Contamination analysis for UV observations as an extension of *Hinode* OTA

Solar-C Science Definition Meeting

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Outline

1. Molecular contamination on orbit
2. Contamination analysis for ***Hinode*** (SOLAR-B) OTA
3. Objectives of contamination analysis for SOLAR-C Plan B
4. Analysis assumptions (Preliminary)
5. Results (Preliminary)
6. Summary

1. Molecular contamination on orbit

International Space Station (ISS) as seen from Space Shuttle

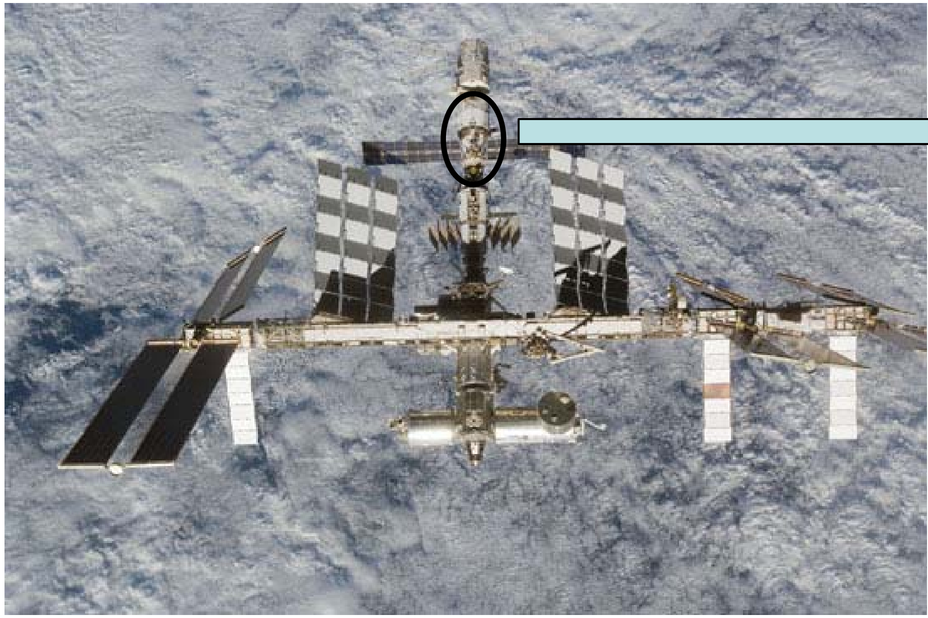
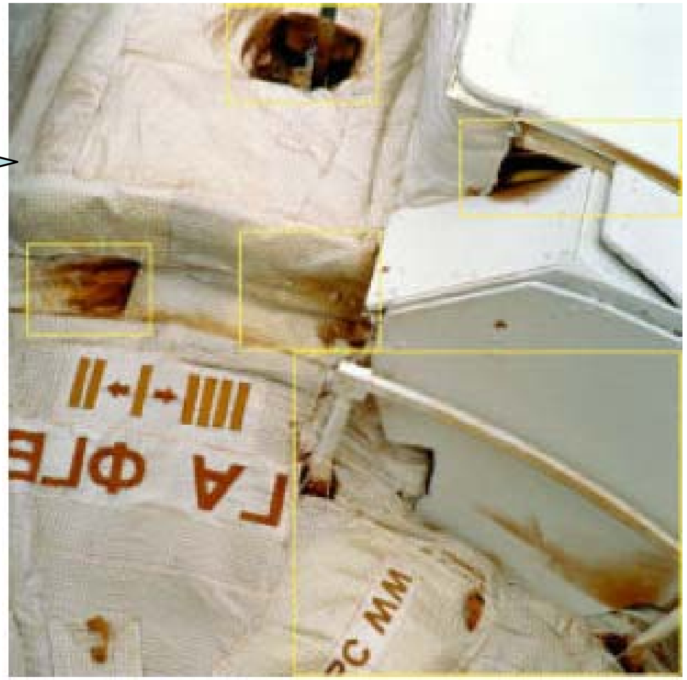


Photo by NASA

Russian segment



Ref.: C. E. Soares, R. R. Mikatarian‡a, R. A. Scharf and E A. Miles: ISS Flights 1A/R-6A External Contamination Observations and Surface Assessment, Proc. SPIE, 4774, pp.210-221, 2002.

