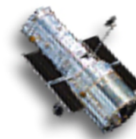




Goddard Space Flight Center

Hubble Space Telescope Program



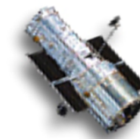
HST/GSFC Project Scientists' Report – Part 2

Presentation to: **STUC**

Kenneth G. Carpenter
Operations Project Scientist

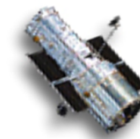
6 April 2011



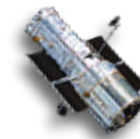


Topics

- **Hubble Legacy Archive (HLA) Status & Plans**
- **Summary of Final Report from COS FUV Sensitivity Decrease Anomaly Resolution Board (ARB)**

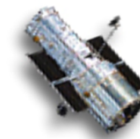


Hubble Legacy Archive (HLA) Status and Plans



HLA Governing Board

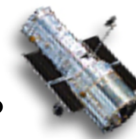
- **Purpose:** Guide the overall strategic development of the HLA and ensure quality of the formal data and interface releases
- **Board Members**
 - Stefano Casertano, STScI Project Scientist for HST Data
 - Kenneth Carpenter, GSFC HST Operations Project Scientist
 - Mario Mateo, STUC Rep., rotating off - *need replacement*
 - Lee Quick, HLA Coordinator/STScI
 - Piero Rosati, ST-ECF HLA Rep.
 - David Schade, CADC Rep.
 - Rick White, PI of MAST/STScI
- **Additional Participants**
 - Daniel Duran, CADC
 - Richard Hook, ST-ECF -> ESO
 - Mark Kyprianou (previously HLA Coordinator) & Brad Whitmore (previously HLA Project Scientist) , STScI



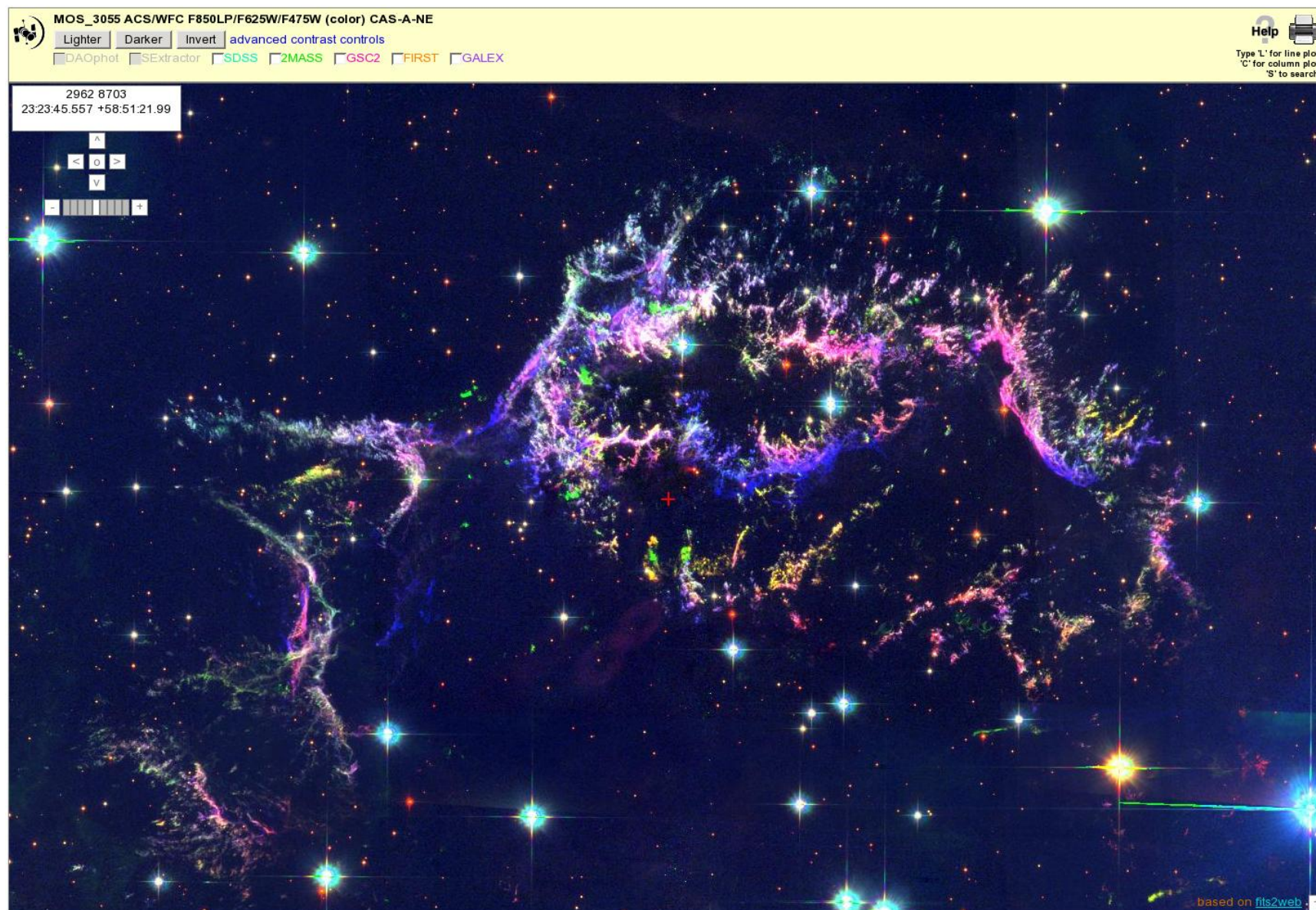
Data Release 4 – March 24, 2010

● New data products included:

- Level 2, fully-reprocessed, images for all NICMOS science data
 - The SAAClean procedure (which removes some of the persistence induced by cosmic rays during SAA passages) was not applied in OPUS because of a pipeline error
(update: now complete & ready for delivery - April 2011)
- ACS Level 2 data and source lists complete through February 2010
(now being updated as part of post-DR5 activities)
- Level 2 images and source lists for all WFPC2 data after reprocessing
 - includes better bias subtraction for WF4 images and a header keyword to correct the UV photometry for the monthly post-decontamination throughput variation
 - About 50% of WFPC2 source lists were available at release; the rest in early May
- 60 new ACS mosaics
 - Multi-visit combination allows deeper images, knitting multiple FOVs for larger area coverage
 - Current mosaic pipeline requires cosmic ray rejection separately for each epoch; a pipeline upgrade to improve image registration and sky matching and allow multi-epoch cosmic ray rejection is planned for the near future
- New High-level science products (including WFC3 ERO)
- Public WFC3 data for several projects viewable in Interactive Display

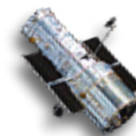


Mosaic: ACS image of the supernova remnant CAS A in F475W, F625W, & F850LP

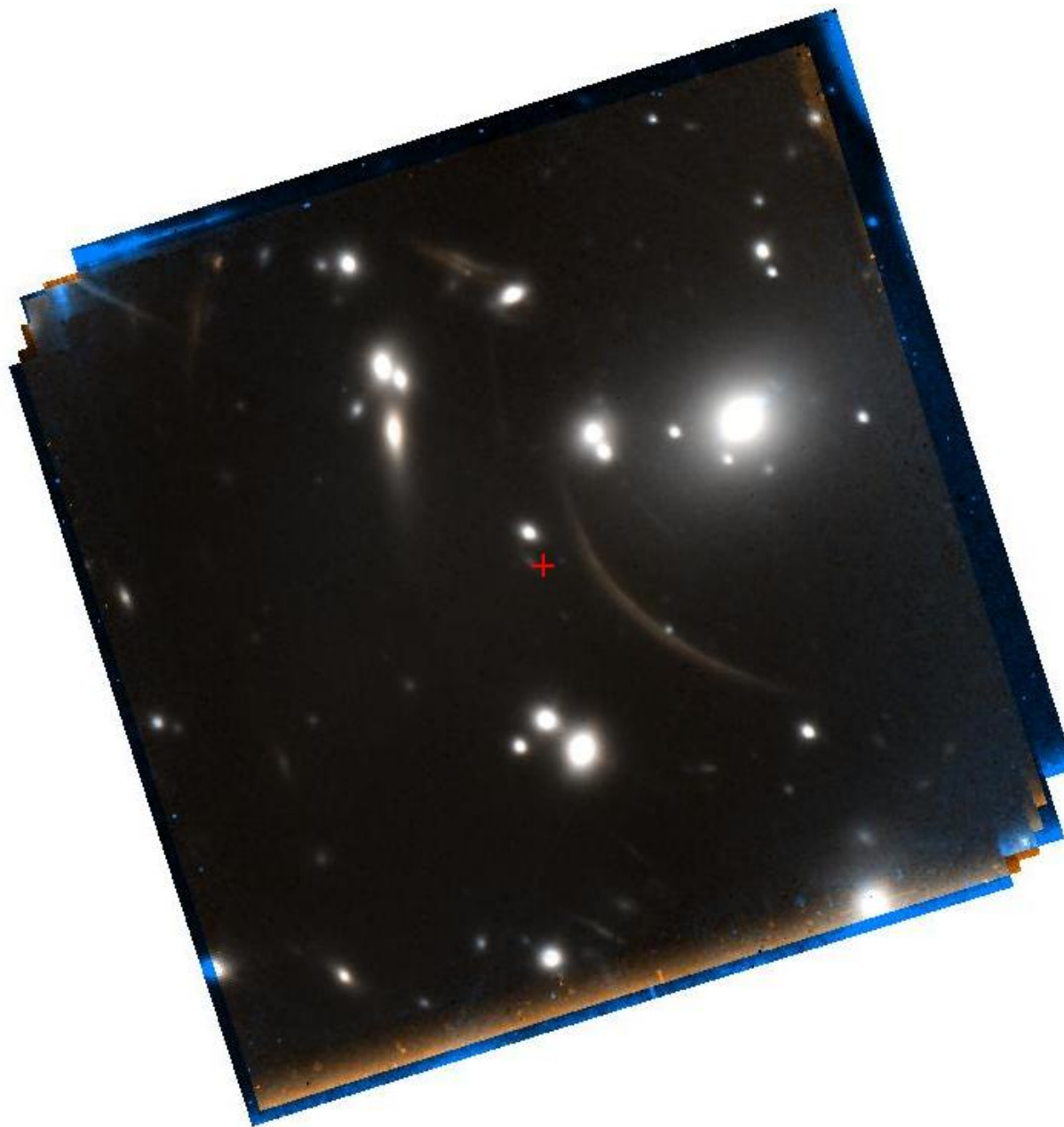


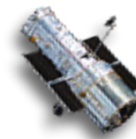


Hubble Space Telescope Program



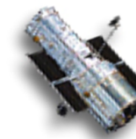
NIC3 observation of a region in the lensing cluster Abell 2390 (F110W+F160W)





ERO: WFC3/UVIS image of PN NGC6302 (F373N, F502N, F673N)





