

Cosmic Origins Spectrograph: On-Orbit Structural and Thermal Stability

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DATA and MEASUREMENTS

NUV IMAGE Mode: The data are 18,100s near continuous, MIRROR 1, TIME-TAG imaging of the Solar analog, HST Standard, P177d. 15s images of the wavecal lamp are superimposed on the detector every 200s. We measure the x and y offsets by fit of a gaussian to the peak of the image psf in 20s sub-exposures. We use 1s sub-exposures for the image of the internal lamp and use a running average of each 7 measures in the plot. See **FIGURE 1a**

The BREATHING MODEL presented in **FIGURE 1a**, is that of D. Di Nino et al. in HST Instrument Science Report (ISR) ACS-2008-3, 7May08. It uses a number of temperature records from the engineering telemetry prior to and during our observations to calculate the amount of defocusing movement of the HST secondary mirror.

FUV Spectroscopic Mode, Grating G160M: The data are 22,800s of nearly continuous, TIME-TAG spectra of the emission line object Lindsay-358. Every 200s, a 15s exposure with the wavecal lamp is superimposed. The COS FUV detector consists of two nearly abutted long segments. Thus Segment A and Segment B subsections of the spectra are recorded. We use 2m sub-exposures of the 2d image of the spectra, again omitting WAVECOR, and run a gaussian fit of x,y positions of the 3 brightest lines. One line for Segment A and for Segment B, two, whose measures we average. Again we use the CALCOS produced measurements from the wavecal spectra to track internal induced drifts of the spectrum on the detector. For plotting, the external dispersion shifts have a 6 time-sample wide smoothing, and 9 sample smoothing in cross-dispersion. The lamp measures are 3 sample smoothed. See **FIGURE 1b**.

NUV Spectroscopic Mode, grating G225M: We obtained 23,500s of nearly continuous, TIME-TAG spectra of the emission line object, AG Draconis. Every 200s during the exposures we turn on the wavecal lamp for 15s. COS Time-Tag mode tags each photon with its arrival time along with detector X,Y position. For the NUV detector the spectra is split into 3 subsections and directed along parallel horizontal "strips" on the detector as are the lamp spectra. We work with 8m sub-exposure, CALCOS X1D extractions of the 3 spectral stripes in which which the WAVECOR calibration step, which would remove the TAGFLASH tracked shifts we wish to compare to the external shifts, is turned off. We cross-correlate these sub-exposure's versus the wavelength calibrated summed X1D spectrum from the full 5 orbits of exposure to obtain relative offsets in pixels along the dispersion axis. For the internal instrument component of the spatial drifts we use the CALCOS produced cross-correlated shift measurements of the wavecal spectra versus wavecal template spectra. Those two sets of offsets are shown in **FIGURE 1c**. In cross-dispersion we use gaussian fit centroid measurements of a single bright line from stripe C in 2d, two minute long, sub-exposures. See **FIGURE 1d**.

INTRODUCTION: We report on three experiments performed during the 4th HST Servicing Mission Observatory Verification (SMOV) as HST/COS Proposal IDs 11480 and 11493. Their purpose was to test the thermal and structural stability of COS. Using data from three separate five orbit long nearly continuous 20,000s exposures we find the targets drifting as much as several pixels across the COS detectors. These motions are dominated by internal OSM mechanism settling, also observed in ground testing. We find that these motions were well tracked by the TAGFLASH mode implemented to correct for this motion. We measure additional, external, spatial drifts that are attributable to HST orbital "breathing" plus the thermal settling of multi-orbit pointings. Those externally induced drifts are as much as several tens of milli-arcseconds, as commonly seen in all the instruments on HST. We could not link the motions to any COS internal temperature measures. Those remained stable during these multi-orbit exposures. **Post-AAS work in progress shows an orbital period in the FUV stim-pulse positions and COS interior temperatures that were considered only suggestive of orbital periodicity, but possibly just a noisy lsb are now being re-examined. The full analyses will be available by the end of January 2010.