<u>Mechanism of molecular contamination on orbit</u>

- Molecular contaminants were outgassed from organic materials.
- The contaminants reached and accumulated on the surfaces.
- Solar UV light changed the contaminants to dark color.

2. Contamination analysis for *Hinode* OTA

Overview of OTA

Critical components

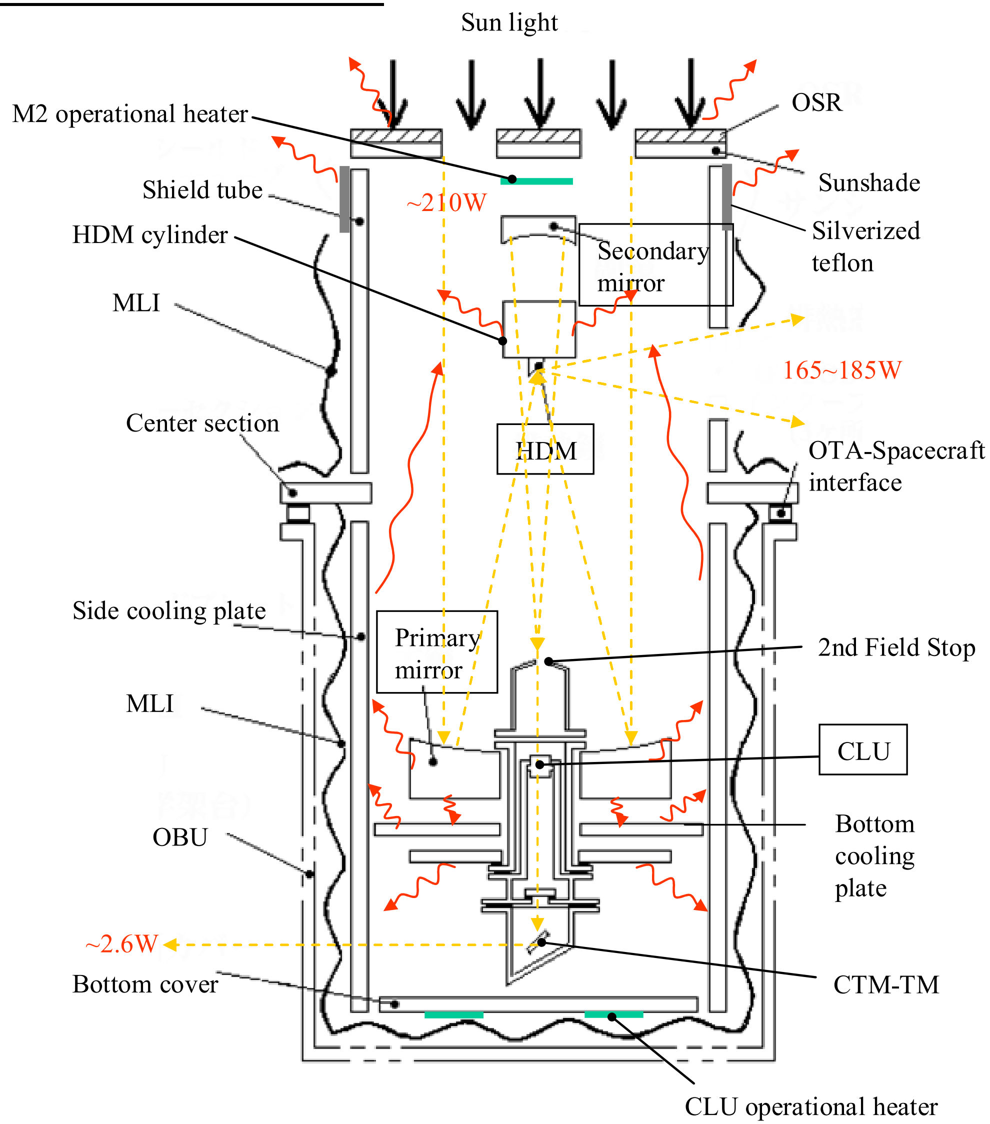
- Primary Mirror (M1)
- Secondary Mirror (M2)
- Collimating Lens Unit (CLU)

Observation wavelength

- 388-688 nm (visible light)

Outgassing sources

- CFRP
- Adhesives etc.