Using the improved Plotting Tool



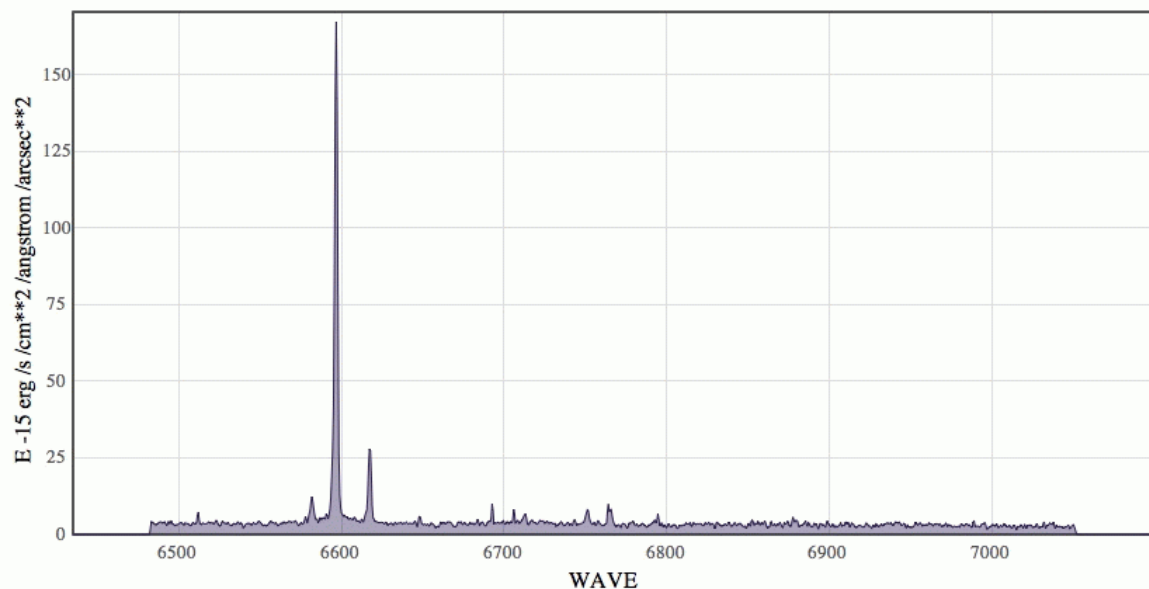
Hubble Legacy Archive

Image of the Month for June 2010

Antennae Galaxy: Emission Line Spectra from Young Star Clusters

O5HE06010 (Line 758)

Click point to get value



6611.2178, 3.8998

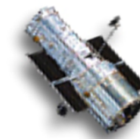
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Continuum	55.1387
Flux Wt. Cent.	6596.3648
Equiv. Width	-56.6792
Rest Wave	<input type="text" value="6564.614"/>
Redshift	0.0048
Velocity	1.45E3

Central Row:

Coadd (total rows):

X Axis Units:

Smooth (width in pixels):



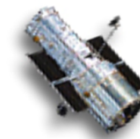
Data Release 5 (DR5) – March 8, 2011

● User Interface Enhancements


- A completely new footprint interface, featuring:
 - Panning and Zooming in/out capabilities
 - New footprint table with filtering and ordering controls, fully integrated so that selections in one screen remain valid in the others
 - Selection across instruments possible
 - Option to search through proprietary and/or non-proprietary data
- Improved flow control for shopping cart retrievals
 - Single or sequential download
 - Partial downloads can be restarted
- Interactive retrieval of source properties (sources clickable)
- When filtering RA or Dec columns, the values may be entered either in decimal degrees or in "sexagesimal" format (hh:mm:ss, dd:mm:ss)

● New Data Products

- Completed WFPC2 processing (over 300 new visits with source lists)
- New High Level Science Products (HLSP), including Early-Release Science data from WFC3 and the first combined images released by the Multi-Cycle Treasury Program CANDELS.
- Multiband source lists (ACS and WFPC2)
- ECF-generated ACS and NICMOS extracted GRISM data hosted at STScI



Example of new footprint display



Hubble Legacy Archive

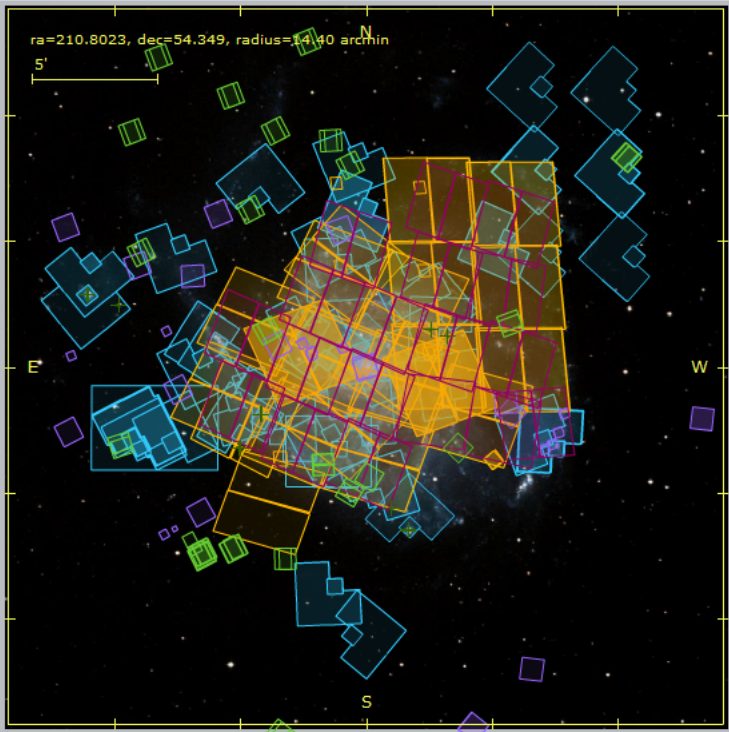
[advanced search](#)

