Instrument Science Report COS 2018-17

COS FUV Aperture and Spectrum Placement at LP4

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ABSTRACT

Program 14875 was executed to determine the spacecraft pointing offset and aperture offset needed for the fourth COS FUV Lifetime Position (LP4). The spectrum was shifted approximately -2.52 arcseconds in the cross-dispersion direction, then the aperture was scanned across the stationary spectrum in both directions to identify the optimum location of the aperture, along with the entries in the Science Instrument Aperture File at LP4.

Contents

1. Introduction

In order to routinely obtain high-quality data at Lifetime Position 4 (LP4) on the COS FUV detector, the SIAF (Science Instrument Aperture File) entries for that LP must be properly populated so that the telescope points to the proper location to put the spectra at the desired location in the cross-dispersion (XD) direction on the detector. The cross-dispersion aperture position that best centers the target in the aperture is then determined. In the along-dispersion (AD) direction, the SIAF is adjusted so that the telescope is pointed to the center of the COS aperture when commanded to the correct XD position.

Program 14875 was designed to determine the SIAF values (expressed in spacecraft [V2,V3] coordinates) and aperture positions (expressed in COS keywords [APERXPOS (AD), APERYPOS (XD)]) for this purpose. The program was similar to Programs 12795 (FENA2) and 13634 (LENA1), which performed the same function at LP2 and LP3.

2. Using the LIFETIME-POS Optional Parameter

Program 14841, "Optimization of COS/FUV spectrum placement at lifetime position 4" (PI: DeRosa), which executed in August 2016, verified that a cross-dispersion offset of approximately -2.52 arcseconds from LP3 (XAPER = +53) was large enough to ensure that the gain sag holes from the LP3 spectra were sufficiently far away to avoid impacting the LP4 region, and close enough so that the resolving power and detector distortion were acceptable (DeRosa et al, 2017). The pointing offset in that program was specified via POSTARGs.

The [V2,V3] location corresponding to the Program 14841 offset was then loaded into the HST SIAF file as specified in PR 86315 with the values shown in Table 1. LFBOA4 and LFPSA4 are the positions of the BOA and PSA when they are being used as the observing aperture. LAPTFBOAF4 is the position of the BOA when the PSA is used for observing, and LAPTFPSAF4 is the positon of the PSA when the BOA is used. These two entries are used by the bright object checking procedures in APT to ensure that field targets do not pose health and safety risks to the COS detectors.

Table 1 SIAF Values used for Program 14875

Aperture	V2 (arcsec)	V3 (arcsec)
LFBOA4	229.1073	-241.0320
LFPSA4	229.1073	-241.0320
LAPTFBOAF4	219.7331	-250.4062
LAPTFPSAF4	238.4815	-231.6578

Program 14875 used the LIFETIME-POS optional parameter in APT. By setting LIFETIME-POS=LP4, the post-14841 SIAF, aperture positions and High Voltage

(HV) values for LP4 were used during execution of the program. The use of this parameter meant that no special commanding was needed to adjust the HV or aperture, as had been necessary when preparing for the moves to LP2 and LP3.

The flight software (FSW) patchable constant table pcmech_ApMXDispPosition was used to specify the cross dispersion (XD) aperture positions. It was defined in PR 86334 and GSFC FSW change request SCR 371. The values are shown in Table 2.

Table 2 FSW patchable constant table pcmech_ApMXDispPosition

Aperture	FUV	NUV
PSA_LP4	234	126
BOA_LP4	-45	-153
FCA_LP4	-45	-153
WCA_LP4	234	126

The FSW patchable constant table pcmech_OSMTbl used the following focus position for G130M/1309, based on the results of Program 14527 (FUV Focus Sweep Exploratory Program for COS at LP4):

{0, 1309, 7991, 170, 290, 352, 392, -147, 898, 206, 126, 2218, 6857},

where the columns are grating index, cenwave, rotation motor step number, focus motor step numbers for LP1 – LP8, MEB1 resolver counts, and MEB2 resolver counts.

The HV values for G130M/1309 were set to 163/163 for Segments A/B for this program, based on the the results of Program 14525 (Characterization of the COS/FUV detector modal gain at Lifetime Position 4).

