Improvements to the FUV and NUV Wavelength Calibrations of the Cosmic Origins Spectrograph

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The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope in 2009 during Servicing Mission 4. Since then, the teams at the Space Telescope Science Institute have striven to provide the highest quality scientific products to the community. Over the past two years the COS team has been implementing improved wavelength calibrations for both the FUV and NUV channels. Here we present the current results of these new wavelength calibration solutions.

Overview

The dispersion solutions for COS can be found in the dispersion reference file (DISPTAB) and are defined using the equation: $\lambda = a_0 + a_1 \times pix + a_2 \times pix^2$ (COS ISR 2010-06). In the FUV channel, the medium resolution grating dispersion solutions are linear ($a_2 = 0$). In the NUV channel, the dispersion solutions are quadratic (a_2 ~10^{-6} to 10^{-8}). For the FUV we updated both a_0 and a_1 for the G130M and G160M standard modes. However, for the NUV channel, only the zero-points of the dispersion solution needed to be updated (a_0) and only for certain cenwave/stripe combinations for which accurate zero-points had not been determined during commissioning.

We used a cross-correlation technique, correlating COS data to STIS data of the same target to derive zero-points (FUV and NUV) and dispersion coefficients (FUV only). We used STIS as a reference spectrum when possible because of its higher wavelength accuracy. The absolute wavelength accuracy of the STIS detectors is ~2 km/s compared to the current COS wavelength accuracy of ~15 km/s. With this effort, we aim to increase the FUV wavelength accuracy to ~7.5 km/s, i.e, from one COS resolution element (6 pixels) to half a resolution element (3 pixels).

FUV

- Dispersion solutions in the FUV were found to be focus dependent.
- For every Lifetime Position (LP), ray-trace models were fit to the data to determine the dispersion coefficient.
- The focus changes with LP, so each circle in Figure 1 corresponds to a COS cenwave at different LPs.
- Zero-points were determined by cross-correlating different COS exposures of the same target obtained in the same visit (to remove uncertainties due to target acquisition).
- Examples of the COS-to-STIS cross-correlation residuals across the detector are shown below for each LP in Figures 2-4.

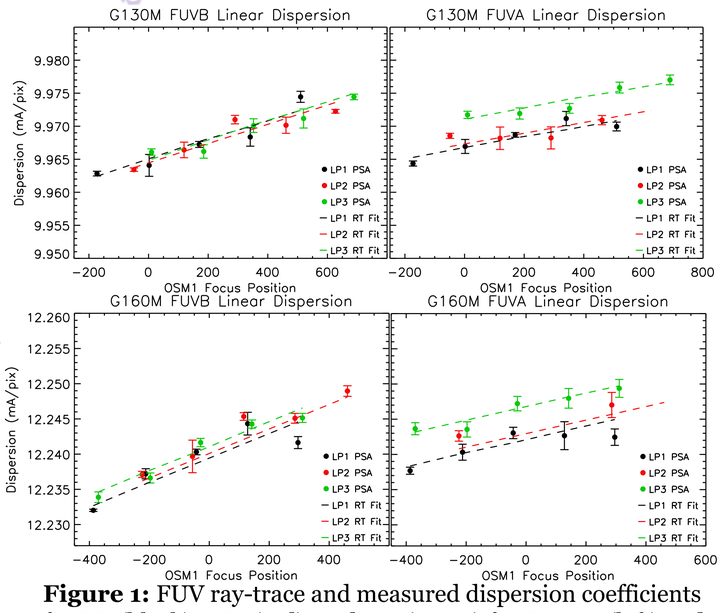
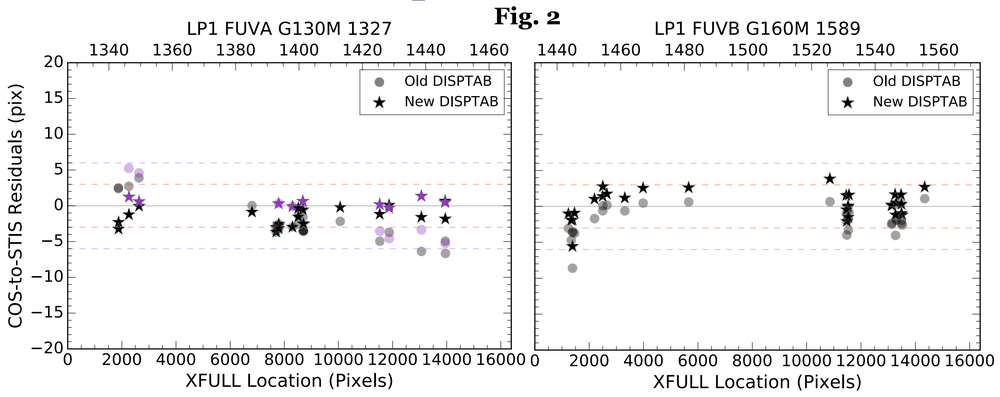


