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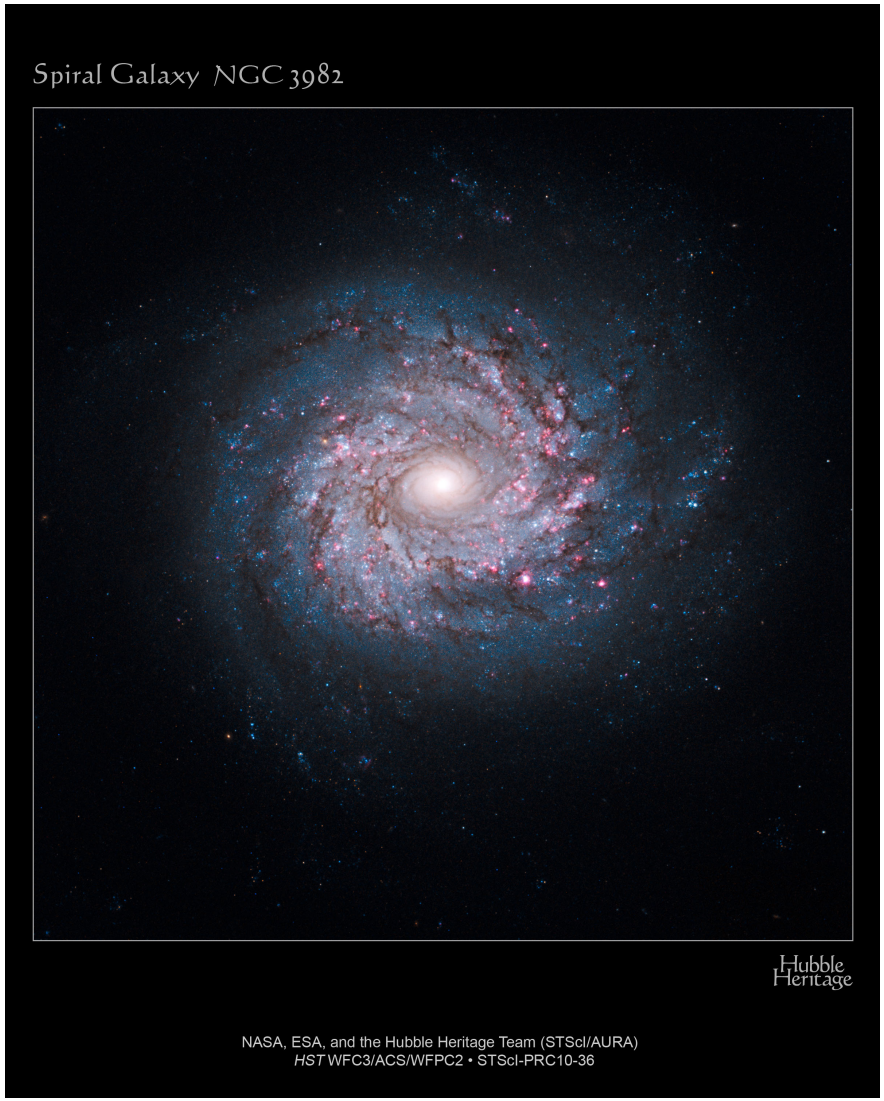
Hubble Space Telescope Program



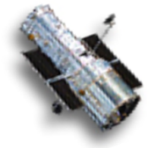
HSTP/GSFC Project Science Report, cont'd

Presentation to:

Space Telescope User's Committee

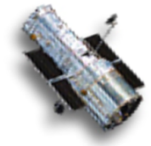
Malcolm Niedner
HST Observatory Project Scientist

November 1, 2010



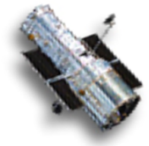
Topics

- **COS FUV sensitivity degradation**
  - **Status of Anomaly Review Board (ARB) investigation**
- **GSFC Detector Characterization Laboratory activities**
  - **ACS CTE mitigation**
  - **WFC3 issues**



COS FUV—at the top level

- **Extensive fault-tree analysis by ARB (R. Kimble, Chair) points to *photocathode degradation* as the root phenomenon**
  - No evidence for optical contamination
    - Initial degradation went the "wrong way" (*worst* losses at *long* λ)
    - Overlapping NUV wavelengths with MgF2-coated gratings show no changes in sensitivity, despite 3 more optical bounces
  - No evidence for electronics degradation
    - e.g., hard to see how this would produce λ-dependent effect
  - Many other mechanisms examined and rejected
- **FUV CsI detector is *open-face*, unlike STIS and ACS/SBC MAMAs, which have windows**
  - COS FUV detector therefore exposed to local gaseous environment (internal outgassing and external residual atmosphere)



CsI photocathodes in presence of water and atomic oxygen (AO)