3. Observations

Program 14875 (Verification of Aperture and FUV Spectrum Placement for COS at LP4) consisted of a single, two-orbit visit. The target was the DB white dwarf WD0308-565, which was also used in the aperture verification/spectrum placement programs for previous Lifetime Positions: 12795 (LP2) and 13634 (LP3). Aside from the BOA/MIRRORA NUV ACQ/IMAGE, all of the exposures were designed to be identical except for the aperture location, each being a 25-second G130M/1309/FP-POS=3 exposures at the estimated LP4 position. However, due to an error when the Phase II was prepared, the last two exposures were only 15 seconds long. The program executed on December 29, 2016, and ran successfully. The full list of exposures is shown in Table 3.

The visit was sequenced as follows:

- ACQ/IMAGE with BOA/MIRRORA to obtain S/N = 60
- Spectrum with the aperture at the nominal location to obtain S/N = ~6 per resolution element

- Sequence of identical exposures, but each with the aperture in a different position in the cross-dispersion direction and at the nominal location in the dispersion direction
- Repeat of exposure with the aperture at the nominal location in both directions
- Sequence of identical exposures, but each with the aperture at a different position in the dispersion direction while it remained at the nominal location in cross-dispersion
- Repeat of exposure with the aperture at the nominal location

Table 3 List of exposures in Program 14875, showing the commanded (XAPER, YAPER) and measured (APERXPOS, APERYPOS) aperture positions, the calculated offset in arcseconds, and the counts in each segment.

Rootname	Along-Dispersion Direction			Cross-Dispersion Direction			Counts in Extraction Region	
	YAPER (steps)	APERXPOS	arcsec	XAPER (steps)	APERYPOS	arcsec	Seg A	Seg B
lddm01teq	0	22.1	0.00	0	235.1	0.00	69,275	95,640
lddm01tgq	0	22.1	0.00	-29	206.1	-1.38	20,922	29,576
lddm01tjq	0	22.1	0.00	-23	212.1	-1.10	43,363	60,695
lddm01tlq	0	22.1	0.00	-18	217.1	-0.86	52,768	73,727
lddm01tnq	0	22.1	0.00	-14	221.1	-0.67	59,736	83,067
lddm01tpq	0	22.1	0.00	-10	225.1	-0.48	66,341	91,083
lddm01trq	0	22.1	0.00	-6	229.1	-0.29	68,658	94,470
lddm01ttq	0	22.1	0.00	-3	232.1	-0.14	68,912	94,938
lddm01tvq	0	22.1	0.00	0	235.1	0.00	68,995	95,874
lddm01txq	0	22.1	0.00	+3	238.1	+0.14	69,089	95,728
lddm01tzq	0	22.1	0.00	+6	241.1	+0.29	68,727	94,896
lddm01u1q	0	22.1	0.00	+10	245.1	+0.48	67,348	92,558
lddm01u3q	0	22.1	0.00	+14	249.1	+0.67	59,595	81,920
lddm01u5q	0	22.1	0.00	+18	253.1	+0.86	53,050	72,532
lddm01u7q	0	22.1	0.00	+23	258.1	+1.10	42,790	58,653
lddm01u9q	0	22.1	0.00	+29	264.1	+1.38	18,622	25,637
lddm01ubq	0	22.1	0.00	0	235.1	0.00	68,808	95,612
lddm01uyq	0	22.1	0.00	0	235.1	0.00	69,629	95,224
lddm01v0q	+29	51.1	-1.38	0	235.1	0.00	22,142	31,679
lddm01v2q	+23	45.1	-1.10	0	235.1	0.00	42,949	58,486
lddm01v4q	+18	40.1	-0.86	0	235.1	0.00	53,529	73,252
lddm01v6q	+14	36.1	-0.67	0	235.1	0.00	59,233	80,705
lddm01v8q	+10	32.1	-0.48	0	235.1	0.00	65,538	89,841
lddm01vaq	+6	28.1	-0.29	0	235.1	0.00	68,835	94,249
lddm01vcq	+3	25.1	-0.14	0	235.1	0.00	69,118	94,848
lddm01veq	0	22.1	0.00	0	235.1	0.00	68,967	94,669
lddm01vgq	-3	19.1	+0.14	0	235.1	0.00	69,191	95,170
lddm01viq	-6	16.1	+0.29	0	235.1	0.00	69,192	95,186
lddm01vkq	-10	12.1	+0.48	0	235.1	0.00	66,991	91,833
lddm01vmq	-14	8.1	+0.67	0	235.1	0.00	60,569	82,922
lddm01voq	-18	4.1	+0.86	0	235.1	0.00	55,310	76,142
lddm01vqq	-23	-1.1	+1.10	0	235.1	0.00	46,977	64,363
lddm01vsq	-29	-7.1	+1.38	0	235.1	0.00	16,521*	22,925*
lddm01vuq	0	22.1	0.00	0	235.1	0.00	41,735*	57,483*

