COS/FUV Wavelength Calibration

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COS/FUV Wavelength Calibration

- Heard STUC concerns about COS/FUV wavelength calibration
  - This is now the highest priority work of the COS/STIS team
  - Working group in place since late June 2015: C. Oliveira (chair), T. Ake, J. Ely, S. Penton, R. Plesha, C. Proffitt, J. Roman-Duval, D. Sahnow, and P. Sonnentrucker

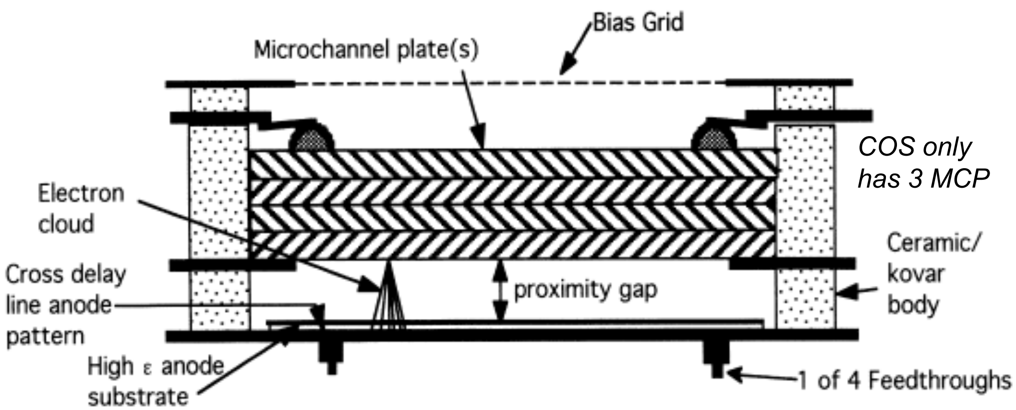
- Pursuing 3 major tasks under this working group
  1. Improve wavelength calibration using STIS wavelength calibration as reference
     - Expect to have updated coefficients by late 2015 - early 2016, for the most used settings
  2. Improve x-walk correction
  3. Improve geometric distortion correction

➽ *Goal is to have dispersion solution accurate to within +/- 3 pix (~10 km/s) for M gratings (1 σ) - initial requirement was +/- 6 pix or ~20 km/s*

- Executive summary of what we have achieved so far
  1. Have derived preliminary linear dispersions solutions for many settings – for a large number of settings (cenwave/seg/LP/FP) the residuals are within +/- 3 pix
  2. x-walk can be as much as ~6 pix in certain areas of the detector
  3. Preliminary analysis of TV03 geometric correction data indicates that ~87% of the lines used in the analysis have dispersion errors < 3 pix (data probes effects on the scale of 30 to 200 pix) – geometric correction residuals not a major contributor

COS/FUV Detector

COS/FUV detectors are analog – signal is digitized at the end



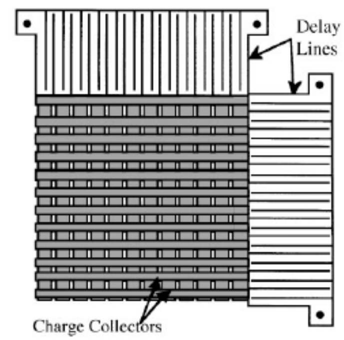
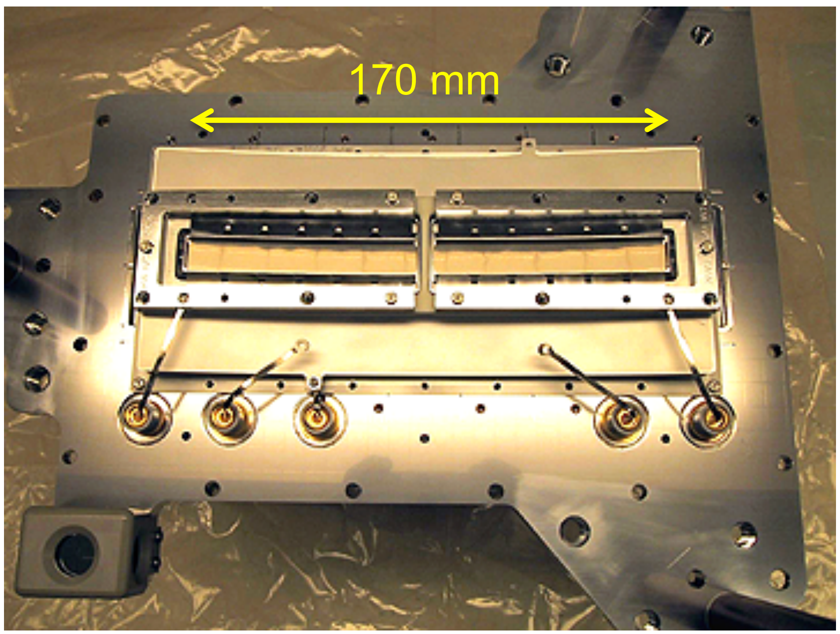
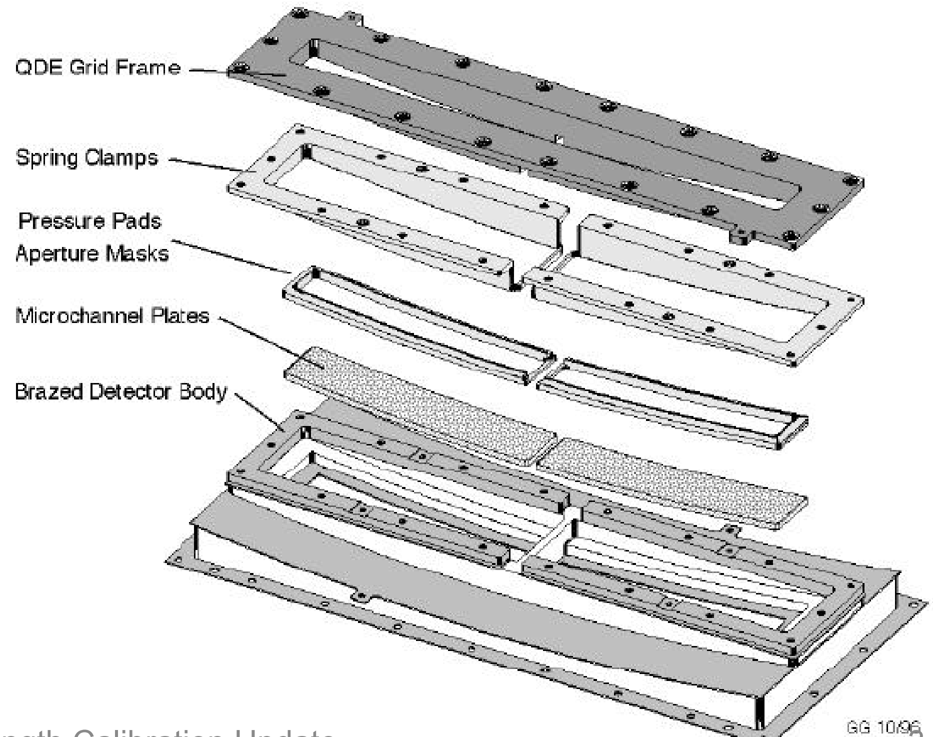
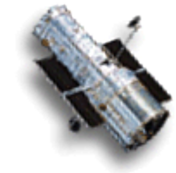


Fig. 2. Schematic view of a crossed delay anode design showing the X and Y charge collection fingers and external delay lines.





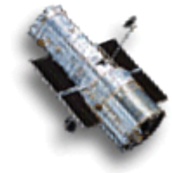
COS/FUV Wavelength Calibration: Using STIS as Reference

