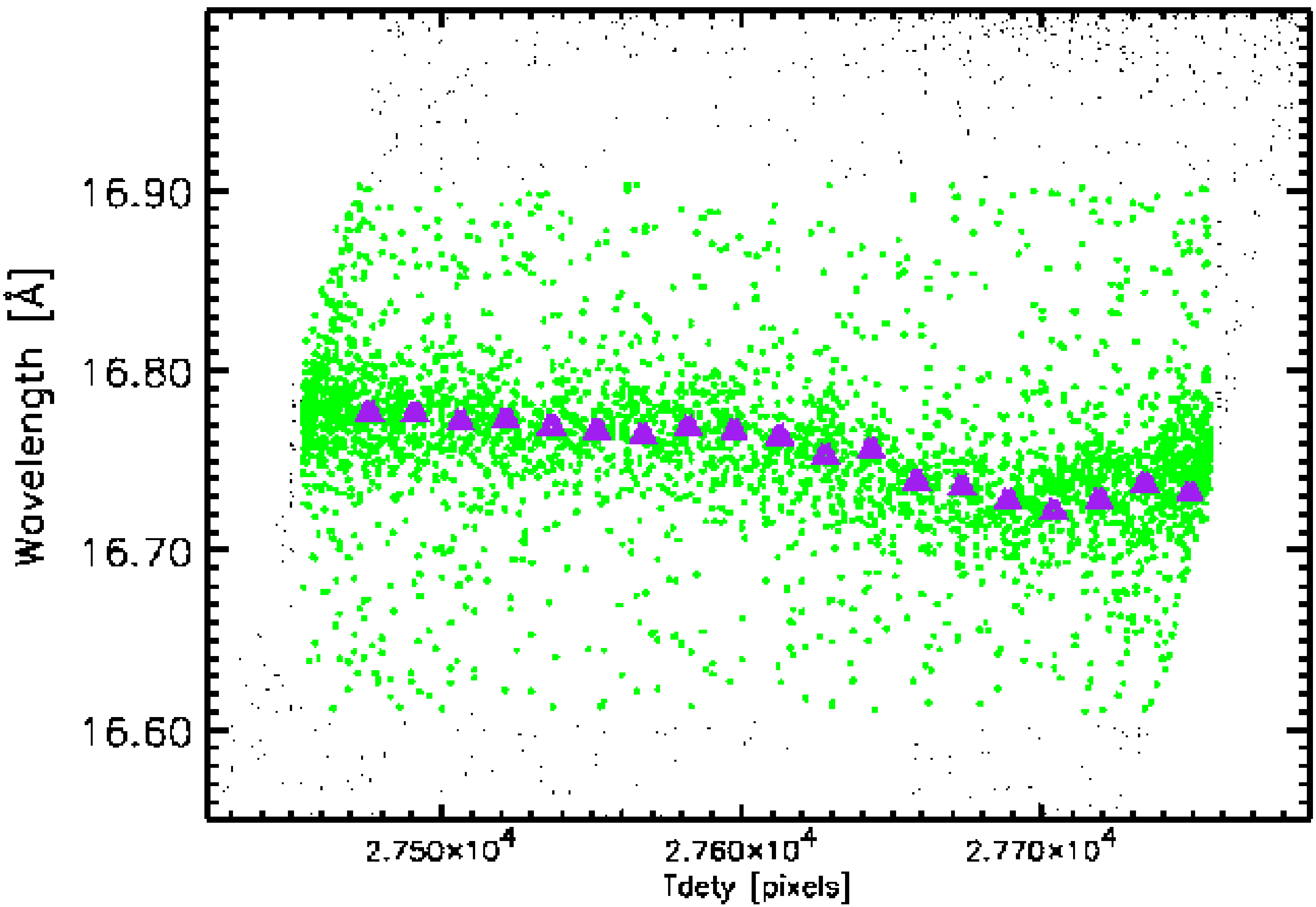
- Removes discontinuities between plates
  - Resulting RMS deviation=0.013 AA (~0.01% @100AA)



# Mapping HRC-S Spatial Non-Linearity

- Examine events from bright well-understood lines in detector coordinates (`tdety`)
  - BUT: Relatively few bright lines - poor coverage
- Cross-correlate spectra in small wavelength intervals extracted from different dither phases
  - At any given wavelength, maps out relative position error between areas of the detector ~1mm apart.
  - Effective for any spectra with significant structure; does not require "high quality" lines

# Mapping Non-Linearity in `tdety`



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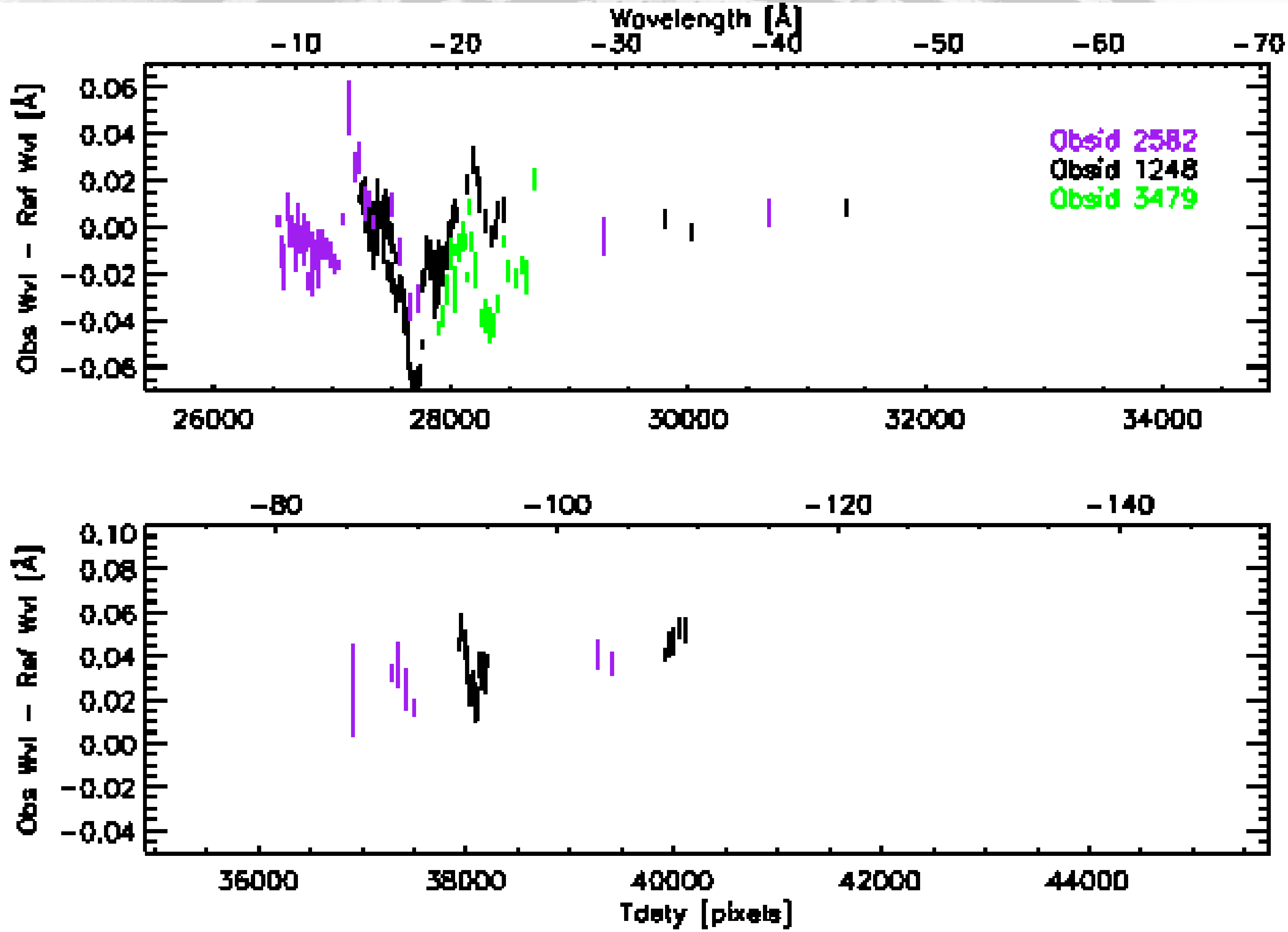