* The last two exposures had an exposure time of 15 seconds; all others were 25 seconds

For both dispersion and cross-dispersion direction, the relative aperture offsets (XAPER and YAPER) specified for the scans were -29, -23, -18, -14, -10, -6, -3, 0, +4, +6, +10, +14, +18, +23, +29 steps. Assuming a nominal plate scale of 21 steps/arcsec, this is equivalent to -1.38, -1.10, -0.86, -0.67, -0.48, -0.29, -0.14, 0.00, +0.14, +0.29, +0.48, +0.67, 0.86, +1.10, +1.38 arcseconds. The two scans were each in their own non-interruptable sequence to ensure that the data for each direction was taken without an interruption. In the cross-dispersion direction, the offset numbers increased with each step, while it decreased for the dispersion scan; this ensured that the aperture moves were all in the preferred direction of the mechanism. The extra spectra taken at the nominal location were included in order to estimate the repeatability of the measurements.

All exposures used the FLASH=S0027D025 Optional Parameter to keep the wavelength calibration lamp on for the entire exposure. This provided additional wavecal spectra which were used to investigate how the wavelength calibration was affected by the low gain at LP2; the analysis of this data is not described here.

4. Analysis

Three IDL programs were used in the analysis of the data:

- *Apsweep.pro* reads in each of the corrtag files, calculates projections in the *x* (AD) and *y* (XD) directions over a user-defined area, and saves the results in an IDL save file for use by other programs. For Segment B, the extraction region selected excludes the bright Lyman-α airglow line; the counts from other airglow lines are negligible and thus are not removed. The program also creates figures which can be inspected to ensure that the regions are not contaminated by the wavecal spectra, hot spots, airglow, etc.; see Figure 1 for an example.
- *Apsweepplot.pro* reads in the save file from apsweep.pro, makes plots of relative throughput as a function of aperture position, and calculates the best center position.
- *LPlocations.pro* displays the cross-dispersion profiles on the detector for the aperture placement data for all Lifetime Positions and calculates the median of each.

All of the results described here are based on these programs.