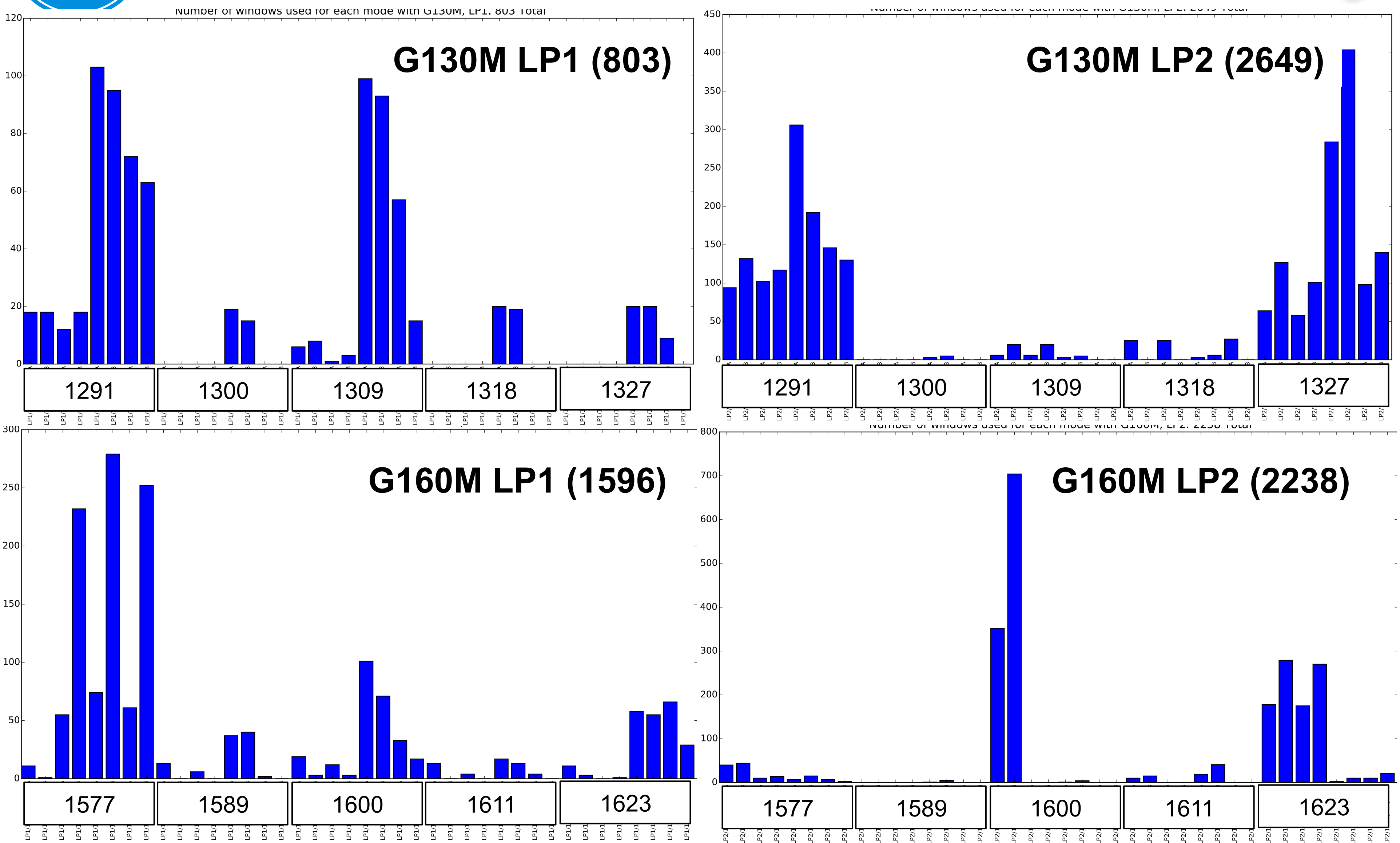


- Effort is focused on improving the G130M and G160M dispersion solutions
  - These are the gratings used by most of the people that need an improved λ solution
  - Current dispersion solutions used by CalCOS are linear, we are investigating linear and quadratic fits

- Have 25 targets that have COS (G130M, G160M) and STIS (E140H, E140M, E230H, E230M) data
  - STIS wavelength accuracy is at least 0.5 km/s (H gratings) and 1.5 km/s (M gratings)
  - For each target, wavelength windows with emission/absorption features were carefully selected, with the goal of maximizing wavelength coverage, while avoiding variable stellar wind lines and regions of airglow in the COS/FUV data (~640 unique windows)
  - For which window, the COS and STIS data are cross-correlated so that a shift can be determined (~7300 COS windows used)
  - Lines at the edge of detector are discarded, and DQ values are taken into account
  - Lifetime positions (LP), cenwaves, and FP-POS are being kept separate at this point
  - We are in the process of fully vetting all the windows used using diagnostic plots
  - For some targets the TA strategy might not be optimal for this purpose – zero point of the wavelength scale will be affected, but valuable information can still be extracted from the data
    - Targets with best-centering TA will be used to bootstrap settings where zero-point might not be accurate, can be expanded to targets without STIS data

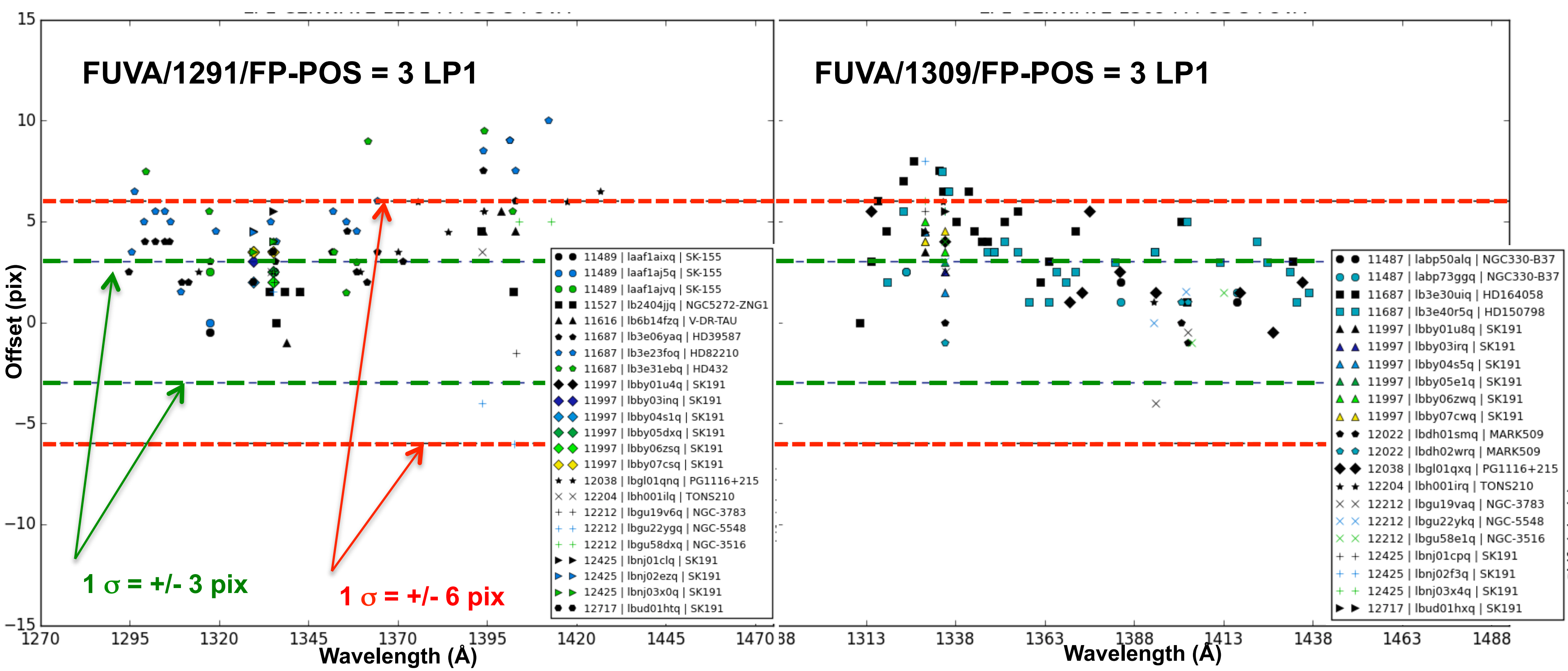
Distribution of Cross-Correlation Windows per Setting



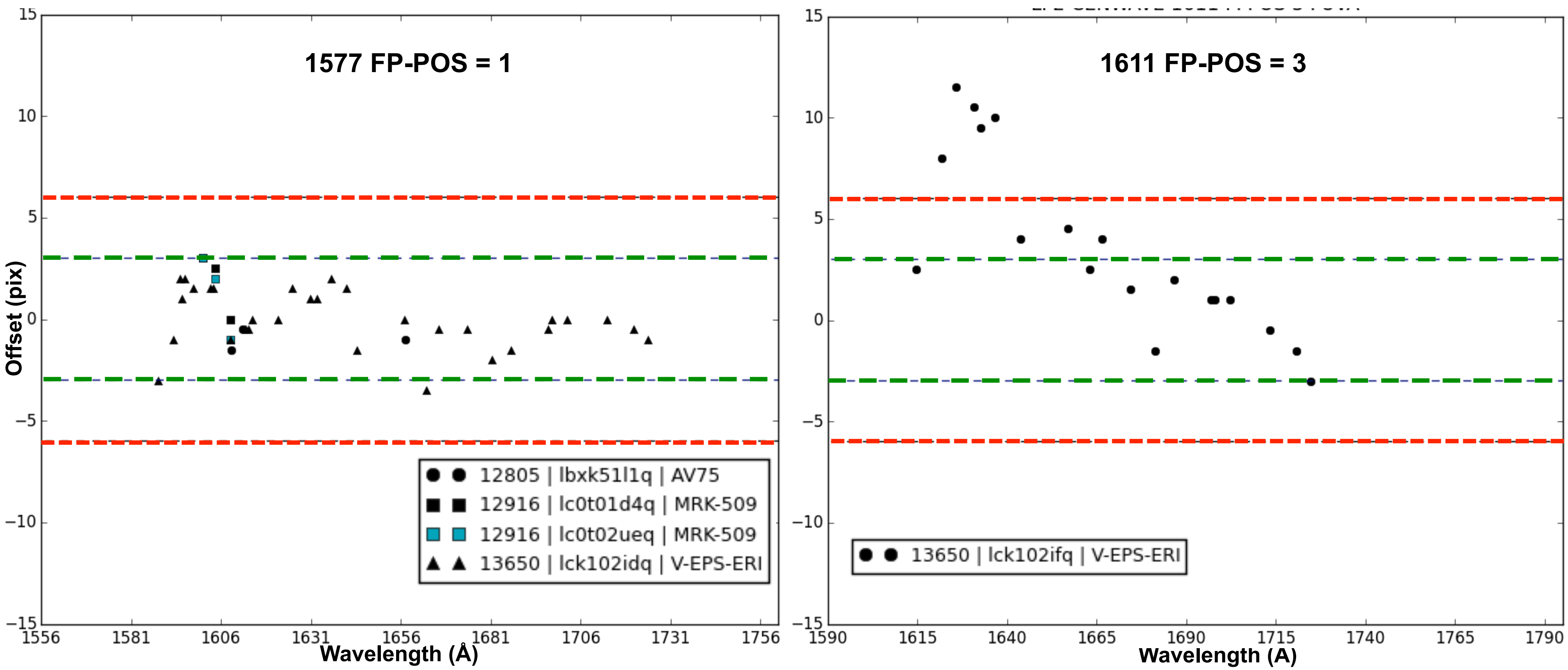


order of histogram is A/1, B/1, A/2, B/2, left to right.

