COS2025: A strategy to extend the lifetime of the FUV detector on the Cosmic Origins Spectrograph

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The microchannel plate (MCP) detector for the FUV channel of the Cosmic Origins Spectrograph (COS) on the Hubble Space Telescope (HST) is subject to gain sag, and eventually a permanent loss of efficiency where the most counts have fallen. To maximize the scientific productivity of the instrument over the five-year design lifetime, we periodically adjusted the high voltage and moved the spectra to different locations on the detector to minimize gain sag. In late 2016 we began to investigate ways to extend the life of the detector and adopted a new strategy by placing restrictions on the G130M observing modes that put Lyman-α airglow lines on the detector. As a result of these changes, most G130M central wavelengths are no longer permitted to illuminate Segment B of the detector, and G130M/1291 is permitted on that segment only for FP-POS values 3 and 4. These changes limit the damage from gain sag "holes" due to airglow to only two locations on the detector, rather than the twenty at the previous Lifetime Positions. Models of gain loss as a function of exposure suggest that by adopting this strategy and giving up these small regions of the detector, we will be able to use the latest Lifetime Position for six or more years, as opposed to the ~2.5 years that was available at previous positions.

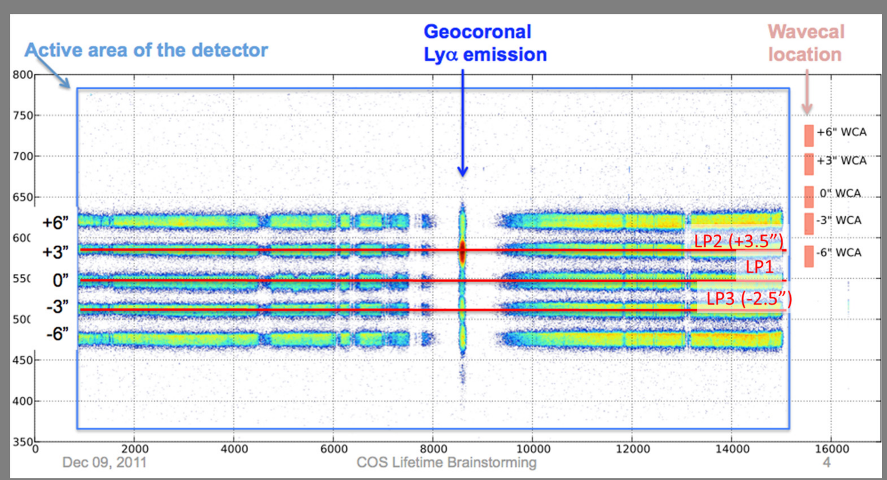
Detector Gain Sag and Mitigation

The COS FUV detector uses a stack of MCPs and a cross delay line anode. The typical number of electrons, or modal gain, varies as a function of position on the detector and the high voltage (HV) applied. With each additional photon collected, the modal gain decreases, until eventually the number of electrons in the output cloud is too small for the electronics to reliably centroid. This causes gain sag "holes" where the sensitivity is reduced.

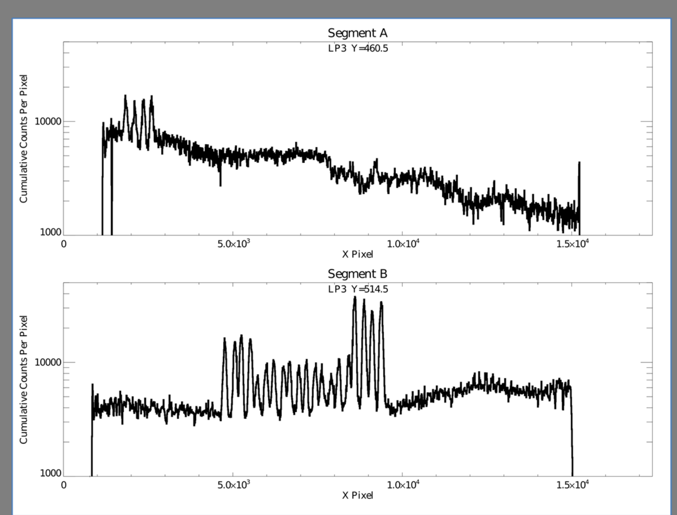
Bright emission lines from the earth's geocorona, primarily at Lyman-α, can be much brighter than the target spectra, and are responsible for most of the damage to the detector. In order to minimize the effect of these gain sag holes, a multi-pronged strategy was developed early in the mission:

- The MCP HV was kept as low as practical in order to minimize the gain sag
- Once the gain sag caused a ~5% loss of sensitivity, the HV was increased
- When the HV had been raised to the launch value and holes reappeared, the spectra were moved to a different Lifetime Position (LP) – see the figure below.

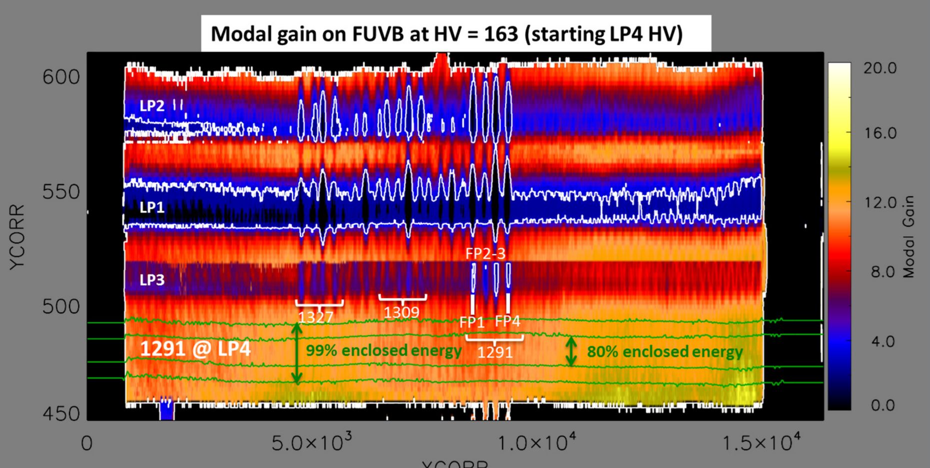
In order to maximize the time at each LP, a requirement to use all four FP-POS aperture offset positions was imposed in order to maximally spread the damage from the airglow lines around.



Even with this approach, however, the number of counts falling on the most illuminated regions was a factor of ~3 or more higher than that falling on the nearby continuum regions, creating wide variations in the modal gain, as shown below.



Left: Cumulative counts as a function of x pixel at LP3, showing the large number of counts at the 20 airglow locations on Segment B and 4 on Segment A.



Above: Modal gain map for Segment B taken while operating at LP3. Low gain regions mark the regions with the most counts.

This strategy provided ~2.5 years at each LP. Since it was known that positions after LP4 would be more difficult to use efficiently, in 2016 we began the process of identifying ways to remain at LP4 for as long as possible –with the goal of extending the instrument lifetime to at least 2025.

COS2025 Strategy and Implementation

The strategy adopted for LP4 reverses the previous one. Instead of intentionally spreading out the damage, for LP4 the goal is to concentrate the worst detector damage in just two locations on Segment B. To accomplish this, we implemented the following "COS2025" policy when the spectra were moved to LP4 on October 2, 2017:

- G130M/1291 observations are only permitted to use FP-POS=3 and 4 on Segment B. All FP-POSs are allowed on Segment A at LP4
- G130M/1300, 1309, 1318, and 1327 may only be used with Segment A at LP4
- G140L/1105 retains its previous restriction on using Segment A only
- All other central wavelengths can use both segments at LP4, since they do not put Lyman-α on Segment B
- Spectroscopic target acquisitions for G130M/1300, 1309, 1318, and 1327 can only be used with Segment A

