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Target Placement for COS/FUV at LP6 with G160M/1600

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ABSTRACT

We determine the position of the aperture center of the Cosmic Origins Spectrograph (COS) at Lifetime Position 6 (LP6). This work determined the location of maximum instrument throughput for LP6 in the HST focal plane, enabling targets to be centered in the aperture. Program 16849 was observed on 20 December 2021 and was comprised of one two-orbit visit of the target star WD1337+705, during which position target (`POS_TARG`) values were varied over several step sizes (typically ∼0.2 arcsec) across both the dispersion and cross-dispersion axes. By comparing throughputs at each position relative to the measured maximum, mean offsets of −0.07208 arcsec and −0.00143 arcsec were calculated for the V2 and V3 coordinates, respectively. These adjustments to the Science Instrument Aperture File (SIAF) were tested for scientific accuracy and then uploaded to the flight software (FSW) in 2022 February for use in HST Cycle 30.

Contents

1. Introduction

For Cycle 30, the default position for observations utilizing the Cosmic Origins Spectrograph far-ultraviolet (COS/FUV) G160M grating was moved to Lifetime Position 6 (LP6). This change was enacted in an effort to preserve the longevity of the COS instrument by avoiding areas on the detector that have become subject to gain sag, whereby prolonged exposure to photons reduces the modal gain of the COS detector. When this modal gain becomes lower than a value of 3, flux losses greater than 5% occur (Sahnow et al. 2011). Most recently, G160M data had been taken exclusively at LP4 since the commissioning of this LP in October 2017.

One of the earliest tasks when commissioning a new LP is the multi-step process to establish the optimum location on the detector, and the corresponding aperture location and focal plane positions, for science spectra to be observed. First, an approximate position for the spectrum on the detector at the new LP is chosen based on information obtained from earlier exploratory work. The appropriate column in the Science Instrument Aperture File (SIAF) is then updated to determine the pointing (in V2/V3 coordinates) in order to place the spectrum at this location. Analysis from this program is then utilized to refine the centering, which is anticipated to be very near to the estimated position. Finally, the SIAF is updated again to reflect the results from the measured center, ensuring that spectra of a given source taken at this LP will be centered in the aperture. Here we describe how the optimum (most central) position to place observed sources within the Primary Science Aperture (PSA) were derived for the SIAF, which contains the positions of the apertures for all the science instruments in the focal plane. This report forms one of a number of Instrument Science Reports (ISRs) on the enabling phase of observing modes at LP6, which is located 6.5” above LP1 (Fischer et al. 2022; Dieterich et al. *in prep.*).

In order to determine the optimum position for placement on the detector, we measure counts from a standard source while varying values of the position target (POS_TARG) parameter, which moves the target across the fixed aperture along both the dispersion and cross-dispersion axes. From a measure of the counts at each position as a fraction of the maximum, we then determine the coordinates of the optimal location for target placement. These optimal coordinates are used to refine the V2/V3 values of the SIAF at LP6.

2. Observations

The LP6 target placement observations (Program 16849) consist of one non-interruptible two-orbit visit of the HST standard target star WD1337+705 with G160M/1600, taken on 20 December 2021. The program design follows that of the LP5 program 16430 (PI E. Frazer; Frazer et al. *in prep.*), which observed HST standard target star WD0947+857 at LP5 with G130M/1291. The overall goal of this program is to establish the V2/V3 coordinates of the PSA aperture at LP6 for G160M, the only grating moving to this LP at this time. The visit begins with a three-second imaging acquisition with MIRRORA/BOA of the target. This is followed by a non-interruptible sequence with 21-second exposures using FUV/PSA and the G160M/1600 grating/cenwave combination at FP-POS = 3. Exposures begin at the POS_TARG offset of (0,0), with WAVECAL and FLASH both set to NO. Subsequent exposures are obtained by changing the POS_TARG value through seven steps on either side of the zero-point along the Y-axis. These exposure times were designed to obtain approximately 50,000 counts at the nominal central position. This process is then repeated during the subsequent orbit, along the X-axis.

