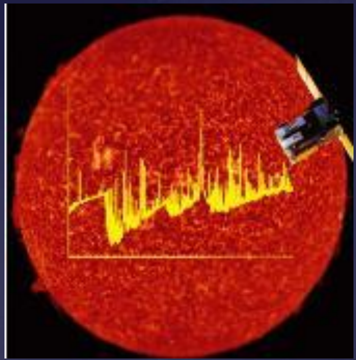
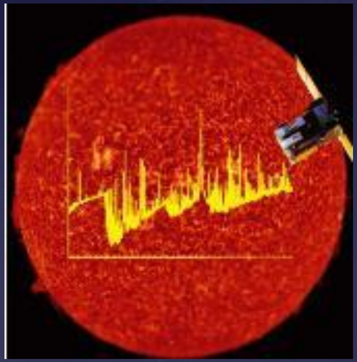


Contamination and Cleanliness of UV and EUV space instruments

Udo Schühle

Max-Planck-Intitut für Sonnensystemforschung
37191 Katlenburg-Lindau, Germany



Outline of the talk

- Calibration stability of UV space instruments
- Degradation of UV space instruments
- Cleanliness efforts and lessons learned
- Cleanliness design guidelines
- Relevance to future missions

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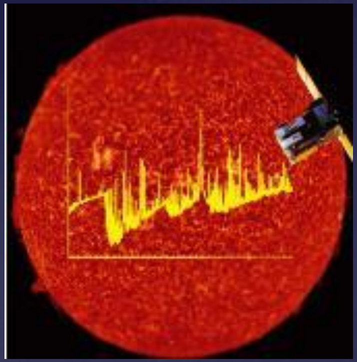


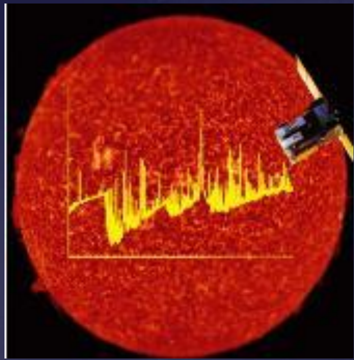
Calibration stability, In-flight calibration

Laboratory calibration:

1. By primary source standard, i.e., synchrotron beamline
2. By transfer light source, i.e., secondary standard traceable to a primary standard.

In-flight calibration:

1. By tracking by observing a constant source:
   - the “quiet Sun”
   - celestial standards (stars)
   - calibration lamps (not for SOHO)
2. By calibration updates by rocket “underflight”



Stability of calibration: concerns for space instruments

- Molecular contamination
  - From ground facilities and test environment
  - From outgassing organic materials
    - used in construction of instrumentation
    - used in construction of the spacecraft
    - from spacecraft exhaust (fuel)

- Polymerisation of organic contaminants by solar UV
  - especially on mirrors of solar instruments !
  - even more so on windowless EUV solar instruments !!!

- Laboratory and space experiments have quantitatively measured the UV-degradation.

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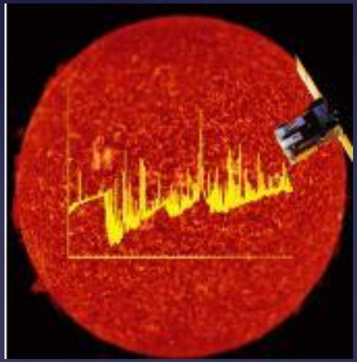
Degradation of solar UV space instruments: OSO 8



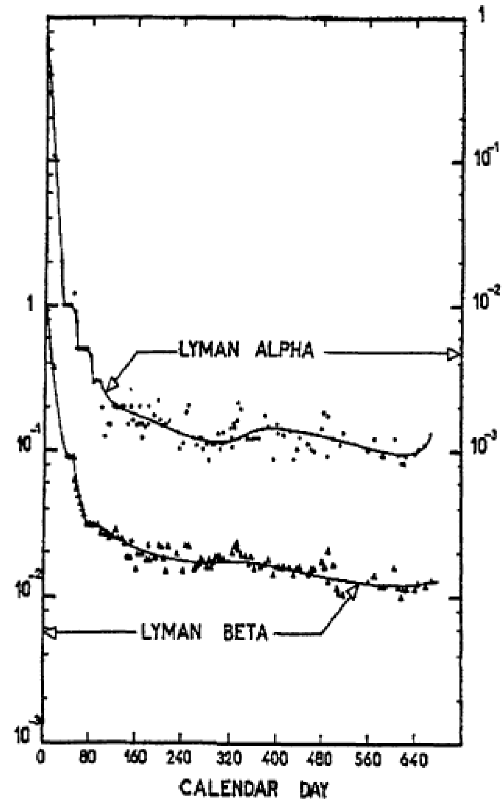
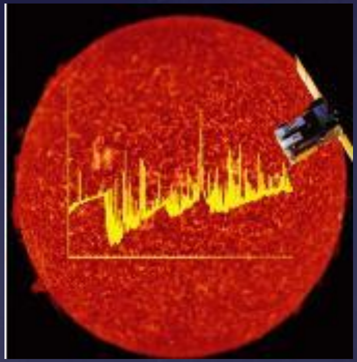
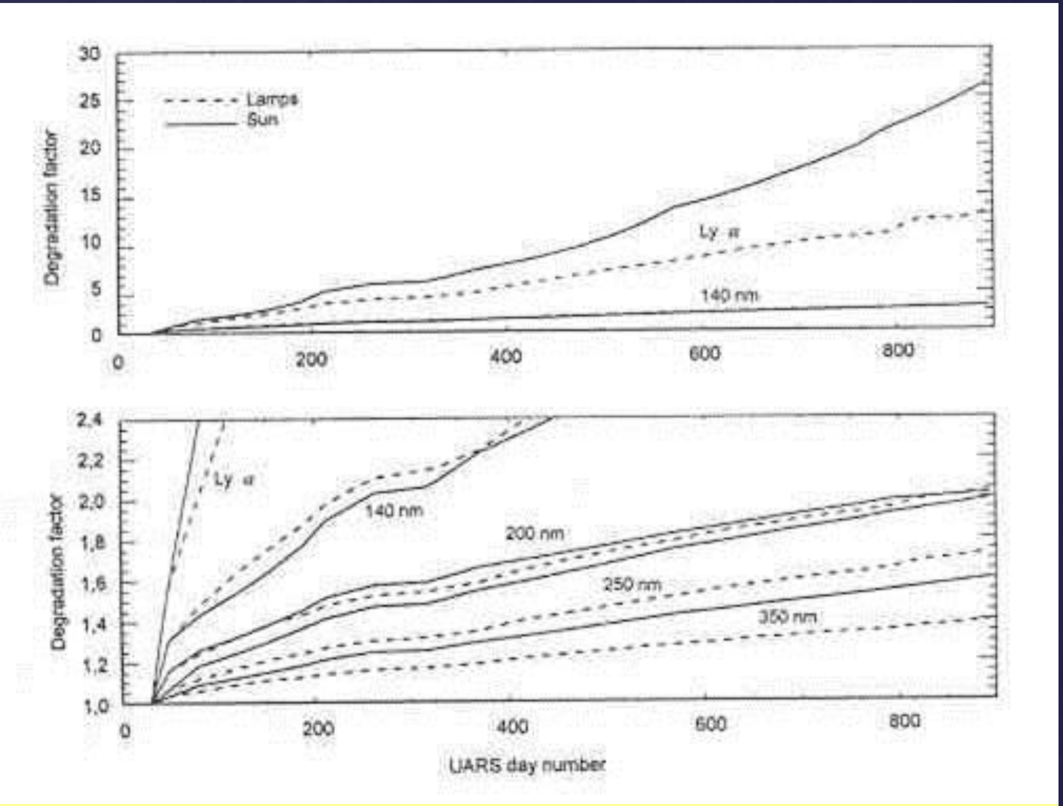


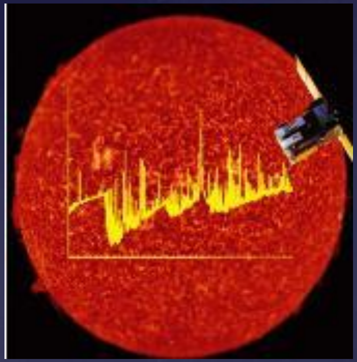
Figure 6 — Variations of the sensitivity of the LPSP instrument on OSO-8. The ordinate gives the value relative to that at launch, and time on the abscissa is given in days after launch.



Degradation of solar UV space instruments: UARS-SUSIM



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



The Solar and Heliospheric Observatory (SoHO)

Remote sensing Instrumentation:

- CDS (Coronal Diagnostics Spectrometer)
- EIT (Extreme ultraviolet Imaging Telescope)
- SUMER (Solar Ultraviolet Measurements of I
- SWAN (Solar Wind Anisotropies)
- UVCS (Ultraviolet Coronagraph Spectrometer)
- LASCO (Large Angle and Spectrometric Coronagraph)

Ultraviolet remote sensing telescopes and spectrographs:
CDS
EIT
SUMER
UVCS

Helioseismology Instrumentation:

- MDI/SOI (Michelson Doppler Imager/Solar Oscillations Investigation)
- GOLF (Global Oscillations at Low Frequencies)
- VIRGO (Variability of Solar Irradiance and Gravity Oscillations)

In-situ instrumentation:

- CELIAS (Charge, Element, and Isotope Analysis System)
- COSTEP (Comprehensive Suprathermal and Energetic Particle Analyzer)
- ERNE (Energetic and Relativistic Nuclei and Electron experiment)

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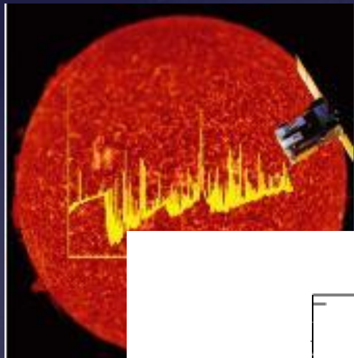
Tracking by observing quiet Sun radiance



The cleanliness program was successful!

