Medium Resolution "LUV" Observing With HST+COS in Cycle 20

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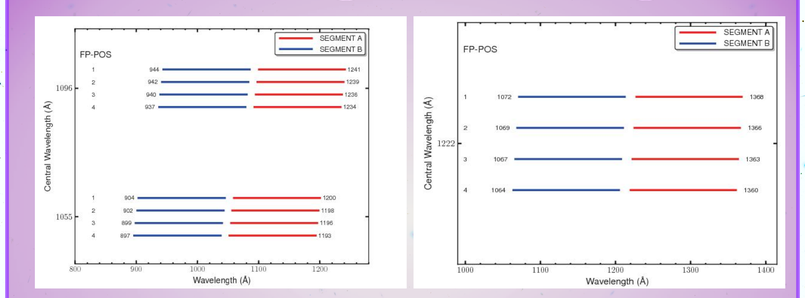
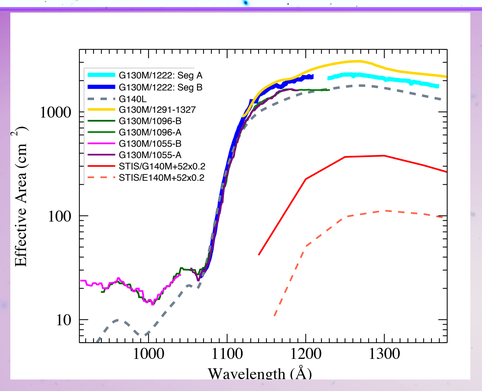
The combination of the Hubble Space Telescope (HST) and the Cosmic Origins Spectrograph (COS) has been shown to be sensitive down to 912 Å. However, the available cycle 19 central wavelength settings that sample below 1150 Å (G140L/1280, G130M/1055, & G130M/1096) are all low-resolution (**R** < 4,000). In 2011, a new central wavelength, G130M/1222, with **R** > 10,000 from 1064-1368 Å, was approved for cycle 20. Plans were also set into motion to adjust the focus positions of the internal mechanisms in a way that could more than double the resolution of the existing G130M/1055 &1096 modes with no loss of sensitivity. Here we present the current status of these three G130M central wavelengths with an emphasis on HST cycle 20 observational implications over the "Lyman Ultraviolet" or LUV bandpass from the hydrogen Lyman limit (912 Å) to Lyα (1216 Å). All cycle 20 HST+COS LUV observations will be performed at the new, second, lifetime position (SLP).

Wavelength Coverage

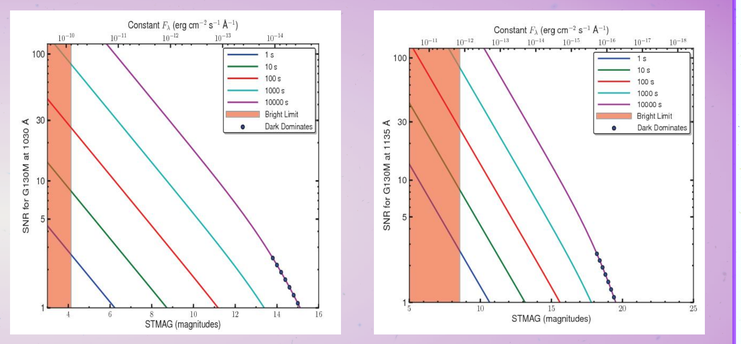


The left figure shows the wavelength coverage of the four FP-POS positions of the G130M/1055 & 1096 G130M central wavelengths for both the 'A' and 'B' segments at the original lifetime positions (OLP). (Cycle 20 Instrument Handbook, Dixon). The right figure shows the wavelength coverage for the G130M/1222 central wavelength. Note that Geocoronal Lyα is entirely contained between the two COS FUV detector segments when observing with the G130M/1222 central wavelength. By placing the Geocoronal Lyα on the detector gap, this mode removes the dominant source of the FUV detector gain sag 'holes', and if routinely used, this mode will extend the lifetime of the COS FUV detector. Calibration plans are underway to remeasure the bandpasses for all three LUV central wavelengths at the second lifetime positions (SLP) using the new focus values outlined elsewhere as part of the supplemental cycle 19 calibration plan.

