The Cosmic Origins Spectrograph: On Orbit Performance Update

Steve Osterman Steve Penton Stéphane Béland













- COS overview
- COS sensitivity and sensitivity trends
- Blue Modes
- FUV gain sag, Y walk and lifetime moves
- NUV detector backgrounds
 CALCOS and Reference Files

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<u>COS FUV Sensitivity</u> <u>Anomaly Review Board</u>

Randy Kimble, chair	David Hughes			
Olivia Lupie, secretary	Jason McPhate			
John Bacinski	Mal Niedner			
Bruce Banks	Steve Osterman			
Carey Cates	Charles Proffitt			
Larry Dunham	Betsy Pugel			
Eric Graham	Tom Wheeler			
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- COS has 2 channels to provide medium and low resolution UV spectroscopy (λ/Δλ~20,000 and ~1500)
 FUV gratings: < 1150-1775Å, G130M, G160M, G140L
- NUV gratings: 1700-3200Å, G185M, G225M, G285M, G230L

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FUV Sensitivity





FUV Sensitivity consistent with prelaunch calibration Exceeds CEI, proposal FUV gains >10 in sensitivity, 70 in observing speed COS gains: faint targets (discovery), observing times (survey)

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NUV Effective Area



- G230L performance exceeds prelaunch predictions (black dotted line)
- Second order light in C strip clearly identified
- Second order light seen in B stripe above 3200Å not easily separated from first order



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<u>COS Time Dependent</u> Sensitivity





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<u>COS Time Dependent</u> <u>Sensitivity: NUV gratings</u>



- G185M: MgF₂/AI, 5870 lines/mm (170nm/line)
- G225M: MgF₂/AI, 4800 lines/mm (208nm/line)
- G285M: MgF₂/AI, 4000 lines/mm (250nm/line)
- G230L: MgF₂/AI, 500 lines/mm (2.0 μ m/line)
- -M gratings performance below expectation in band
- Solution:
 - Use G225M in G185M position
 - G225M, G285M gratings coated with bare aluminum

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<u>COS Time Dependent</u> Sensitivity: NUV gratings



Explanation:

- Small changes in the Al₂O₃ thickness can move the TM minimum to longer wavelengths, dropping the mean efficiency.
- This might also be caused if the structure (and index of refraction) of the existing layer evolved with time.
- Continued decline in vacuum was unexpected
- Since launch t he trend shows no change with time

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<u>COS Time Dependent</u> Sensitivity





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<u>COS Time Dependent</u> <u>Sensitivity: FUV detector</u>



- NUV/FUV overlap the G230L, G185M modes show no decline, despite many more surfaces ⇒ not optical contamination
- Not traceable to pointing, pipeline
- Not explained by MCP gain sag
- Sensitivity decrease initially more severe at longer wavelengths, now 'gray.'
- Principal candidate: Atomic oxygen or AO+water vapor



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<u>COS Time Dependent</u> Sensitivity: FUV detector



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Fault Tree Diagram for Photocathode Degradation

Hydrocarbon Contamination Causes scattering and severe UV throughput loss preferentially at blue wavelengths Rejected:	Chemical Interaction with outgassing Product Unknown chemicals, Unknown process Cannot Rule Out:	Residual gases from Ground Storage Contam during in- huttle bay storage r launch when ion ump was turned ff Cannot Rule Out:	Inter- mediate Energy Ions inergy deposition within CsI from GAA -creates efects in the pper layers of CsI hotocathode Rejected:	Neutrons Energy deposition within CsI from SAA -creates defects in the upper layers of CsI photocathode Rejected: Too few	MCP Diffusion COS MCP is low noise glass with very few impurities Rejected: Saw no such effect in years of ground use; GALEX has
 MgF2 NUV optics unaffected where FUV and NUV band-passes overlap FUV detector is warmer than optics Inconsistent 	 But unlikely to accelerate Although not seen on ground, time on- orbit for such an effect to occur exceeds time in TV 	• But unlikely to accelerate	• Electrons Repe by QE grid @ -1! r to MCP • SAA peak rate FUV counts too l cause degradatio • SAA electrons of	Iled neutrons in 500V / LEO and cross sections too small to account for easily d oft	same MCP and saw no QE losses Potential processes
Photoconversion efficiency of Alkali Halide photocathodes exposed to large UV doses over a long time can be compromised Rejected: • Correlation with	Particles/radiation causes ionization and displacement within photocathode; inclu Gamma, X-ray, Cosm Rays, high energy electrons. Rejected: • Previously flown FUV	Ad Lower energy of particles would background noi Action Mejected: • Low Energy ions rejected by+15V Ion Repeller Grid-	harged cause se ARE consis impac fluen @ CC	hly Reactive 6 of atmos @ 575 km en-face PC 8 Ground Tests stent with strong cts on CsI deled thermal AO ces 05 FUV are	 that could cause Photo- cathode Degradation Large change in QE decline after 4/2010: outgassed component Affects QE more
 Correlation with in-flight illumination totals not seen Need 10000x total number of counts to cause damage UV Flux 	Missions w/ sealed tube detectors should see same degradation but they don' t; •Also expect high backgrounds/hot spots Penetrating Particles/ Padiation	keeps out thermal ions of < 1EV energy • Low Energy Electrons are repelled by the QE grid @ -1500V w/r to MCP Low Energy Electrons/	y Plaus • AO (sola Likel Wor Cano	ible will increase in cycle peak) ly and Most risome didate tomic xygen Wate	at red wavelengths (AO flatter) • Outgassing behavior correlated with initial QE decline /ith AO prior to 4/11 but issipates with time