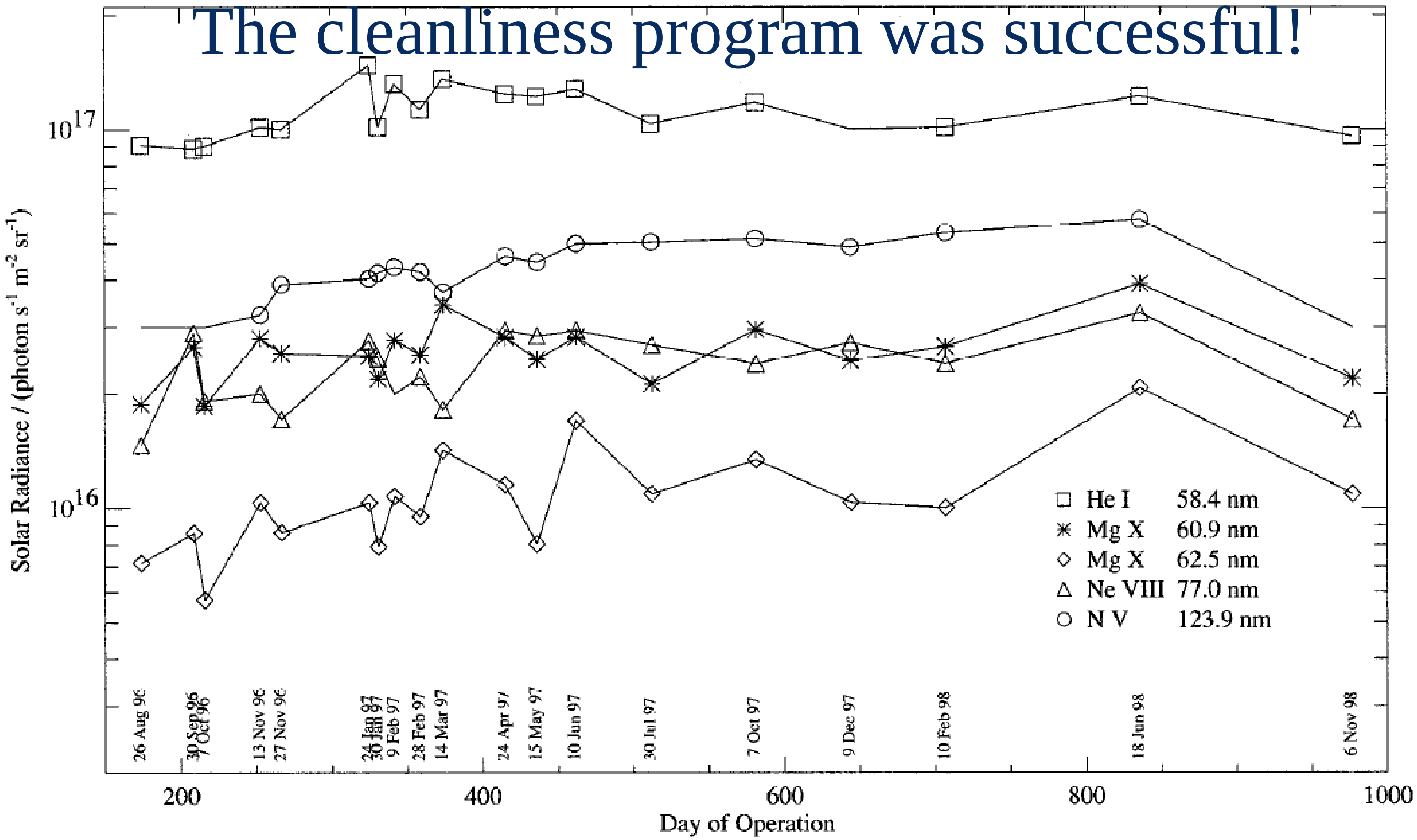


Fig. 3. Radiances of the emission lines of He I (58.4 nm), Mg X (60.9 and 62.5 nm), Ne VIII (77.0 nm), and N V (123.9 nm) measured during several calibration runs between 28 August 1996 and 6 November 1998. The actual dates of the measurements are given at the bottom.

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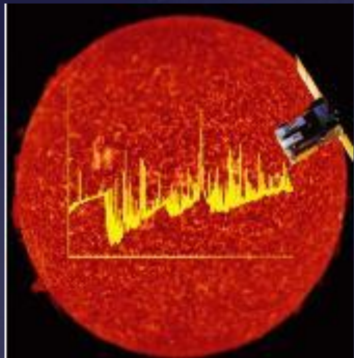
"Radiometric Calibration of the Vacuum-Ultraviolet Spectrograph SUMER on SOHO with the B Detector", U. Schühle, et al., *Applied Optics*, 39, 418-425, 2000



Tracking of calibration by observing quiet Sun

example: SOHO SUMER

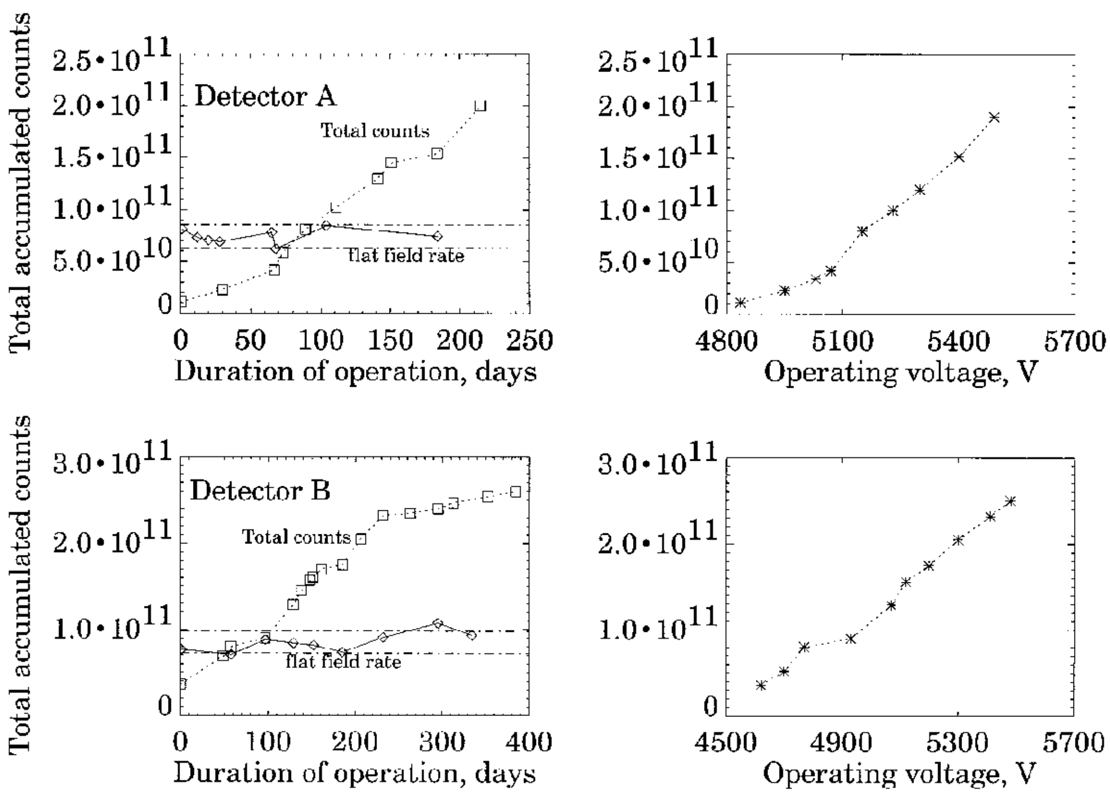
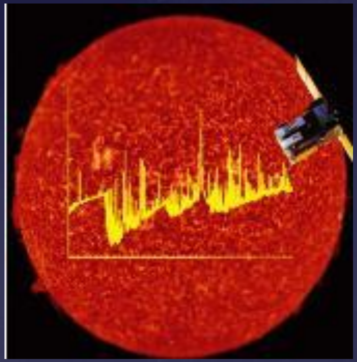


Fig. 1. History of detectors A and B with the count rates detected during flat-field integrations (in relative units dot–dash lines indicate levels of ±15% around mean) and the evolution of total accumulated counts during this period of almost two years (dashed curves). The right-hand panels show on the same scale the high voltage required for maintaining the detector gain, monitored by the pulse height distribution of the amplifier output, at the corresponding level of total counts.

"Radiometric calibration tracking of the vacuum-ultraviolet spectrometer SUMER during the first year of the SOHO mission", U. Schühle, et al., *Applied Optics*, 37, 2646, 1998



How much science can you make with a photon?

(An excursion)

- SUMER total accumulated counts: 10^{12} (during 10^{8} s)
- # of photons per publication: 2×10^{9}

For comparison:

- # of 10eV-photons in one laser pulse of 1 mJ: 10^{15}
- This is a typical laser pulse delivered in 10^{-8} s!