HST+COS Sensitivity



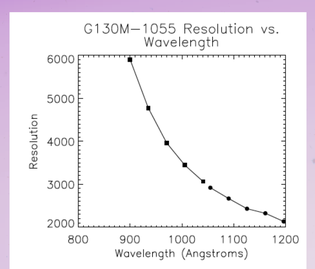
The HST+COS effective area in cm^2 is shown for all COS LUV modes and two comparable STIS modes (in red). The sensitivity of the three COS LUV modes is essentially identical below 1120 Å, with the G130M/1222 mode showing significantly higher throughput than the 1055 & 1096 cenwaves above 1120 Å. The G130M/1291-1327 Å effective area, shown in gold, is that at the beginning of the COS lifetime and does not include the gradual loss of throughput (the negative TDS, time-dependent sensitivity). Preliminary measurements at the new (2nd) lifetime position indicate that the G130M/1222 mode has the same sensitivity above 1180 Å as the other G130M central wavelength settings. For comparison, FUSE had a best effective area of ~8-25 cm^2 from 912-1190 Å, depending on wavelength and channel. Due to dramatic effective area increase between 1070 and 1100 Å, very bright targets (those observable with FUSE) can still be observed in the 912-1100 region with HST+COS with the 1055 & 1096 'B' segments, but this will require that the FUV 'A' segment be turned off to avoid local and/or global count rate violations.

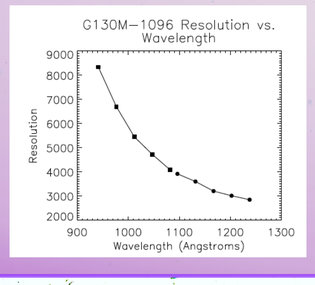


The top axes displays constant F_λ values corresponding to the STMAG units (V+STMAG$_\lambda$) on the bottom axis. STMAG=0 is equivalent to F_λ=3.63E-9 erg cm^{-2} s^{-1} Å^{-1}. Colors refer to PSA exposure times in seconds. The edge of the shaded area corresponds to the bright-object screening limit (Cycle 20 Instrument Handbook, Dixon). The left panel shows the HST+COS sensitivity for the the 1055 & 1096 central wavelength settings at 1030 Å. The right panel is for the G130M/1222 central wavelength setting at 1135 Å. Calibration plans are underway to remeasure the sensitivities for all three LUV central wavelengths at the SLP using the new focus values outlined elsewhere as part of the supplemental cycle 19 calibration plan.

For the original lifetime position (OLP), the G130M/1055 & 1096 central wavelengths employed a focus value of -170. This focus value was conservatively selected as it was the most extreme routinely-used G130M focus. Evaluations for the second lifetime position (SLP) revealed that the extreme position that the focus mechanism had been moved on-orbit with any FUV grating was -1200. For Cycle 20, we plan to use this new focus position for the 1055 & 1096 central wavelengths, which should result in a dramatic improvement in resolving power (**R=λ/Δλ,** resolution).

The figures to the right show the simulated (ray-traced) resolution (**R**) for the G130M/1055 & 1096 modes at the SLP for a focus position of -1200. The actual **R** obtained is likely to be ~20% lower than these values due to the mid-frequency wavefront errors (MFWFEs) of the HST mirrors, which are not included in the simulations. Calibration plans are underway to measure **R** for all three LUV central wavelengths as part of the supplemental cycle 19 calibration plan.

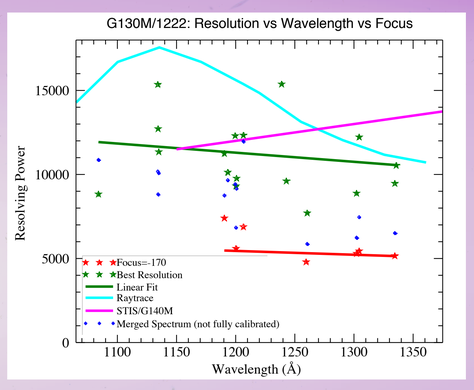




G130M CENWAVE	Focus	Description	Segment B Resolution Max	Segment B Resolution Min	Segment A Resolution Max	Segment A Resolution Min	Maximum R Improvement over OLP	Average R Improvement over OLP	Minimum R Improvement over OLP
1055	-170	OLP	2500	2050	1950	1500			
1055	-1200	SLP	5800	3100	3000	2100	132%	75%	40%
1055	-2600	Optimum-B	10500	6500					
1055	-2900	Optimum-A			11000	6000			
1096	-170	OLP	3200	2550	2450	2000			
1096	-1200	SLP	8400	4100	3900	2800	163%	88%	40%
1096	-2200	Optimum-B	13000	10000					
1096	-2900	Optimum-A			14000	11000			
1222	-850	OLP	20000	16500	15500	13000			
1222	-800	SLP	20000	16500	15500	13000	0%	0%	0%

OLP = original lifetime position. Min = The minimum resolution (**R**) available across the given segment.
SLP = second lifetime position. Max = The maximum resolution (**R**) available across the given segment.
These values do not include the ~20% resolution losses due to the mid-frequency wavefront errors (MFWFEs) of the HST mirrors.