The POS_TARG positions implemented are ±1.30, ±1.10, ±0.86, ±0.65, ±0.48, ±0.29, ±0.14, and 0.00 arcsec (Figure 1). These values correspond to the POS_TARG values used in previous target placement programs, modulo the ±1.30 and ±0.65 arcsec positions were revised from ±1.38 and ±0.67 arcsec, respectively. For the similar programs executed for LP2 through LP4, the design stipulated that the aperture, rather than the target, was moved. This requires an integer number of aperture steps, such that one aperture step is equivalent to 1/21 of an arcsec, which is equivalent to ∼0.048 arcsec. Beginning with the target placement program for LP5 and continuing with LP6, the target itself is moved rather than the aperture in order to better center the target (Frazer et al. *in prep*). For the sake of consistency with work at previous LPs, however, these step sizes were kept the same as before, as this sampling method had been shown to work in deriving the curve of counts versus distance from the center. The revisions undertaken for this program to have POS_TARG positions at ±1.30 and ±0.65 arcsec also allows for a "free" preliminary check of the ACQ centering algorithms for NUMPOS = 3 and 5, for which these values correspond to STEP_SIZE = 1.30 and 0.65, respectively. Observational details are summarized in Table 1. In total, 34 21-second exposures were obtained for this program.

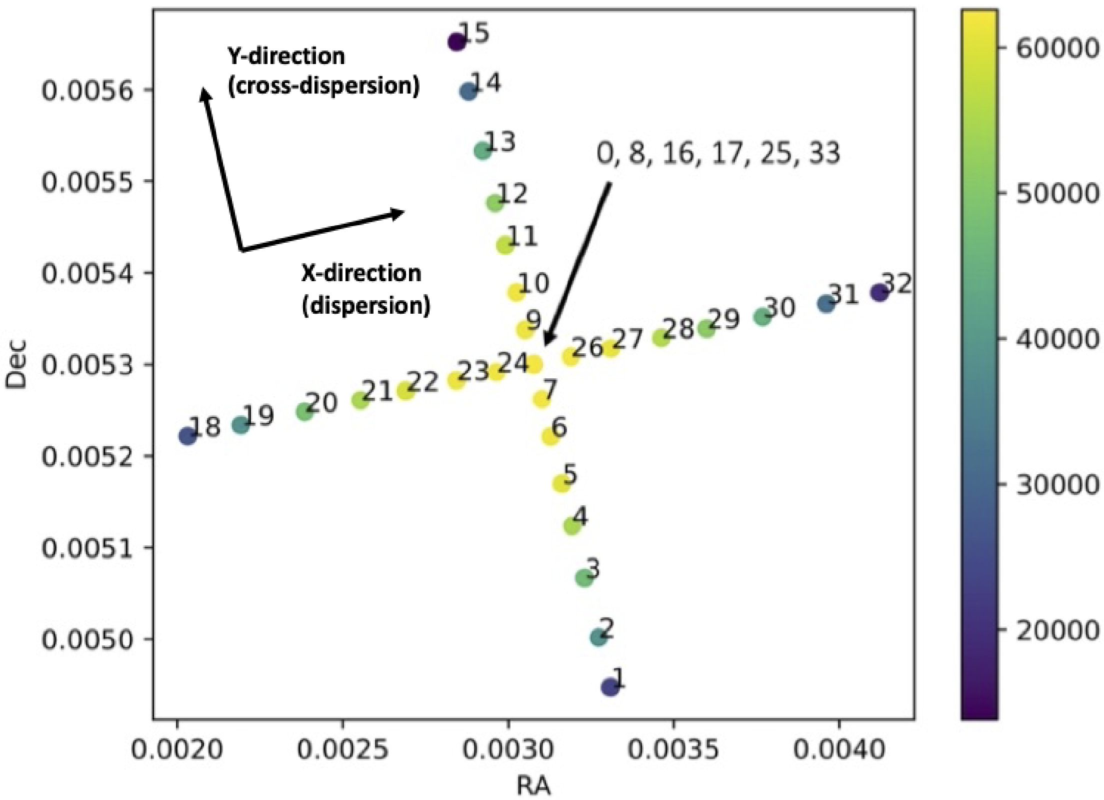

Figure 1. Flux throughput for FUVA relative to maximum value (assumed at nominal [0,0] position) of exposures taken at each `POS_TARG` position along both the cross-dispersion (Y-direction; roughly vertical) and dispersion (X-direction; roughly horizontal) axes. Beginning at the central position (marked as exposure "0"), then following the sequence as labeled here, flux is measured at a variety of positions. The color bar is representative of the counts detected in FUVA. As expected, number of counts is substantially higher near the nominal center as compared to the outskirts.

3. Data Reduction and Analysis

3.1 Data Reduction

Standard calibrations were bypassed since LP6 reference files did not exist at the time of processing, so a manual reduction was performed utilizing the header keywords specified in Table 2, where only changes to the default are listed. Outputs for this process include `CORRTAG` files, from which the `XCORR` and `YCORR` columns were extracted and employed to complete the analysis. We note that, because only total counts are measured, flat-fielding and wavelength calibrations are not required.