➔ SUMER is extremely „photo-science-efficient“

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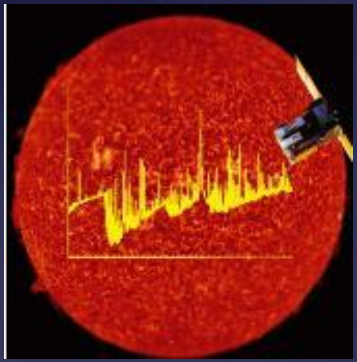
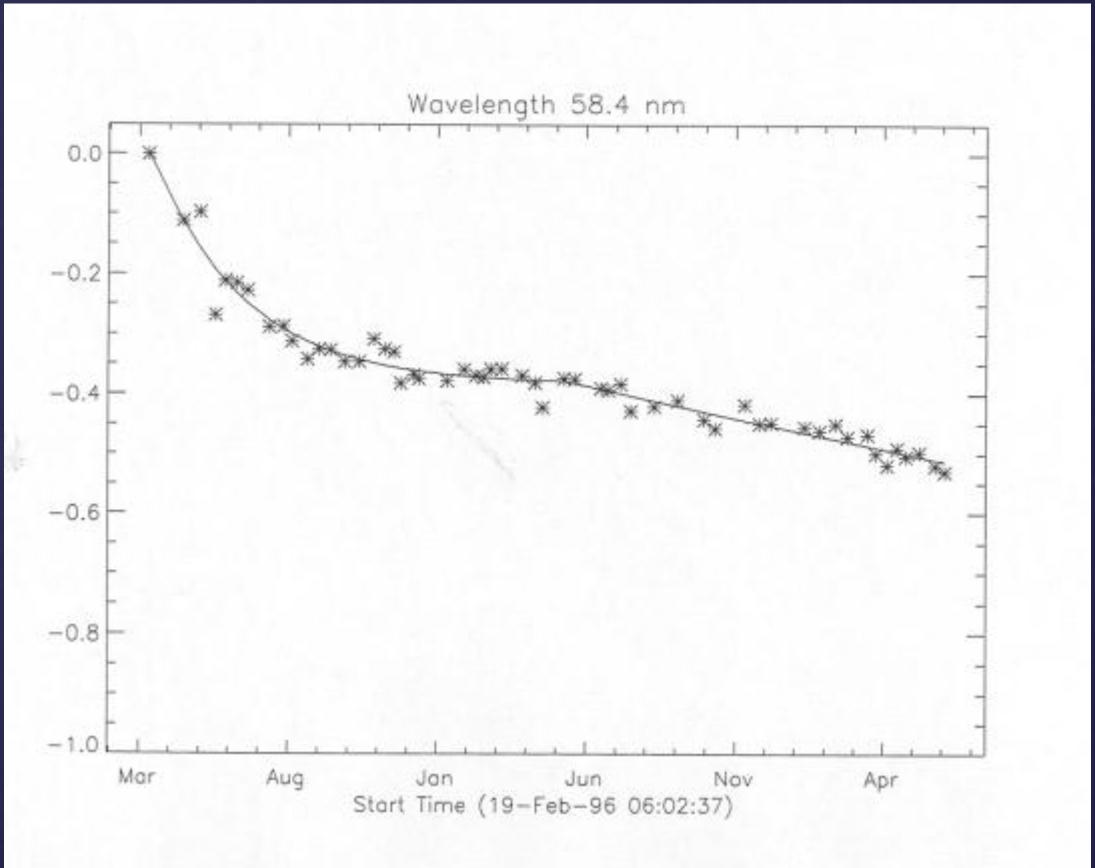


Tracking of calibration by observing quiet Sun

example: SOHO CDS

CDS burn-in of NIS detector at 58.4 nm



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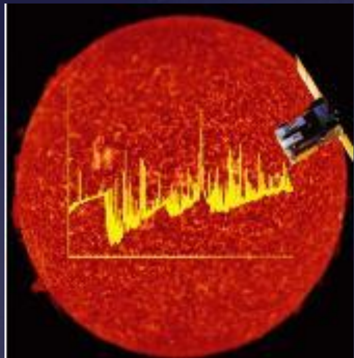
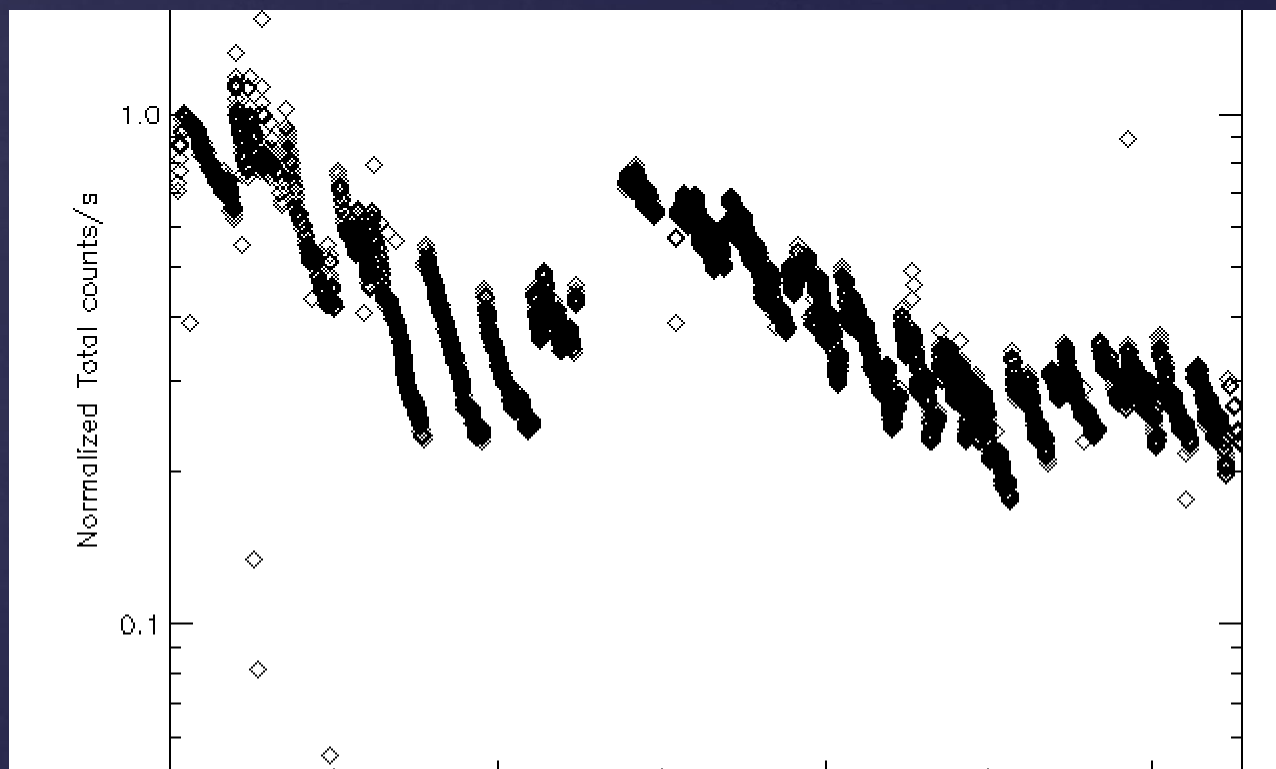


Tracking of calibration by observing quiet Sun

example: SOHO EIT

304Å response vs. time



Courtesy Frédéric Auchère

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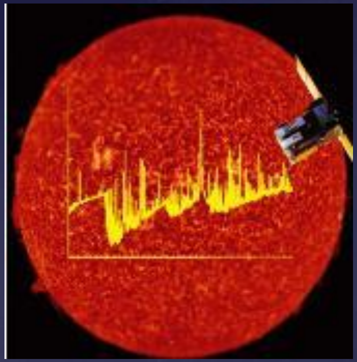
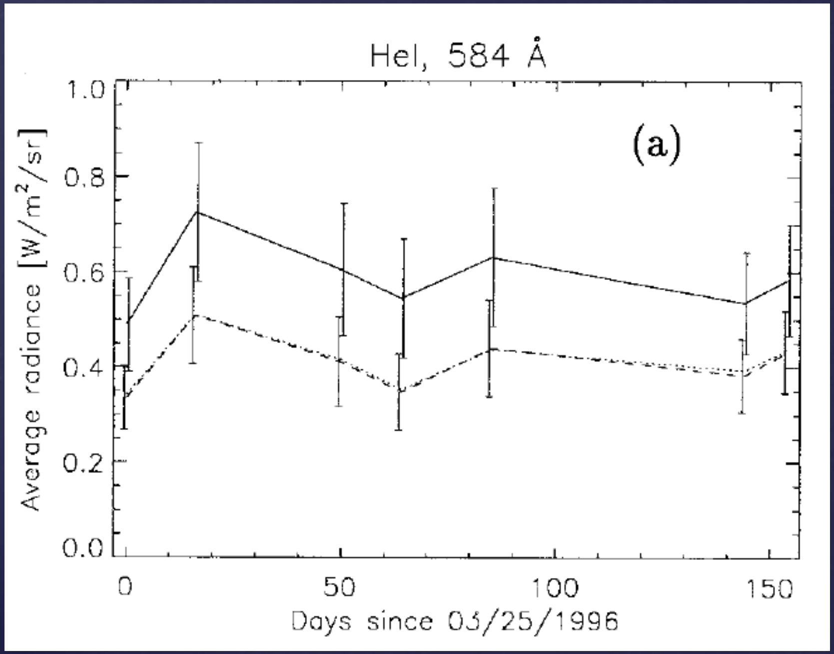
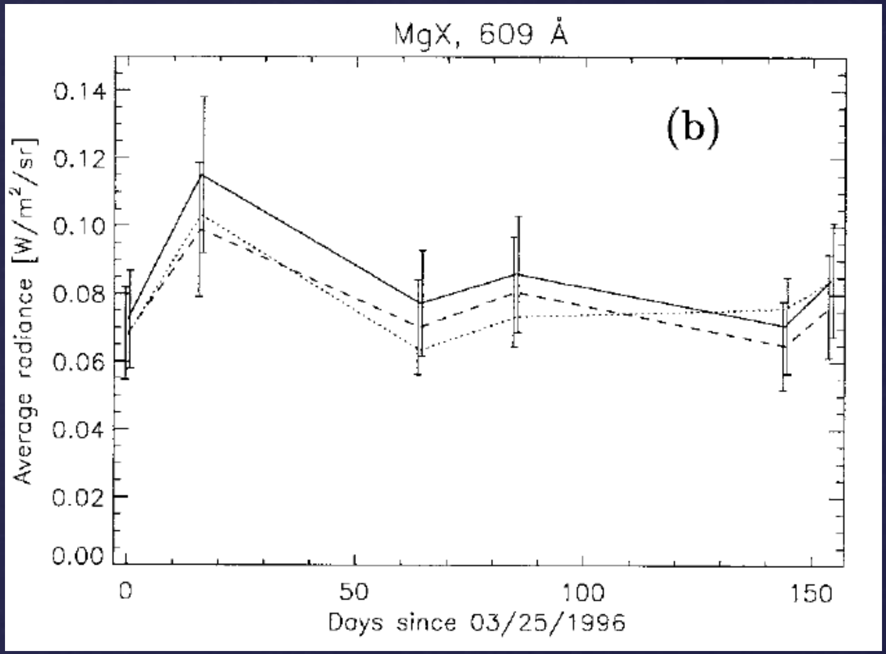