Figure 1: FUV ray-trace and measured dispersion coefficients for LP1(black), LP2 (red), and LP3(green) for G130M (left) and G160M (right)

LP1 (2009 – July 2012) – o5i1639ml_disp.fits

- Archival data at all COS cenwaves was available.
- The LP1 DISPTAB was delivered in May 2016.
- More information for LP1 can be found in the May 2016 STAN.

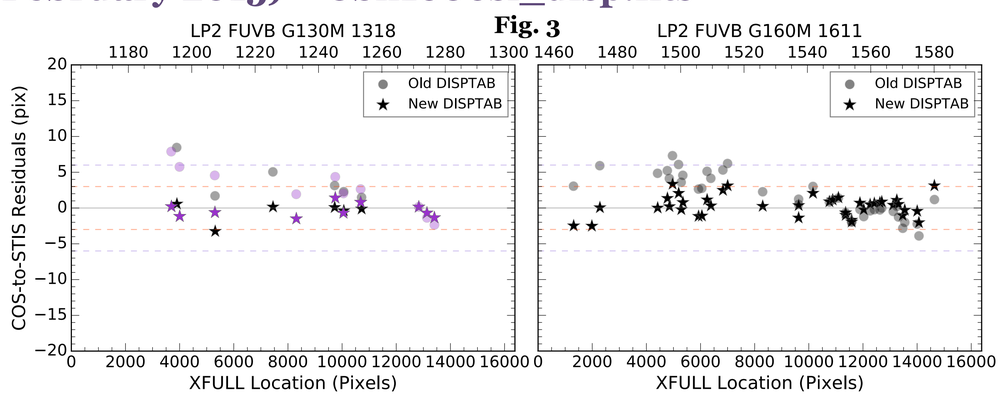
Fig. 2



LP2 (July 2012 – February 2015) – obn1606sl_disp.fits

- Archival data at most COS cenwaves was available.
- The LP2 DISPTAB was delivered in November 2016.
- More information for LP2 can be found in the November 2016 STAN.

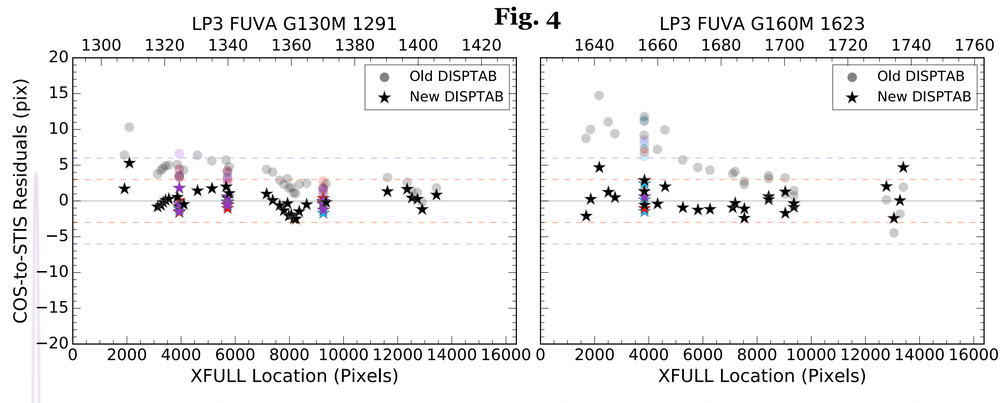
Fig. 3



LP3 (February 2015 – ~October 2017) – coming soon

- Little archival data existed at LP3.
- We crafted a special calibration program (PID 14909) which used Eps Eri and AV75
- Allowed us to determine both the dispersion coefficients and zero-points by taking special care. with target acquisition.
- Finalizing the LP3 DISPTAB.