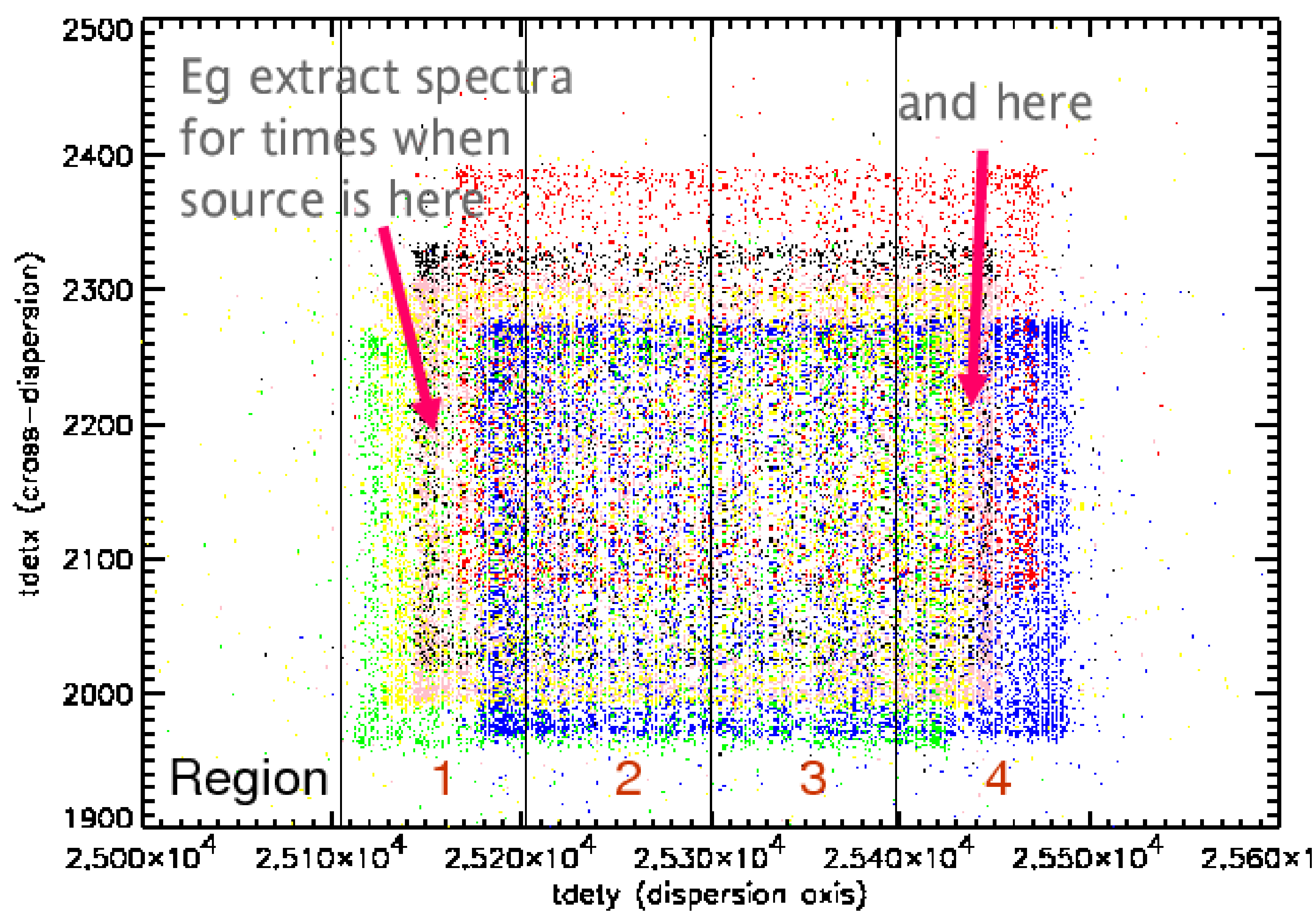
# Mapping HRC-S Spatial Non-Linearity

- Examine events from bright well-understood lines in detector coordinates (`tdet y`)
  - BUT: Relatively few bright lines - poor coverage
- Cross-correlate spectra in small wavelength intervals extracted from different dither phases
  - At any given wavelength, maps out relative position error between areas of the detector ~1mm apart.
  - Effective for any spectra with significant structure; does not require "high quality" lines

# Mapping HRC-S Detector Non-Linearities

- Examine events from bright well-understood lines in detector coordinates (`tdet y`)
  - BUT: Relatively few bright lines - poor coverage
- Cross-correlate spectra in small wavelength intervals extracted from different dither phases
  - At any given wavelength, maps out relative position error between areas of the detector ~1mm apart.
  - Effective for any spectra with significant structure; does not need "high quality" lines

# Dither-Split Cross-Correlation



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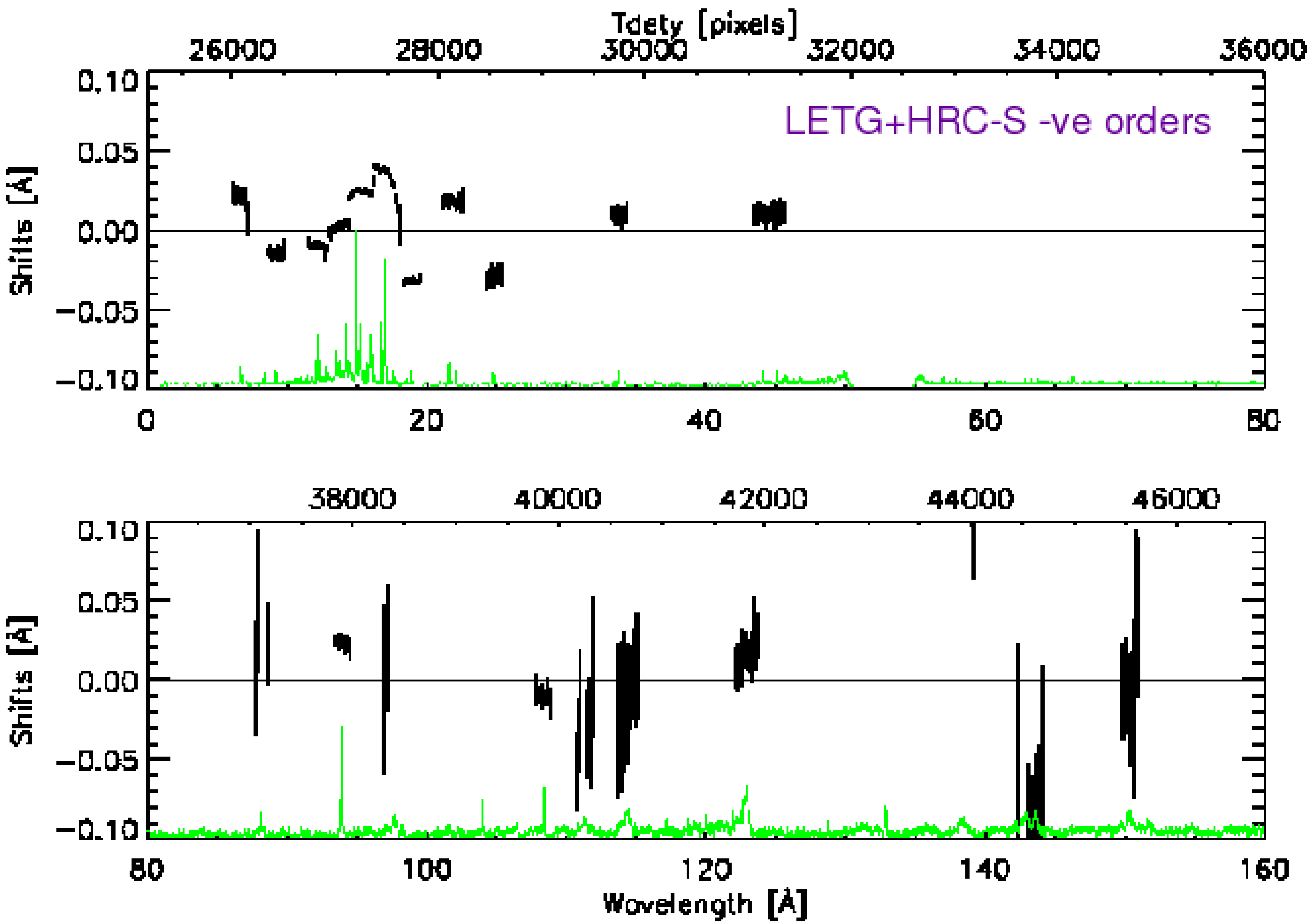
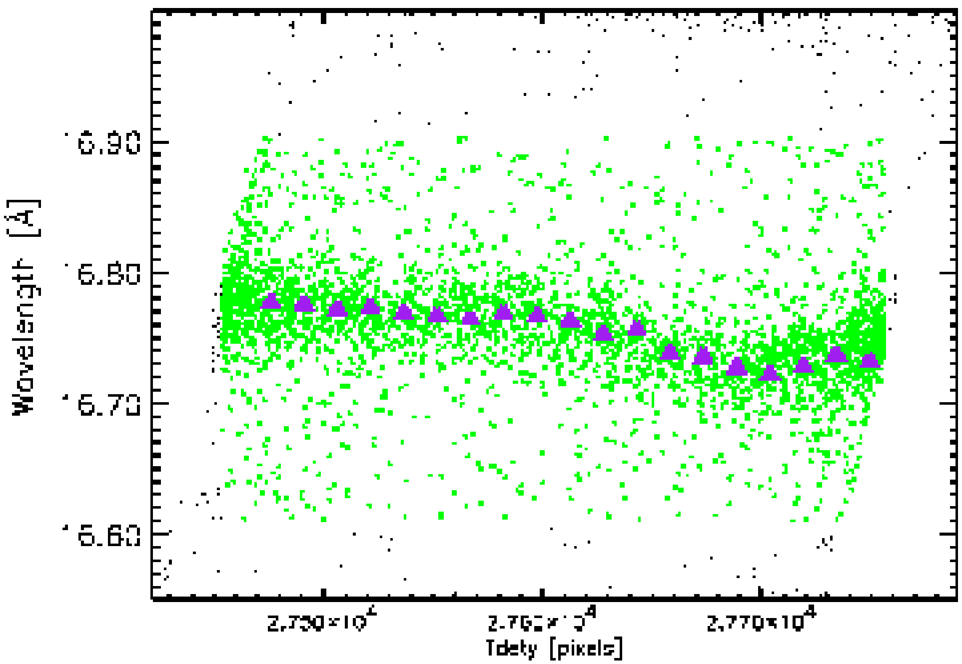