DISCUSSION

These observations were point and stare. No pointing drifts nor changes in instrument configuration, e.g. FP-POS shifts, were performed. High declination targets were chosen to yield extended sampling of any motions. Though not fully Continuous Viewing Zone (CVZ) targets, only the COS aperture was occulted during the two spectroscopy observations. The FGS's were not, so there were no guide star re-acqs during those pointings.

In the imaging mode exposure we see a total change in position along the X-axis of 1.5 pixels during the first orbit. An additional pixel of motion in the second and a slow turnover to yield a total of ~2.6 pixels after 5 orbits. Along the Y-axis the shift is ~0.2 pixels in the first orbit, but accumulating to ~0.75 pixels at the end. The internal motion shown by the lamp positions clearly dominates. But, we also clearly see motion across the detector induced external to COS. The pattern of the external motion is orbital and the overall breathing cycle is correlated to the excursions in X away from the internal motion. As there were re-acqs for this target, we see the pointing recovery of the external positioning at the beginning of each orbit. Though suggestive of linkage during the two NUV datasets, the jitter drifts are only 1 or 2 milli-arcseconds in themselves.

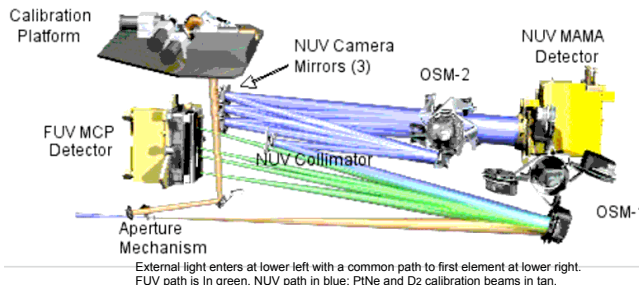
In FUV G160M exposure we see a very small internal excursion in both dispersion and cross-dispersion and no clear evidence of additional external shifts. The maximum excursion during the first orbit being ~0.2 pixels. The ~0.2 pixel amplitude 1/2 orbit period evident in the internal lamp spectra positions in dispersion is not understood at this time. A review of the stim-pulse data may be helpful. Given the lack of evidence for internal COS temperature response to the orbital day/night cycle we lack other suspects at this time.

The NUV G225M exposure is also dominated by the internal motion along the dispersion axis with no clearly identifiable extra external component. The drift is ~0.8 pixels after 1 orbit and accumulating to 1.5 pixels after 5. Along the cross-dispersion axis a shift of ~0.4 pixels after 1 orbit slowly adds up to a maximum of ~0.6 pixels during the 5th orbit. A clear orbital modulation 0.2 pixels amplitude is evident.

The small scale external addition to the internal spatial drifts appear amenable to application of a perhaps modified breathing model. Our follow-up ISR will include our measures of the variation of the FWHM of the PSF input to COS during these experiments and the strong correlation to HST breathing. The cause for a correlation of a focus cycling to measured changes in positions may be an artifact of changing center of light rather than true motion that is being measured.

A characterization of patterns in the internal motions with respect to instrument configuration may be derived from a long term database of shifts measured by the CALCOS pipeline for all TAGFLASH datasets.

COS Optical Path and Layout



External light enters lower left with a common path to first element at lower right. FUV path is in green, NUV path in blue; PNe and D2 calibration beams in tan.

The Fine Guidance Sensor (FGS) jitter measurements are from the real-time FGS pointing measures of the positions of the Guides Stars within the FGS FOV. These are transmitted in the engineering telemetry stream and the portions coincident with Science observations are extracted into fits tables. We perform the rotational transform converting the SL_V2_AVG and SL_V3_AVG records in those tables into COS X,Y. Those samples are at 3 second intervals. Orbit to orbit inconsistency in the jitter zero-points is still under being traced. **FIGURES 3a,b,c**.

Thanks: The COS observations of the irregularly variable Symbiotic Star, AG Draconis, were made possible by over 6 weeks of nightly ground based monitoring leading up to our exposures. This support was performed by the American Association of Variable Star Observers (AAVSO) and the Asiago Novae and Symbiotic stars (ASN) Collaboration led by Ulisse Munari. Otherwise the risk of a sudden instrument damaging bright outburst would have prevented the scheduling of this target.