Fig. 4



Figures 2-4 (above). COS-to-STIS cross-correlation residuals. G130M (left) and G160M (right) examples are shown at each LP. The residuals from the corrected DISPTAB (stars) show we now fall within 3 pixels compared to the old DISPTAB residuals (circles) which fell within 6 pix. Different colors represent different FP-POS.

NUV

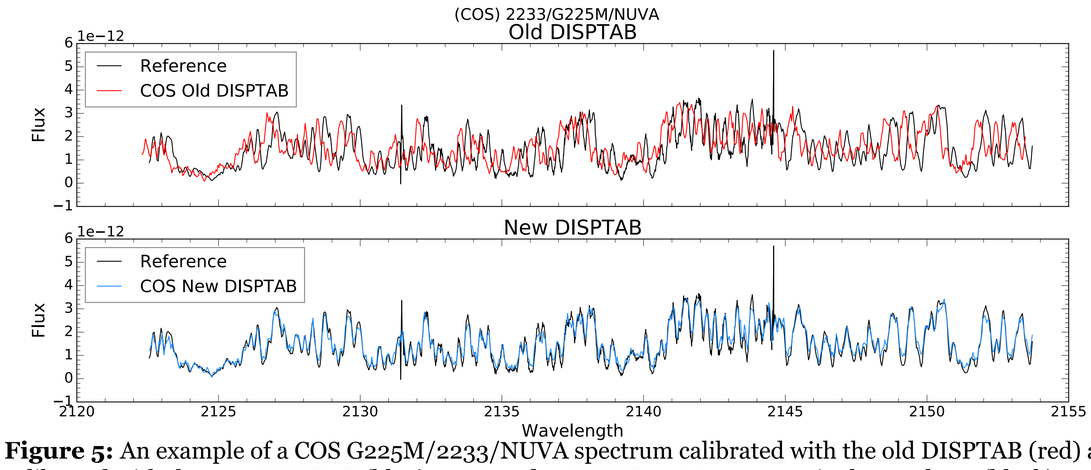
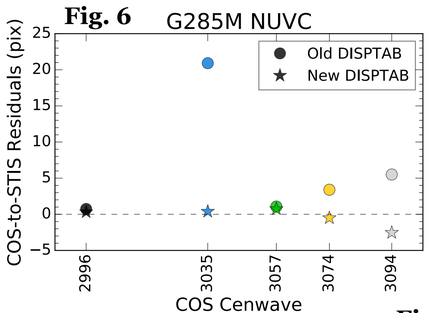


Figure 5: An example of a COS G225M/2233/NUVA spectrum calibrated with the old DISPTAB (red) and calibrated with the new DISPTAB (blue) compared to STIS E230M spectrum is shown above (black).

Three special calibration programs were designed to obtain COS (PID 14503) and STIS (PID 14504 & 14505) data to update the dispersion solution zero-points of some settings. The new NUV DISPTAB is: 12e1345gl_disp.fits, and was delivered in February 2017. The following modes were updated:

- All G185M cenwaves and stripes
- G225M–2186, 2217, 2233, 2250 (NUVA and NUVB)
  2268, 2283, 2306, 2325, 2339 (NUVB only)
- G285M – 2996, 3035, 3057, 3074, 3094 (NUVC)
- G230L – 2950, 3000 (NUVA) 3360 (NUVB)

Fig. 6



An example of a spectrum calibrated with the new DISPTAB and with the old DISPTAB compared to STIS is shown in Figure 5. Cross-correlation residuals between COS and STIS data calibrated with the previous version of the DISPTAB compared to the current DISPTAB are shown in Figures 6-9.

More information can be found in the supporting COS 2017-02 ISR and the February 2017 STAN.