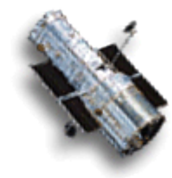
Cross-Correlation Offsets



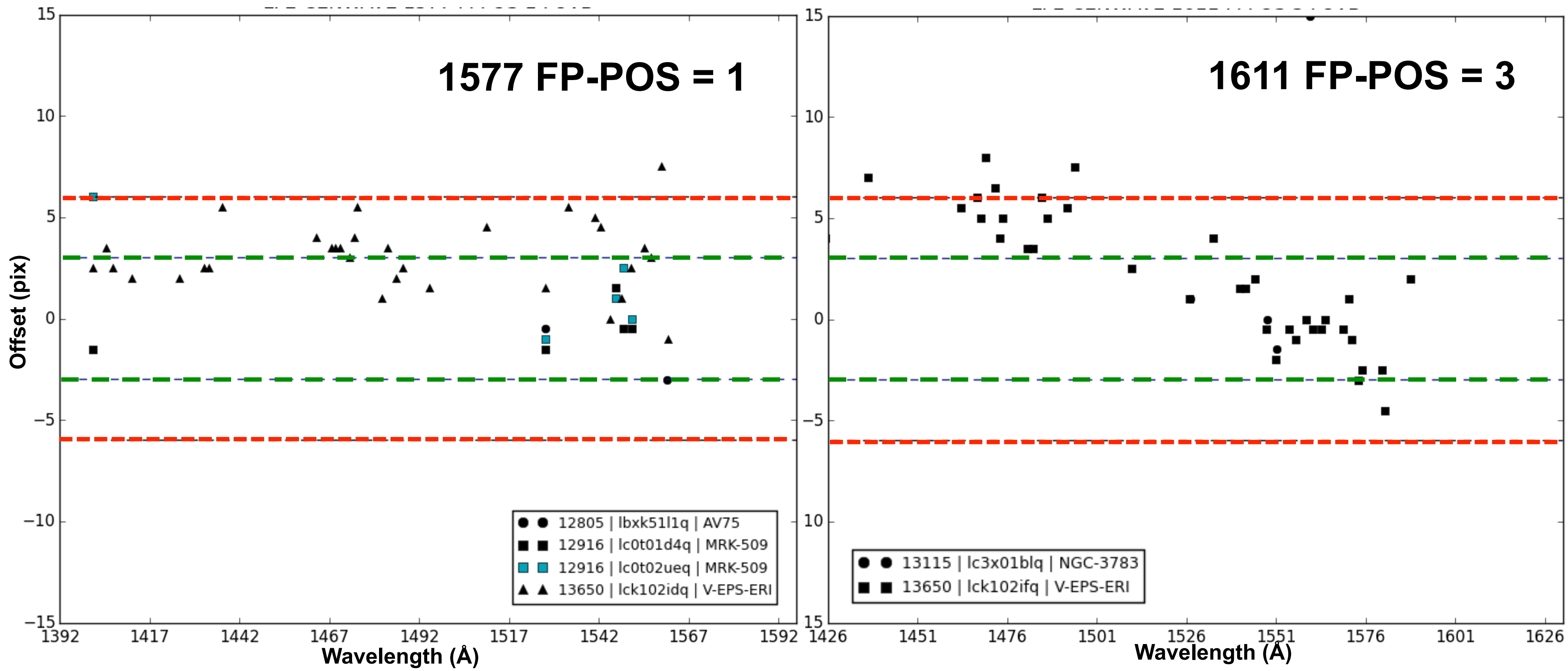
Cross-Correlation Offsets
G160M LP2 - FUVA



- Eps Eri exposures obtained in same 1 orbit visit, consecutively
- TA issues affect both exposures equally, data clearly indicate issue with 1611 dispersion solution.

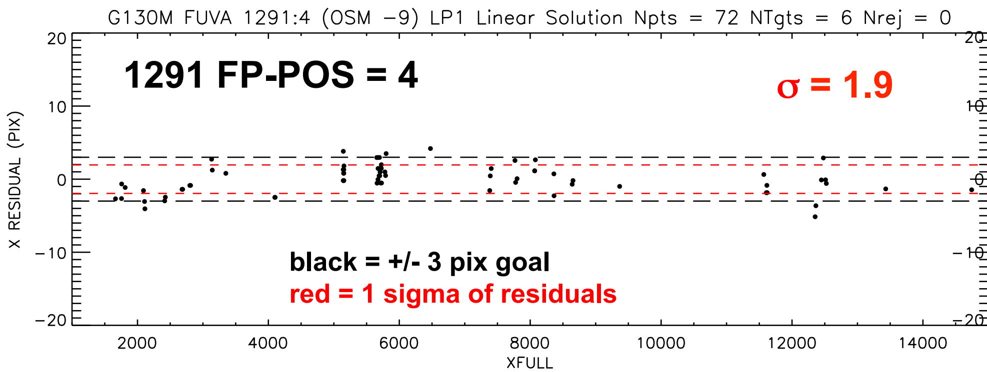


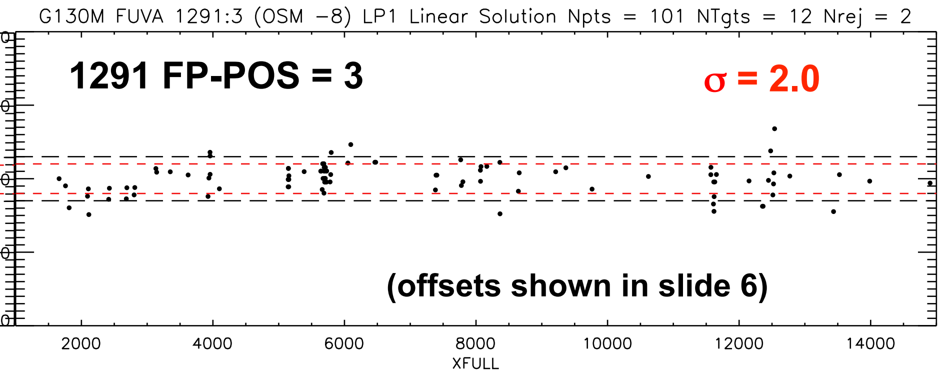
Cross-Correlation Offsets G160M LP2 - FUVB

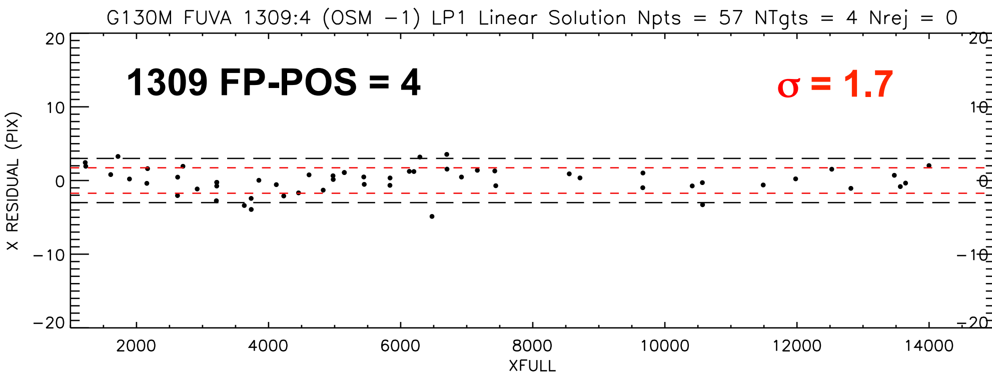


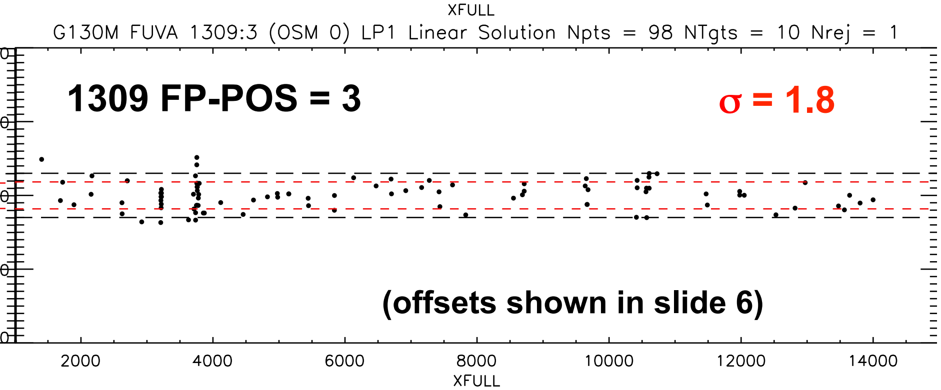
- Eps Eri exposures obtained in same 1 orbit visit, consecutively
- TA issues affect both exposures equally, data clearly indicate issue with 1611 dispersion solution

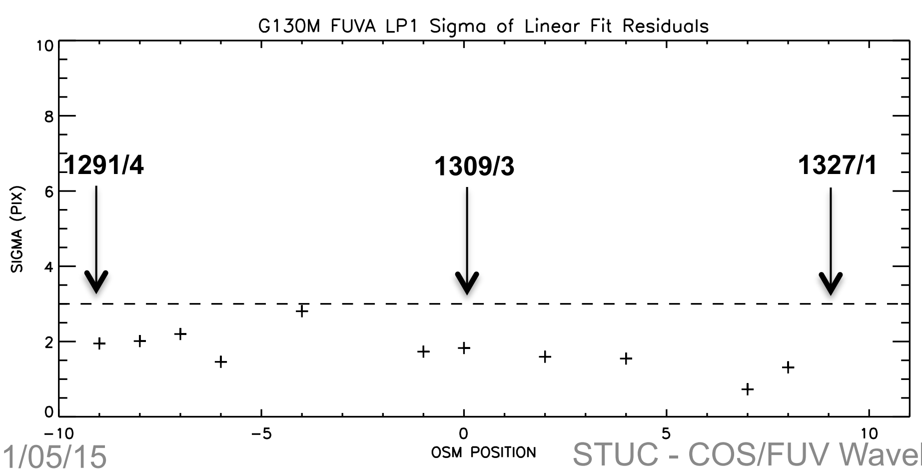
Preliminary Dispersion Solutions G130M/FUVA/LP1