Tracking of calibration by observing quiet Sun

example: SOHO CDS and SUMER co-observations

Co-observations of quiet Sun areas





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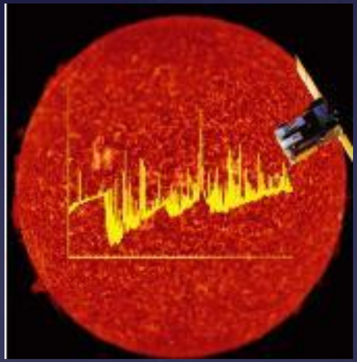
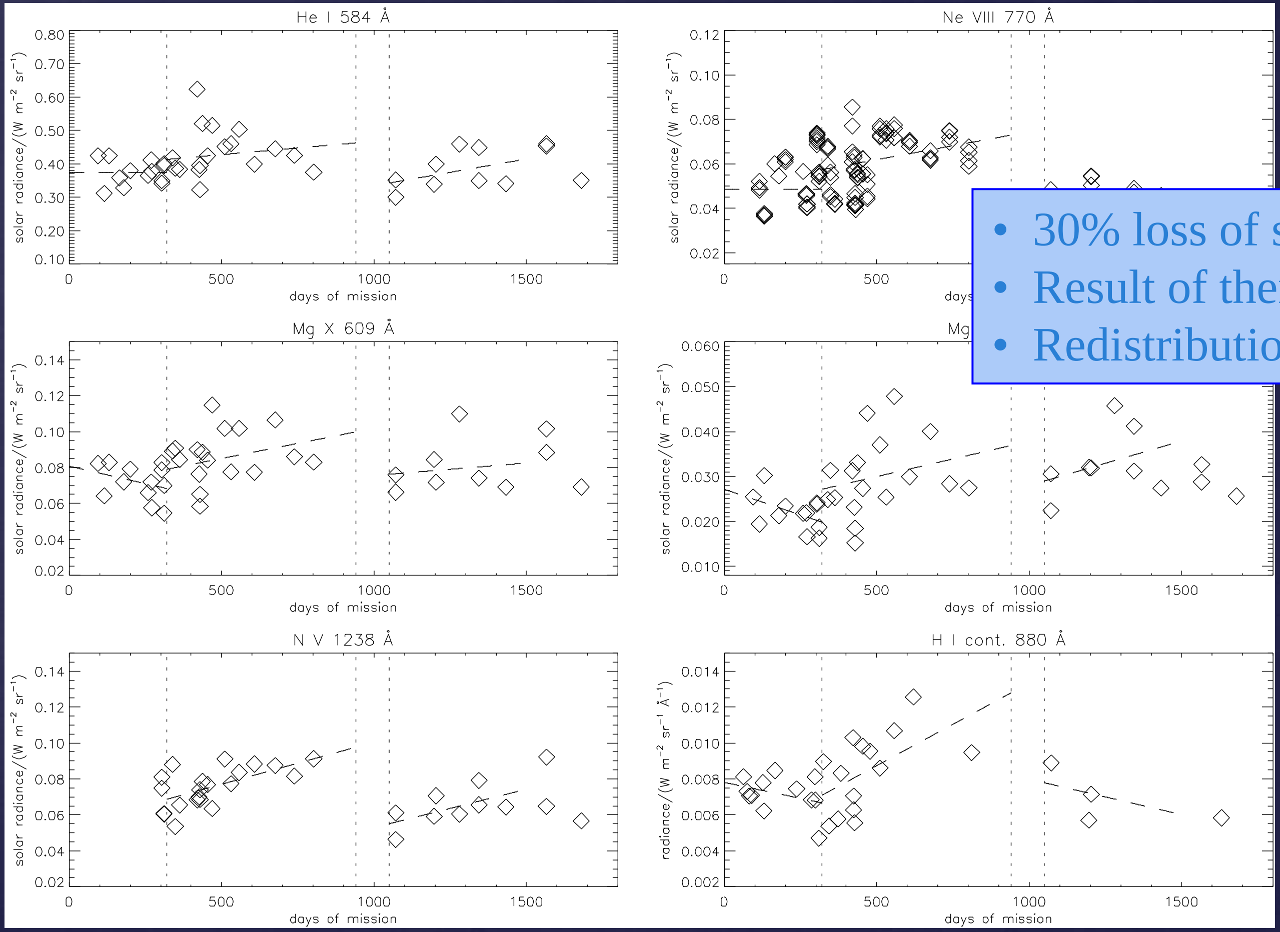
Intercalibration of SUMER and CDS on SOHO. I. SUMER detector A and CDS NIS, A. Pauluhn, et al. ,Applied Optics, 38, 7035-7046, 1999



Calibration stability: Effect of SOHO accidental loss of attitude

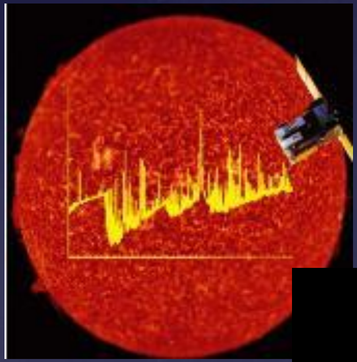


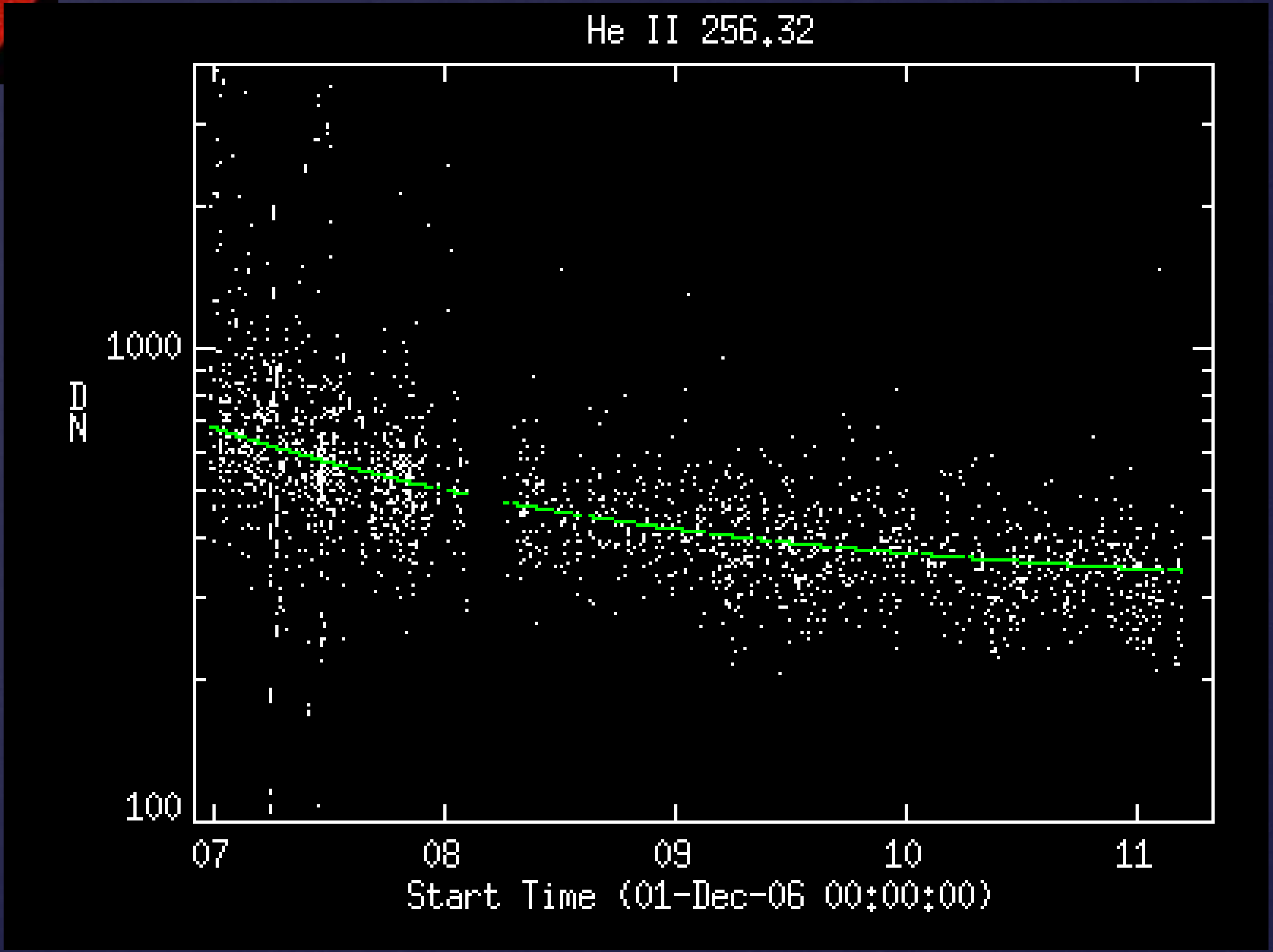
- 30% loss of sensitivity
- Result of thermal cycling!
- Redistribution of contaminants

This can happen to any mission!