Examples: [M101, 14 03 12.6 +54 20 56.7 r=0.2d, more...](#)
 Requires Firefox, Safari, IE, or compatible browser

[Inventory](#)
[Images](#)
[Footprints](#)
[Cart, 0 kB](#)
[Grism Spectra \(ST-ECF\)](#)
[Help Center](#)

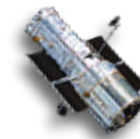
Instruments	#Footprints
<input checked="" type="checkbox"/> ALL	1293
<input checked="" type="checkbox"/> ACS	205
<input checked="" type="checkbox"/> ACSGrism	0
<input checked="" type="checkbox"/> WFPC2	363
<input checked="" type="checkbox"/> WFPC2-PC	355
<input checked="" type="checkbox"/> NICMOS	122
<input checked="" type="checkbox"/> NICGrism	0
<input checked="" type="checkbox"/> WFC3	18
<input checked="" type="checkbox"/> COS	0
<input checked="" type="checkbox"/> STIS	170
<input checked="" type="checkbox"/> FOS	60
<input checked="" type="checkbox"/> GHRS	0

ra=210.8023, dec=54.349, radius=14.40 arcmin



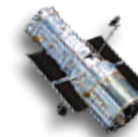
Click to select the interactive footprint graphic: you can then zoom in using the = or + keys, or zoom out using -.

M101 RA = 210.802270 Dec = 54.348950 r = 0.240000 [14:03:12.545 +54:20:56.22]