Fig. 7

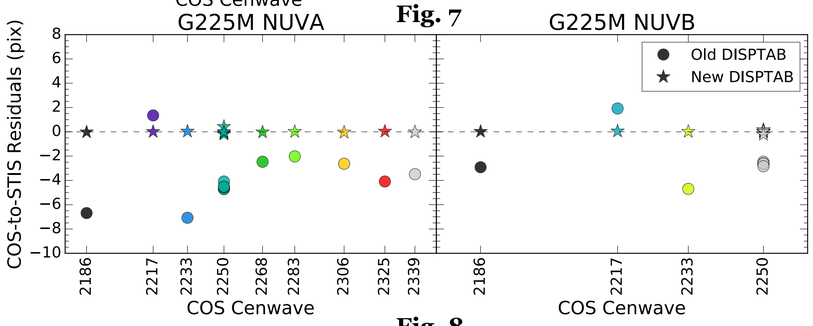


Fig. 8

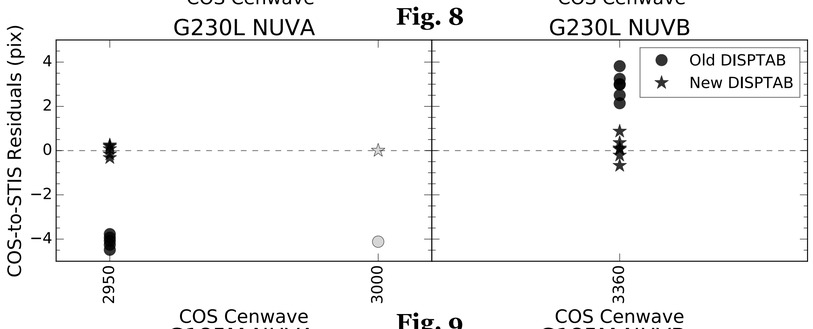
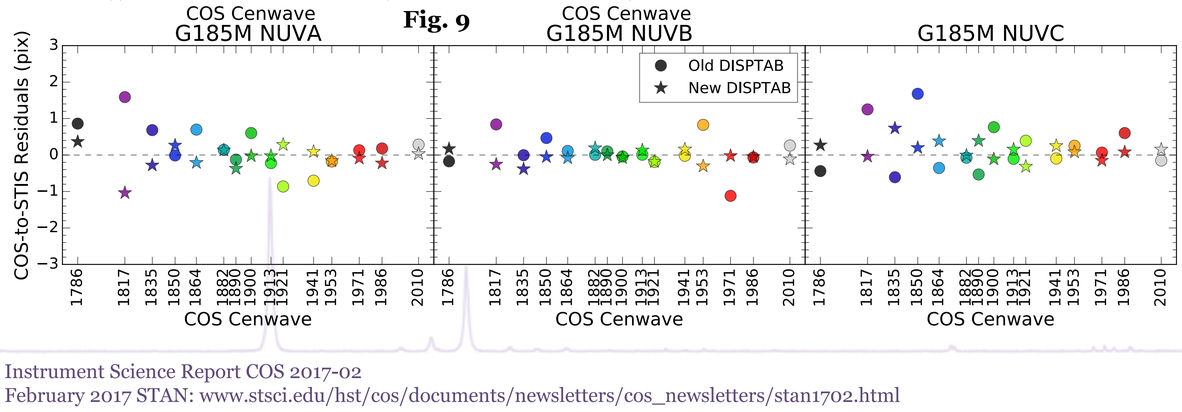


Fig. 9



Each figure shows the COS cross-correlation residuals when compared to STIS for each cenwave and stripe that was updated, with the exception of 3360/NUVB for which no STIS data existed.

Figure 6 shows G285M NUVC residuals for each updated cenwave.

Figure 7 shows the residuals for G225M NUVA and NUVB.

Figure 8 shows the residuals for G230L NUVA and NUVB. The 3360/NUVB spectrum was compared to COS G285M, 3094/NUVC.

Figure 9 shows residuals for all G185M cenwaves and stripes.

November 2016 STAN: www.stsci.edu/hst/cos/documents/newsletters/cos_newsletters/stan1611.html
May 2016 STAN: www.stsci.edu/hst/cos/documents/newsletters/cos_newsletters/stan1605.html
Instrument Science Report COS 2017-02
February 2017 STAN: www.stsci.edu/hst/cos/documents/newsletters/cos_newsletters/stan1702.html