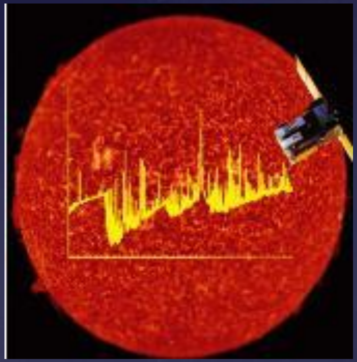
Tracking of calibration by observing quiet Sun

example: HINODE EIS





Long-term Variation of the Corona in Quiet Regions , S. Kamio, J. T. Mariska, Sol.Phys. accepted, 2012



Lessons learned

- SOHO UV instruments have been very stable due to the successful cleanliness program.

but

- SOHO UV detectors have been remarkably unstable.

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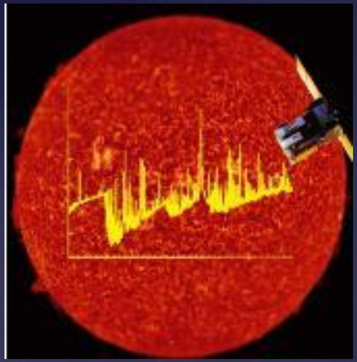

Lessons learned

- Calibration tracking throughout a mission is very difficult. Thus, recalibration, Intercalibration among instruments and calibration underflights are necessary
- The cleanliness efforts have been necessary and were not excessive
- Cleanliness design (at spacecraft and instrument level) greatly reduces contamination

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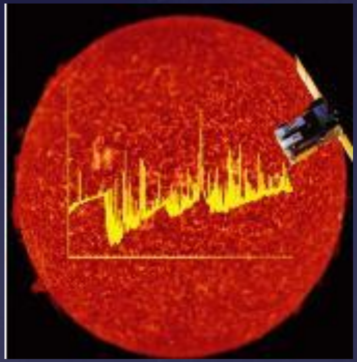

Relevance for future solar missions

- SOHO has extremely stable orbit:
  - Always Sun pointing
  - No eclipses
  - No (almost) changes to the orbit
  - ⇒ Thermal stability

- Solar Orbiter mission will not have such stable conditions
  - ⇒ Redistribution of contaminants, temperature sensitivity

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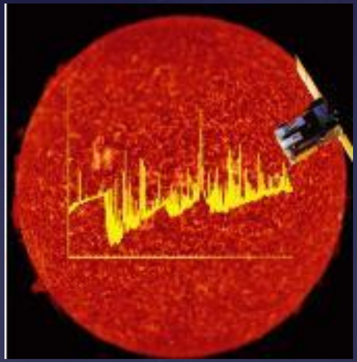

Calibration degradation: preventive measures (1)

- Establishment of SOHO Cleanliness Review Board and SOHO Intercalibration Working Group
- SOHO Cleanliness Control Plan
- Instrument Cleanliness Control Plans

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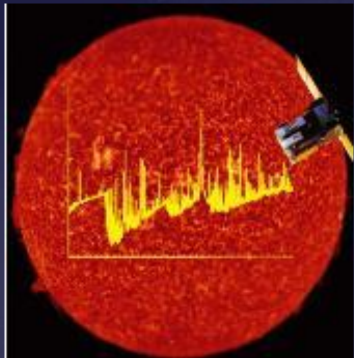

Calibration degradation: preventive measures (2)

- Most important preventive measures for instruments:
  - Determine the contamination sensitivity
  - Design the instrument for cleanliness: Design features, material selection
  - Avoid contamination during ground handling
  - Precision cleaning of all hardware
  - Use oil-free vacuum systems during tests

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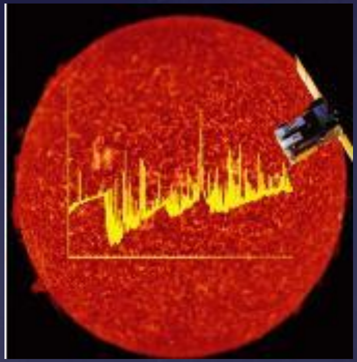
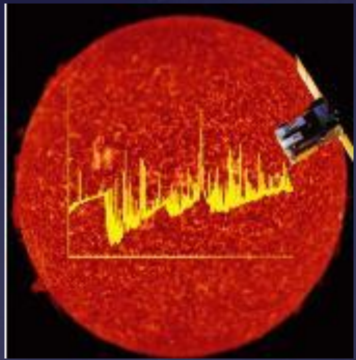


Typical components used for space instrumentation

Materials of TML<1% and CVCM<0.1% :

- Carbon fiber structures
- Electronic boards and harness, cable insulation, shrink tubing, solder flux
- Motors and gear drives
- Adhesives, glues, potting compounds
- Heaters
- Thermal insulation foils
- Surface coatings, paints, lacquers, varnish
- Elastomers, rubbers



Cleanliness design rules

(Ten Commandments ;-)

① Material selection: metal optical housing or organic composite material?

② Avoid or minimize organic material inside optical housing (to minimise potential outgassing)

③ Precision clean and bakeout of all hardware at highest temperature possible (avoid low-T material)

④ Aperture door to close/open the optical compartment (to reduce ingress from outside)

⑤ Solar wind deflector plates (with HV applied to deflect solar wind away from the telescope mirror)

⑥ Use of ultra-high vacuum components/materials inside optical housing (high-T materials)

⑦ Keep electronic components outside optical housing (to keep organic materials outside)

⑧ Purging of optical compartments at all times (to over-pressurise and clean away offgassing species) and vent design

⑨ Keep primary optical element at highest temperature by solar illumination (to reduce deposition on UV-irradiated surfaces)

⑩ Dry lubrication (on MoS_2 basis) for all mechanisms (inorganic lubrication, no outgassing)

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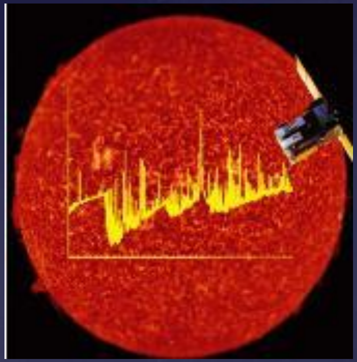
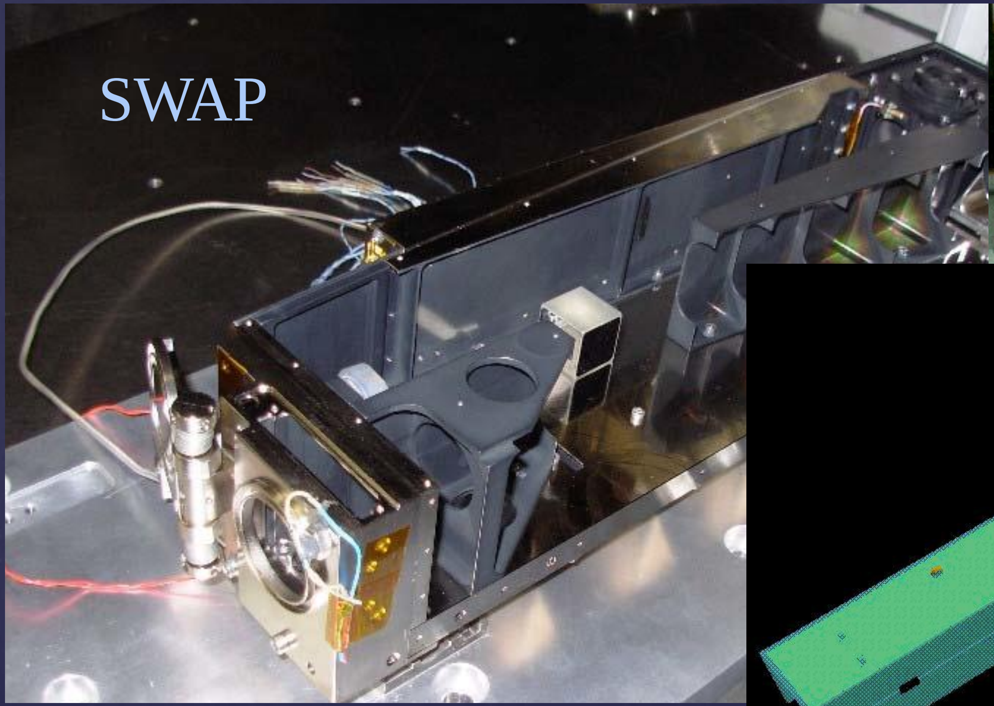
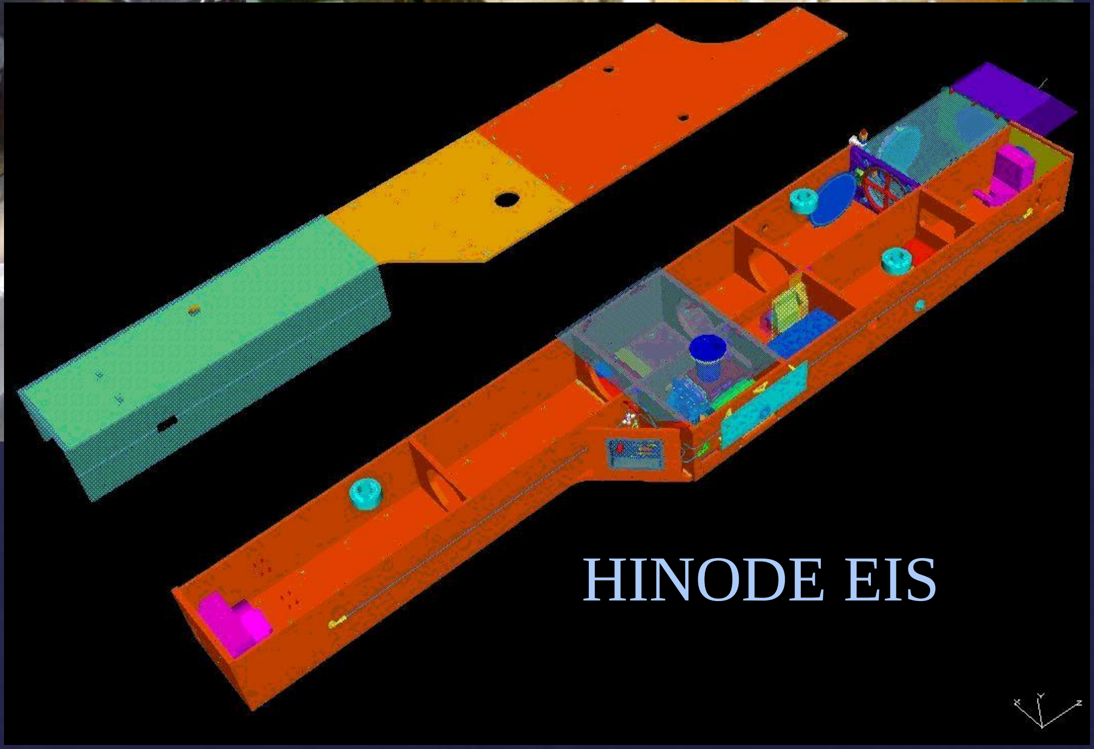