<u>COS Time Dependent</u> <u>Sensitivity: AO Testing</u>



- Does impact performance
- Roughly gray shape (slightly worse at long wavelengths



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<u>COS Time Dependent</u> <u>Sensitivity: AO Testing</u>



SEM reveals morphological changes – erosion of grain boundaries at high fluences – and growth of insulating nodules



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<u>COS Time Dependent</u> <u>Sensitivity: AO Testing</u>



- QE loss appears to go as integrated exposure ^0.3 or ^0.5 - as we are exposed to more AO the rate of degradation should drop
- But we're entering solar max, so more AO exposure expected
- The QE loss for the lowest fluence test point is greater than has been observed to date for COS in flight.
 - At ~90x estimated exposure to date the QE loss is ~50% (the projected solar cycle predicts 20x current fluence by 2015.)

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FUV Projections





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- QE loss is expected to continue but should not rise linearly with AO density
- No action recommended for now ram avoidance, etc. will not reduce exposure
- Loss of performance is not sufficient to front load COS observations
 - Other instruments are either single string (STIS, ACS) or are seeing loss of performance from other modes

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- Several sub-1150Å observing modes have been identified:
- G140L-1280, B segment (Verified in SMOV, available to observers)
- G130M -1055 and -1096 (Verified in 2010, in IHB, not currently supported for cycle 19)
- G130M -1222 (Proposed, CU)
- G140L-800 (G140L gapless, Proposed, JHU/CU)

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FUV Blue Modes



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16:14:22, 24 Feb 2011

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Bonus Slides



AO Fluence Models



NRL (J. Emmert) has provided models of atmospheric density to date (normalized to satellite drag data) based on NOAA projections for the coming solar cycle. Note that while this prediction is for a weak solar cycle, the actual data through 2011.0 are still running below it.



- These are *external* fluences, proportional to, but not equal to the fluences in our lab test.
- Note the increase in daily fluence by a factor of ~40 vs. the period immediately after SM4.
- Includes recent correction to HST altitude projection (now conservative).

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<u>COS FUV Channel</u>



FUV Channel: Holograpically corrected off-Rowland

- Single reflection provides correction for HST aberration, diffraction and grating astigmatism correction
- Low scatter, holographcially ruled gratings with ~ 4880l/ mm provide 16,000 -21,000 Resolution from <1150-1800Å (300-370Å per grating position) in medium resolution modes
- Two segment (2 x 85x10 mm) XDL detector,
 ~36 μ m resolution



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<u>COS FUV Channel</u>



- Two detector segments, 15384x1024 pixels per segment
- Note background (~14 cts/sec/segment)



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<u>COS NUV Channel</u>



COS STM 8 Apr 2011

NUV Channel: Modified Czerny Turner spectrograph

- Holographically ruled gratings with ~ 4000-4800I/mm provide 20,000 - > 24,000 Resolution from1700-3200Å in medium resolution modes
- 34-40Å per stripe, 3
 stripes per grating position
 with 65-70 Å gaps
- 25x25mm MAMA detector (STIS spare) with 25 micron pixels



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COS NUV Channel



- Note that calibration lamp lines are not in focus
- Background on orbit is ~1/10 STIS NUV
- Target acquisition mode with ~ 45mArcsec resolution across ~1 arc sec unvignetted FOV



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COS Performance Summary



Channel	Wavelength Range	Resolution $(\lambda / \Delta \lambda)$	Limiting V _{mag} * (S/N 10 in 10 Ksec)
G130M (FUV)	>1150-1450Å	16,000-21,000	19.1 [16.3]
G160M (FUV)	1405-1775Å	16,000-21,000	16.7 [14.1]
G140L (FUV)	>900-2050Å	1500-4000	20.6 [17.8]
G185M (NUV)	1700-2100Å	22,000-28,000	17.8 [15.7]
G225M (NUV)	2100-2500Å	>25,000	17.5 [15.8]
G285M (NUV)	2500-3200Å	>25,000	16.9 [<u>15.6</u>]
G240L (NUV)	1650-3200Å	2100-3900	20.4 [18.7]
TA1 (NUV)	1700-3200Å	0.05″	(Targ.Acq.)

* S/N 10 per resl in 10Ksec at central λ , assuming B5V star (Castelli-Kurucz model) [V_{mag} assuming a flat (F λ) continuum]

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Spectrograph ground testing showed G285, G225 TM minimum had moved into Band



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