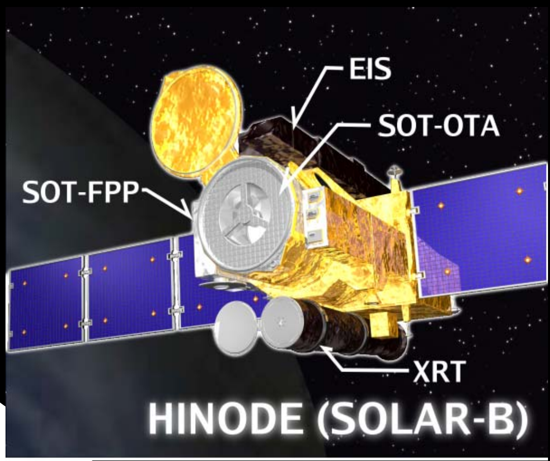
2. Contamination analysis for *Hinode* OTA (Cont'd)

Organic materials contains;

- Plasticizers
- Anti-oxidizers
- UV absorbers
- Monomers

Outgassing and deposition on optics

- Increase in solar absorptance of mirrors.
- Decrease in reflectance of mirrors.
- Decrease in transmittance of lenses.



Contaminants degraded optical systems!

- Increase in temperature of mirrors.

  In worst-case scenario;

  ➡ Thermal deformation of the mirrors.

  ➡ Degradation of diffraction-limited images of OTA.

- Decrease in throughput at shorter wavelength.

2. Contamination analysis for *Hinode* OTA (Cont'd)

Mathematical models for OTA contamination analyses

1. Mass accumulation on the critical surfaces

   (Deposition rate)=(Outgassing rate)*(Transport factor)*(Sticking coefficient)

   Outgassing → Transport → Deposition

2. Optical degradation of the mirrors

$$\rho(\lambda) = \rho_0(\lambda) \cdot \exp\left(-2\alpha_C(\lambda) \cdot \chi\right)$$

λ : Wavelength

ρ : Reflectance of contaminated mirror

ρ_0: Reflectance of clean mirror

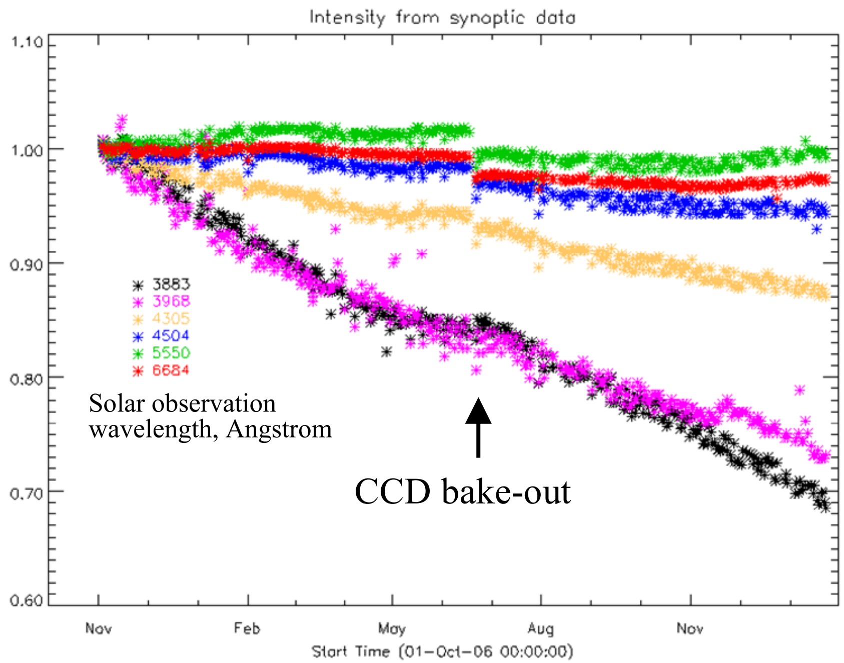
α_c: Absorption coefficient inherent in contaminant.