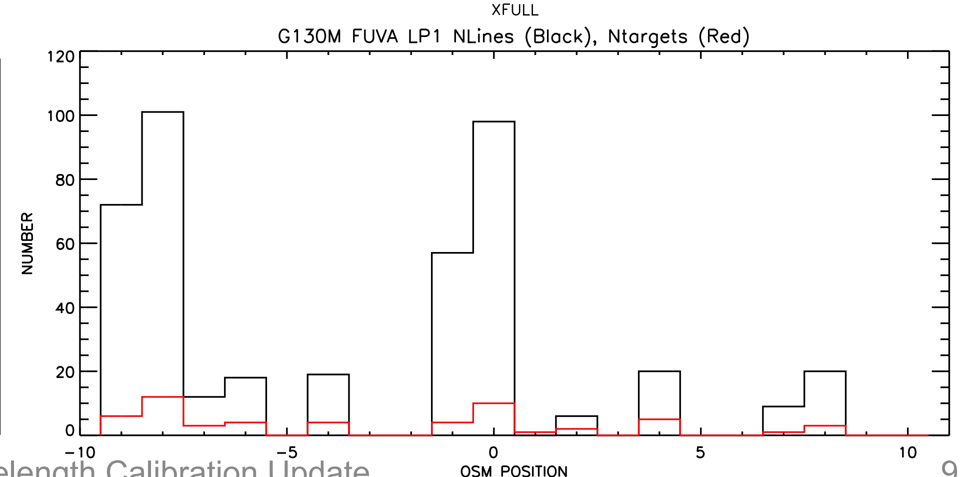




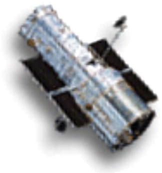


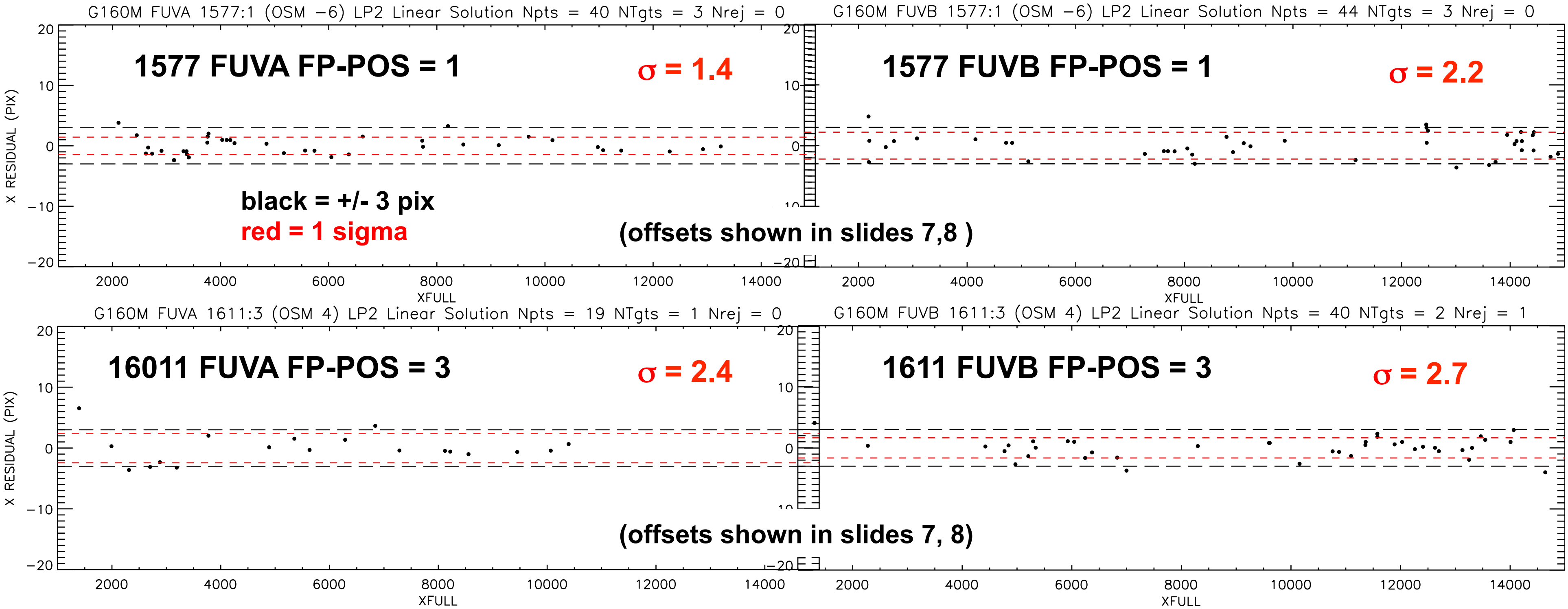


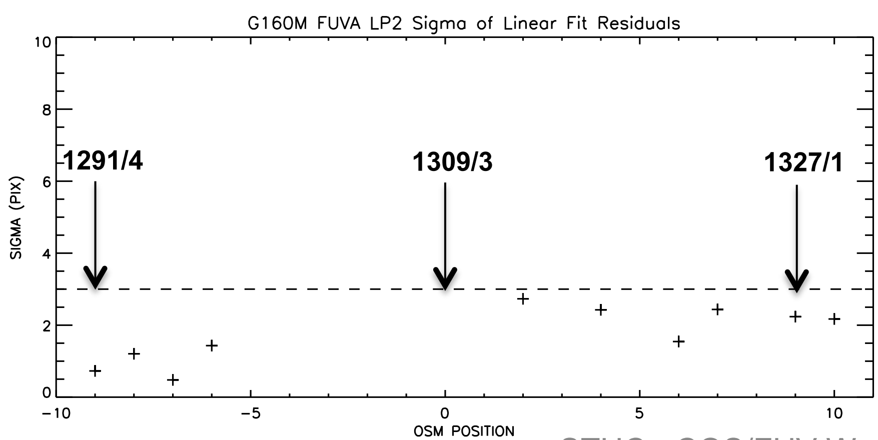


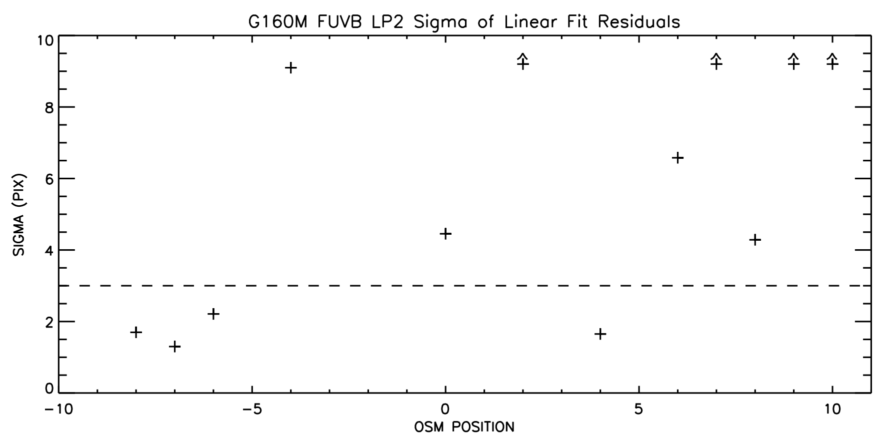


Preliminary Dispersion Solutions
G160M/LP2

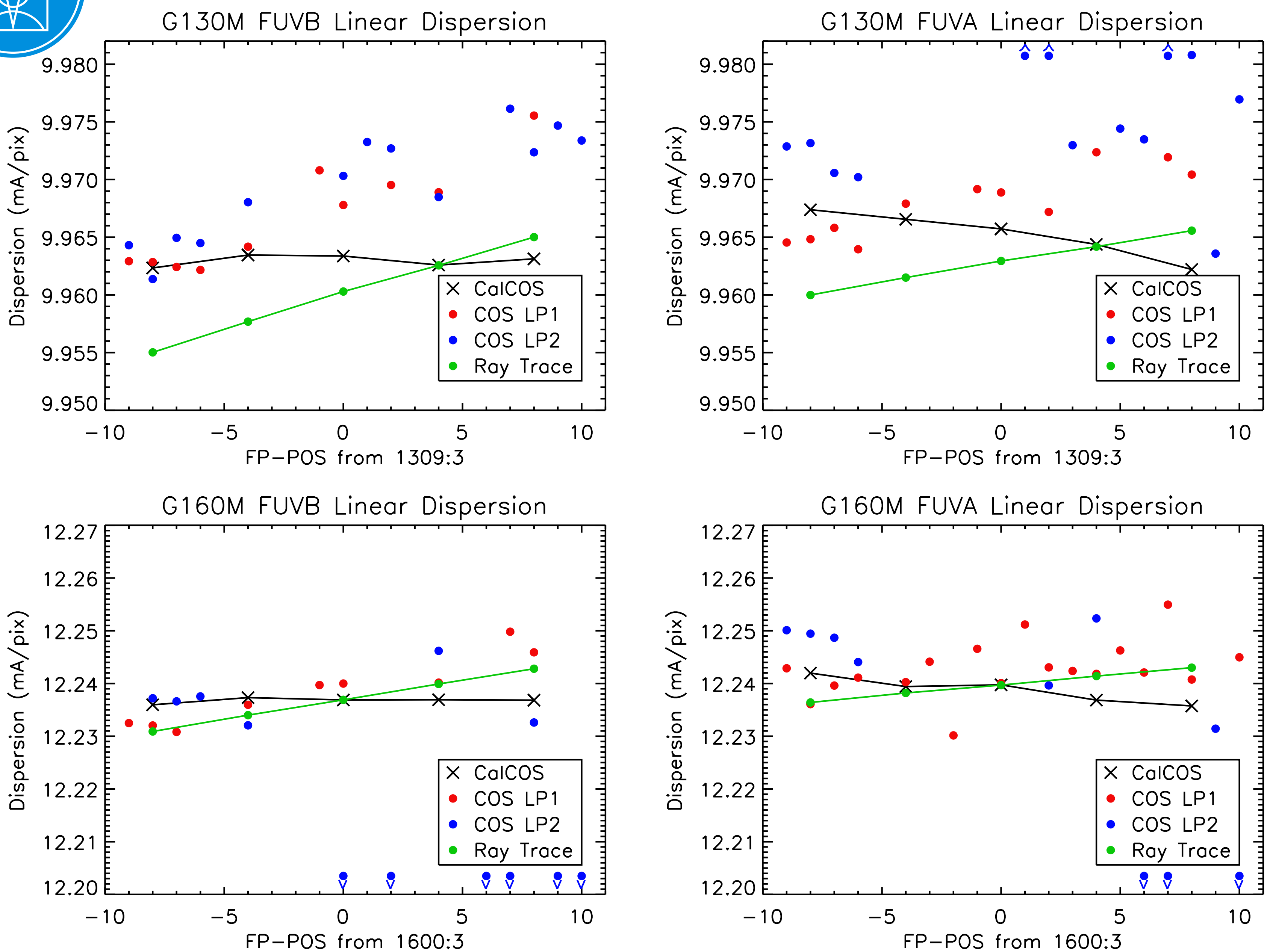




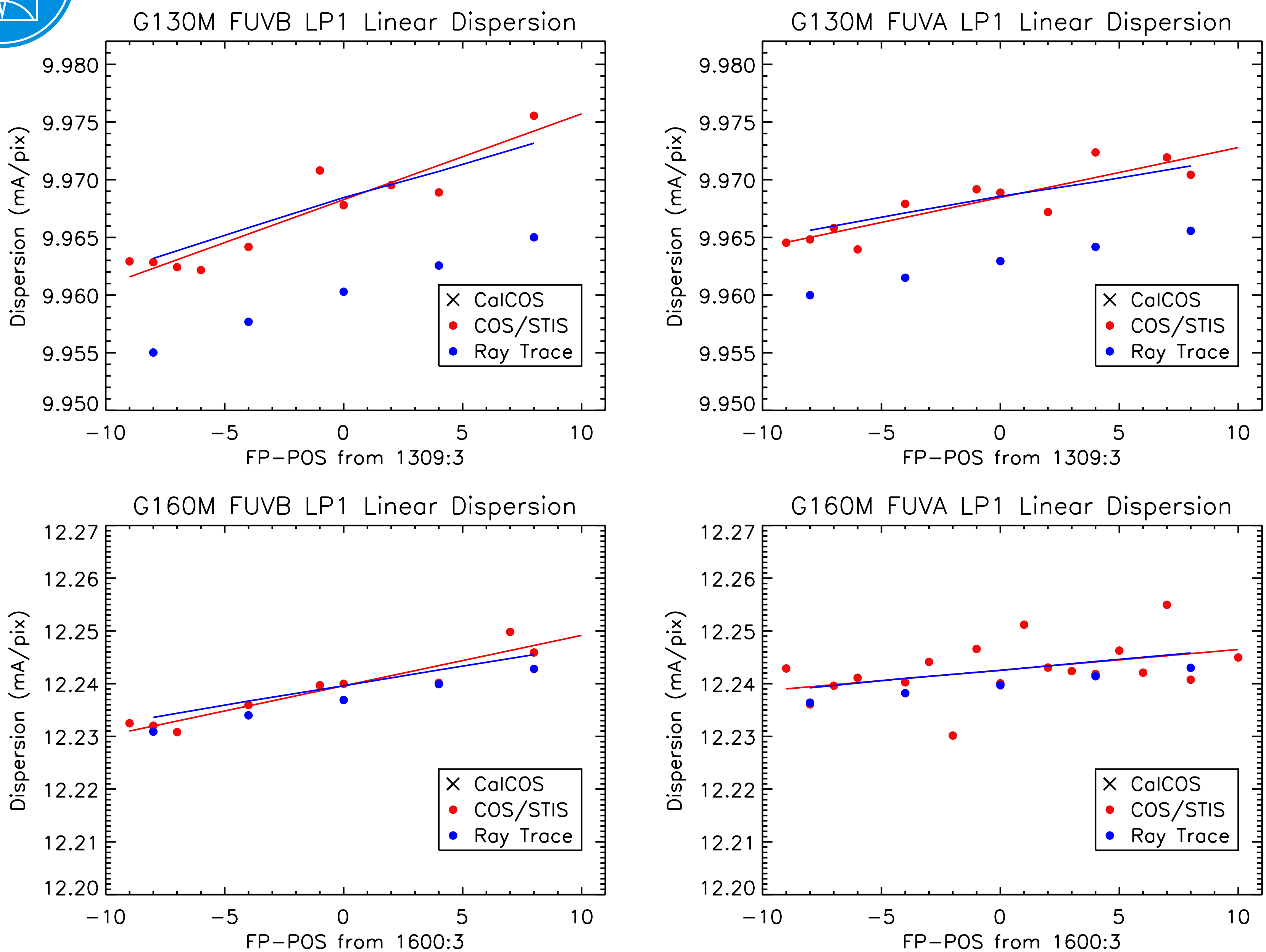




What about Ray Trace Models?



Matching COS/STIS Results and Ray Trace



Updating Dispersion Solutions – Short Term

Goal is to release updated dispersion solutions for some settings by early 2016

- Finish vetting the cross-correlation windows and targets using diagnostic plots
  - Need to access if # of lines used to determine dispersion coefficients and their distribution on the detector is adequate

- Identify datasets where TA uncertainty is minimal and use those datasets to derive zero-point of wavelength solution
  - Identify datasets (no need for COS and STIS overlap) that can be used to bootstrap the zero point for other settings

- AGN dataset compiled by B. Wakker and C. Danforth to test new dispersion solutions
  - Current wavelength dispersion reference file can support up to n=3 polynomial
  - No changes to pipeline required, only updated ref file, no other dependencies

- Community will be informed with STAN

Updating Dispersion Solutions – Longer Term