# Testing an Empirical Degap

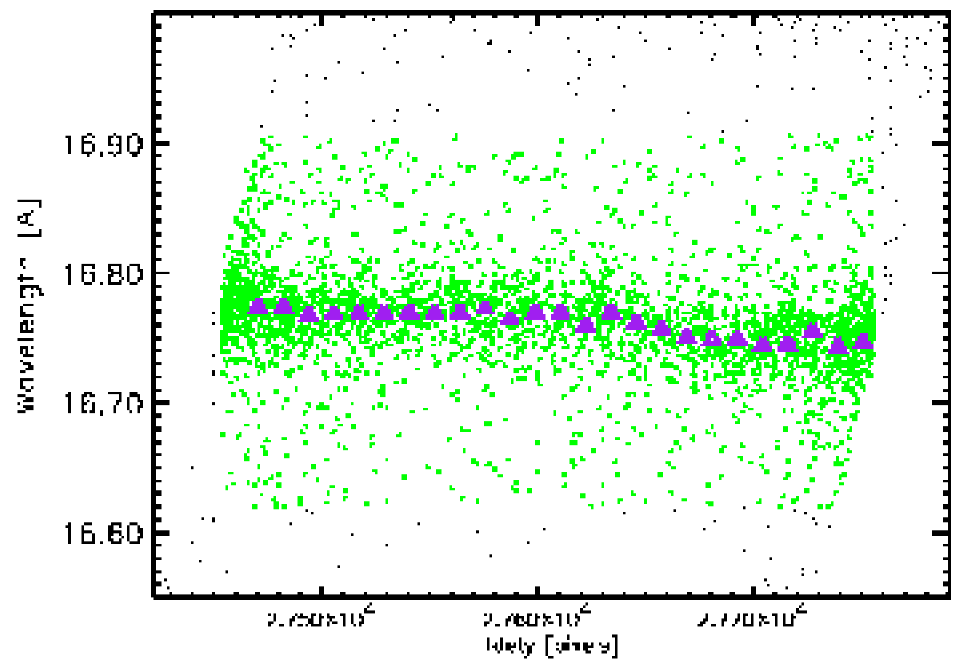
- Is non-linearity caused by degap deficiencies?
- Empirical degap correction derived for "dispersion strip" of HRC-S based on bright continuum source (PKS2155-304)
  - Vinay's talk
- Applied to Capella observations
  - Analysed using cross-correlation and tdety techniques

# In tdety

Standard degap




In-flight degap



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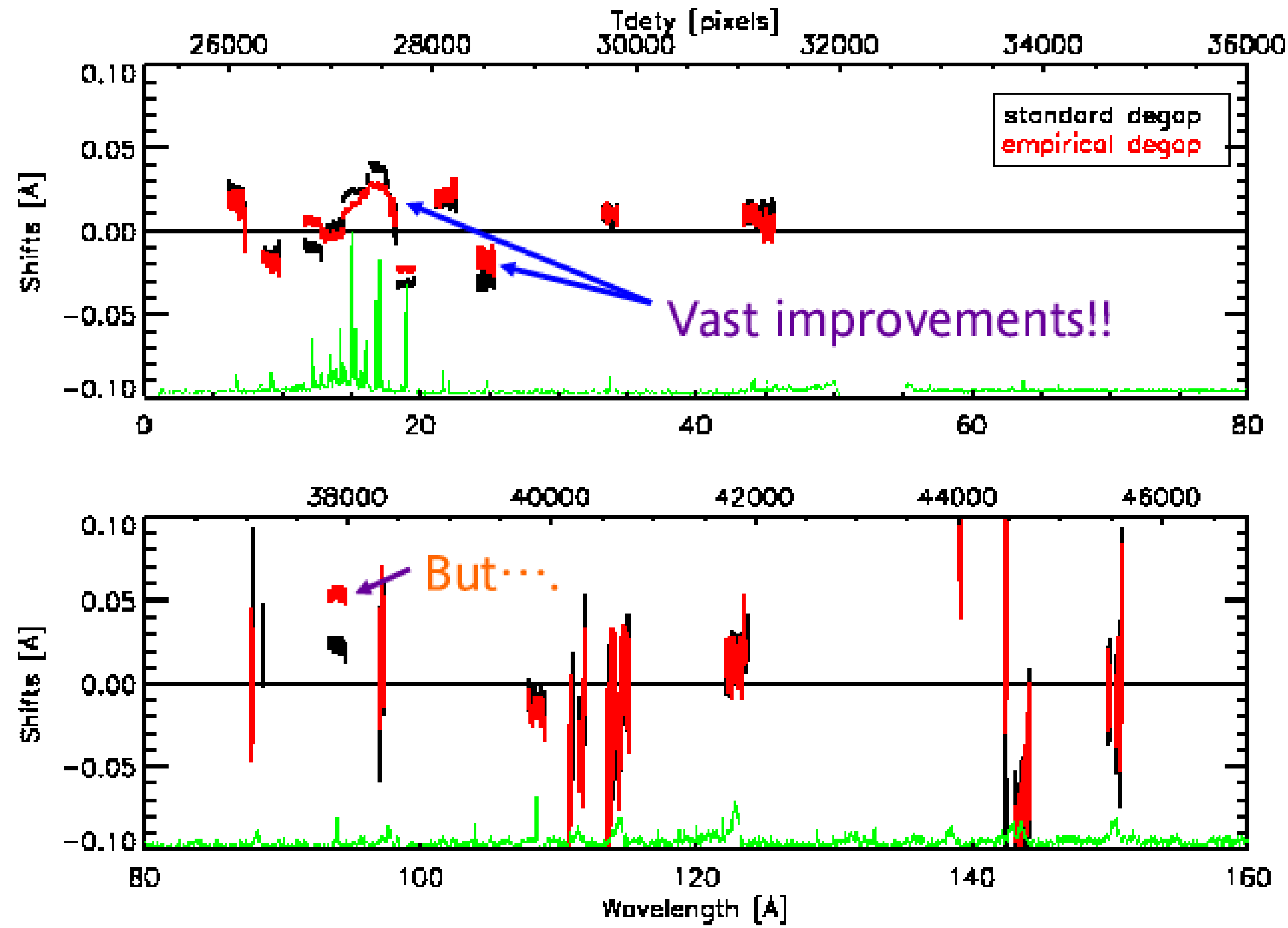
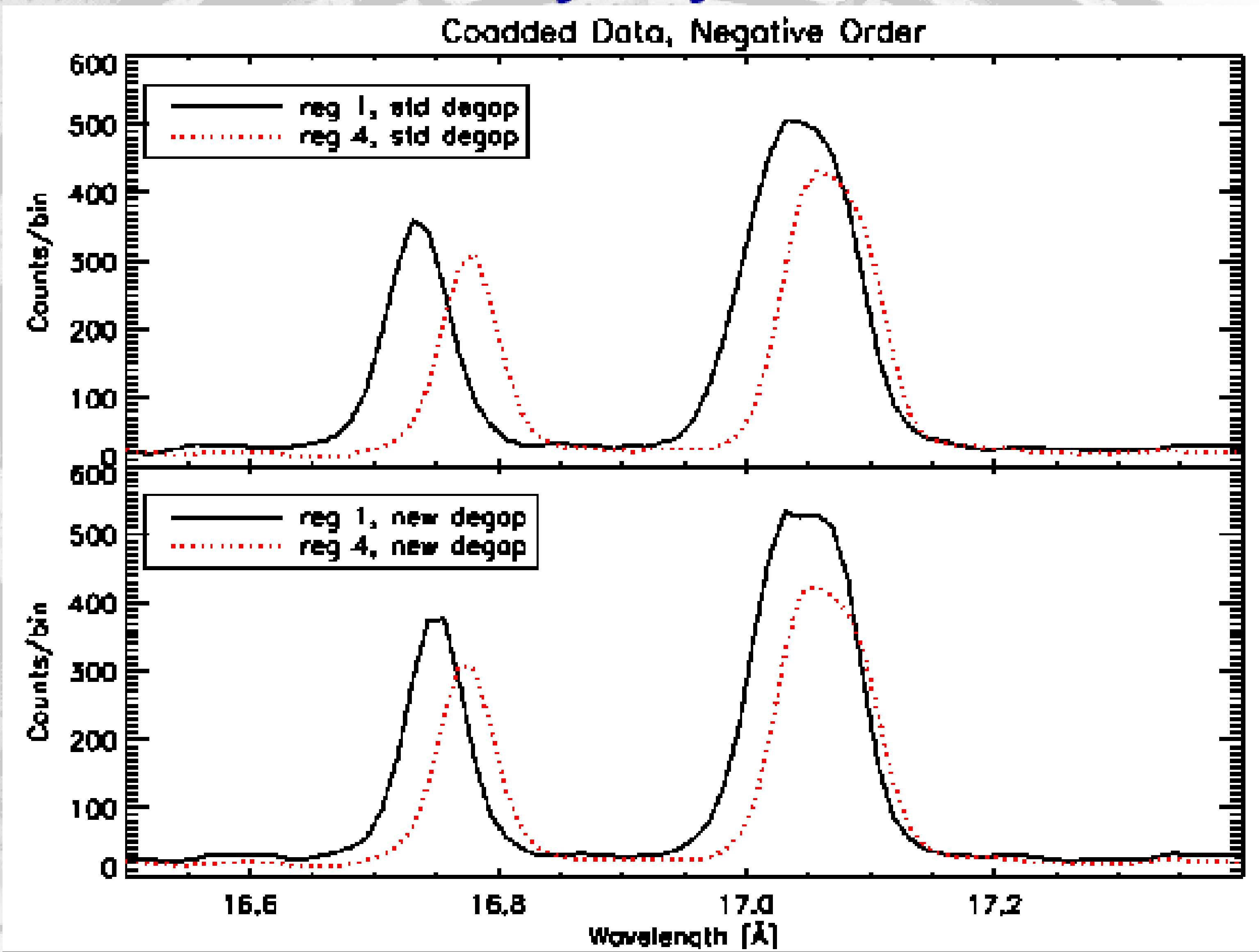