NUV Image Mode

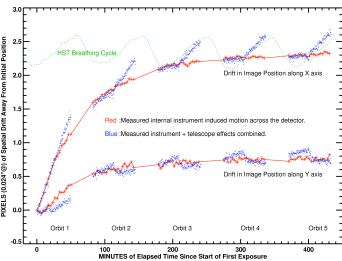


Figure 1a: Filled blue circles are measured offset of the image center from the initial position. Connected Red symbols are the measured offsets of the internal wavecal Lamp image. An HST Breathing Model is overlain using an arbitrary scaling.

FUV G160M

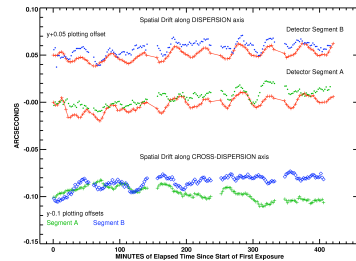


Figure 1b: Blue and Green symbols are the average of measured offsets of bright emission lines on each of the COS FUV Mode detector segments. Connected Red symbols are the measured offsets of the internal wavecal lamp spectra. Offsets now presented in Arcseconds, as FUV X-scale is 0.023"/pixel while Y-scale is 0.17"/pixel.

NUV G225M

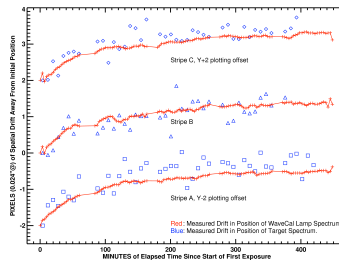


Figure 1c: Blue symbols are the measured offsets in DISPERSION of a bright emission line in each of the three COS NUV Mode spectral stripes. Connected Red symbols are the measured offsets of the internal wavecal lamp spectra.

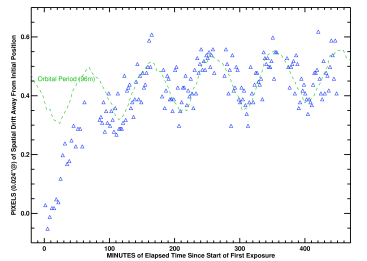


Figure 1d: Blue symbols are the measured offsets in CROSS-DISPERSION of a bright emission line on Stripe C of the NUV Mode spectra. An oscillation with the 96m HST orbital period is overlain using an arbitrary scaling and phase.

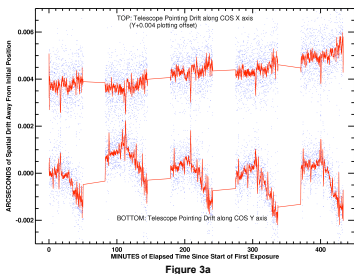


Figure 3a

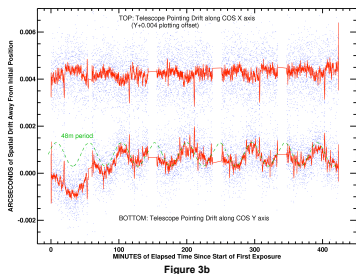


Figure 3b

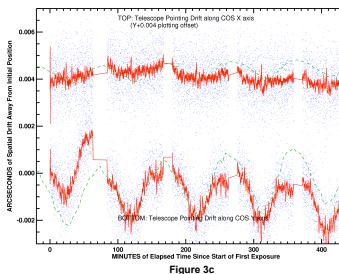
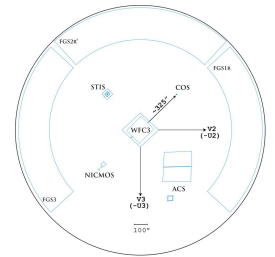


Figure 3c

Figures 3 a,b,c. The HST Fine Guidance Sensor Jitter measures converted to detector X,Y offsets. Blue points are the three second average positions from the HST pipeline tables and the red lines are a running average smoothing of those points.



HST Field of View

The HST focal plane. COS has a 2.5' aperture. Apertures and separations are shown to scale.