1. Material selection: metal optical housing or organic composite material?





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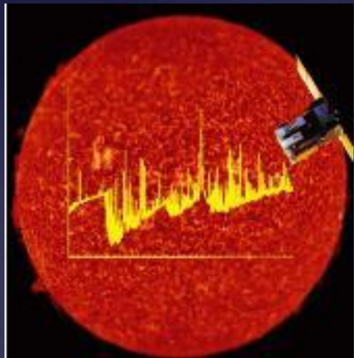

2. Avoid or minimize organic material inside optical housing

- minimise potential outgassing

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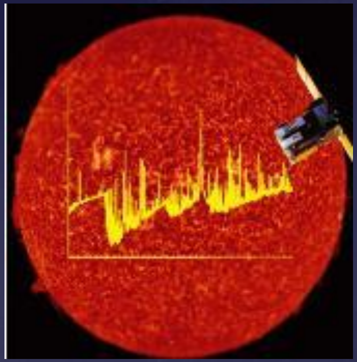

3. Bakeout of all hardware at highest temperature possible (avoid low-T material)

- Bakeout of subsystems
- Bakeout of composite structures
- Use oven with gas purge and pump system
- Bakeout of components before assembly

    e. g., bake motor coils at >200 ° C

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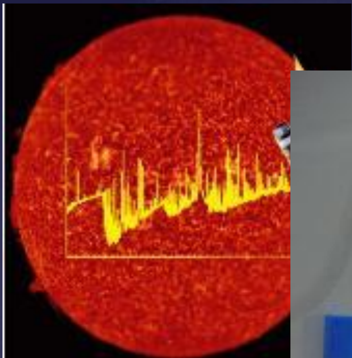
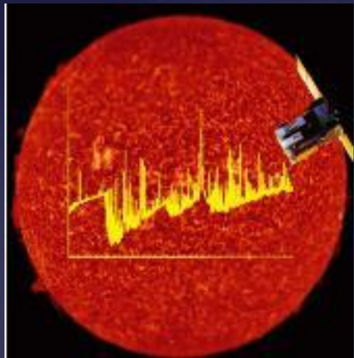
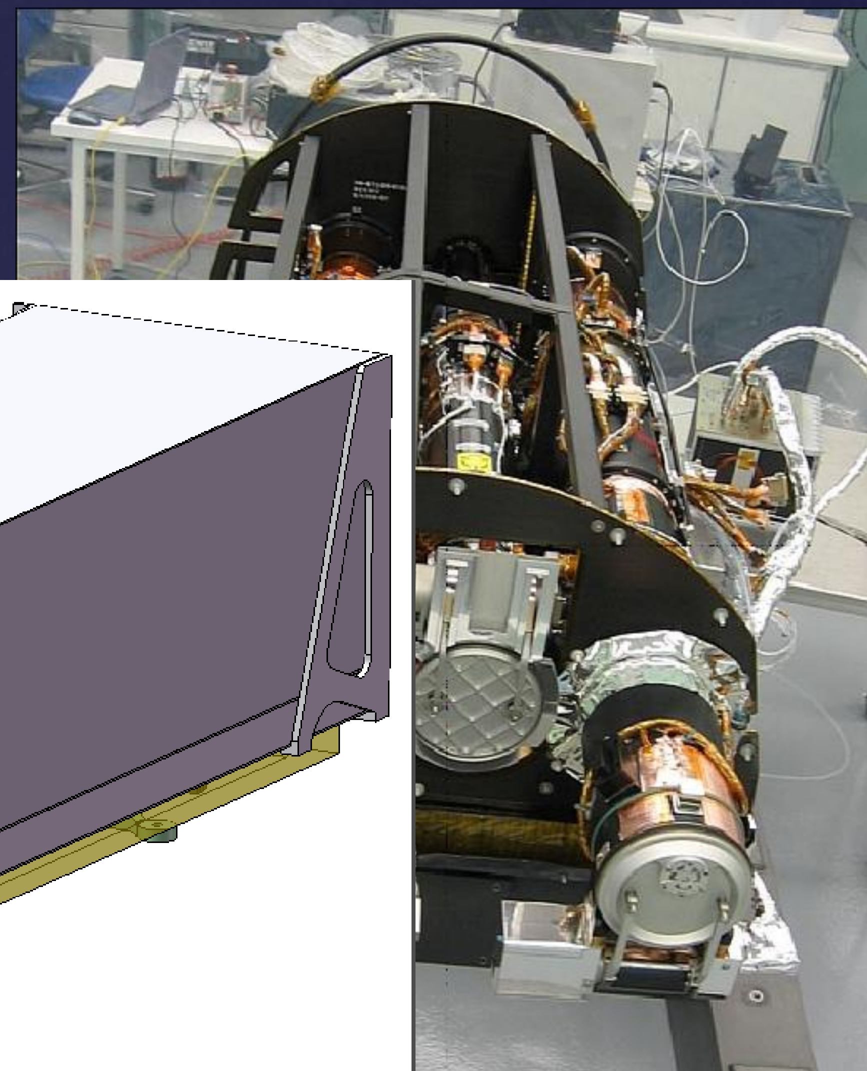


- High-T oven
- Oil-free pump
- Gas purge system

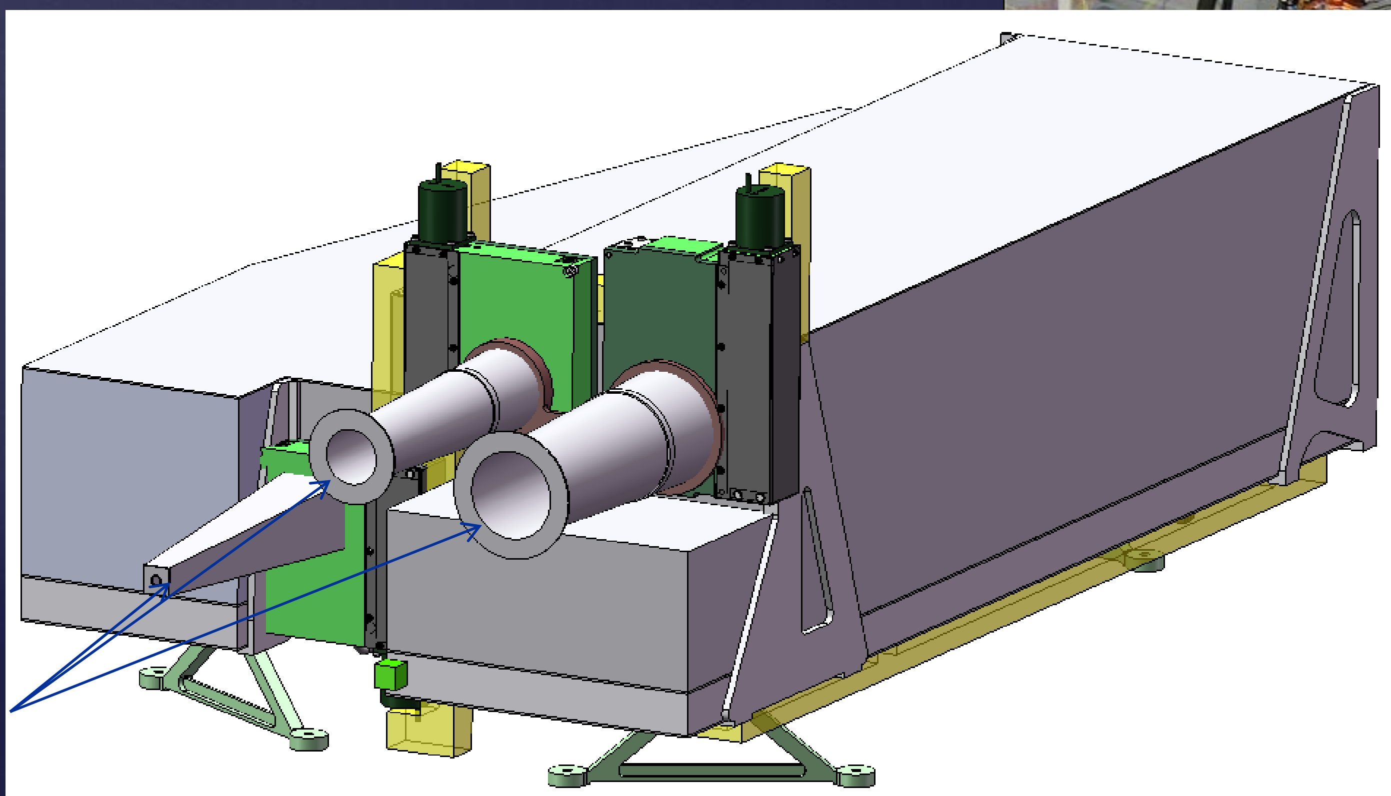


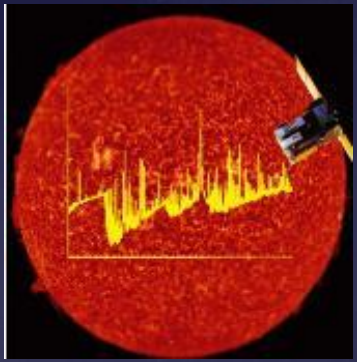
4. Aperture door to close/open the optical compartment