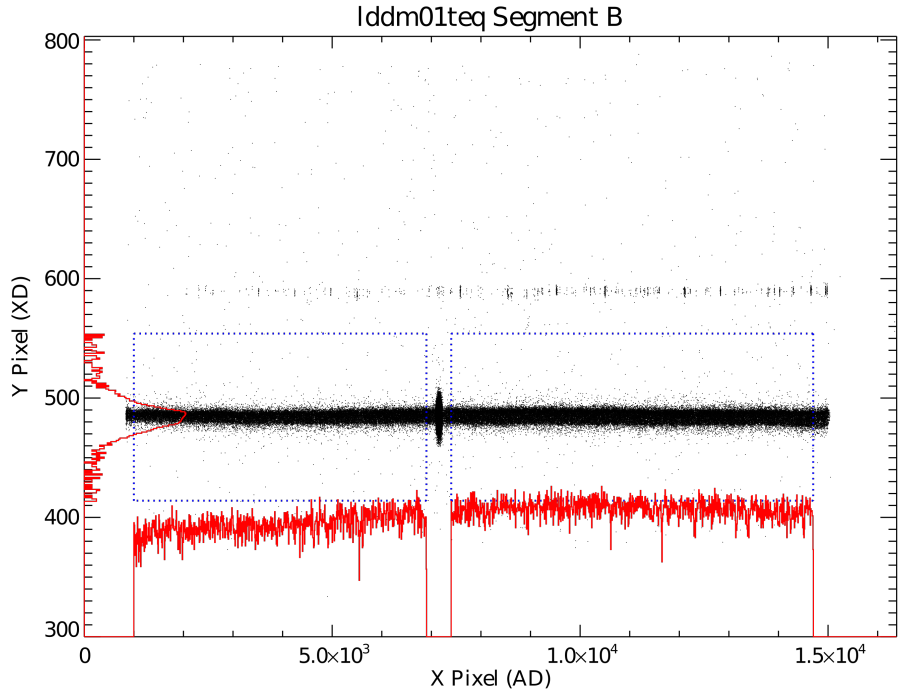

Figure 1 Output figure from apsweep.pro for Segment B. The black points show the events in the corrtag file in (xcorr,ycorr) coordinates. Both the spectrum, centered near y=485, and the wavecal spectrum (near y=590) are visible. The blue dotted lines mark the edges of the extraction windows used. For segment B, it has been adjusted to exclude the bright Lyman-α airglow line. The red curves show the projection in the dispersion and cross-dispersion directions, using just the events inside the blue boxes.

4.1 Aperture Centering

Figure 2 shows the relative throughput as a function of aperture step value for the scan in the cross-dispersion direction; no background was subtracted since the background rate was so low. Poisson errors for the individual points are 3% or less and are not displayed. The two segments were measured separately but are shown on the same figure. They are very similar, as expected, since the aperture throughput is not expected to be a strong function of wavelength.

Also shown in the figure are horizontal lines at 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, and 97.5% of the maximum throughput for each segment. For each of these relative flux values, the center, i.e. the aperture position where 50% of the light falls on either side, is marked. Figure 3 shows this best center data (now relative to the aperture step value when it is at its nominal LP4 position) as a function of the half width in arcseconds. Figure 4 and Figure 5 show the same information (throughput and centering) for the along-dispersion scan.

From figures 3 and 5, we can see that the measured center for the cross-dispersion scan is very close to zero beyond ~0.6 arcseconds from the center, while in the along-

dispersion direction it is shifted slightly, as expected. Table 4 summarizes the results for both directions.

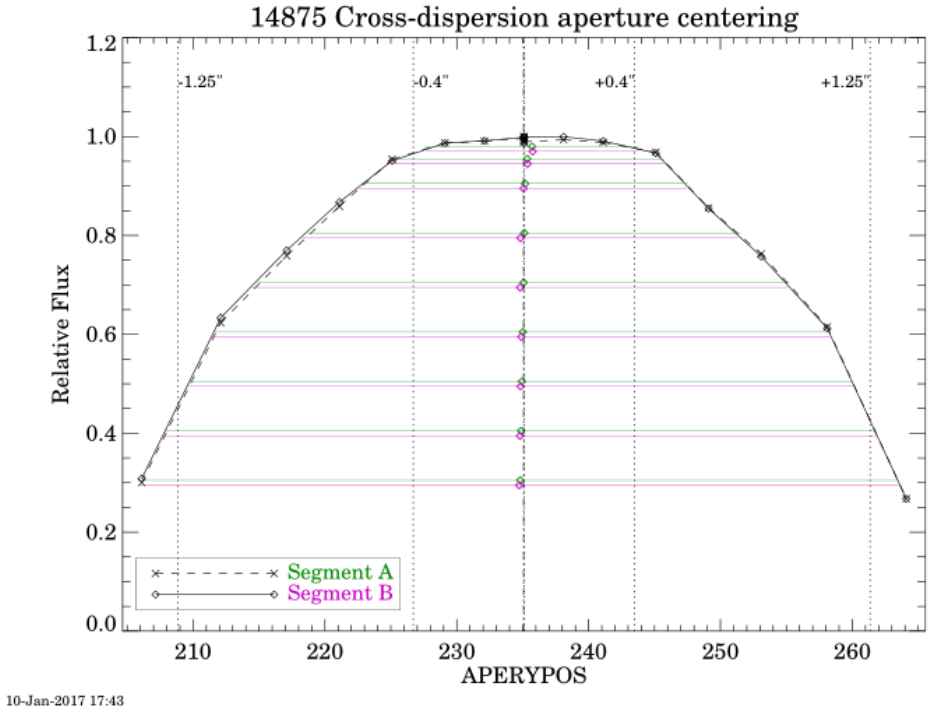

Figure 2 Cross-Dispersion aperture centering data showing the relative throughput as a function of aperture position. Both segments are shown on the same plot and are nearly indistinguishable. The errors on the individual points are 3% or less.