- Might want to consider obtaining new COS+STIS data of emission line target if there are settings for which zero point cannot be determined from current data or settings for which have no data to derive updated dispersion coefficients

- Use AGN dataset compiled by B. Wakker and C. Danforth to test new dispersion solutions
  - Current wavelength dispersion reference file can support up to n=3 polynomial
  - No changes to pipeline required, only updated ref file, no dependency

- Investigate if difference between LP1 and LP2 dispersion coefficients is significant – both with models and from data

- Explore ray-trace models and see if can explain discrepancy between models and new coefficients by adjusting the focus in the models
  - If so, might be able to use ray-trace models coefficients for settings for which we have no overlapping COS + STIS data

- Release fully updated dispersion coefficients by ~ Summer 2016

- To improve dispersion solutions beyond +/- 3 pix need to improve x-walk and geometric distortion corrections

- Improvements to the COS/FUV dispersion solution by cross-correlating COS and STIS data discussed in main part of presentation (previous slides)

- Updates on the Walk Correction and Geometric Distortion are given in the back-up slides (next)

BACK-UP SLIDES

Detector Walk

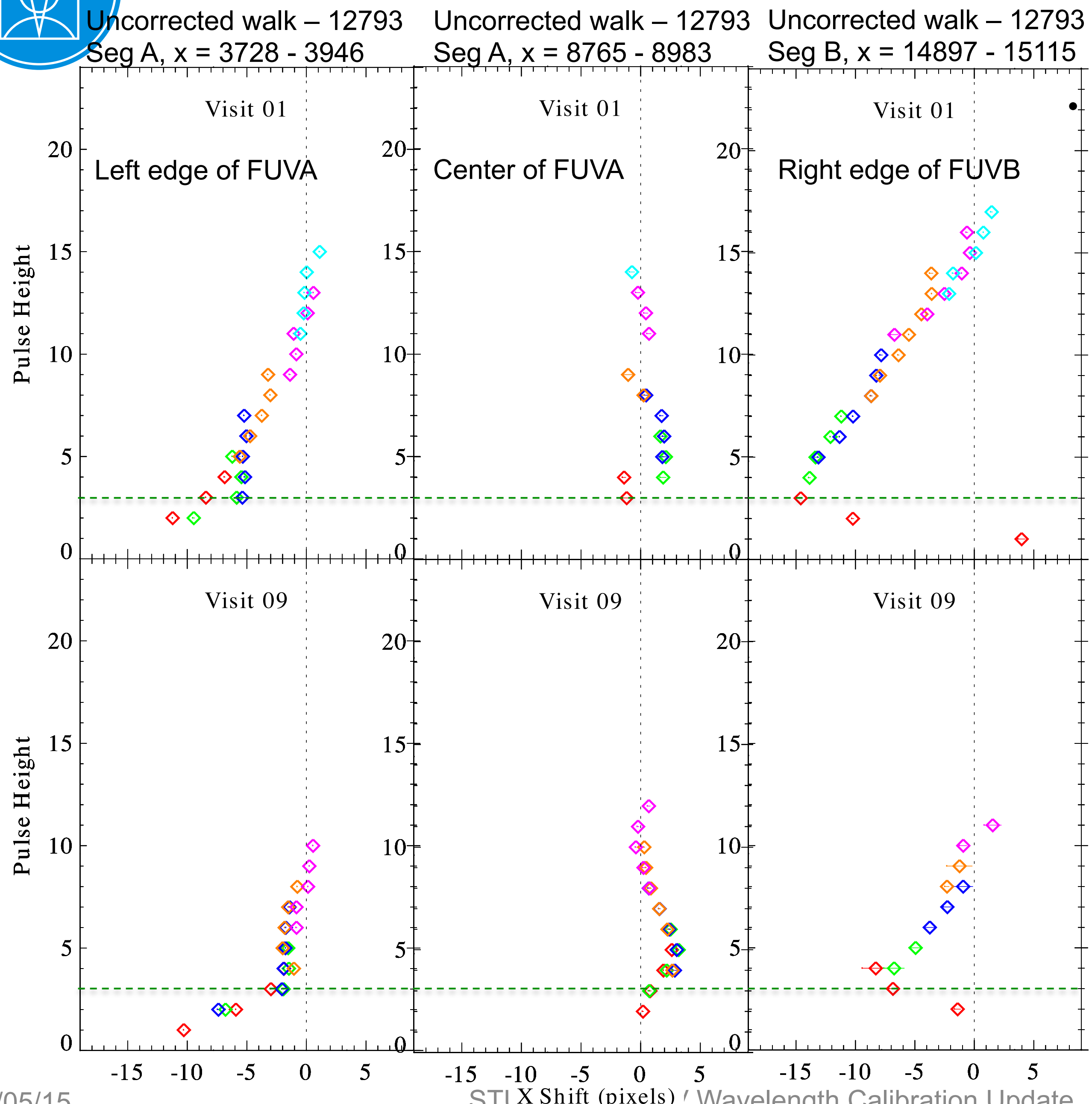
- Detector walk is the dependence of the calculated photon position on the pulse height (see e.g. Sahnow et al., 2011, SPIE proceedings, Vol 8859)