χ : Contaminant thickness

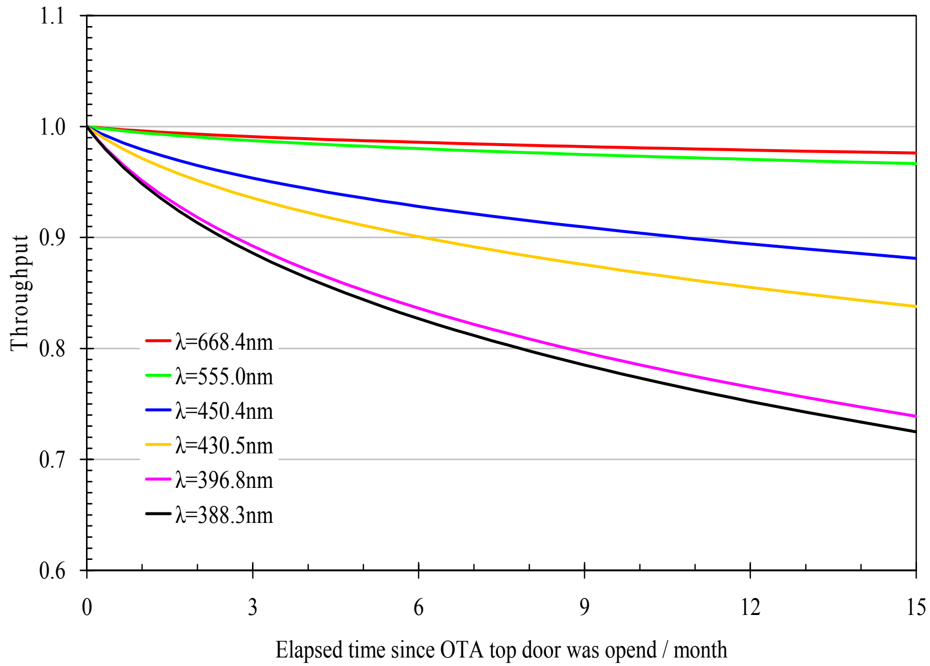
2. Contamination analysis for *Hinode* OTA (Cont'd)

SOT throughput

Observation



Numerical analysis



Note:

1) Contaminated optics: CLU, M1, M2 in degradation order.
2) Model contaminant: Tetra-methyl tetra-phenyl tri-siloxane (MPS).
3) Absorption coefficient: constant with UV irradiation time.

3. Objectives of contamination analysis for SOLAR-C Plan B

- To assess degradation of throughput at wavelength range of solar UV light, induced by molecular contamination.

4. Analysis assumptions (Preliminary)

- SOLAR-C telescope is constructed of same materials and structures (outgassing sources) as OTA.
- Temperature of SOLAR-C telescope is same as the temperature (outgassing rate) of OTA on orbit.
- The mirrors coated with Al and MgF_2 are used for SOLAR-C. UV reflectance of the mirrors is higher than that of OTA mirrors.
- Critical wavelengths of the SOLAR-C observation are 122, 155 and 280 nm.

  Note) Observation wavelengths of OTA were ranged from 388 to 688 nm.
- Absorption coefficients of the contaminants are equal to;