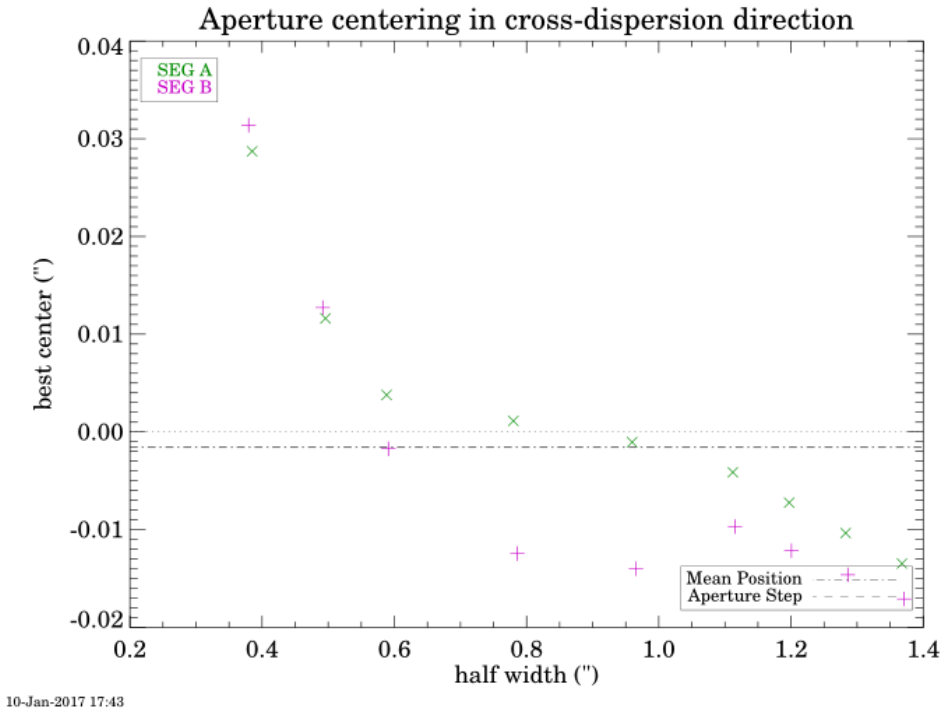

Figure 3 The measured best center relative to the nominal LP4 position as a function of the half width, using the same data as in Figure 2.