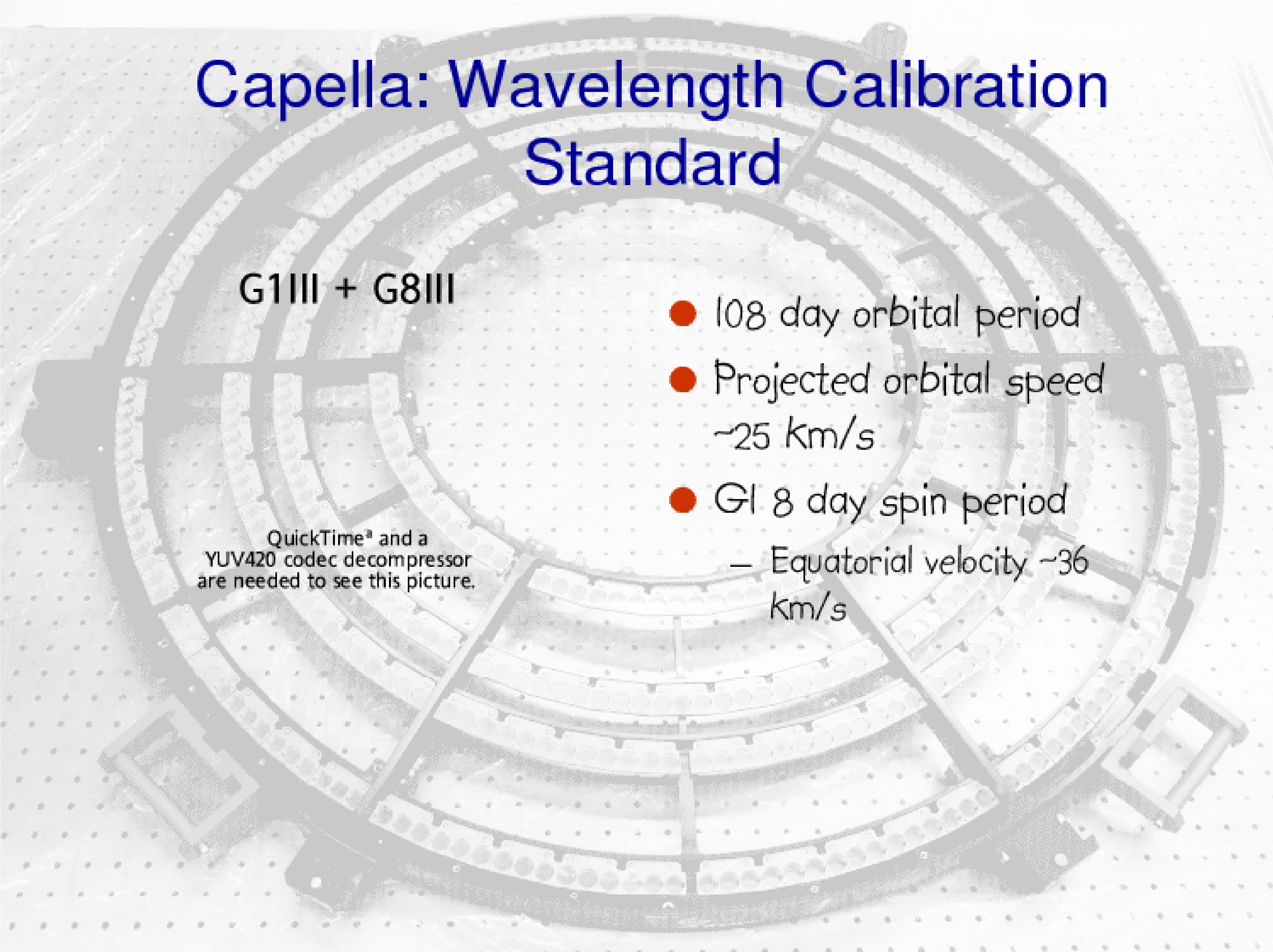
# By Eye


Coadded Data, Negative Order
reg 1, std degap
reg 4, std degap
reg 1, new degap
reg 4, new degap
Counts/bin
0
100
200
300
400
500
600
16.6
16.8
17.0
17.2
Wavelength [Å]

# How accurately can we measure velocities with Chandra?

- Provided line profile is adequately sampled, centroid accuracy in principle depends only on S/N
- BUT: at some level, other systematics will dominate
  - Line blends
  - Detector imperfections
  - Optical bench stability
  - Aspect error
  - etc

# Capella: Wavelength Calibration Standard



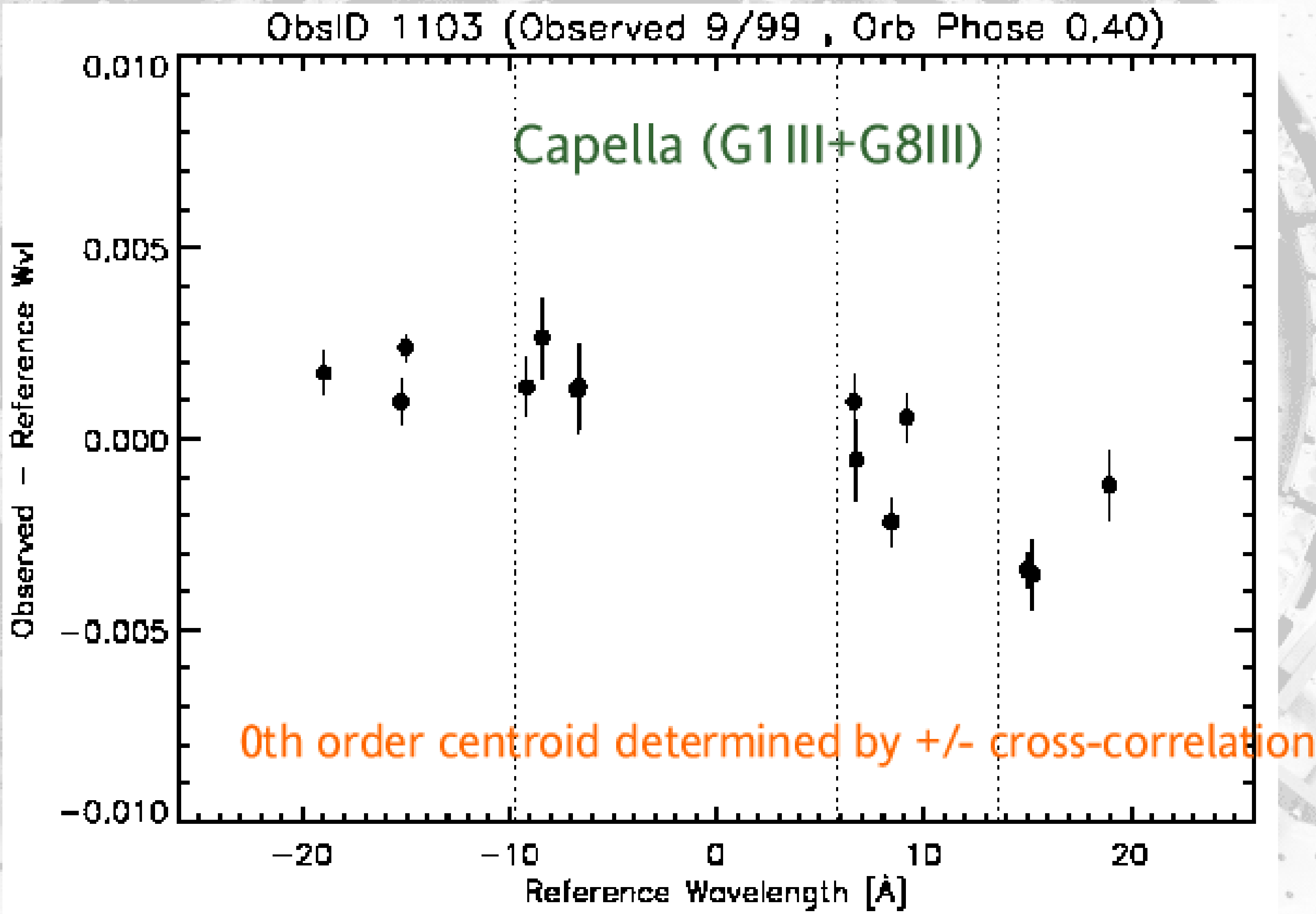
G1III + G8III

QuickTime® and a
YUV420 codec decompressor
are needed to see this picture.