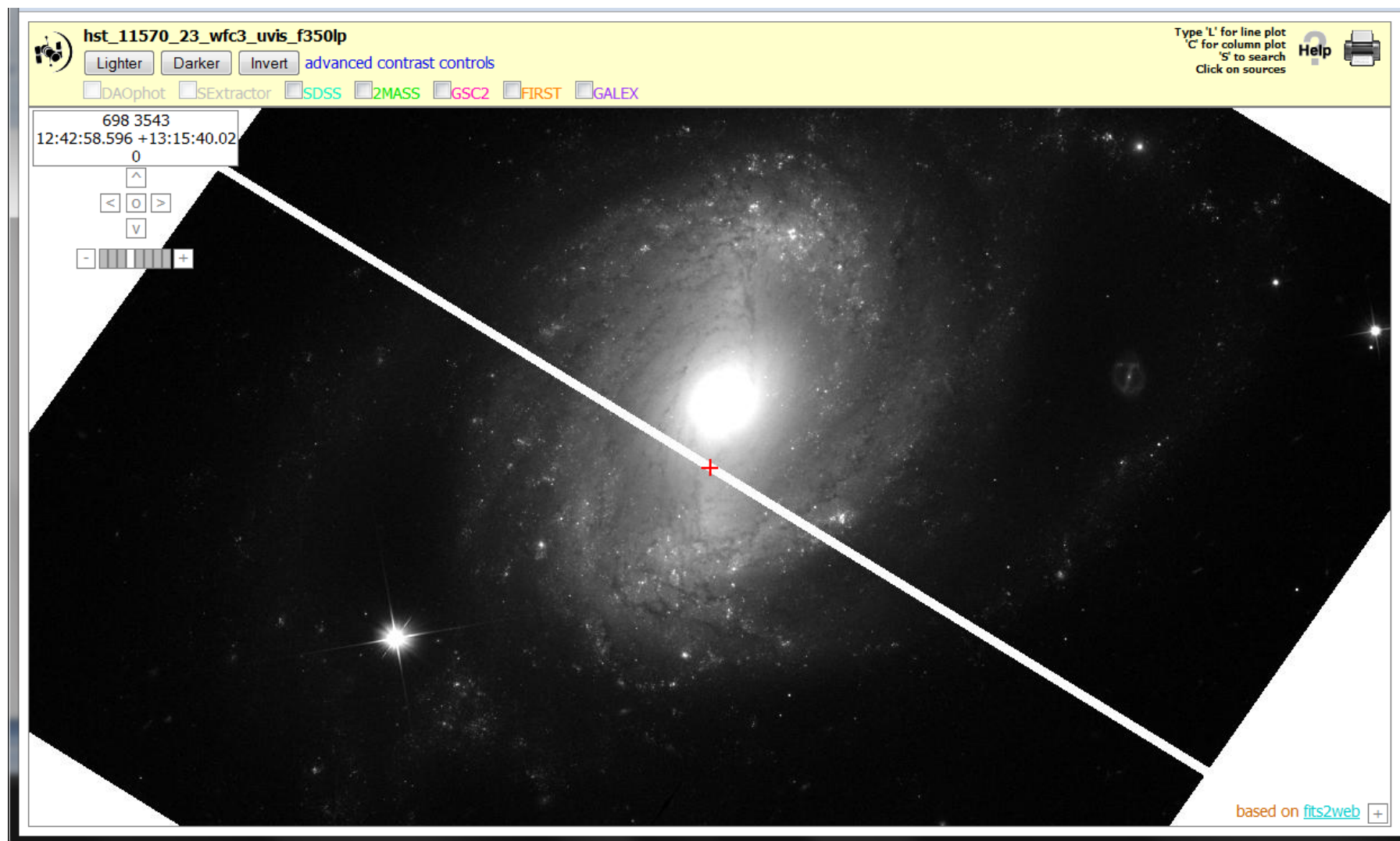


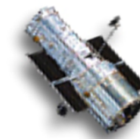
Near-Future Plans

- **Moving toward “progressive” data releases – on-going small releases as new products available vs. all-at-once major data releases**
- **Data to be released in near-term will include:**
 - ACS and NICMOS updates
 - The first generation of WFC3 visit-level combined images (equivalent to current ACS, WFPC2, NICMOS)
 - A subset of the WFC3 data are expected to be processed at release; more data will be processed gradually over the following months
 - The WFC3 combined images will include an additional extension to provide local (per pixel) exposure time and improve bright source shot noise calculations
 - Headers have been redesigned for accuracy/accessibility; will now include parameters used in image combination; individual image information preserved in new extension (binary table)
 - Sky no longer subtracted, use sky equalization across images (offsets recorded)
 - Prototype combined COS spectra provided by the IDT
 - Processed spectra resulting from combination of multiple datasets at different grating settings
 - Direct visualization of the spectra may be delayed a few weeks because of needed interface changes
 - These spectra will serve as examples of new spectral products to be developed by the HLA; user feedback will be utilized to guide developing future COS products



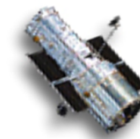
Example new WFC3 data: NGC 4639, uvis_f350lp





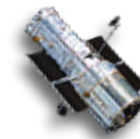
Longer-Term Future Plans

- **Extend absolute astrometry enhancement to all HST data**
 - Expected worst-case accuracy 0.4''
 - Typical accuracy 0.1-0.2''
 - Already included in WFC3 images, from initial release
- **Work with Instrument Teams to understand best products for COS, STIS**
- **Integrate user interface with MAST portal**
 - Enable persistent user-specific preferences
 - Facilitate operations that require validation
 - Common look-and-feel for seamless integration across interfaces
- **ACS data enhancements (CTE correction, destriping)**
- **Possible areas for longer-term development:**
 - Work with WFC3 on possible grism analysis tools; test WFC3 pipeline being dev.
 - Develop source lists and produce uniform metadata for High-Level Science Products; will be included in WFC3 data from initial release
 - Continue work with Chandra, Spitzer to integrate our footprint data
 - Evaluate new software tools for enhanced interface
 - Prototypes allow concurrent display of multiple image layers, contextual data through browser
 - Stability, availability, and resource demands of software will be considered



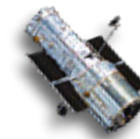
Summary of Final Report from COS FUV Sensitivity Decrease Anomaly Resolution Board (ARB)

[Based on slides extracted from the ARB Final Report, edited and condensed by KGC.
Thanks to the ARB Chair, Randy Kimble, for supplying a “prepublication” copy!]



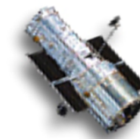
Motivation for ARB

- **Standard trending of the sensitivity (counts out per photon in) of the FUV Channel of COS revealed a more-rapid-than-expected loss of sensitivity with time; absolute losses of $>6\%$ were noted at the longest FUV wavelengths by March 2010, with a loss rate of $>10\%/year$ for the most affected spectral regions.**
- **COS is a critical, highly productive part of the HST observatory, so this unexpected decline appropriately attracted immediate attention.**
- **Initial tiger team discussions of this phenomenon were underway by March 2010.**
- **The formal ARB was chartered April 16, 2010.**



ARB Charter

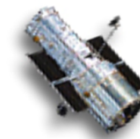
- 1. To the extent practicable, determine the cause of the COS FUV detector's sensitivity degradation. As part of this assessment, identify any additional laboratory and/or on-orbit testing that would contribute to the investigation.**
- 2. For the probable cause(s) identified in objective 1, provide a forecast of the continuing degradation trend.**
- 3. Determine if there are any operational changes that could be employed to either eliminate or mitigate this anomaly.**



ARB Members

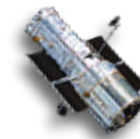
Randy Kimble, chairperson	Code 667/443
Olivia Lupie, secretary	Code 441/584
John Bacinski	Code 441/MOSES
Bruce Banks	NASA Glenn, BAB Technology LLC
Carey Cates	LMSS/ATC
Larry Dunham	PPI/Code 441
Eric Graham	Code 441/MOSES
David Hughes	Code 546
Jason McPhate	University of California, Berkeley
Mal Niedner	Code 667/440
Steve Osterman	University of Colorado/CASA
Charles Proffitt	STScI
Betsy Pugel	Code 553
Tom Wheeler	STScI

Additional key contributors: Joshi Anne (LMSS/ATC), Paul Christensen (LMSS/M&P), Brett Cruden (NASA/Ames Research Center), John Emmert (NRL), Rachel Osten (STScI), Aaron Paterson (LMSS/M&P), Steve Penton (University of Colorado), Marjorie Sovinsky (GSFC/541)



FUV Sensitivity Trending Update

- Over the extended time period of the ARB's activities (~1 year), the sensitivity trend has changed significantly:
 - The rate of sensitivity decline has slowed markedly, with an inflection point in early 2010. Gain-corrected rates of loss ranged from 3-15%/year when fitting the time period from 2009.6 through 2010.2, but only from 2.5-5%/year from 2010.2 through 2011.0 – a significant reduction, though still higher than for modes at these wavelengths in STIS (1.1-2.9%/year) or ACS (2.1-3.9%/year) in their corresponding post-launch periods.
 - Wavelength dependence that favored higher losses at the red end of the FUV spectral coverage prior to April 2010 appears to have flattened significantly
 - Slopes at similar wavelengths but different gratings/detector segments are not always consistent
 - *Change in trend is suggestive of more than one cause, e.g., a wavelength-dependent factor that has decreased in strength (e.g. reduced outgassing), leaving a spectrally flatter component dominant now*