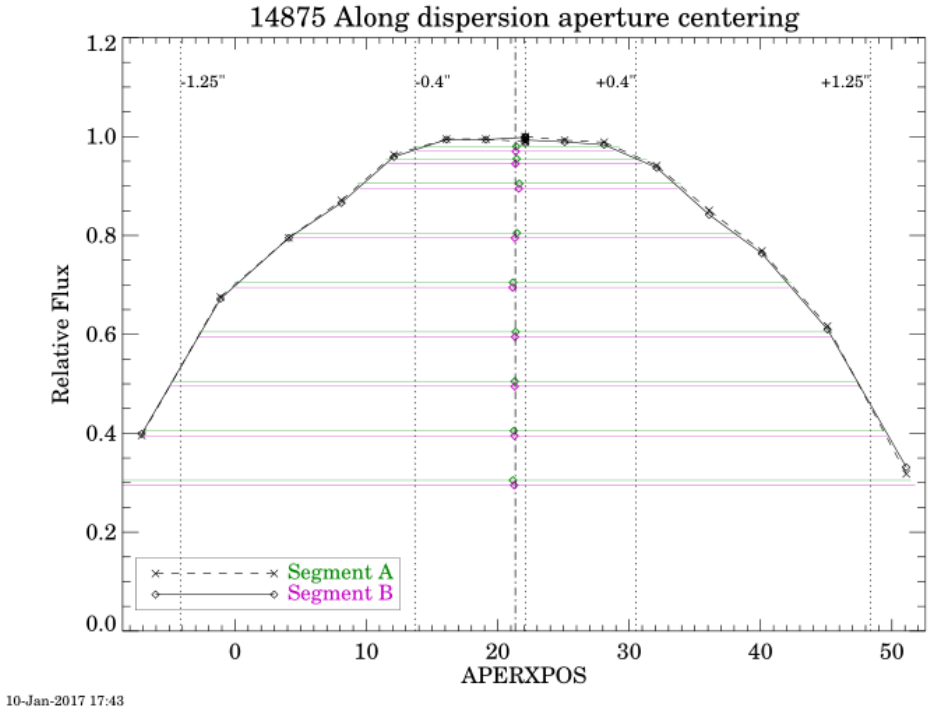

Figure 4 Same as Figure 2, but for the along-dispersion direction

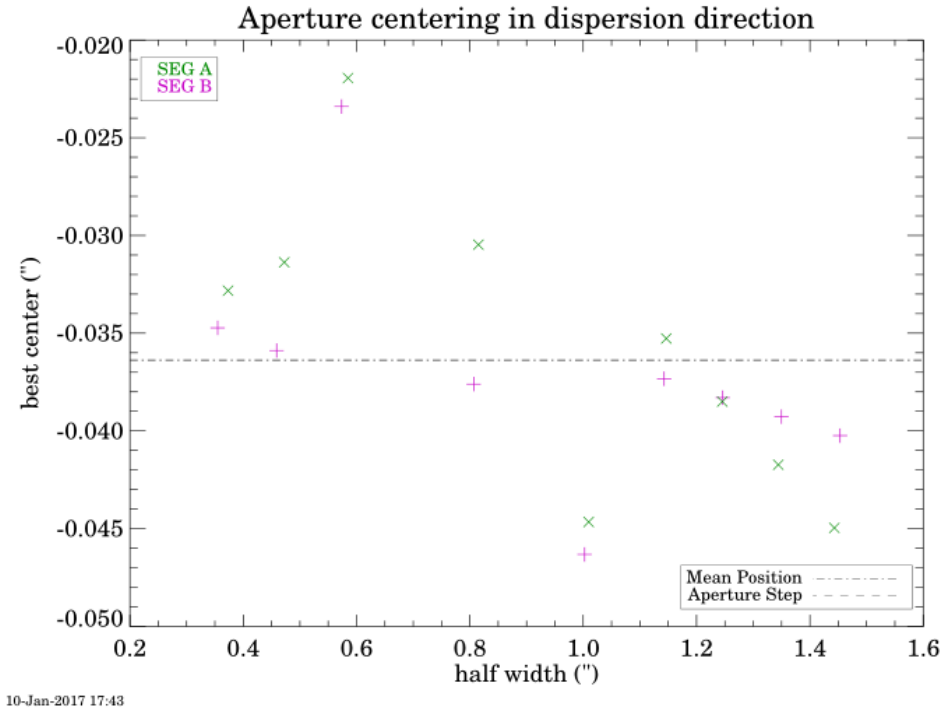

Figure 5 Same as Figure 3, but for the along-dispersion direction

Table 4 Measured aperture shifts

Direction	Nominal APERXPOS	Calculated Mean APERXPOS	Measured Shift (steps)	Measured Shift (arcsec)
Cross-dispersion	235.1	235.1	0.0	-0.002
Dispersion	22.1	21.3	-0.8	-0.036

4.2 Location of LP4 on the Detector

Figure 6 shows normalized G130M/1309 cross-dispersion profiles and medians for the data from this program and spectra from the same target taken at LP1 (Program 12426), LP2 (12715, 12806), and LP3 (13634). These data are consistent with the results from Program 14841, i.e. that an offset of ~ -2.5 arcseconds is adequate to ensure that there will be minimal overlap between the LP3 and LP4 spectral regions.