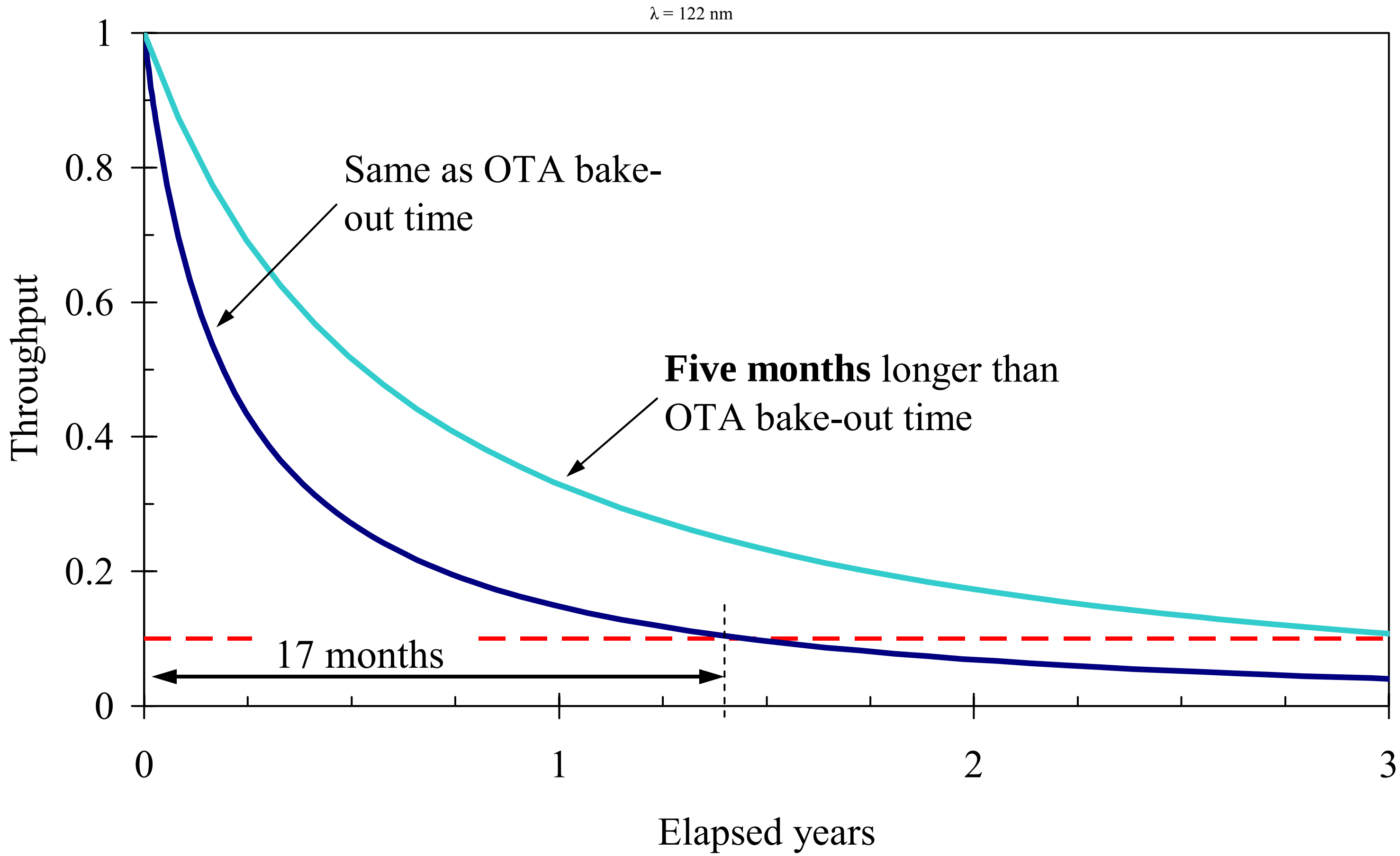
  average value of the absorption coefficients of several materials at wavelength of 122 or 155 nm. These coefficients were derived from report No. MCR-80-637.

  the absorption coefficient of photo-deposited Methyl Phenyl Siloxane (MPS) at wavelength of 280 nm.

  Note) The absorption coefficients of photo-deposited MPS at wavelength range of visible light were used for OTA analysis.
- Photo-deposition of the molecular contaminants occurs on M1 and M2. Other optical elements are not taken into account.
- Threshold of SOLAR-C throughput is 10% for three years.

5. Results (Preliminary)

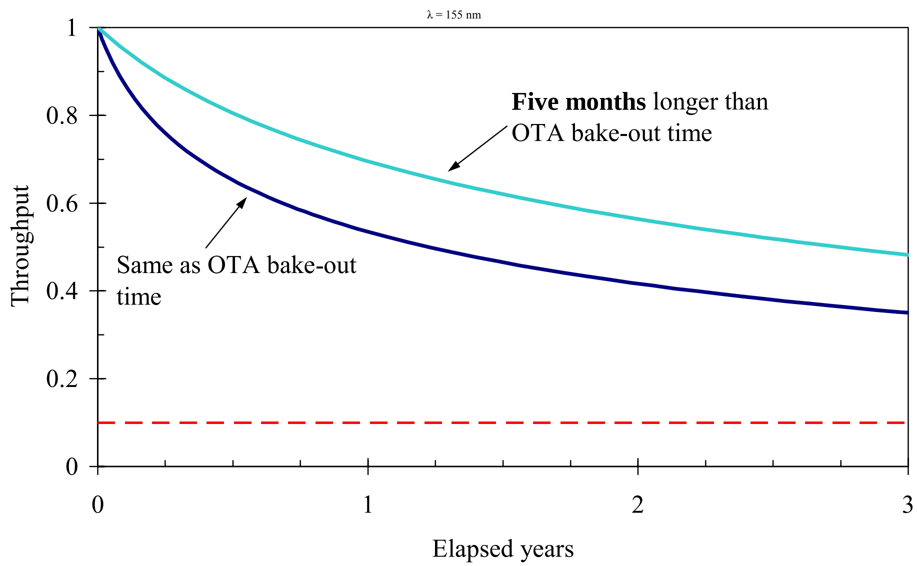
Wavelength: 122 nm (Ly α)