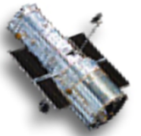


The Fundamental Observable – Time Dependent Sensitivity (Throughput)

- The extended duration of the ARB has led to the accumulation of a very rich data set on the fundamental observable – the time-dependent sensitivity (TDS) of the FUV channel of COS.
- The extended time period has revealed the change in rate and spectral character of the decline.
- Concurrent investigations by STScI have quantified the effects of MCP gain sag on the observed throughput of COS:
 - These investigations have confirmed the ARB's early conclusion that gain sag was not a significant contributor to the steep initial decline
 - They have identified the need for proper choice of minimum pulse height amplitude in the data analysis to minimize gain-related effects
 - All TDS data shown here are based on that optimum pulse height choice; residual gain effects are $<1\%$.
- The following charts show a detailed example of the TDS results (for G140L) and a summary of the TDS results for all gratings, as derived by members of the STScI COS team (C. Proffitt, R. Osten, D. Massa, D. Sahnou, C. Oliveira)

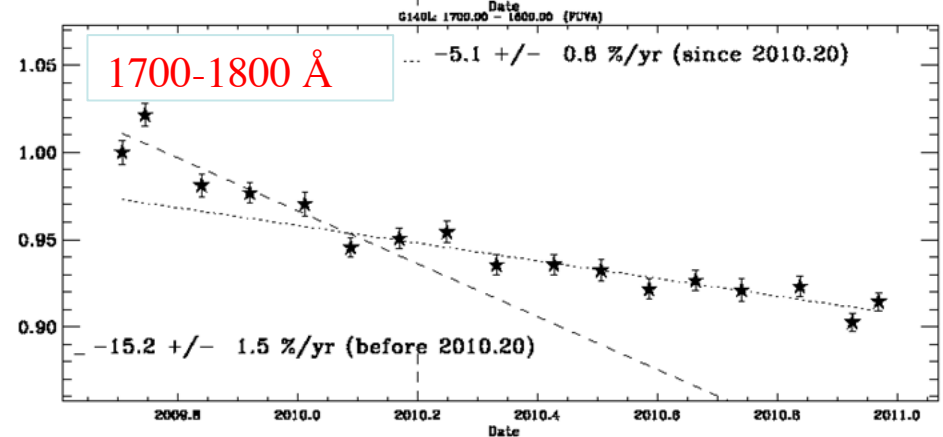
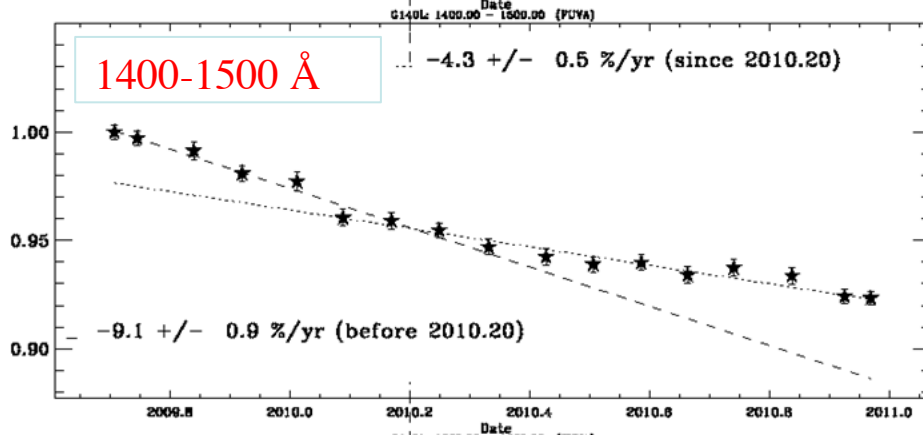
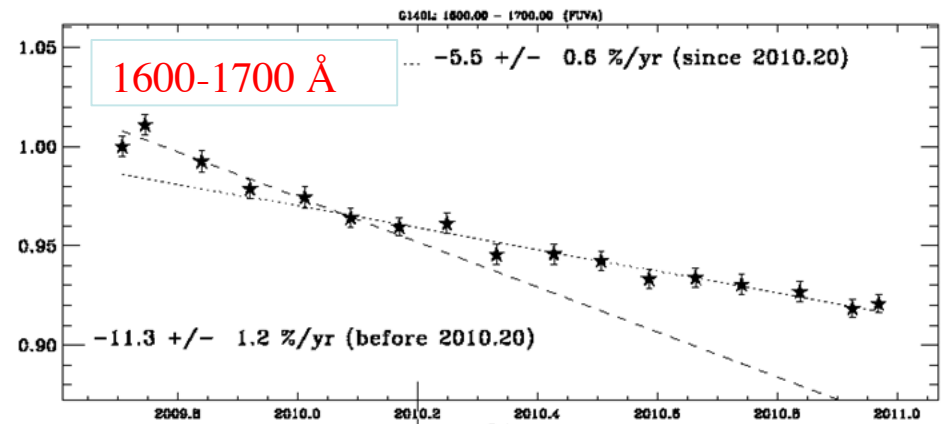
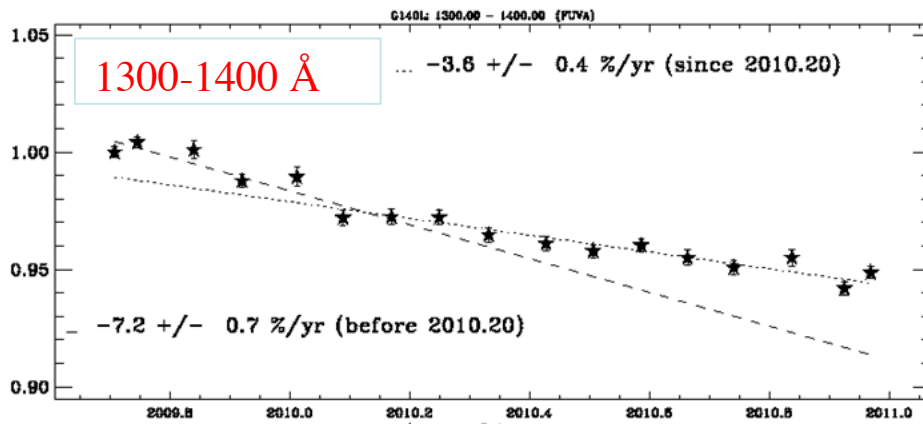