- Affects both the dispersion (x-walk) and cross-dispersion (y-walk) directions

- Figures in next slide are "interesting" examples of x-walk in the COS/FUV detector
  - x-walk is worse in some localized areas

- COS pipeline
  - Y-walk correction is currently applied
  - No x-walk correction is implemented

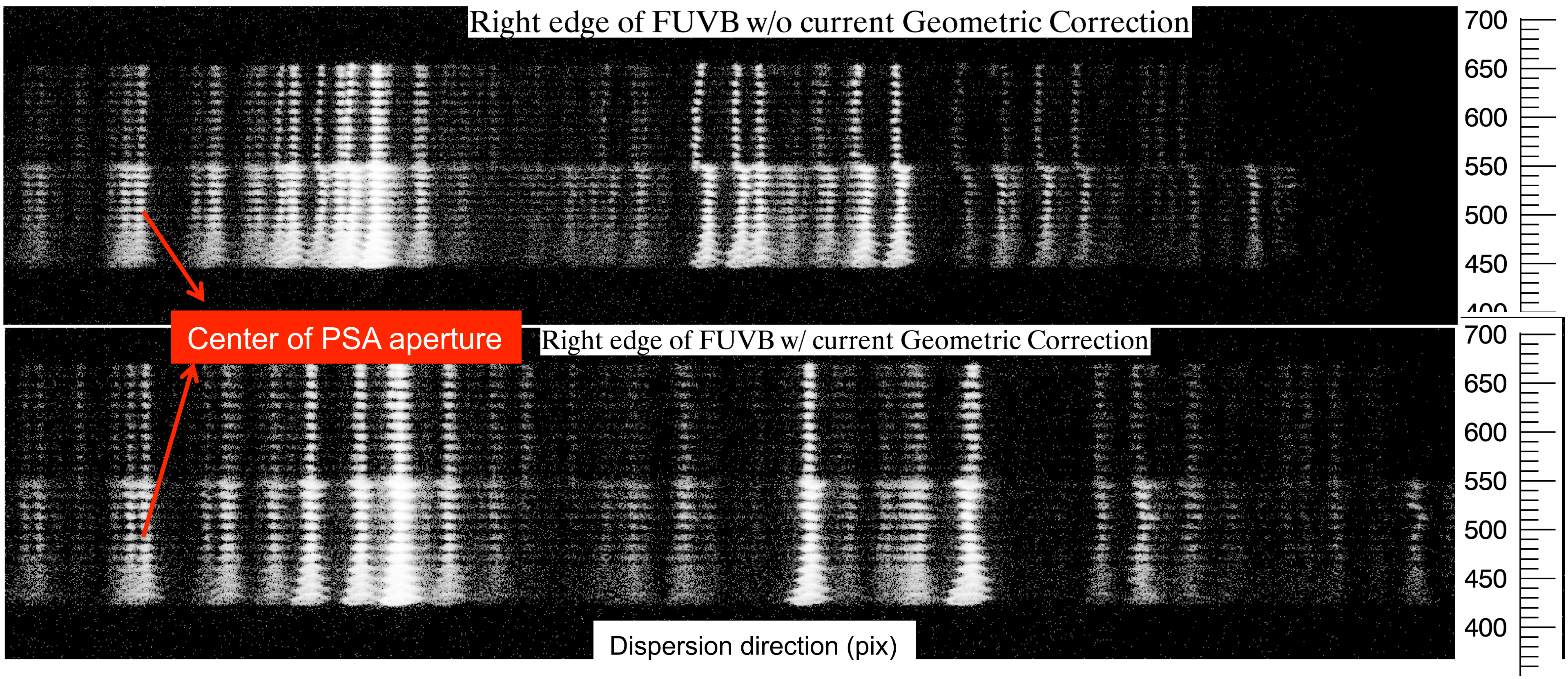
Walk Correction



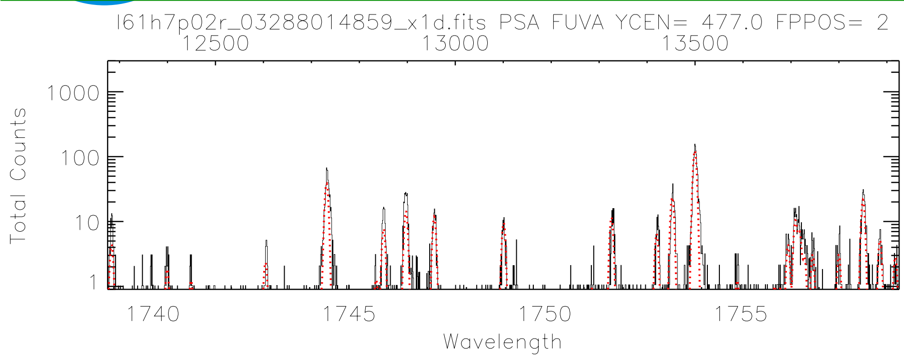
- Analyzing lamp data taken at different HV to evaluate x- and y-walk
  - Want to determine how the registration of events on the detector varies depending on the PHA
  - Affects both the dispersion (x) and cross-dispersion directions (y)
  - COS pipeline contains currently a y-walk correction only, that will be revisited in this work. Higher priority is to tackle the x-walk
  - x-walk varies in detector and in some areas can be up to ~6 pix, over the PHA range used in normal operations (PHA > 3, marked by green dashed line)
  - Edges of the detector are worse

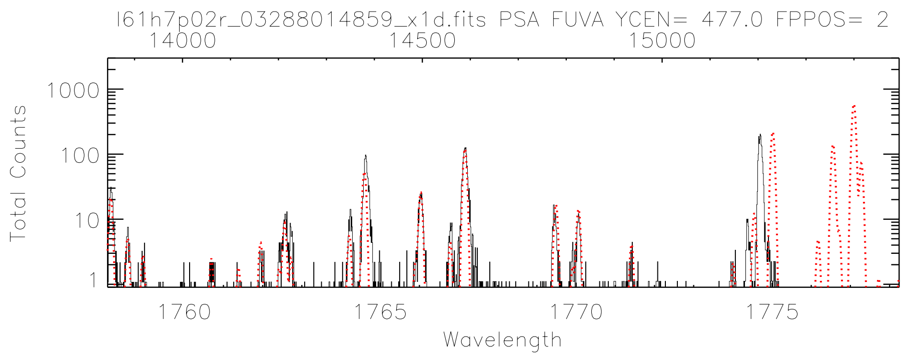
Geometric Distortion Correction

- Have processed through CalCOS the TV03 data used to determine geometric distortion correction to assess how well it does
  - Have a lamp line every 30 to ~ 200 pixels, so can only probe on those scales
  - Determined that 87% of the lines are within 3 pix of expected position (by fitting centroid of line)
  - Edge effects are very noticeable even in geometrically corrected data
- Figures show geometrically uncorrected (top) and corrected (bottom) data

