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Quick-check of the COS/FUV G130M Spectral Resolution at Lifetime Position 4

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ABSTRACT

Optimization program PID14842 was primarily designed to determine the impact of the move of COS/FUV operations to Lifetime Position 4 (LP4; -5.02" from LP1 in cross-dispersion direction) on the G130M spectral resolution and to generate new LSFs at LP4. Observations of external target AV75 were taken with the G130M/1291&1327 and required that the best focus and the HV values relevant for LP4 operations be known. In this ISR, we outline the methodology adopted to evaluate the G130M spectral resolution change for LP4 operations. Our analysis shows that the resolution for G130M at LP4 can be lower by up to ~15% relative to LP3. The COS and HST documentation was updated, where relevant, to inform the community of this change in time for the HST Cycle 25 Call for Proposals. The generation of LSFs in support of LP4 science operations was deferred to a later time when the optical models are available to the team. We also note that G130M/1327 spectra were taken at two additional cross-dispersion positions different from the LP4 position to spot-check the new geometric distortion correction. Analysis of these data will be discussed elsewhere.

Contents

1. Introduction

Since the beginning of its on-orbit operations the COS FUV detector has experienced sustained gain sag at the location used for science operations. Owing to the accelerated rate at which gain sag affects the FUV data on local scales and to maintain optimum science data quality, the physical location of the FUV spectra has been regularly moved on the detector since the Summer of 2012. COS/FUV operations are currently taking place at LP3 which is located 2.5” below the original position (XD=-2.5” relative to LP1) on the FUV detector, and the COS Team is presently preparing to move to Lifetime Position 4 (LP4).

Each new Lifetime Position (LP) move is articulated around three major phases: an optimization phase, an enabling phase and a calibration verification phase once the move to the new LP has occurred. Program 14842 (PI: Sonnentrucker) is part of the optimization phase of the move of COS/FUV operations to LP4. This program is designed to measure the spectral resolution at the LP4 position relative to LP3 to evaluate the resolution degradation at LP4. This knowledge is critical to evaluate the feasibility of a science program, to determine the S/N requirements when planning observations and to perform line profile fitting from which accurate column densities are usually derived.

Securing this information for inclusion in all documents pertaining to the Cycle 25 Call for Proposals heavily drove the creation, scheduling and analysis for this program. Prior knowledge of the best LP4 focus value for the G130M grating and of the relevant HV values at the start of LP4 operations was required before program 14842 could be executed. To maximize return of this optimization program for the overall LP4 move effort, we also obtained a series of G130M/1327 spectra at two additional cross-dispersion positions different from the actual LP4 position to spot-check the new geometric distortion correction and to support implementation of this correction for the entire FUV detector. The results of the geometric distortion spot-checking will be presented elsewhere. The generation of new LSFs will be performed at a later time when the Code V optical models for LP4 are available to the COS Team. This ISR describes the method used to estimate the change in spectral resolution for G130M at the LP4 location relative to LP3 and summarizes our results and their implementation.

2. Observations

In program 14842 we acquired G130M/1291 and G130M/1327 spectra of external target AV75 to cover the full wavelength range for this grating. AV75 is a well-known SMC star that is routinely used as the COS/FUV dispersion solution monitoring target and has been successfully used as the spectral resolution calibration target during the preparation of the move to LP3 (Roman-Duval et al., 2017). We obtained spectra at all 4 FP-POS positions in order to achieve S/N=60 per resolution element indispensable to evaluate resolution degradation greater than ~10%. Since this program was executed with FUV operations nominally at LP3, a series of parameters needed to be replaced with values relevant for operations at LP4. Special commanding was used to reset the relevant parameters from the nominal LP3 to the appropriate LP4 values, as follows.

- The best focus for G130M was set with the special instruction ALIGN/OSM FOCUS=+40 (Sonnentrucker et al. 2017, PID14527)- This value needs to be reset after every OSM move.
- The HV values were set to 163/163 (SEGA/SEGB, PID14525) during a DARK exposure with the special instructions: ELHVADJPROP, QESIPARM and special observation requirement SAA CONTOUR 31- Once set, these values only change using another special command or at the end of an obset.
- The aperture position was set to -2.52” relative to LP3 in the cross-dispersion direction using the COS, ALIGN/APER instruction. With -21 motor steps per arcsec, the aperture move from LP3 to LP4 corresponds to 53 motor steps (XAPER=53).
- The target position was then displaced to the new aperture location using POS TARG of X=0.0” and Y=-2.52” (relative to LP3). These values need to be reset for each new exposure.
- All parameters were reset to the nominal LP3 values at the end of the visit using a DARK exposure.

A short 0.1s science exposure with the G130M/1291 configuration was needed after the target acquisition sequence and before the first G130M/1291 exposure in order to reset the LP parameters from their nominal values (LP3) to the needed LP4 values. A short 0.1s science exposure with the G130M/1327 configuration was also needed to set the LP FOCUS parameter backto the LP4 value (+40) before the 1327 observing sequence started.

The automatic wavecal exposure was disabled (TAGFLASH=NO) and replaced by deeper lamp exposures (FLASH=S0055D030: one 30s exposure every 55s) to support efforts to characterize the effect of gain sag on the lamp spectra once FUV operations start at LP4.

In support of the efforts to characterize the geometric distortion correction at LP4, we also obtained spectra using the G130M/1327 at two additional cross-dispersion locations of XD=-2.00” and XD=-3.52” relative to LP3, and alternating the 4 FP-POS.