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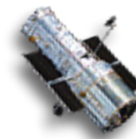
Sample Data in G140L

- Demonstrating the stronger decline at longer wavelengths and the change in slope in early 2010



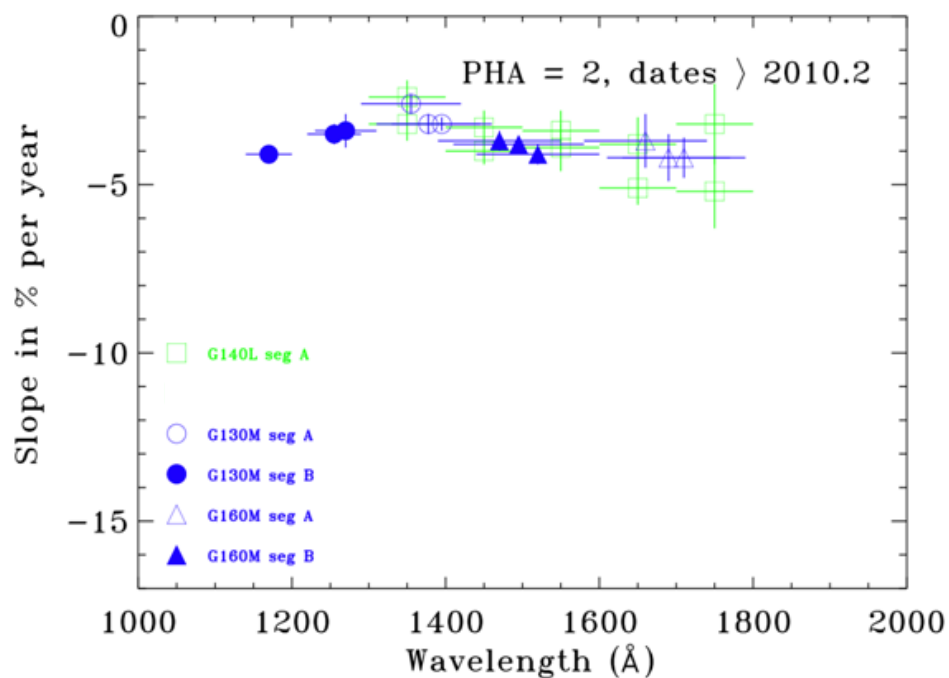
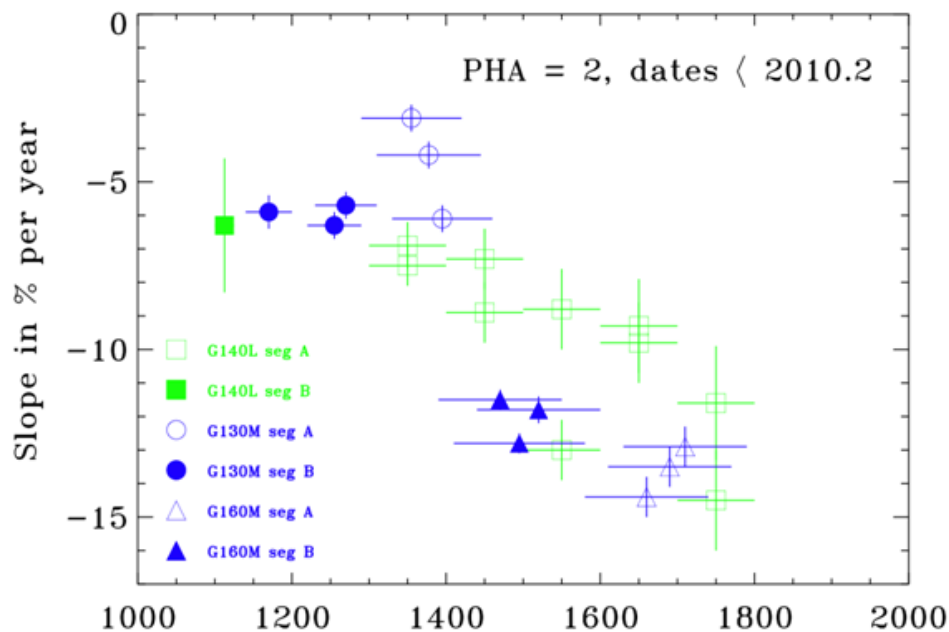


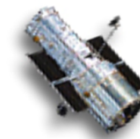
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Summarizing All TDS Slopes

- Divided into the early (pre-2010.2) and late (post-2010.2) time periods
- Note the dramatic decrease in the rate of decline slopes

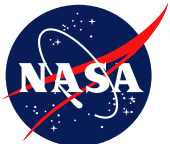




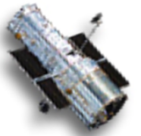
Summary of ARB's Conclusions – Cause

The ARB has carried out a fishbone analysis of possible causes and has evaluated those causes through analysis of on-orbit data as well as a program of laboratory investigation. This work has led to the following conclusions:

- **The principal contributor to the sensitivity decline of the COS FUV channel is degradation of the quantum efficiency (QE) of the CsI photocathode on the front microchannel plate of the windowless FUV detector, due to environmental factors encountered in flight.**
- **The strong change in the rate and the indications of change in the spectral dependence of the sensitivity decline suggest that two different environmental factors are involved:**
 - 1) An outgassing product (water vapor is the most likely candidate) whose instantaneous effect on the detector has declined significantly with time since SM4, and whose effect on QE is significantly stronger at the long wavelength end of the COS FUV band
 - 2) A second factor with a longer timescale and ... a spectrally flatter effect on QE. Atomic oxygen (AO) in the residual Earth atmosphere at HST altitude is a strong candidate. AO is of particular interest because of the expected *increase* in the rate of exposure as the solar cycle increases the AO density at HST altitudes – this aspect has led the ARB to focus on AO.

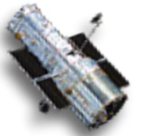


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Summary of ARB's Conclusions – Projection

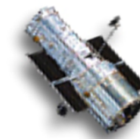
- The maximum total decline observed over the period from year 2009.6 to 2011.0 is 10% at the long wavelengths of the G140L and G160M observing modes; the minimum total decline over the period is 4%
- Accurate separation of the effects of the two components is difficult, but the best fits to the behavior over the monitoring period *indicate that the spectrally steeper contributor is insignificant at the present time and that future behavior will be dominated by the spectrally flatter contributor*, which, as noted, is potentially atomic oxygen:
 - *If atomic oxygen is not a factor*, there is no identified mechanism that would predict an increase in the rate of decline from current values. Continued degradation at 2.5-5% per year projects to 10-20% additional QE loss by 2015 (COS at 5.5 years post-launch) – and the rate of loss could well continue to decrease
 - *If atomic oxygen is (or soon becomes) the dominant factor*, the bounding estimates on degradation are somewhat more severe: ranging from ~24% at 1168 Å by 2015 to ~40% at 1743 Å; more reasonable estimates are in the range of 18-30%; more extreme atmospheric assumptions can increase this modestly (5-8%)
 - *Projected losses of >50% are only found if all lab and normalization uncertainties are pushed in the same direction; such models will soon be falsifiable*



Summary of ARB's Conclusions – Mitigations (1)

The ARB has not identified any mitigations of sufficient benefit to be recommended.

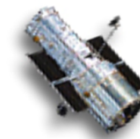
- *If the longterm degradation factor is AO* (likely but not proven), then *some* mitigation of the sensitivity decline could be achieved with a ram avoidance constraint.
- Note, however, that all AO paths to COS involve many bounces, so there is no strong hyperthermal AO component dominating the degradation that could be totally eliminated with ram avoidance.
- Because the trend of QE loss vs. fluence has been found to be significantly weaker than linear, *the modest reductions in fluence for fairly significant ram constraints yield only a few % reduction in sensitivity loss*
- Given the enormous impacts to the scheduling system and the loss of target visibility windows (e.g. 15 deg ram avoidance around an orbit = 26% of the sky), *for modest mitigation of an unproven contributor*, the ARB does not recommend such a step.



Summary of ARB's Conclusions – Mitigations (2)

No significantly beneficial modifications to the operation of COS itself have been identified. There are very few “changes in state” possible for this elegantly simple observing mode. *Note that the instrument's external shutter is already closed whenever COS is not observing.*

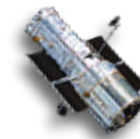
- Closing the FUV detector door between observations would reduce the exposure to the environment, but:
 - The door was designed for very few actuations (<20) and COS would be severely limited if the door failed in the closed position
 - The slow rate of decline does not justify moving all COS observations to a small number of campaigns with very infrequent door closings between
- Significant heating of the photocathode, which has been seen in lab tests to anneal some types of damage, is not possible in the flight configuration (only a few degrees heating above room temperature could be achieved)
- The HV state of the detector could in principle be altered (to be OFF a higher proportion of the time) but that should have no effect on the interaction of the photocathode with residual AO, which is neutral



Summary of ARB's Conclusions – Mitigations (3)

The only other operational mitigation identified is to frontload COS observations in the longterm schedule.

- COS is a highly successful, productive instrument. While any loss in sensitivity is undesirable, the large COS observing advantages of $>10x$ to $\gg 10x$ in its FUV modes are not dramatically undermined by loss rates of 3-5% per year.
- COS is competing for observing time with:
 - ACS and STIS, which are single string instruments with probabilities of *total failure* that are almost certainly $>5\%$ per year
 - WFC3, which is still dual string, but which has a comparable loss of faint end sensitivity in its UVIS channel due to radiation damage on the CCDs (CTE loss)
- *Hence, while such scientific decisions are the province of the HST Project and STScI, the ARB does not recommend overturning TAC-selected scientific prioritizations for such a modest loss rate.*
 - *The GSFC Project Science Office concurs with this recommendation.*



Summary of ARB's Conclusions – Recommendations

- **Continue the monitoring of the sensitivity of COS vs. time (a natural part of the calibration program of course)**
- **Advise the Cycle 19 and subsequent TAC's of the best available projections of COS sensitivity**
- **Continue to track the strength of the solar cycle vs. current projections**
- **Continue to assess the actual atmospheric density (from HST altitude loss rates or by obtaining continued updates from NRL)**
- **Track the sensitivity vs. time against the potential future tracks derived by the ARB, in order to continue to refine the future projections**
 - **If trends unexpectedly start taking one of the steep trajectories, can revisit the ram and scheduling questions**