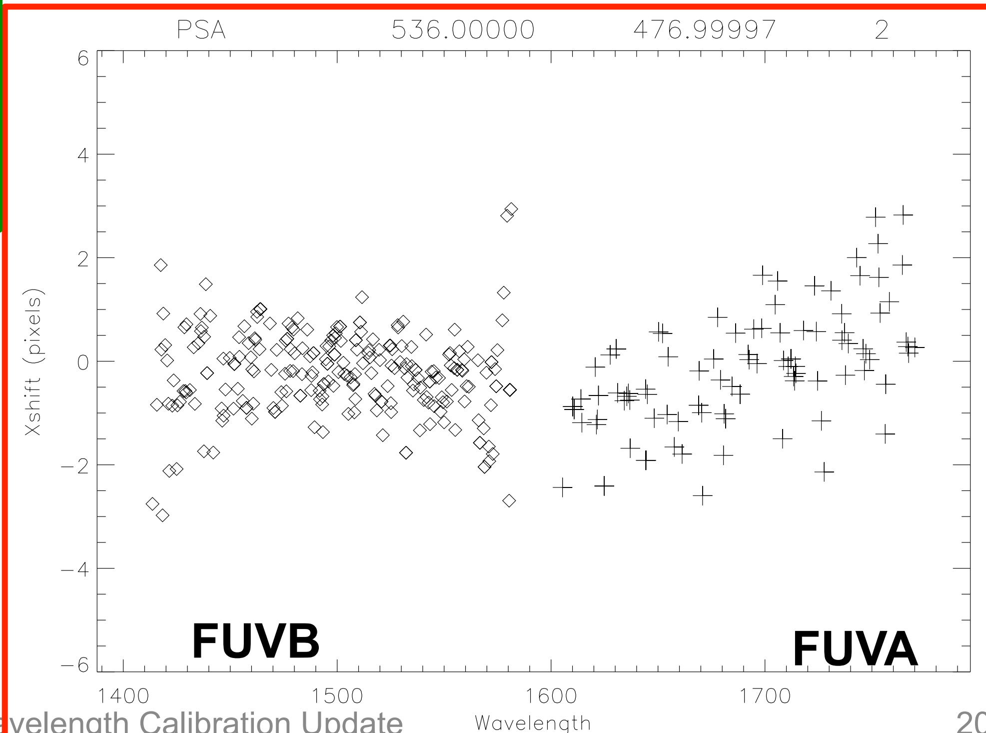


Matching NIST PtNe Line Atlas to Geometric Distortion TV03 Data





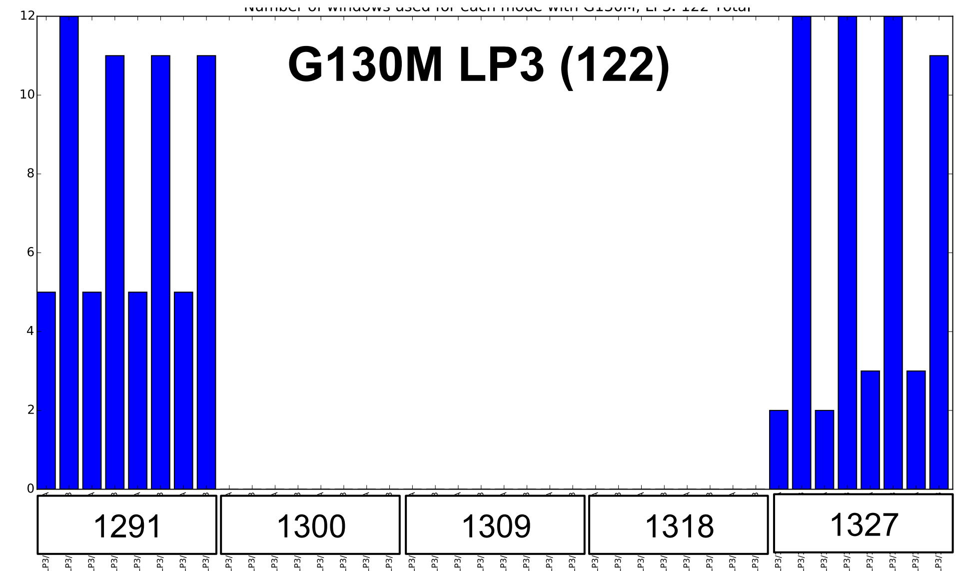
- Goal is to further improve geometric distortion correction
- NIST atlas is convolved with Gaussian LSF, line intensity is scaled to match COS
- Offsets between simulated (re lined) and observed (black line) spectra are determined by cross-correlation

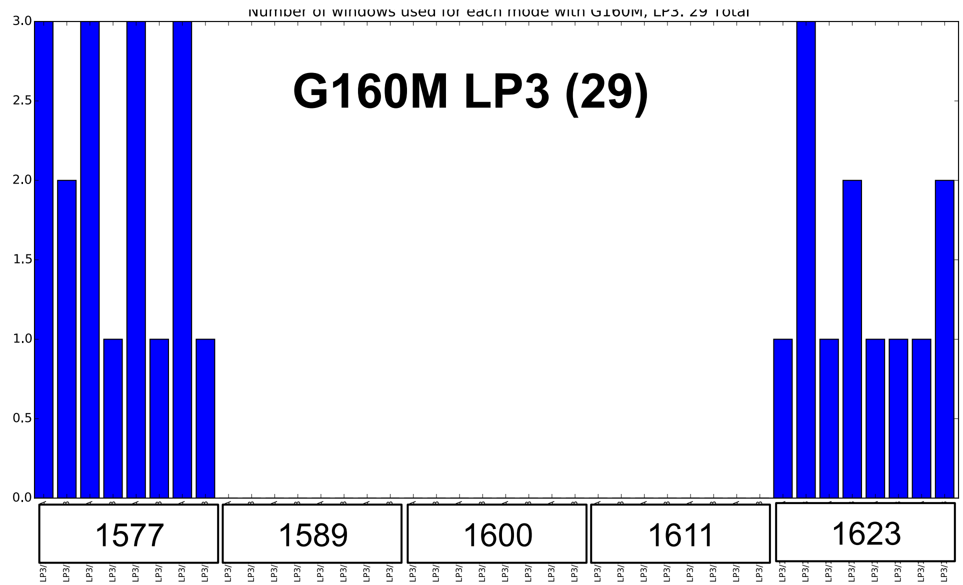


- Measured offsets shown for spectra obtained close to LP1 (TV location ~1.2" above LP1)
- Preliminary measurements indicate that most offsets are within ~ +/-2 pix

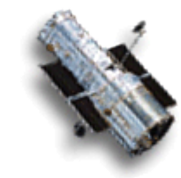
=> Geometric correction residuals not a huge factor in wavelength dispersion uncertainties

Distribution of Cross-Correlation Windows per Setting (LP3)

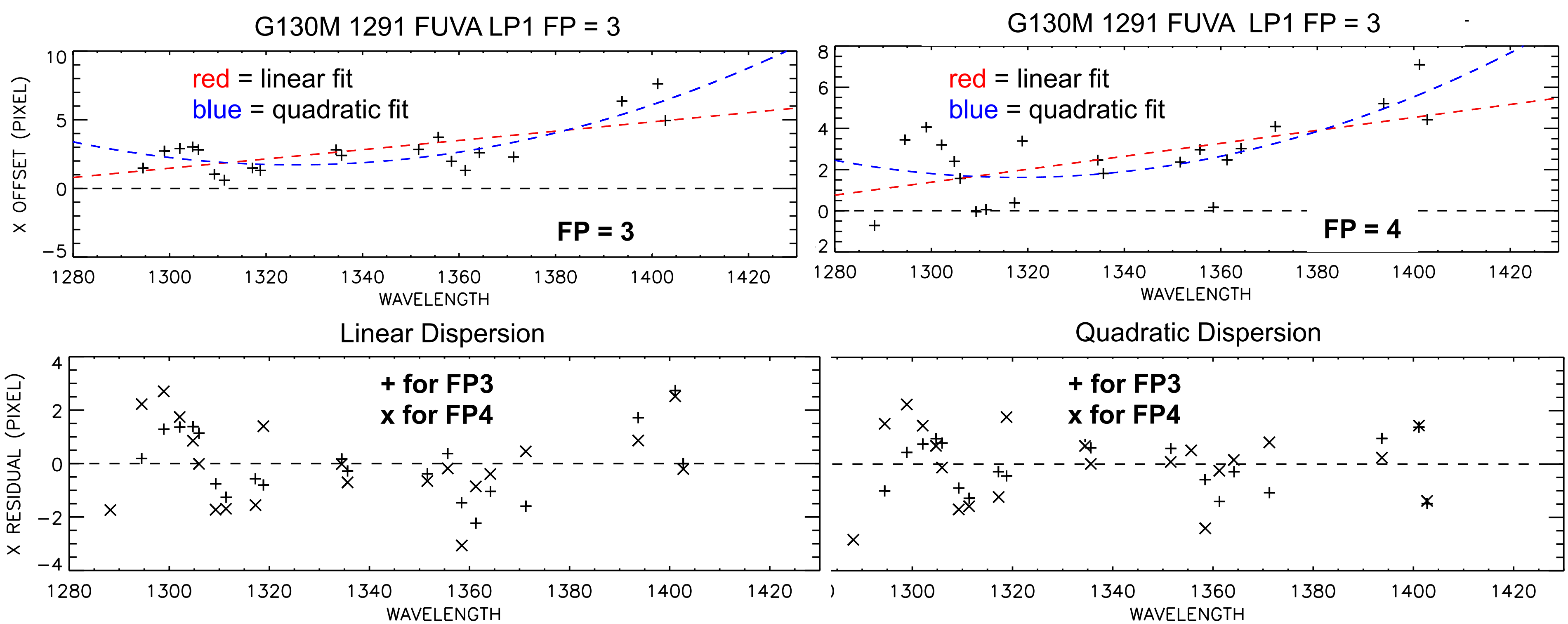




Limitations of Using STIS as Reference



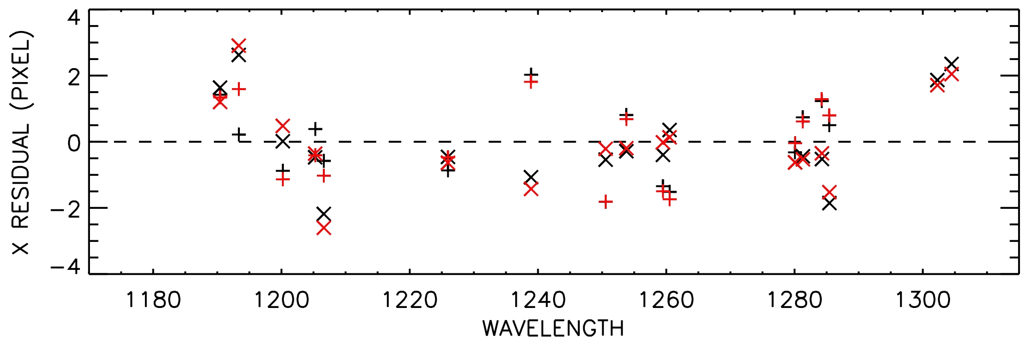
- HD39587 has COS and STIS data
- Fitting a linear (red) or quadratic (blue) polynomial to G130M/1291/FP-POS=3, 4 data, independently, yields residuals within ~ +/- 3 pix
  - Data not evaluated for uncertainty in zero point due to TA strategy used
  - Gives an idea of the limitations of this method when trying to determine an updated dispersion solution applicable to all targets