- 108 day orbital period
- Projected orbital speed ~25 Km/s
- GI 8 day spin period
  - Equatorial velocity ~36 km/s

# HETGS (MEG) Dispersion Relation

Based on "unblended" lines with accurately-known wavelengths



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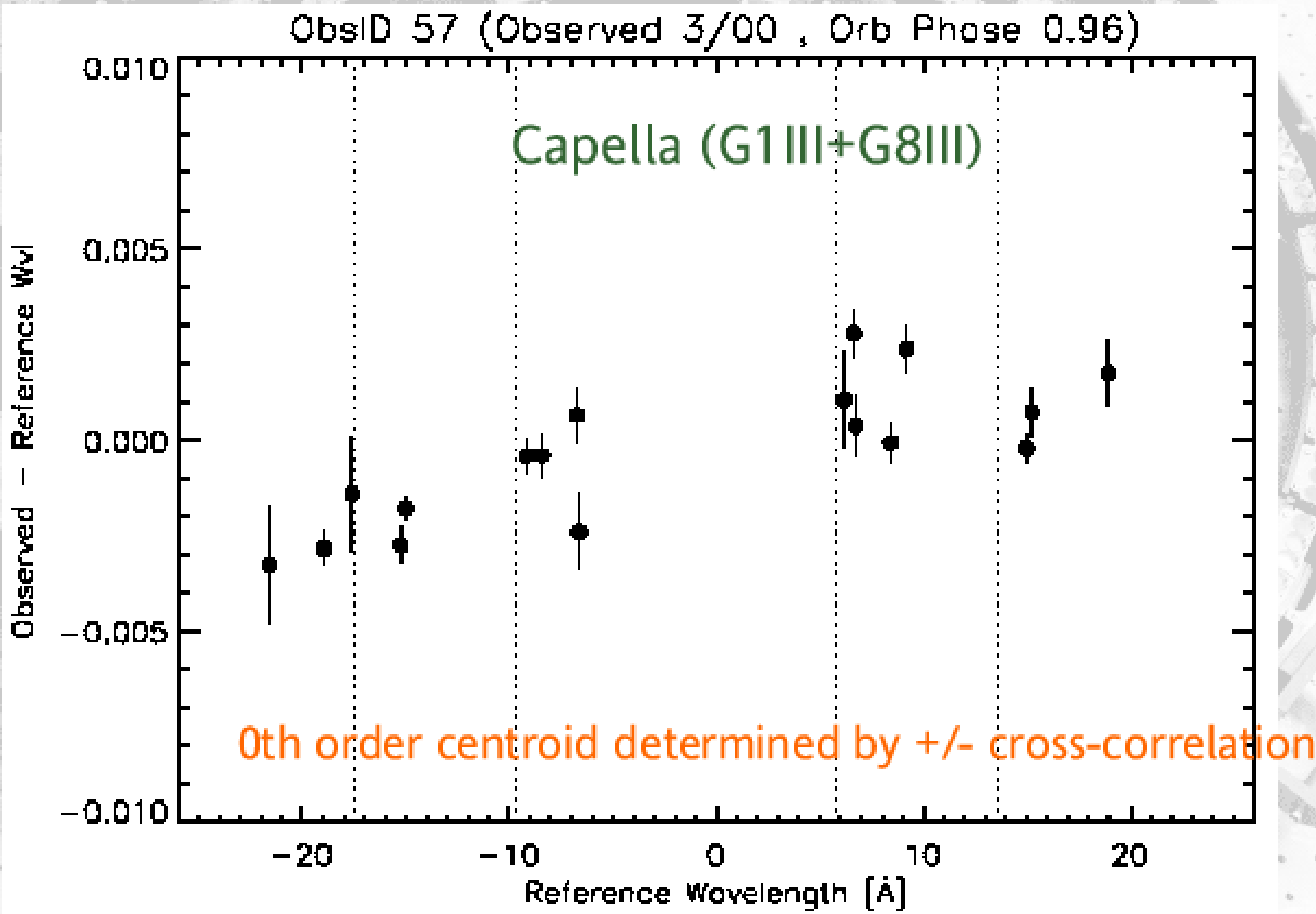

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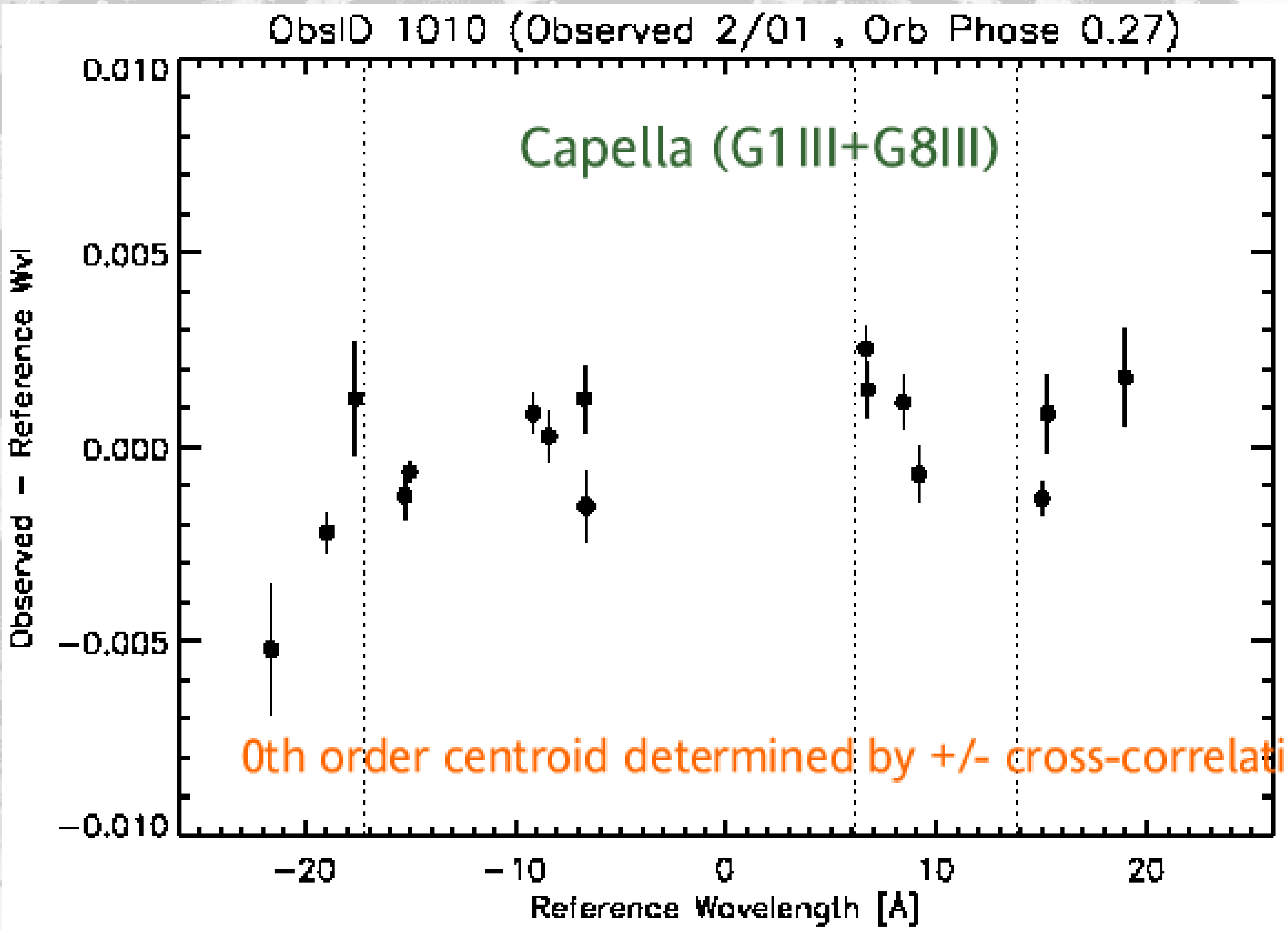

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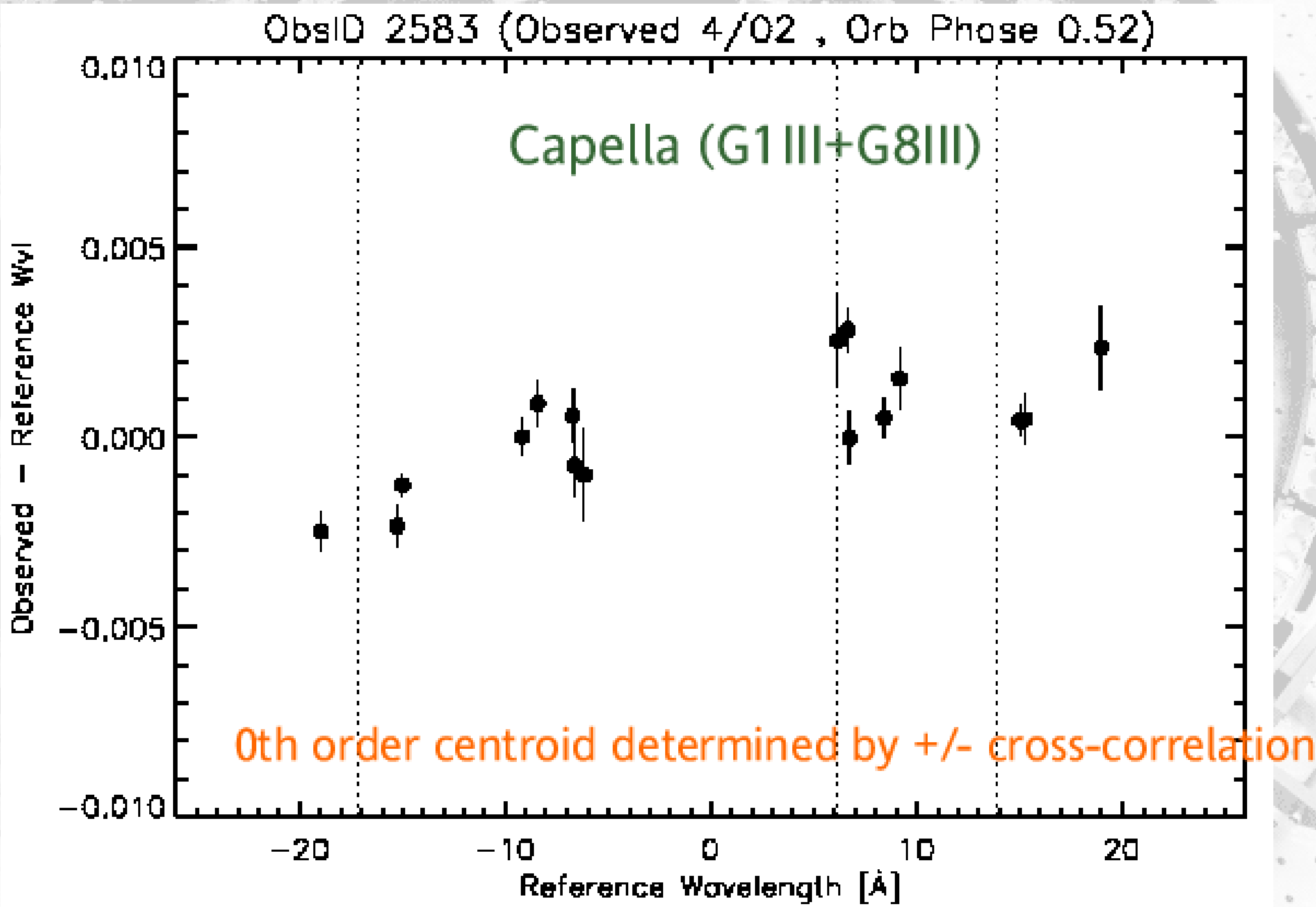