The calculated medians of the profiles for each LP (or the average of multiple measurements if more than one dataset was available) are collected in the first two columns of Table 5. Also shown in that table is the difference from the LP1 position, in pixels, for each segment separately and averaged. The last two columns list the

SIAF location, in arcseconds, with respect to LP1 for each LP; and then the calculated pixel scale in pixels/arcsecond using the numbers in the previous two columns.

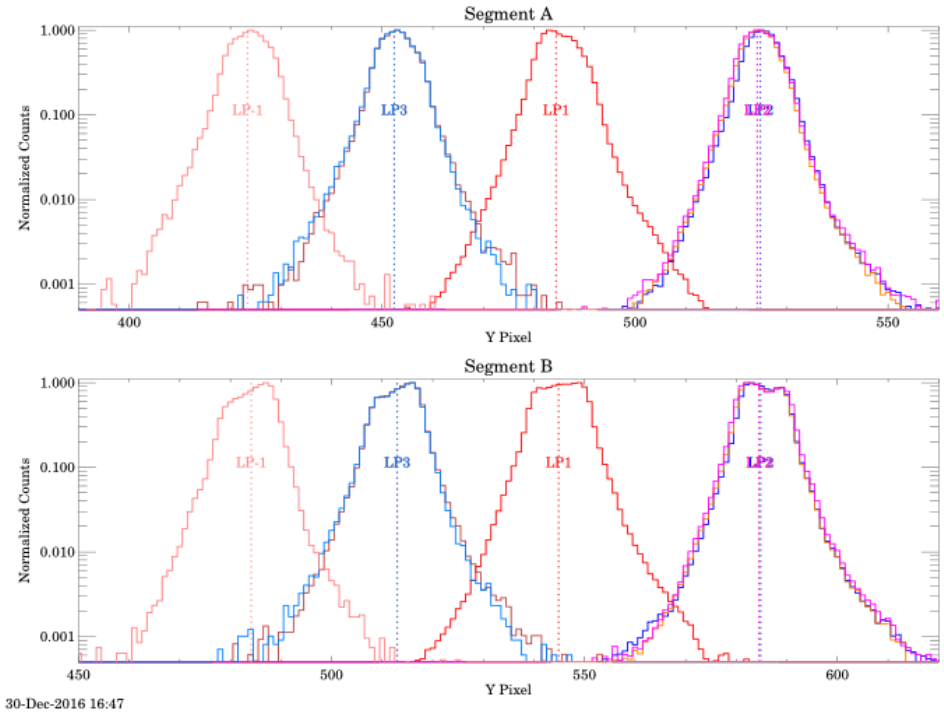

Figure 6 Normalized cross-dispersion profiles for WD0308-565 for LP1 - LP4. For LP2 and LP3, more than one exposure is shown. The median of each distribution is marked by the dotted lines. Note that LP4 is labeled as LP-1, since at the time this data was processed by CalCOS, the keyword rules did not have an aperture position range defined for LP4.

Table 5 Positions and separations based on the profiles shown in Figure 6

	Seg A	**Seg B**	**ΔLP1A**	**ΔLP1B**	**Average**	**ΔSIAF XD (″)**	**Pix/arcsec**
LP1	484.37	544.87	0.0	0.0	0.0	0.0	-
LP2	524.35	584.61	+39.98	+39.74	+39.86	+3.500	11.39
LP3	452.39	512.97	-31.98	-31.90	-31.94	-2.523	12.66
LP4	423.37	484.13	-61.00	-60.74	-60.87	-5.043	12.07

5. SIAF Change

As summarized in Table 4, the measured cross-dispersion aperture shift was very close to zero; as a result, no adjustments were required in that direction. In the dispersion direction, the measured shift was -0.036 arcseconds, so a SIAF change was required. The instrument coordinate system is rotated ~45° with respect to the detector coordinate system, so the -0.036” shift corresponds to a SIAF change of (+0.0255”, -0.0255”) in (V2,V3). Adding this shift to the initial SIAF values in Table

1 for all four apertures gives the numbers shown in Table 6. These values were specified in PR 86877, installed in February 2017, and were used operationally at LP4 starting on October 2, 2017.