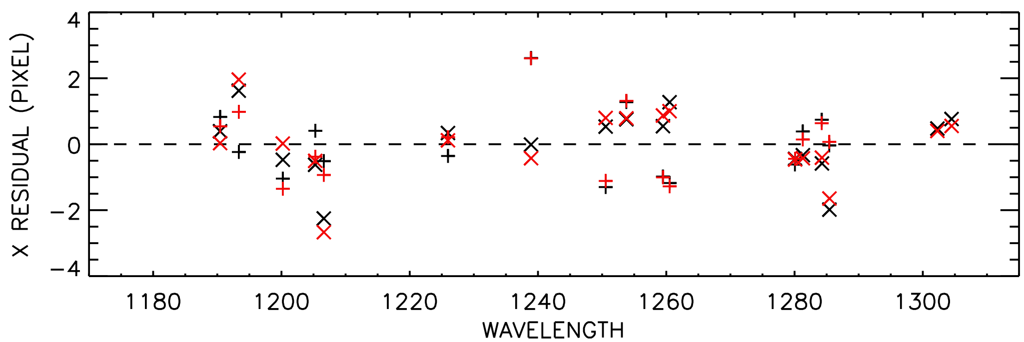
Using STIS as Reference – MRK 509

MRK 509 - FUVB - LP1

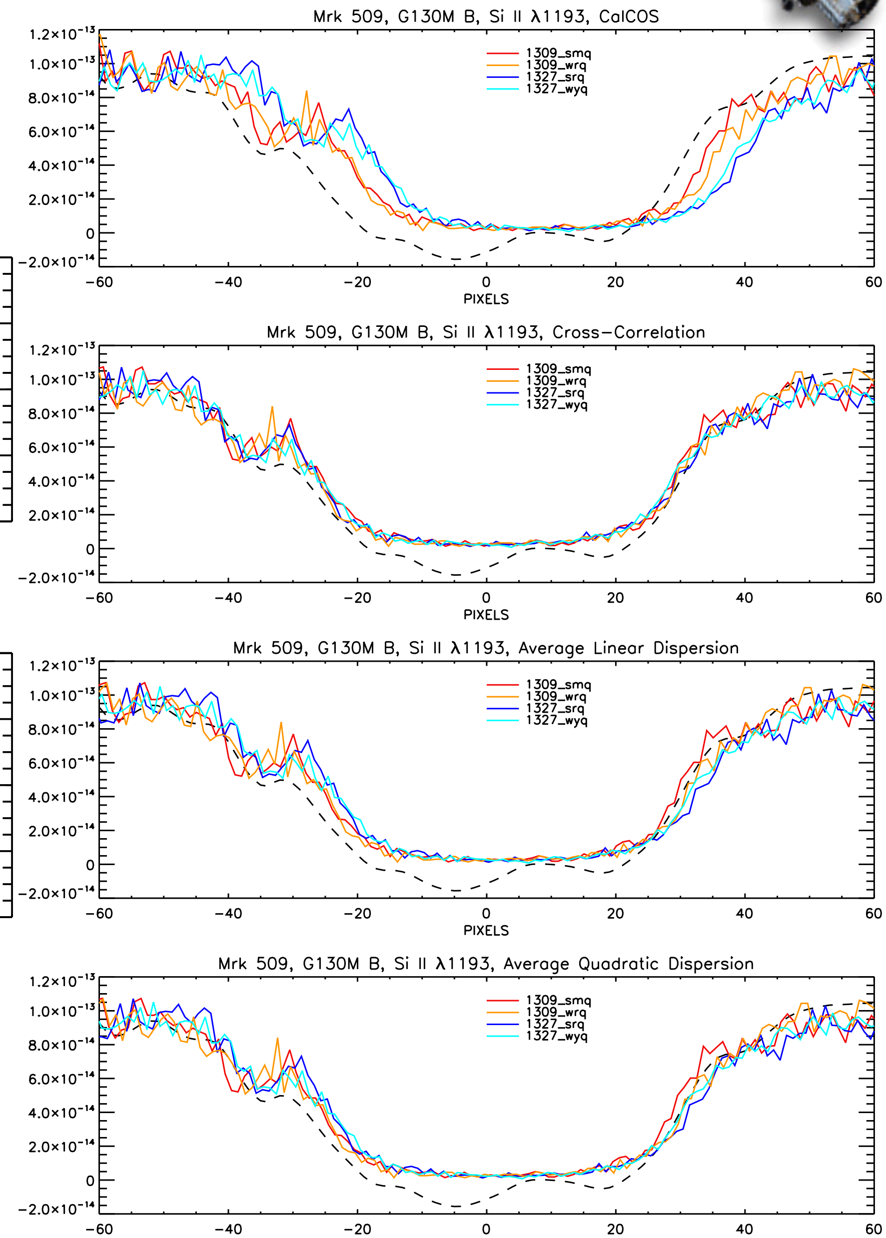
Linear Fit Residuals



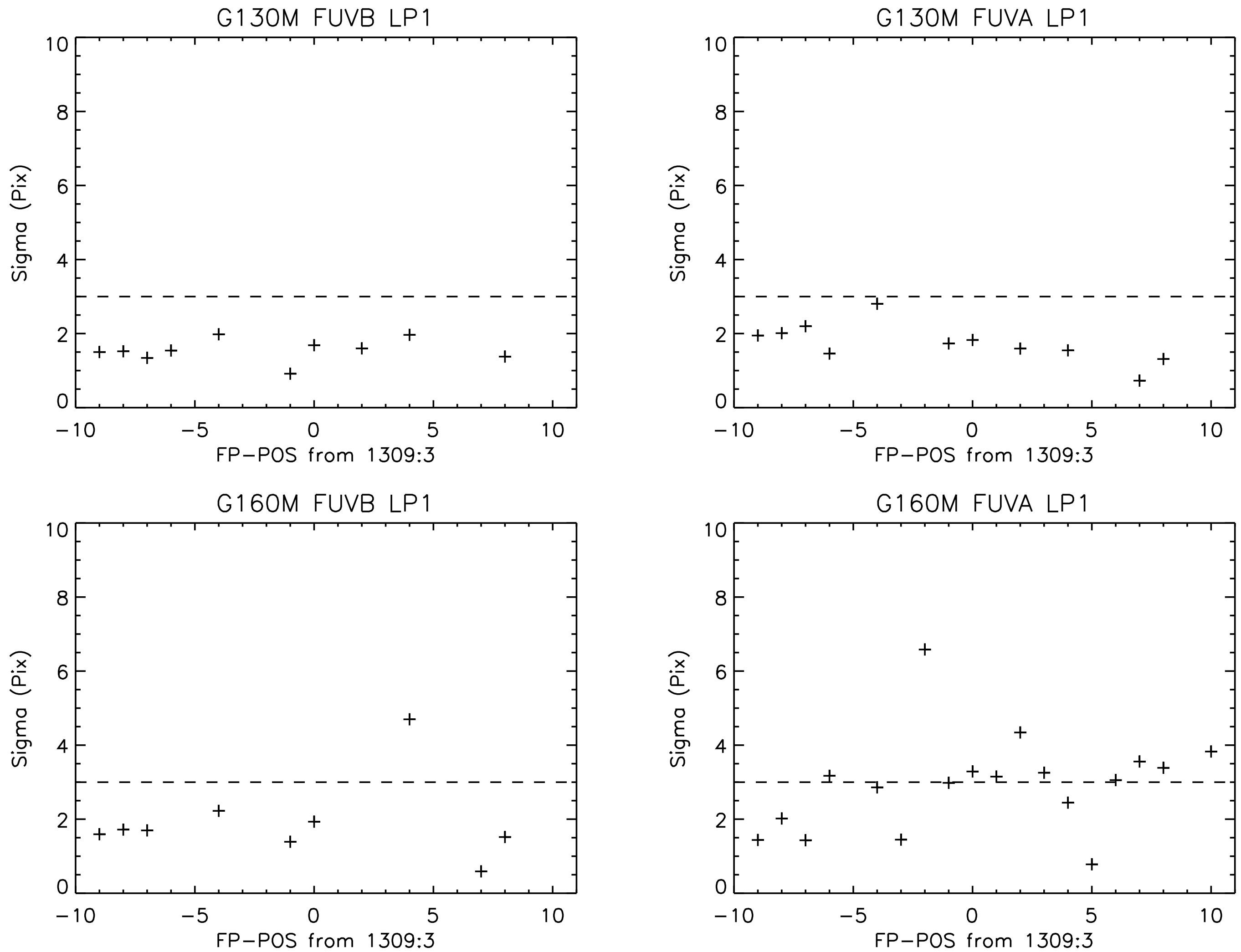
Quadratic Fit Residuals



+ = G130M/1309, x = G130M/1327
different colors for different exposures



Sigma of Residuals of Preliminary Dispersion Solution – LP1



Sigma of Residuals of Preliminary Dispersion Solution – LP2