This table summarizes the achievable model resolutions (**R**) of the three new G130M central wavelengths at the original lifetime position (OLP), the second lifetime position (SLP), used in Cycle 20, and at the optimum focus position (1055 & 1096 only). Should sufficient demand arise for improved **R** of the G130M/1055 & 1096 central wavelengths exist, further focus mechanism adjustments will be considered. Note that the largest **R** improvements are at the shortest wavelengths, exactly the wavelengths these modes were designed to explore!



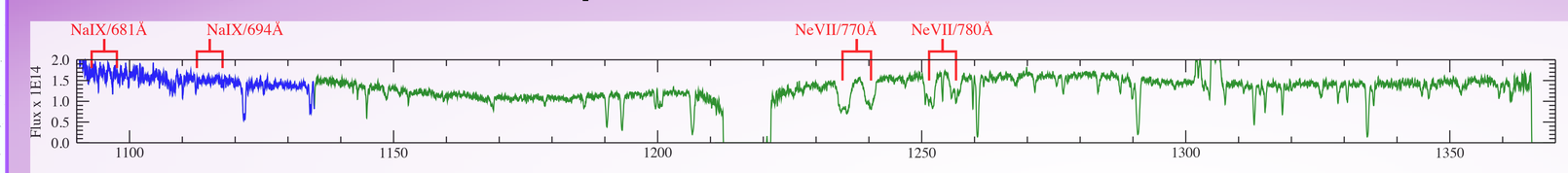
Resolution

For the G130M/1222 central wavelength setting, a focus setting of -850 optimized the resolving power (**R=λ/Δλ**) in the 1100-1150 Å region at the original lifetime position (OLP). For the new second lifetime position (SLP), a move to a focus position of -800 retains this optimization for Cycle 20.

During OLP calibration of this setting, we first measured **R** of the G130M/1222 setting at the -170 focus position, these results are shown in red. The solid red line is simple linear fit to the measured lines (★). When moved to the -850 focus position (green), **R** is more than doubled and is > 10,000 over the bandpass. The actual resolving power is likely to be above the green line as no doppler or drift correction has been applied to the merged data from the four FP POS positions (★). The light blue curve shows the expected **R** from ray trace modeling. For comparison, **R** is shown in magenta for the STIS/G140M grating.

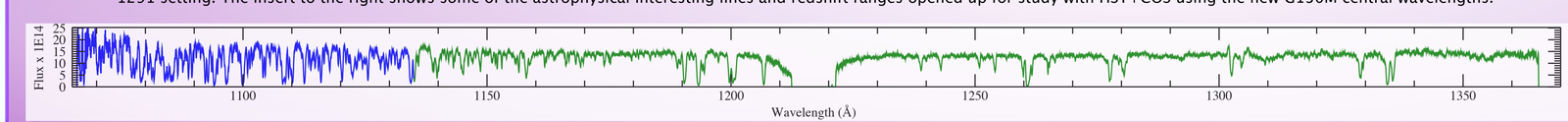
Summary: Beginning in HST cycle 20, HST+COS will provide three fully calibrated G130M central wavelengths capable of observing in the Lyman Ultraviolet (LUV, 912-1216 Å). By moving the internal focus mechanisms, two of these modes (the 1055 and 1096 central wavelengths) can achieve 40-163% higher resolution (a 1.4 - 2.6x increase) with no loss of sensitivity.

G130M/1222 Examples:



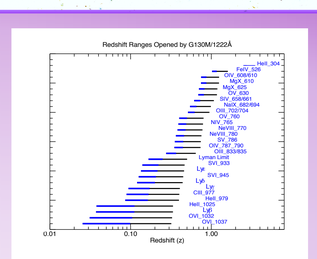
Example 1: High Ionization AGN outflow (HE0238-1904)

This 3-orbit spectrum of the AGN HE0238-1904 was designed to search for outflowing NaIX (681 Å & 694 Å). Previously, NeVII (770 Å & 780 Å) had been detected in the intrinsic AGN outflow. However, as indicated in the spectrum, no NaIX is detected. G130M/1222 is optimized over the newly available COS blue wavelengths between 1060-1145 Å. The green wavelengths as those obtainable with the G130M/1291 setting. The insert to the right shows some of the astrophysical interesting lines and redshift ranges opened up for study with HST+COS using the new G130M central wavelengths.



Example 2: The Southern Ring (NGC3132)

This 3-orbit spectrum of the central star of NGC3132 demonstrates the excellent sensitivity and resolution of the G130M/1222 setting.
The figure on the right shows a N(H_2)=10^{19} cm^{-2}, T=750K model of the intervening H_2.



Some of the astrophysically interesting atomic transitions in the LUV bandpass. The redshift ranges shown in blue are those that are available with COS for the first time at **R**>10,000 with the G130M/1222 setting.