- **Ground-based experience with CsI exposure to water vapor is extremely variable and unpredictable**
  - In one instance, QE(λ) loss per torr-hour exposure to water vapor nearly identical to *early* on-orbit situation, assuming HST aft shroud gas pressure dominated by water
  - But other cases exist with many orders of magnitude discrepant results (no degradation w/ 1e3 more exposure; 5x more degradation with 5e6 more exposure)
  - Water still in play but difficult to assess. "Favorable" aspect is that it will decrease with time
- **AO known to be highly reactive with polymers and external spacecraft surfaces, but reactivity with CsI not something you can look up**
  - ~ 30x N_{AO} enhancement at HST orbit in going from solar min to max is worrisome; *hence AO has become ARB's principal focus*

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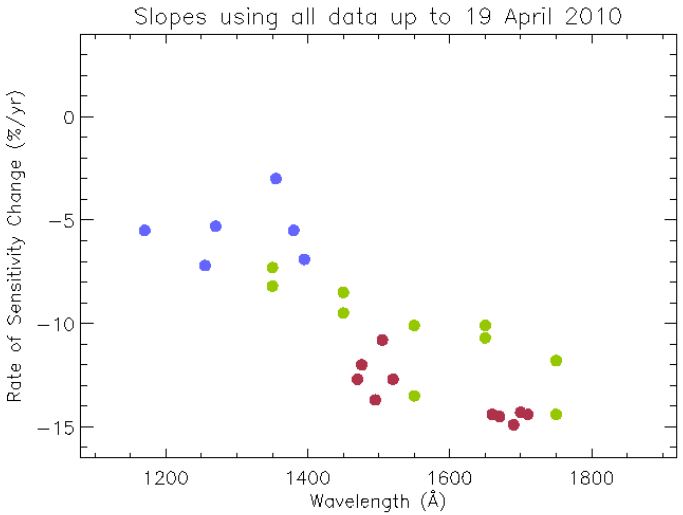
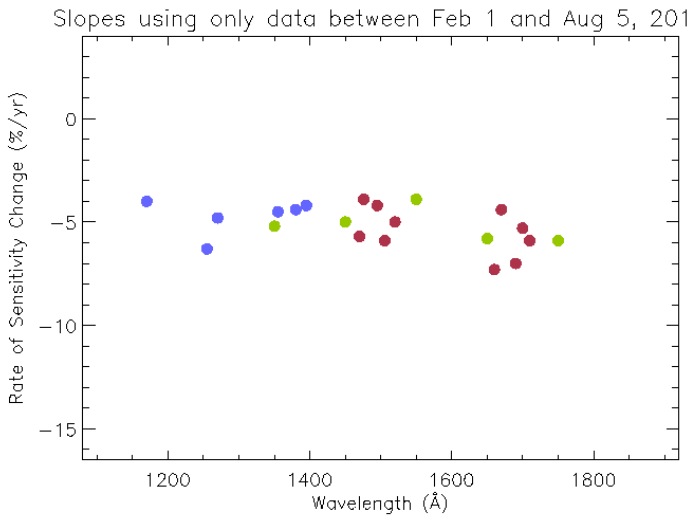
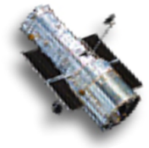
Changes in degradation rate and λ-dependence since last STUC

- **Initial 3-14%/yr λ-dependent loss has changed to nearly gray ~ 5-6%/yr loss (figures below from Charles Proffitt)**





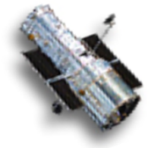
- **ARB feels changes probably indicate two mechanisms**
  - Initially dominant, now weakening outgassing mechanism (H_2O?)
  - Something else now asserting itself—possibly, but not provably AO



ARB principal lines of inquiry

- **Establish from ground testing whether "thermal AO" reacts with CsI and degrades QE**
  - What is the QE loss as a function of both λ and AO fluence?
  - How are CsI material properties changed with AO exposure?
  - ("thermal" because many bounces are required for AO to enter COS, and we are not talking about a "ram" effect)

- **Using the best available thermospheric modeling and data, predict the fluence curve $F_{AO}(t=\text{solar max})/F_{AO}(t)$**
  - *If time comes* when the QE loss rate appears to be tracking the fluence change rate—which would support AO as the dominant loss mechanism—the thermospheric fluence curve and the QE(λ,fluence) curve (cf. above bullet) would predict future QE loss