LP6 uses SPLIT wavecals to avoid light leak, whereby lamp exposures are not taken concurrently with science exposures, but rather are executed after moving the aperture to a different position on the detector (James et al. 2022). Because there is no

Table 1. Program 16849 Exposure Layout

Orbit	Grating	Cenwave	LP	FP-POS	Exposure Time [seconds]	POS-TARG X [arcsec]	POS-TARG Y [arcsec]
01	G160M	1600	6	3	21	0.00	±1.30, ±1.10, ±0.86, ±0.65, ±0.48, ±0.29, ±0.14, 0.00
02	G160M	1600	6	3	21	±1.30, ±1.10, ±0.86, ±0.65, ±0.48, ±0.29, ±0.14, 0.00	0.00

Table 2. CalCOS FITS Initial Manual Calibration Switches (Changes from Default)

Extension	Parameter	Value
ext = 0	FLATCORR	OMIT
	RANDSEED	123456789
	X1DCORR	OMIT
	WAVECORR	OMIT
	FLUXCORR	OMIT

spectrum obtained through the wavelength calibration aperture (WCA), as there would be at all other LPs, such a reference spectrum does not exist here. We also note that the singular extraction region used for FUVB with G160M/1600 is simpler than for the equivalent program at LP5. Analysis of the G130M/1291 spectrum had required a bifurcation of the extraction region in order to avoid an airglow line.

3.2 Spectral Analysis

Relative counts along both the dispersion and cross-dispersion directions for all POS_TARG positions are illustrated in Figure 2. The counts are measured relative to the point with the maximum number of counts. In both the cross-dispersion and dispersion plots, FUVA is represented by magenta dots, while FUVB is represented by cyan crosses. The horizontal dashed colored lines are various levels of the maximum throughput for each segment, from 40% (Y scan) or 50% (from X scan) up to 97.5%. In each case, the mid-distance between the left and right side of the curve is calculated for each segment and is marked by an appropriately-colored X symbol. The mean value of these central points is plotted by the black dashed line, which represents the offset value in arcsec used to adjust the SIAF. In the Y (cross-dispersion) direction, this offset was measured as -0.0520 arcsec, while in the X (dispersion) direction, this offset was measured as -0.0500 arcsec.

As an alternative visualization, in Figure 3 we plot points representing the mid-distance values for each half width (the absolute value of the FP_POS) similarly marked in Figure 2. For the FUVA (magenta crosses) and FUVB (cyan crosses) segments of both the Y (cross-dispersion; *top*) and X (dispersion; *bottom*) scans, we compare the displacement of each half width's mid-distance value against the calculated mean offset value, represented by the dashed black line (the final position adjustment value for a given coordinate; equivalent to the same from Figure 2). From this we see that these mean offset values reflect the averages of the half-width mid-distance values; the black dashed line generally traces the position of the colored crosses. We note, though, that the smallest half-width mid-distance values for the along-dispersion scan are offset somewhat high. Removing these outliers resulted in only a very small revision to the overall offset value, and so was not implemented into the final reported numbers.

4. Final PSA SIAF Adjustments

With the measured offsets in the Y (cross-dispersion) and X (dispersion) directions of -0.0520 arcsec and -0.0500 arcsec, respectively, we then convert these values into the V2/V3 coordinate system of the SIAF. As the V2/V3 coordinate system is rotated by 45 degrees from the COS X/Y coordinate system (see Figure 4), the sine or cosine of a π/4 radian angle rotation was implemented, as follows:

$$\mathrm{V2}_Y = sin(\pi/4) \times (-0.0520"), \tag{1}$$

$$\mathrm{V3}_Y = cos(\pi/4) \times (-0.0520"), \tag{2}$$

$$\mathrm{V2}_X = sin(\pi/4) \times (-0.0500"), \tag{3}$$

$$\mathrm{V3}_X = -cos(\pi/4) \times (-0.0500"). \tag{4}$$

From this we find that the offset for V2 is -0.03675 arcsec (Y) and -0.03533 arcsec (X) and the offset for V3 is -0.03675 arcsec (Y) and $+0.03533$ arcsec (X). When total V2 = V2$_X$ + V2$_Y$ and total V3 = V3$_X$ + V3$_Y$, we therefore obtain an overall V2 adjustment of -0.07208 arcsec and an overall V3 adjustment of -0.00143 arcsec.