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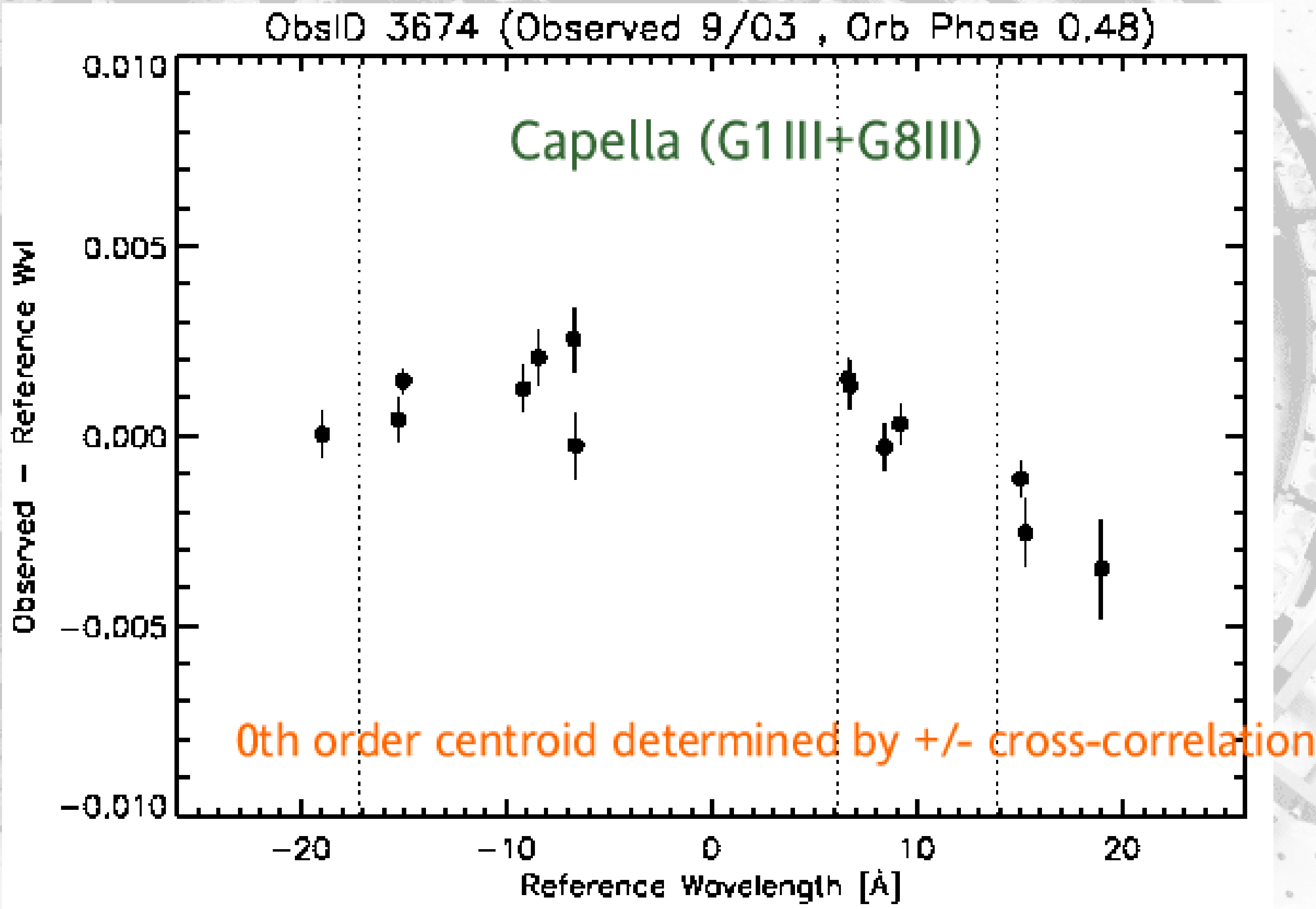
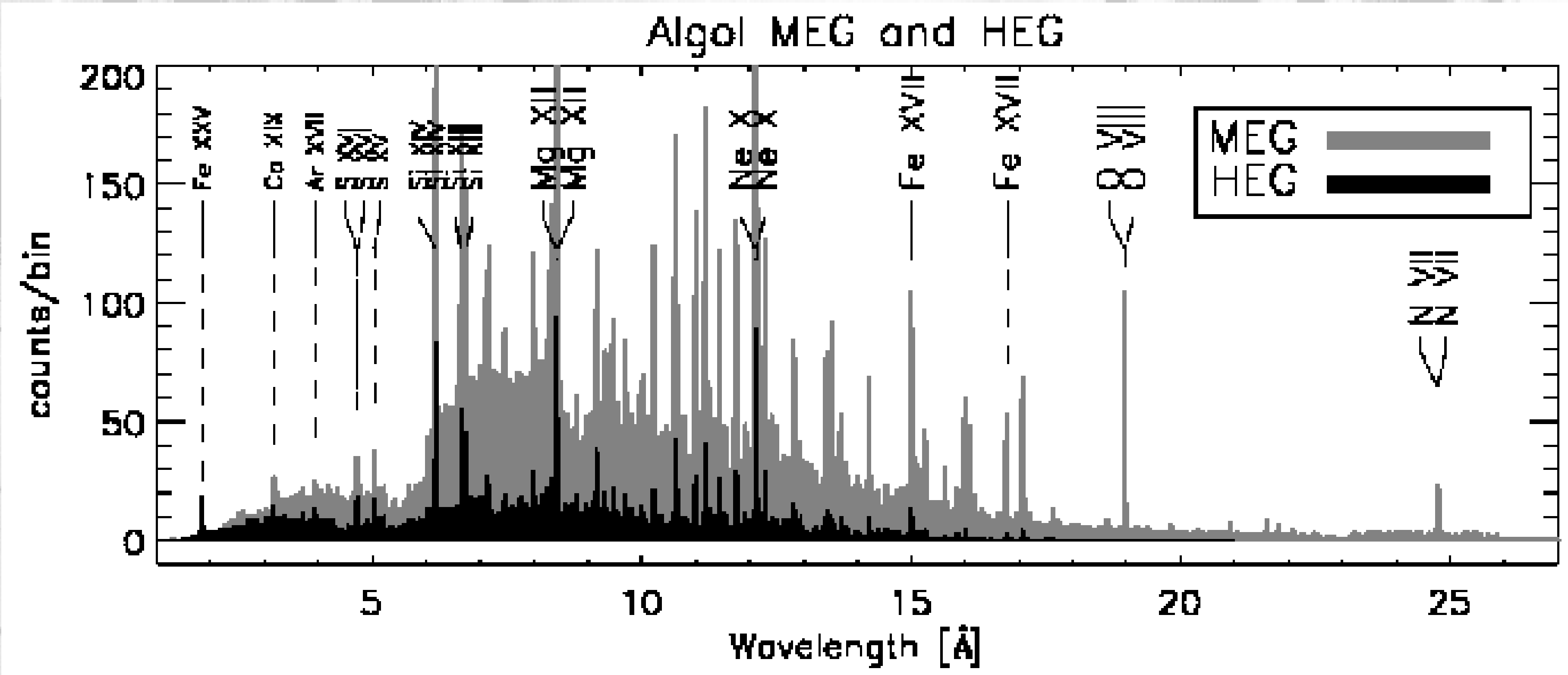