AO and CsI QE loss: test results

- **Ground testing at UC Berkeley of CsI samples exposed to "thermal AO" showed that QE loss *is produced***
  - 40-60% *loss* at $10^{18.2}$ AO atoms/cm^2—much grayer than earliest λ trend, not inconsistent with *recent* on-orbit behavior
  - $\geq$ 90% loss at $10^{18.9,19.7}$ fluence levels: no stabilization seen, produces unusable detector
  - These initial (over-) exposures were not well-matched to the AO fluence COS FUV detector has seen to date, but they *were* useful in establishing that stabilization does not occur
- **Currently planning "Phase 2" of QE loss-fluence determination**
  - Objective is to subject more CsI samples to lower-fluence AO, and thereby "fill in the curve," at least down to the level of the QE losses seen to-date on COS

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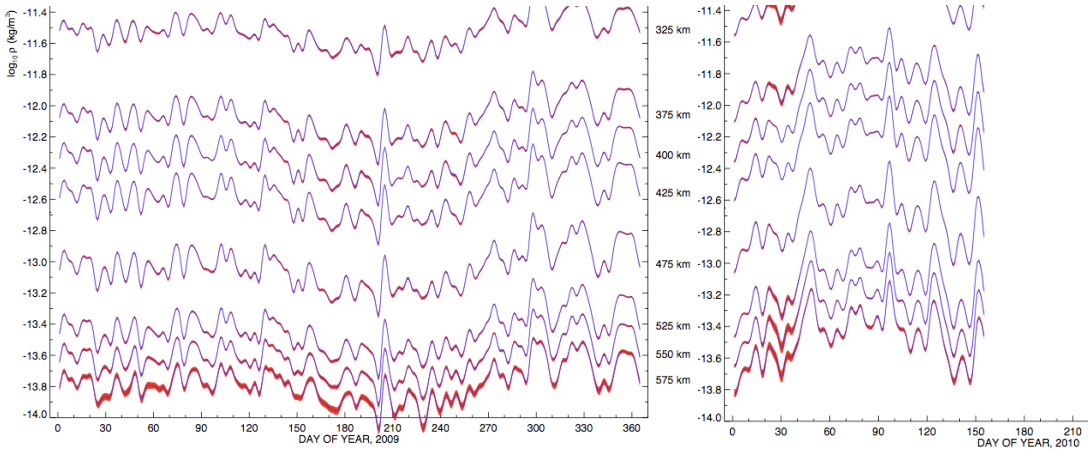
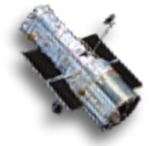
Understanding the thermosphere: 1.) SM4 to now, and 2.) now to Solar Maximum

- **ARB has engaged atmospheric expertise resident at Naval Research Lab (NRL)**
  - Through atmospheric drag/orbit decay analysis of ~ 800 objects, NRL team has assembled empirical record of ρ_{total} as functions of altitude and recent time

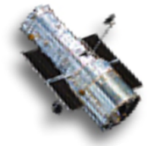


- **NRL will update above plot, convert ρ_{total} to N_{AO}, and make best projections to solar maximum**



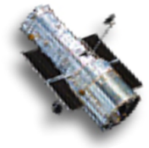
COS FUV: Current understanding

- **QE loss has evolved from initial λ-dependent, water-like (?) curve to a slower, more gray trend (AO-like?)**
- **But: QE loss slow-down first manifested itself close to the time thermospheric densities were increasing**
  - Hence little or no evidence that AO is ***yet*** the dominant degradation mechanism on orbit
- **ARB feels that AO is the only degradation mechanism that presents a potential "cliff" in performance**
- **Continuing to work with Berkeley and NRL on filling in the QE loss—AO fluence relationship, and modeling/predicting AO at Hubble, is important: the majority of the solar cycle ascending branch is still ahead of us**
- **The ARB has identified no effective or practical mitigations that can or need to be taken at this time**



ACS CTI Efforts at DCL

- **GSFC Detector Characterization work on ameliorating ACS CTI is coming to an end**
  - Via ground testing on ACS-like detector, Team had shown that charge injection (CI) *was possible* on ACS/WFC, even though unit had not been built for it! (unlike WFC3/UVIS)
  - As of April STUC, 15 e- was demonstrated to be effective read noise after 10k e-/pixel CI. Further, *CTE was restored to nearly pristine (pre-radiation) level*
  - Runs of the Anderson-Bedin pixel-based CTE correction algorithm showed that to be competitive, however, the hardware (CI) approach had to reach ~ 7 e- read noise
  - DCL Team has tried in recent months to modify their CI scheme to lower the RN, but has concluded that 15 e-, or something very close to it, is all that is possible
  - Results to be formally presented to Project in mid-Nov.



WFC3 Efforts at DCL

- **DCL has been studying the IR subarray "banding" reported by STScI**
  - To-date, DCL has been unable to reproduce the exact anomaly
  - Briefing in mid-November to Program office
  - It would be good at this time to understand how serious a problem this occasional phenomenon is to observers

- **DCL is not (yet) working on the UVIS CTI situation, but is aware of the issue and prepared to start work when/if needed**