From these calculations, the SIAF V2 and V3 values for LFPSA6 and LAPTFBOAF6, the PSA position at LP6 and the BOA location when the PSA is in use at LP6, respectively, have been updated. For LFPSA6, the V2 value was adjusted from $+237.3192$ to $+237.2471$, while the V3 value was adjusted from -232.9188 to -232.9202. For LAPTFBOAF6, the V2 value was adjusted from $+227.9450$ to $+227.8729$, while the V3 value was adjusted from -242.2930 to -242.2944. Note that because the BOA cannot be utilized at LP6 due to hardware constraints, its position

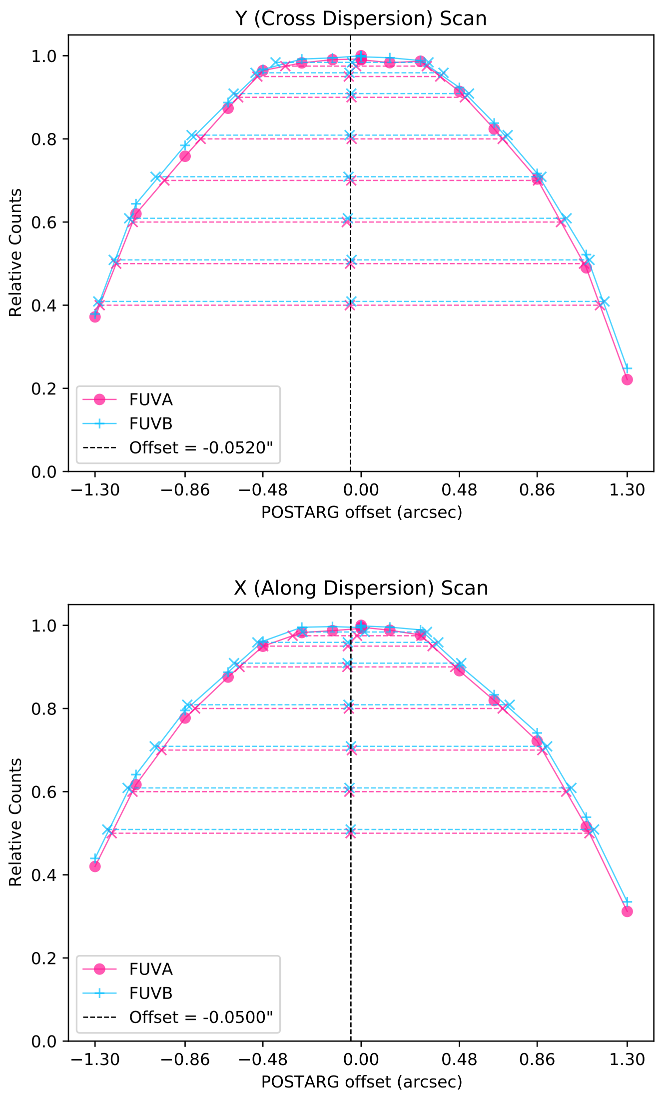

Figure 2. Measured counts relative to the nominal maximum value fraction as a function of POS_TARG offset in arcsec for the cross-dispersion (Y; *top*) and dispersion (X; *bottom*) directions. FUVA is signified by a magenta dot while FUVB is marked with a cyan cross. Horizontal dashed colored lines represent various levels of the maximum throughput for each respective segment, from 40% (Y scan) or 50% (from X scan) up to 97.5%. For each segment, an appropriately-colored X symbol marks the calculated mid-distance point between the curves' left and right sides. A black dashed line indicates the mean value of said central points, signifying the SIAF offset adjustment value.

was set to be identical to the LP3 position, which is the default position for all unused rows in the SIAF, and so its corresponding columns LFBOA6, the BOA position at LP6, and LAPTFPSAF6, the PSA location when the BOA is in use, were not updated.