# Algol (B8V + K2 III)

X-ray dark

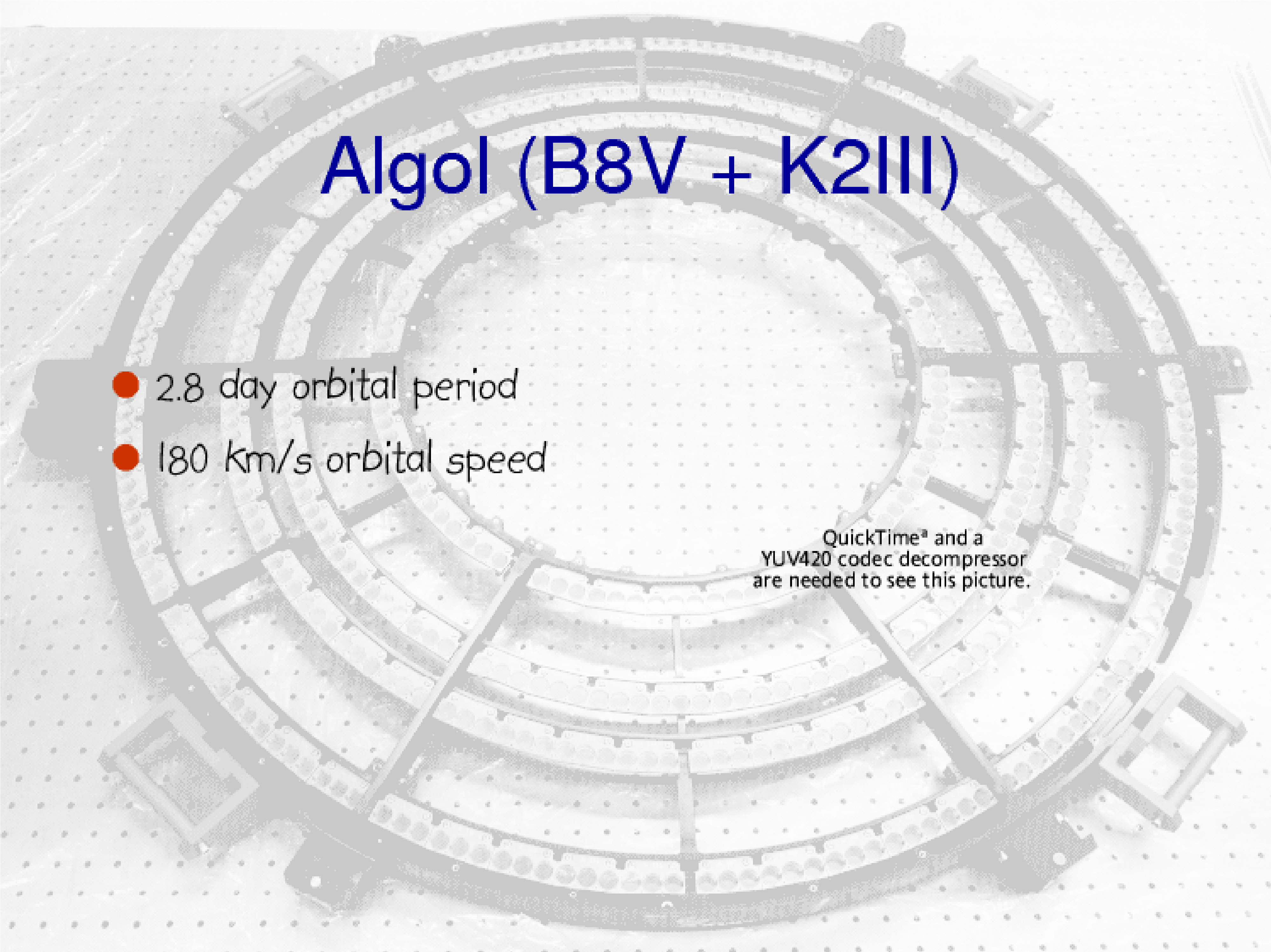
Roche-lobe filling, coronally active



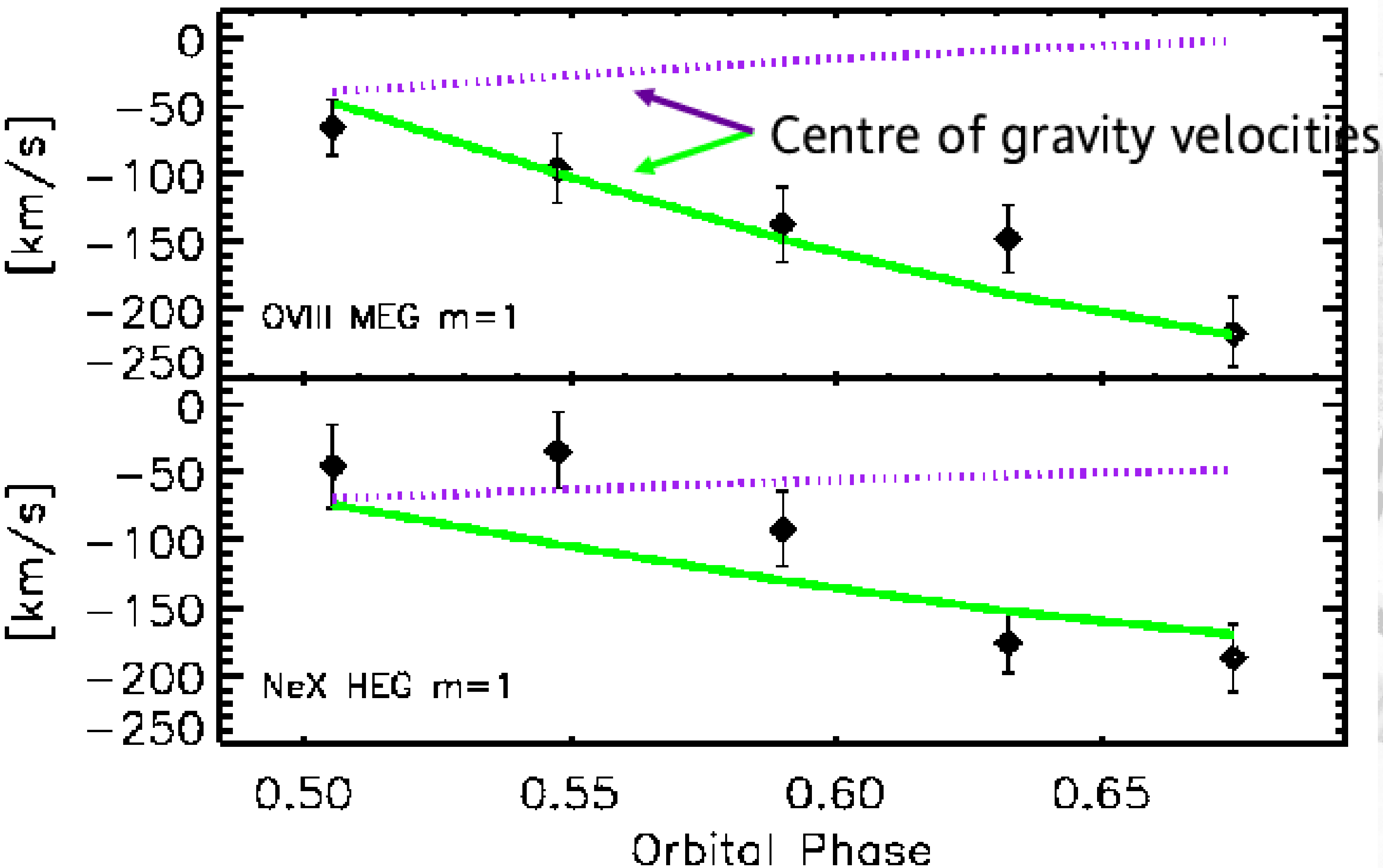

Period =2.8d; secondary orbital speed ~180 km/s

# Algol (B8V + K2III)

- 2.8 day orbital period
- 180 km/s orbital speed

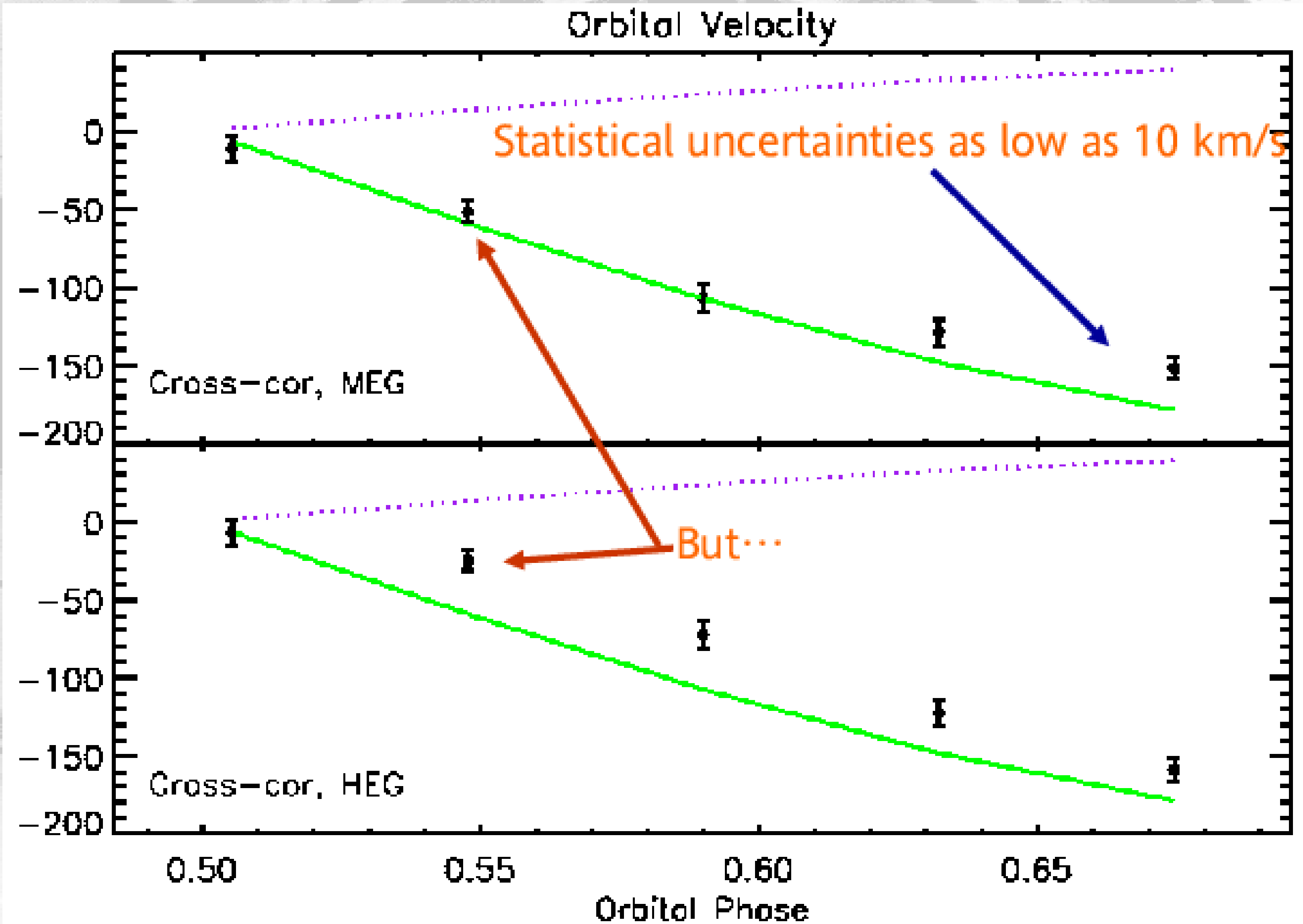


# Algol Line Centroid Analysis

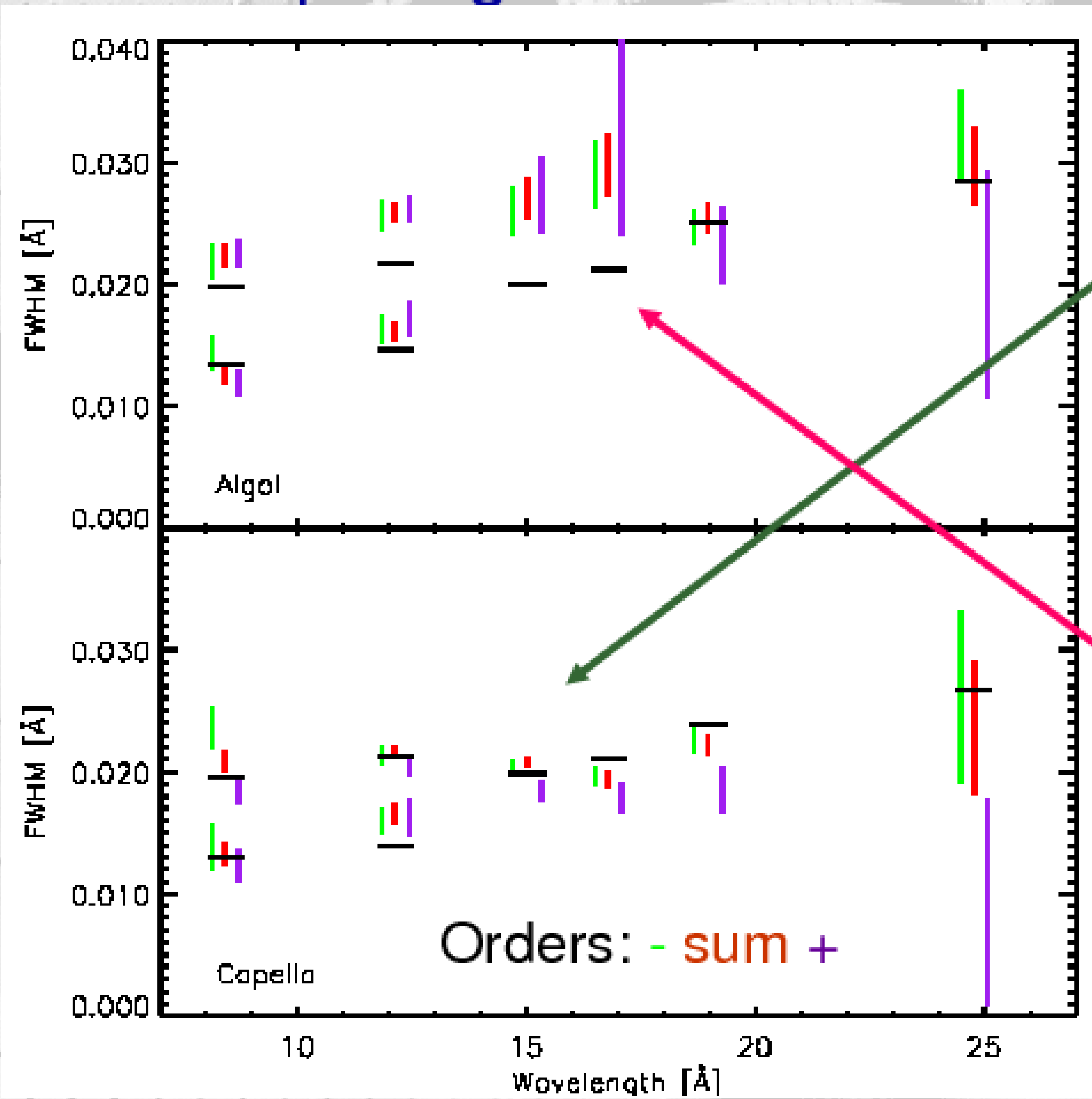


# Algol Cross-Correlation Analysis

Use all of MEG spectra of Algol vs Capella - greatly increase S/N