Table 6 Adopted LP4 SIAF values

Aperture	V2 (″)	V3 (″)
LFBOA4	229.1328	-241.0575
LFPSA4	229.1328	-241.0575
LAPTFBOAF4	219.7586	-250.4317
LAPTFPSAF4	238.5070	-231.6833

Figure 7 shows the FUV SIAF positions for LP1 – LP4. Since the BOA is moved to the PSA position when used, those two apertures show the same physical location. The other entries show the BOA when the PSA is in use (LAPTFBOAF*), and the PSA when the BOA is in use (LAPTFPSAF*). Note that the COS LP1 – LP4 aperture placement programs indicate that the cross-dispersion direction on the FUV detector is at a 44.2 degree angle with respect to V2.

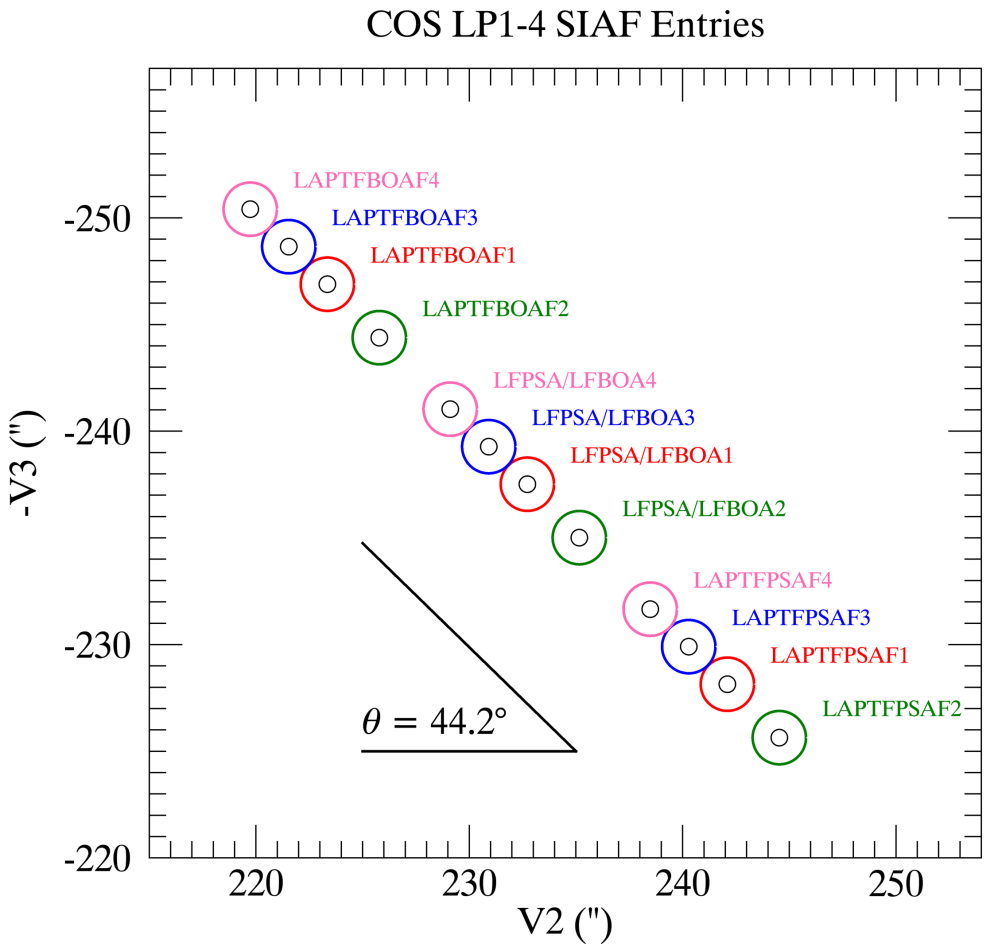

Figure 7 SIAF positions in V2-V3 coordinates for LP1 – LP4.

Change History for COS ISR 2018-17

Version 1: 15 August 2018 – Original Document

References

DeRosa, G. et al., 2017, Instrument Science Report COS 2017-19, "Optimization of COS/FUV Spectrum Placement at Lifetime Position 4"

Proffitt, C. et al., 2013, Instrument Science Report COS 2013-03, "Second COS FUV Lifetime Position: Verification of Aperture and FUV Spectrum Placement (FENA2)"