Re-closable doors of STEREO SECCHI



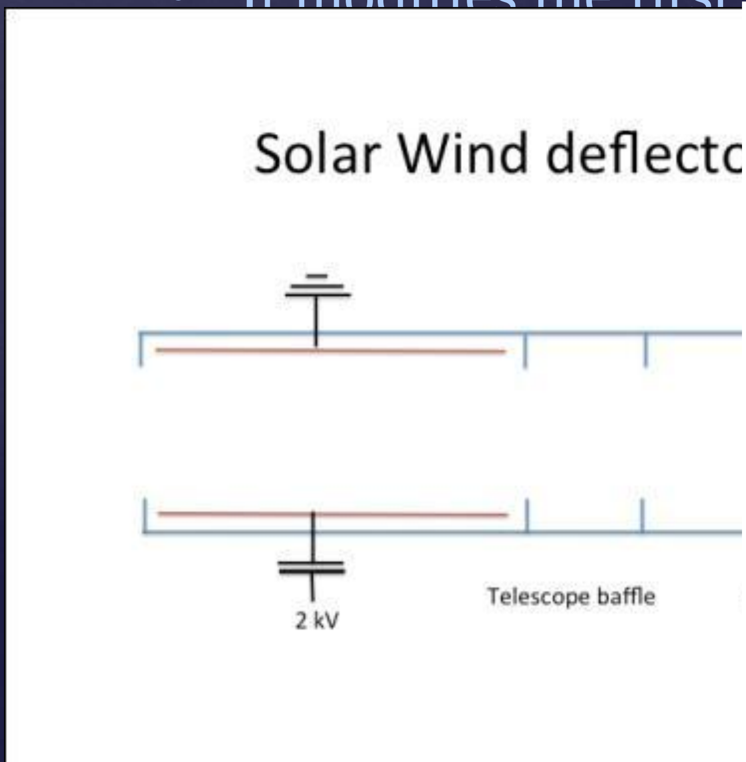
Re-closable doors of Solar Orbiter EUI

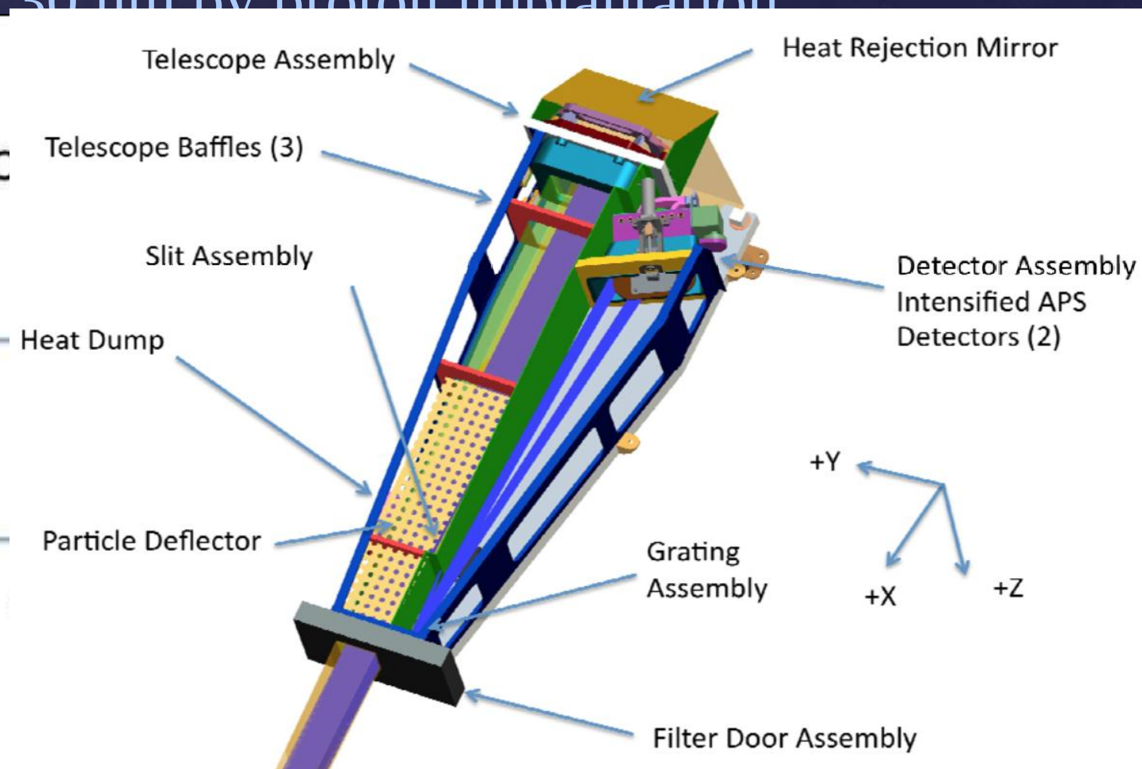


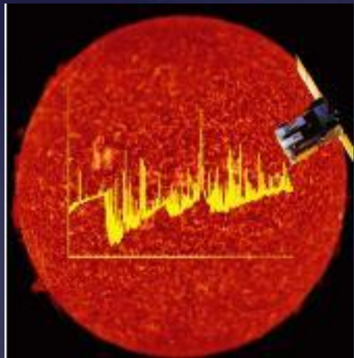


5. Solar wind deflector plates (with HV applied to deflect solar wind away from the telescope mirror)

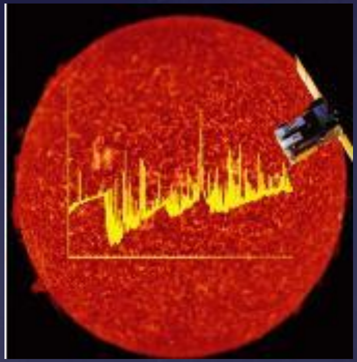
- Solar wind flux is very high (10^9 p/cm^2/s)
- It affects the optical surfaces exposed
- It modifies the first 30 nm by proton implantation







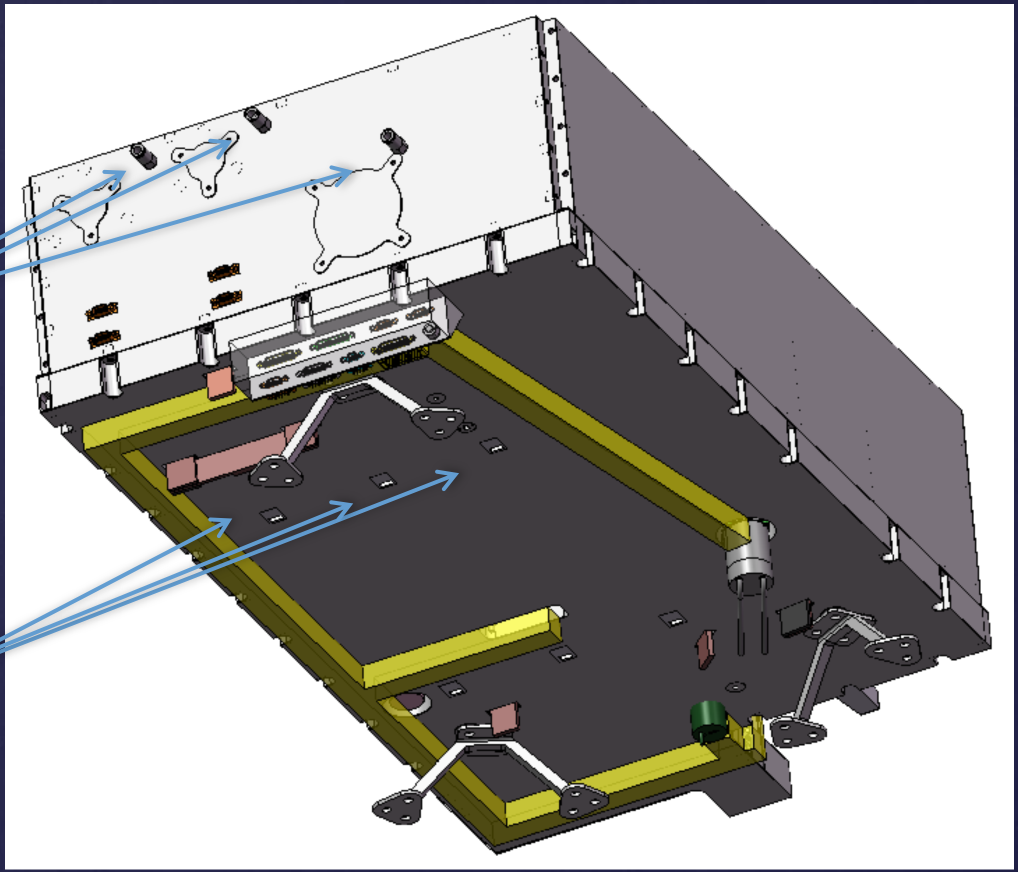
7. Keep electronic components outside optical housing with electrical feedthroughs



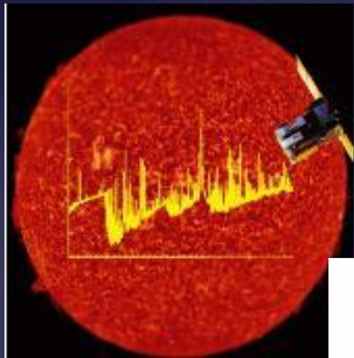
8. Purging of optical compartments at all times (to over-pressurise and clean away offgassing species)