# Comparing Observed FWHM and RMF

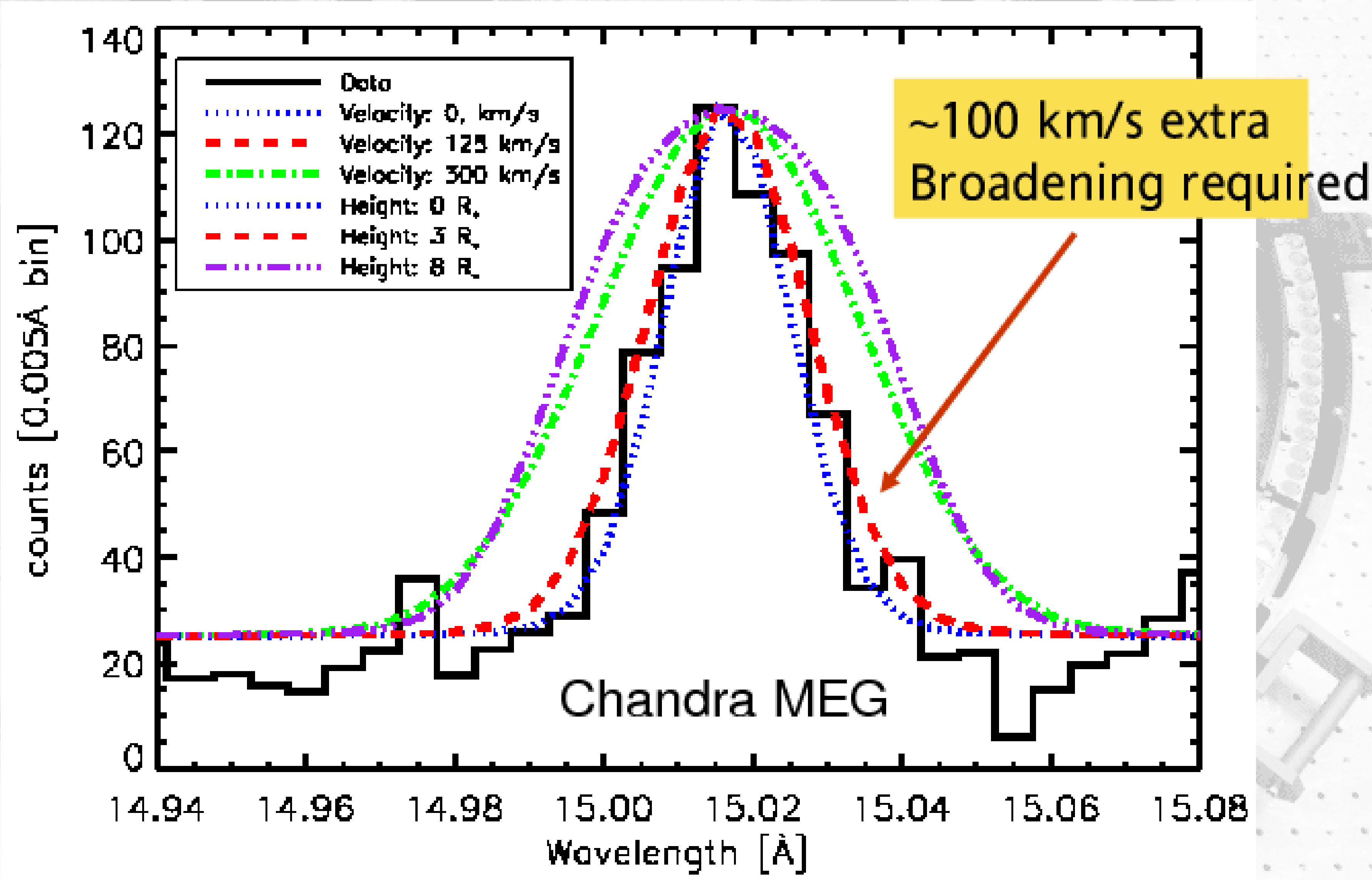



Capella FWHM in fairly good agreement with RMF

Evidence for excess

Line width in Algol

# Algol Line Profiles



# Conclusions

- RMS devations in LETG+HRC-S now down to 0.013 AA
- Have tools to probe dispersion non-linearity
  - In-flight degap helps but does not solve the problem
- Cross-correlation techniques permit potentially very accurate velocity studies (~10 Km/s)
  - BUT systematics seem to dominate at 20-30 Km level