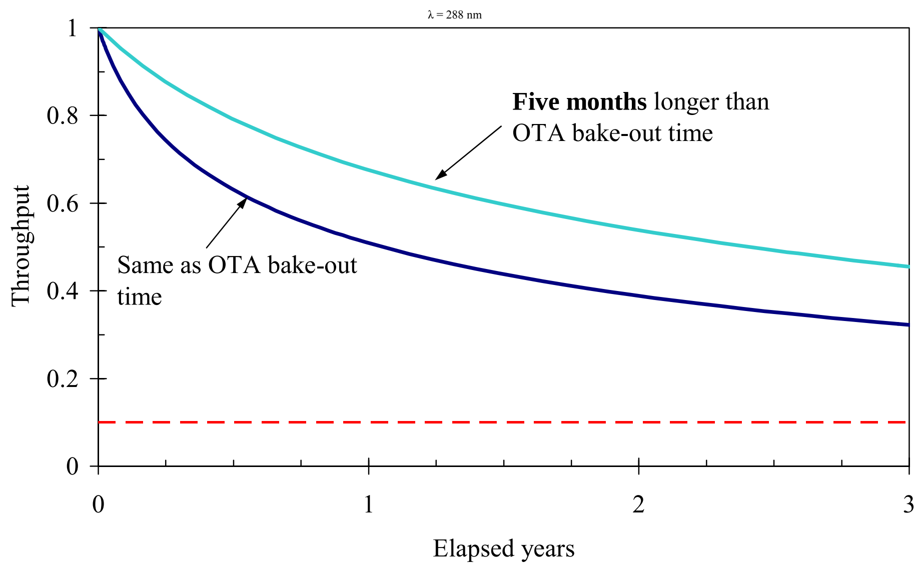
Note) Bake-out time of OTA CFRP structures: **four months**
In vacuum chamber: three months
On-orbit: one month

5. Results (Preliminary) (Cont'd)

Wavelength: 155 nm (CIV)



Wavelength: 280 nm (Mg II)



6. Summary

- Preliminary analysis for SOLAR-C Plan B shows;
  - ✓ Throughput at wavelength of 122 nm decreases to 10% for 17 months.
  - ✓ Throughput at wavelength of 155 nm or 280 nm maintains above 10% for three years.
- In order to achieve the SOLAR-C Plan B mission success by using **one telescope**, **bake-out** of the components in vacuum chambers and on orbit will take **a lot of time and effort!**
- If wavelength of 122 nm is important for SOLAR-C science, redesign of telescope may be required. The redesign includes preparation of a special telescope for 122 nm.