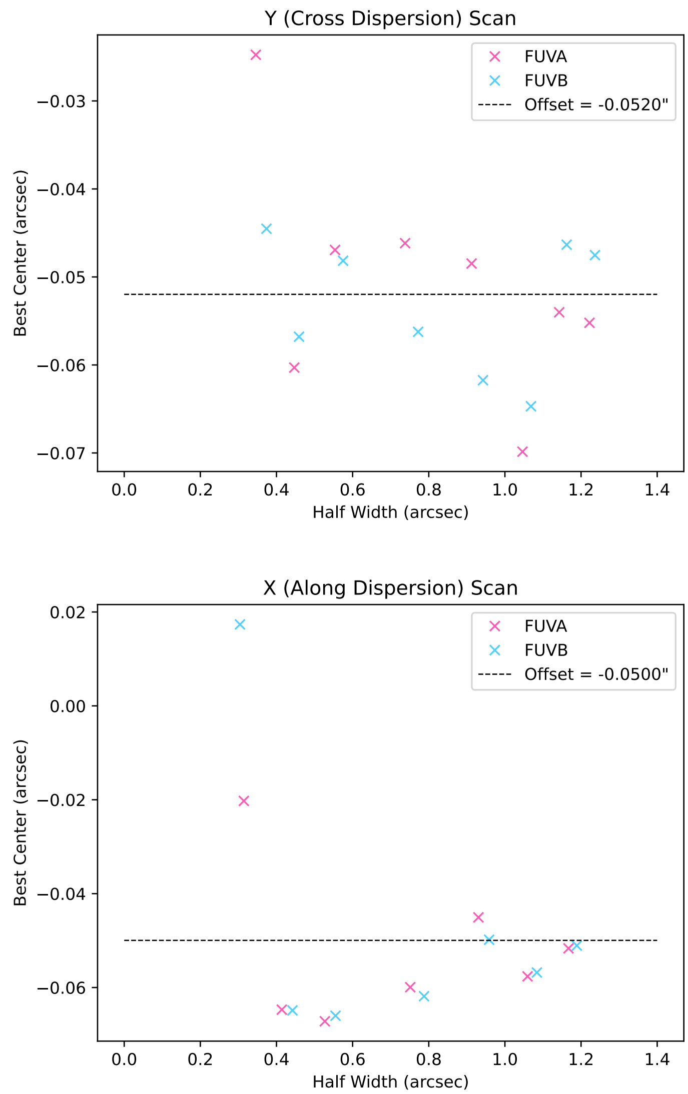

Figure 3. Mid-distance values of the half width (the absolute value of the `POS_TARG`, measured in arcsec) of the FUVA (magenta crosses) and FUVB (cyan crosses) segments for the cross-dispersion (Y; *top*) and dispersion (X; *bottom*) scans plotted against the displacement from the calculated mean offset value (the final position adjustment for the given coordinate), represented by the dashed black line.

These results are summarized in Table 3.

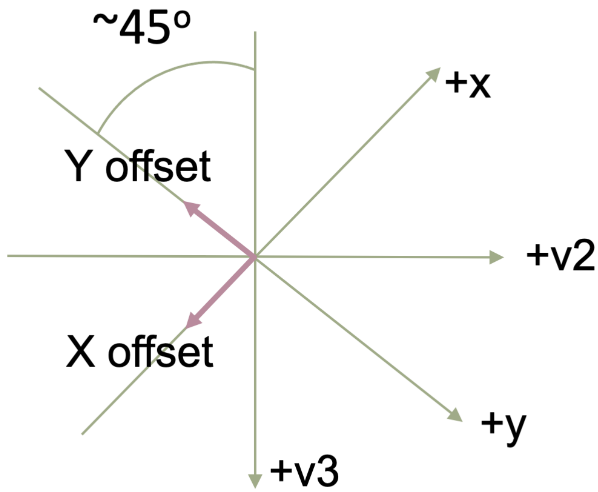

Figure 4. Relative orientation of the user's X and Y coordinate plane with the V2 and V3 coordinate plane. In order to convert from the X/Y offset determined by this analysis to the V2/V3 system employed by instrument system of HST, the cosine of a $\pi/4$ radian angle rotation was implemented.

Table 3. Initial and Final V2/V3 Values

Aperture	Initial V2	Initial V3	Final V2	Final V3
LFBOA6	230.9137	-239.2749	230.9137	-239.2749
LFPSA6	237.3192	-232.9188	**237.2471**	**-232.9202**
LAPTFBOAF6	227.9450	-242.2930	**227.8729**	**-242.2944**
LAPTFPSA6	240.2879	-229.9007	240.2879	-229.9007

5. Summary

The optimal location for placement of targets through the PSA at LP6 was determined via analysis of throughput as a function of position in both the cross-dispersion (Y) and dispersion (X) directions. This program was carried out with G160M/1600 observations of the HST standard star WD1337+705 over one two-orbit visit. Along both directions, counts from the source were measured at different POS_TARG values symmetrically located on either side of a central position. These data were obtained on 20 December 2021, from which our analysis indicated that the V2 and V3 coordinates of the SIAF necessitated adjustments of -0.07208 arcsec and -0.00143 arcsec, respectively. Results were delivered in an updated SIAF which was installed onboard HST on 21 February 2022 for use with observations beginning on 28 February 2022.

Change History for COS(or STIS) ISR 2023-06

Version 1: 10 April 2023- Original Document

References

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