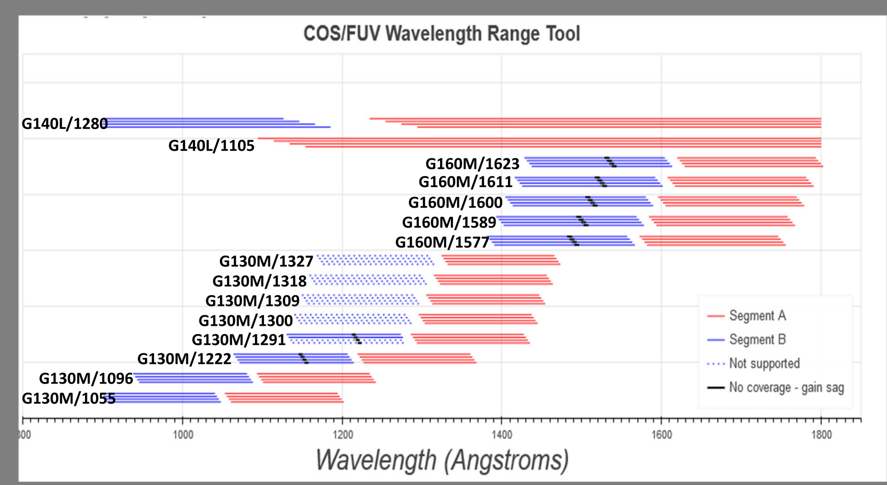
Table 1: Summary of supported and available **science modes** vs. Lifetime Position
COS/FUV – Cycle 25 programs - GO

LIFETIME POSITION	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4
FP-POS	1	2	3	4	ALL	1	2	3	4	ALL	1	2	3	4	ALL
G130M/1055	✔	✔	✔	✔	✔	X	X	X	X	X	X	X	X	X	X
G130M/1096	✔	✔	✔	✔	✔	X	X	X	X	X	X	X	X	X	X
G130M/1222	X	X	X	X	X	X	X	X	X	X	✔	✔	✔	✔	✔
G130M/1291	X	X	X	X	X	AVAIL	AVAIL	AVAIL	AVAIL	AVAIL	FUVA	FUVA	✔	✔	FUVA
G130M/1300	X	X	X	X	X	AVAIL	AVAIL	AVAIL	AVAIL	AVAIL	FUVA	FUVA	FUVA	FUVA	FUVA
G130M/1309	X	X	X	X	X	AVAIL	AVAIL	AVAIL	AVAIL	AVAIL	FUVA	FUVA	FUVA	FUVA	FUVA
G130M/1318	X	X	X	X	X	AVAIL	AVAIL	AVAIL	AVAIL	AVAIL	FUVA	FUVA	FUVA	FUVA	FUVA
G130M/1327	X	X	X	X	X	AVAIL	AVAIL	AVAIL	AVAIL	AVAIL	FUVA	FUVA	FUVA	FUVA	FUVA
G160M/ALL	X	X	X	X	X	X	X	X	X	X	✔	✔	✔	✔	✔
G140L/ALL	X	X	X	X	X	X	X	X	X	X	✔	✔	✔	✔	✔

AVAIL = Available mode use only (approval needed)
✔ = Supported mode (all GOs can use, no approval needed)
FUVA = Supported mode, but only with Segment = FUVA (all GOs can use)
X = Not supported or available to GOs

Left: Observing modes available with the new COS2025 rules

Right: Wavelength coverage with the COS2025 rules



These restrictions force the airglow lines to be in the gap between the segments (G130M/1222), on Segment A (G140L), or at one of two locations on Segment B (G130M/1291/FP-POS=3,4) for LP4. The two Segment B locations will be allowed to sag, and the voltage will not be adjusted to keep holes from appearing. The pixel locations corresponding to these wavelength regions will be treated as an additional gap (~5 to 6 Å in M-modes). Once those holes appear, it will not be possible to obtain a single spectrum with full wavelength coverage on Segment B, but the use of all four FP-POSs will still ensure full spectral coverage.

Complete details are given at **http://www.stsci.edu/hst/cos/cos2025**

After LP4

When the continuum regions of LP4 show ~5% loss at the current maximum HV, further steps can be taken to ensure high quality data. Options might include:

- Choosing a new LP near the top of the detector; this will require changes to the wavelength calibration strategy.
- Return to previous LPs with a higher voltage across the MCPs. No known detector limitation precludes this, but further study will be required to ensure this is safe.