Backup Chart

Degradation of solar UV space instruments: OSO-8

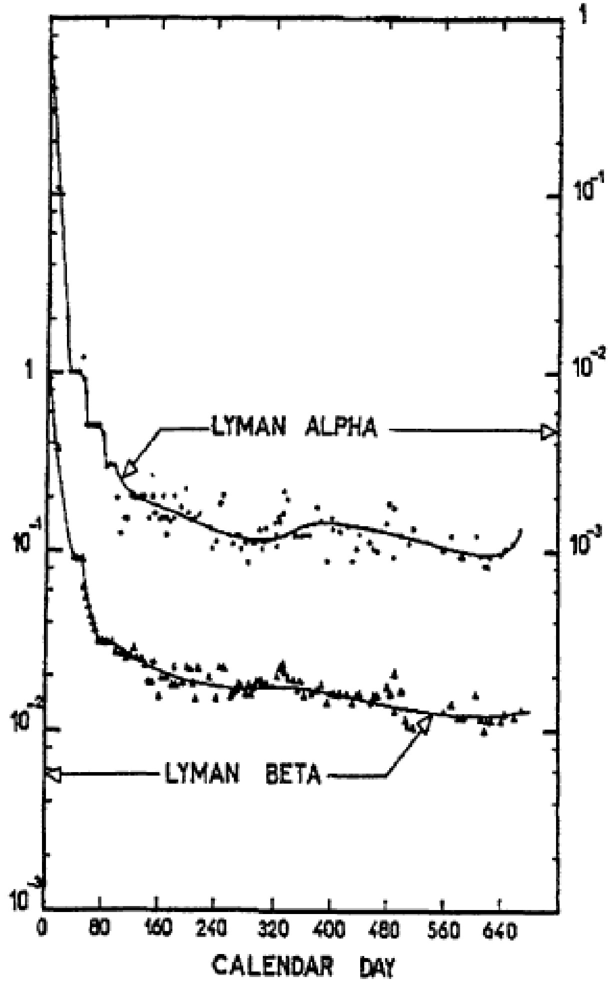


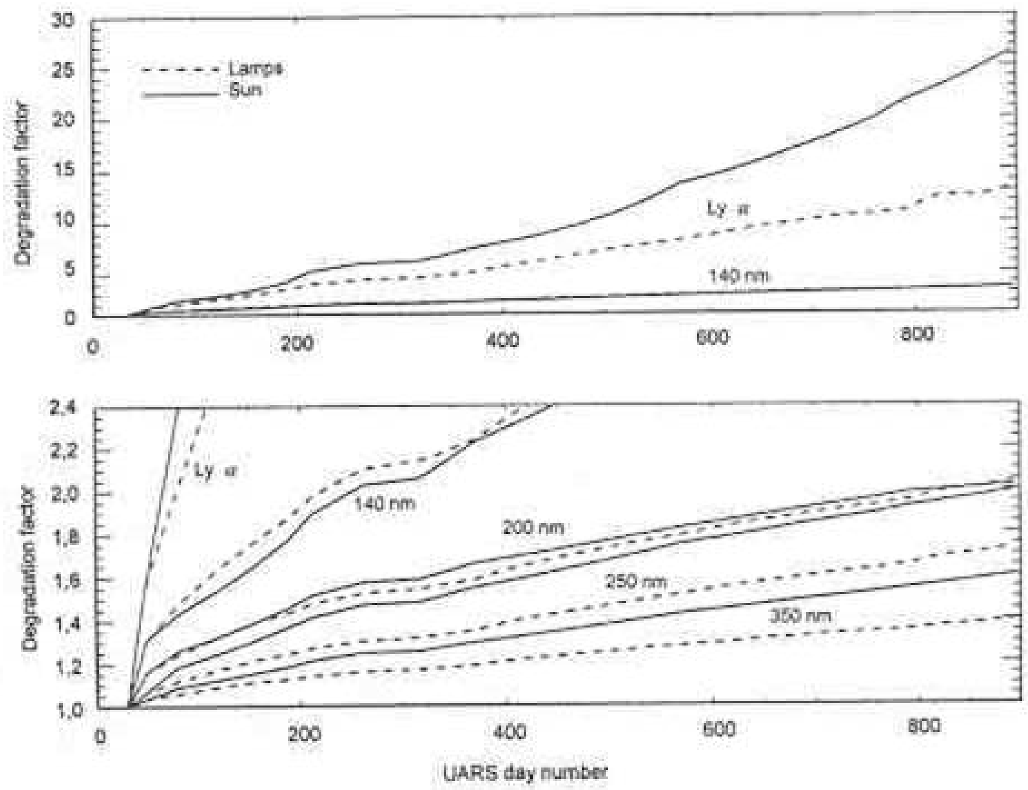
Figure 6 — Variations of the sensitivity of the LPSP instrument on OSO-8. The ordinate gives the value relative to that at launch, and time on the abscissa is given in days after launch.

OSO-8: 8th Orbiting Solar Observatory

LPSP: multichannel high resolution UV and visible spectrometer

Ref.) Udo Schühle: Cleanliness and Calibration stability of UV instruments on SOHO, 2004.

Degradation of solar UV space instruments: UARS-SUSIM



UARS: NASA's Upper Atmosphere Research Satellite

SUSIM: Solar Ultraviolet Spectral Irradiance Monitor

Optical path degradation of SUSIM during 2.5 years of the UARS mission

Ref.) Udo Schühle: Cleanliness and Calibration stability of UV instruments on SOHO, 2004.