Program 14842 executed successfully on Aug 29, 2016 for a total of 3 external orbits.

3. Data Analysis & Results

3.1 Data Analysis

As the optical path of the FUV light changes slightly with every lifetime position move, so do the spectral and spatial resolutions of the COS FUV data. To estimate those changes, in the past we have modeled the COS FUV LSF at each LP using code V optical models (e.g., Roman-Duval et al. 2017). Since these models were not available at the time an estimate of the spectral resolution change was needed, we adopted a more direct method to evaluate the changes to FUV data quality. This method relies on fitting the profile of pre-selected and well-known isolated and resolved ISM lines to derive their FWHM and the corresponding resolving power. For the AV75 sight line, three ISM lines (C I and Mg II species) were deemed adequate for this analysis in the G130M/1291 data and two lines (Cl I and Mg II species) were deemed adequate in the G130M/1327 data. For comparison, these same ISM lines were then fitted in data taken at LP3 with the G130M/1291-1327 configurations (PID13931).

A 4-parameter model that consisted of a constant term and a Gaussian line profile was used to model the pre-selected ISM lines. The profile fitting package mpfitfun (Markwardt 2009) was used to derive the FWHM and formal error for each ISM. The modeling was performed on the spectra obtained at each FP-POS and on the FP-POS co-added spectrum to check for consistency. During the analysis, we noted that the G130M/1291 FP-POS=1 spectrum taken at the LP4 position displayed a wavelength zero-point shift of about 6 pixels compared to the other spectra taken in program 14842 and compared to similar data taken at LP3. Since the highest spectral quality and highest S/N ratio are essential to derive accurate FWHM for the selected ISM lines, we shifted and re-coadded the LP4 G130M/1291 spectra obtained at each FP-POS by hand. The line profile fitting was then repeated on the hand-coadded LP4 G130M/1291 spectrum. No significant wavelength zero-point shifts were observed in any of the G130M/1327 observations.

3.2 Results

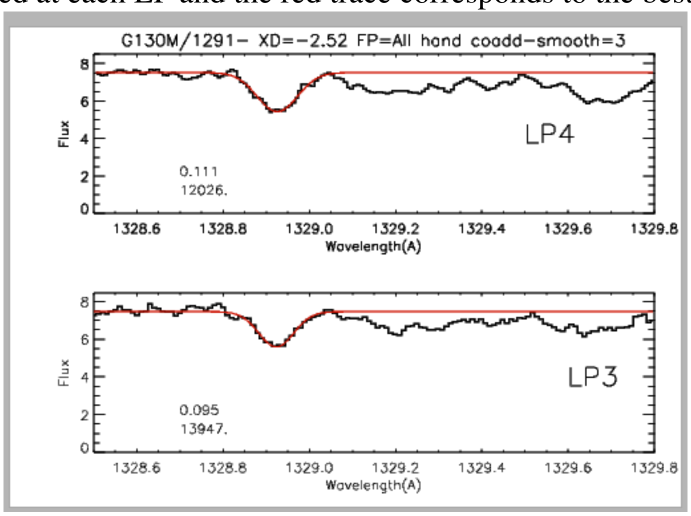
The profile fitting analysis was also applied to similar data obtained at LP3 (PID13931) and the FWHMs returned by the modeling at both LPs were compared to evaluate the spectral resolution changes pertaining to the LP4 move. Table 1 reports the values of the resolving power derived from the best fit to each ISM absorption line considered in the analysis. The formal errors associated to the resolving power estimates range from 700-1000. Figure 1 displays one example of profile fitting result for the C I ISM line that absorbs at 1328 Å.

Table 1. Measured resolving powers at LP3 and LP4 (XD=-2.52" relative to LP3) using select ISM lines.

G130M/1291	**ISM C I 1328 Å**	**ISM C I 1265 Å**	**ISM MgII 1240 Å**	**ISM Cl I 1347 Å**
LP3 (FP-ALL)	13947	9115	11258	…
LP4 (FP-ALL)* **Resolution change**	12026 13.8% loss	8973 1.5% loss not significant	10183 8.5% loss not significant	…
G130M/1327				
LP3 (FP-ALL)	…	…	11675	13161
LP4 (FP-ALL) **Resolution change**	…	…	12733 9% gain not significant	11379 13.6% loss

* Data were coadded by hand to correct for the wavelength zero-point shift measured in the G130M/1291 FP-POS=1 spectrum.

Figure 1. Example of profile fitting results for the C I line absorbing at 1328 Å for data taken with the G130M/1291 configuration at LP4 (top, PID14842) and at LP3 (bottom, PID13931). The resulting FWHM (in Å) and corresponding resolving power are reported at the bottom left of each panel. The black line represents the coadded spectrum obtained at each LP and the red trace corresponds to the best fit model.



4. Conclusion

We find that the spectral resolution at LP4 can be lower by up to ~15% relative to LP3. The COS and HST documentation was updated, where relevant, to inform the community of this change in time for the HST Cycle 25 Call for Proposals. Generation of COS LSFs appropriate for data taken at LP4 will be completed once the optical models are available to the COS Team.

References

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Roman-Duval et al., 2017, COS ISR 2017-06, “Spectral Resolution of the COS/FUV M-gratings at Lifetime Position 3”
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