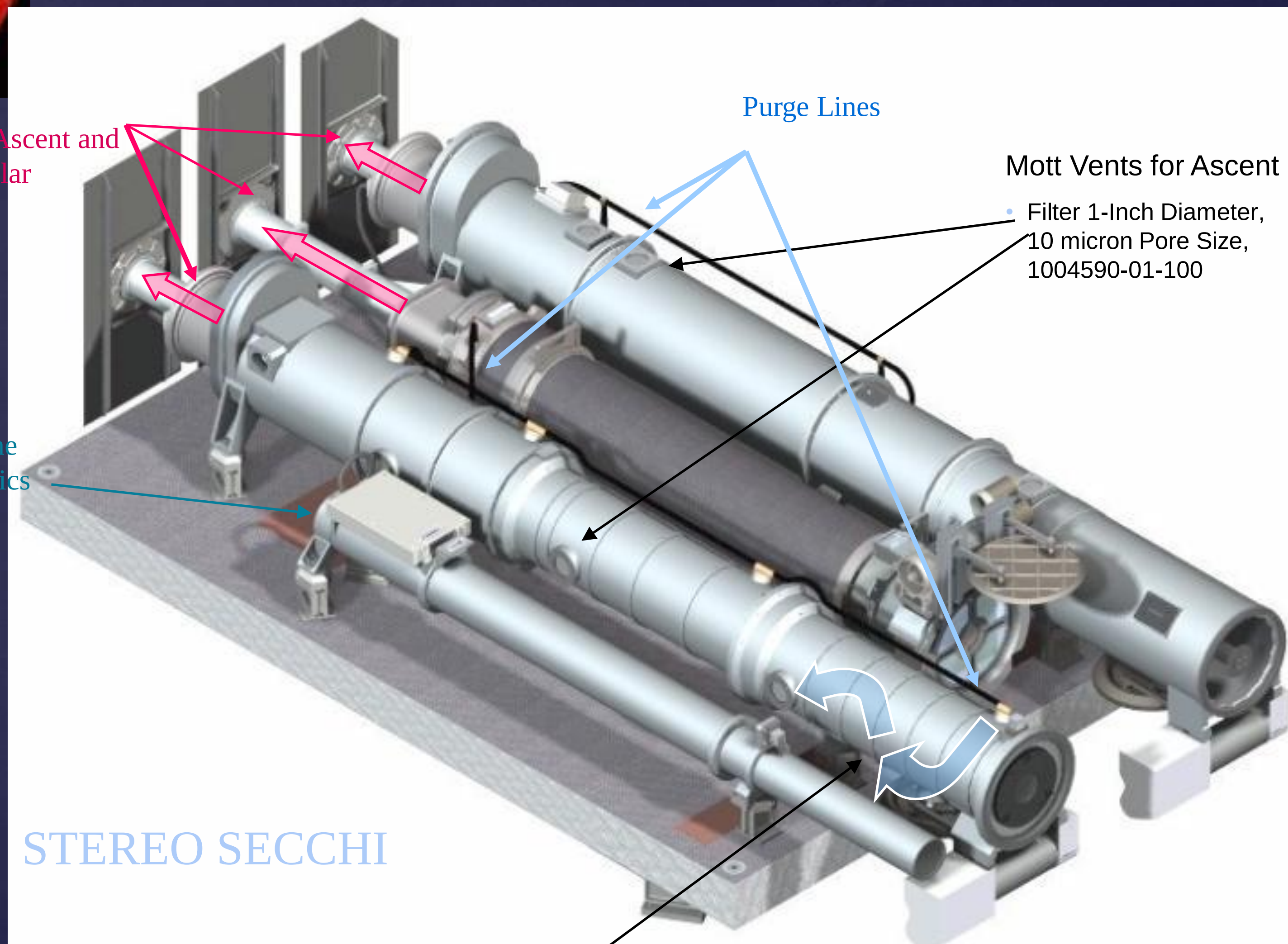
Purge inlets

Purge outlets



8. Purging of optical compartments at all times and vent design





Courtesy Therese Errigo (Swales)

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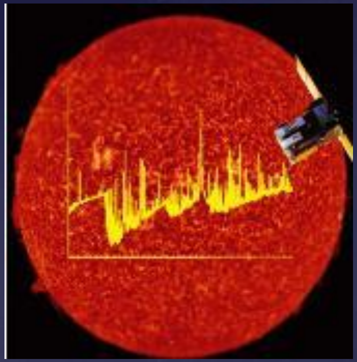

9. Keep primary optical element at highest temperature by solar illumination (to reduce deposition on UV-irradiated surfaces)

e. g., UV filter door window

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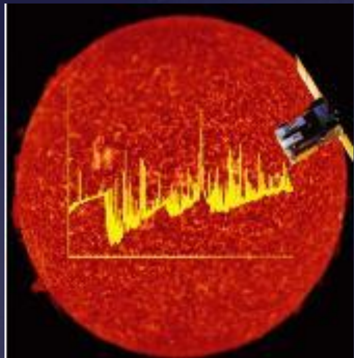
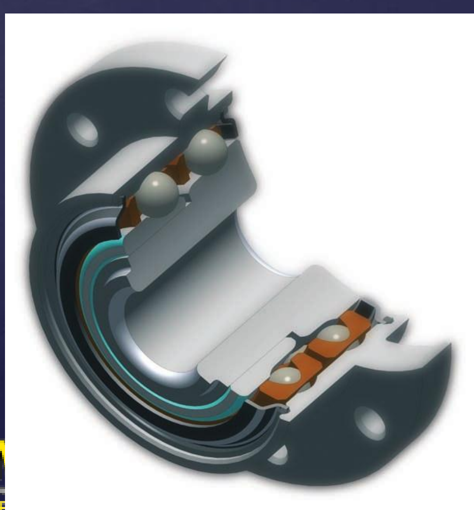
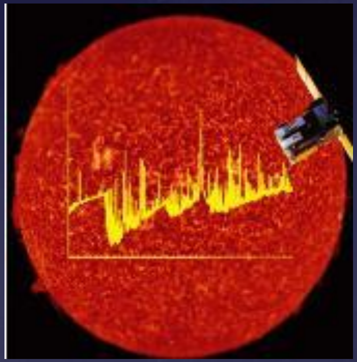


10. Dry lubrication for all mechanisms

- inorganic lubrication
  - no outgassing
- MoS_2 or WS_2 coatings

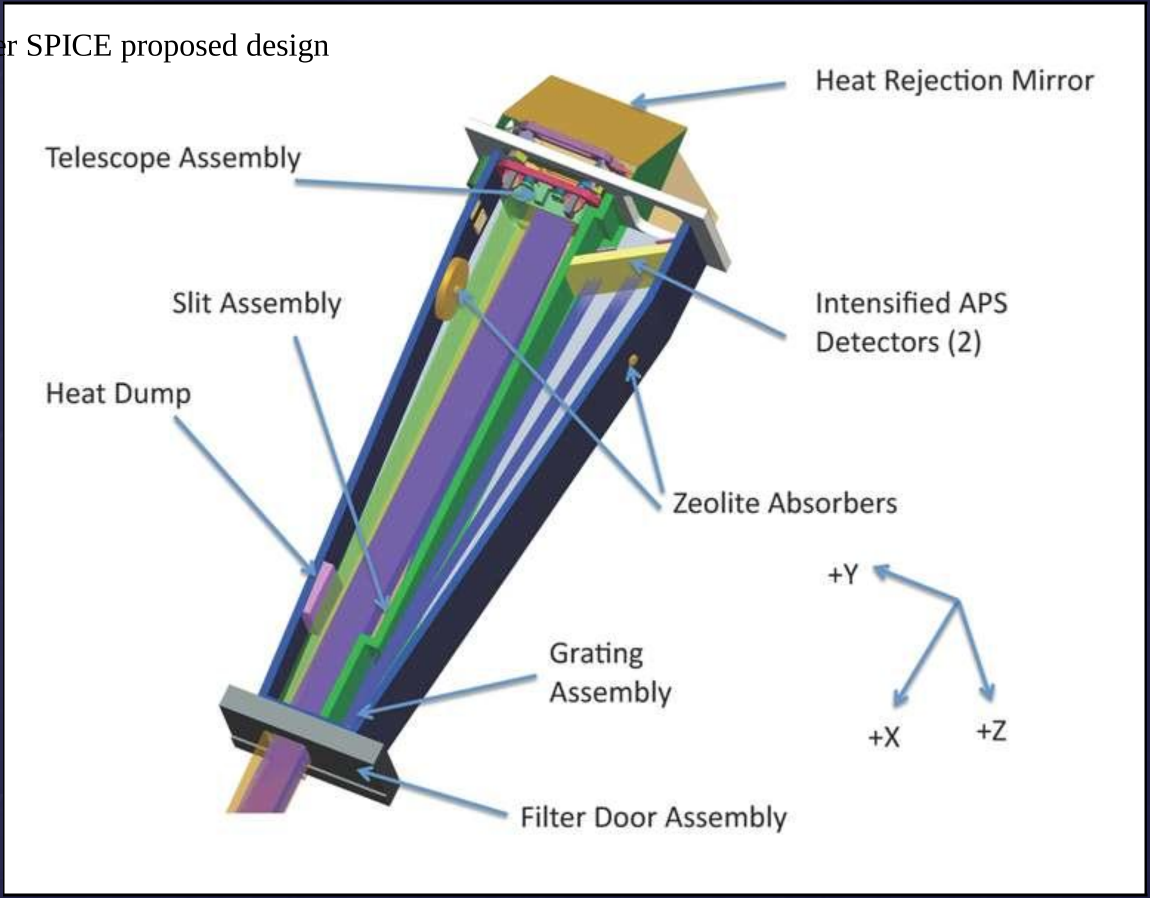




Zeolite absorbers

D. Faye et al., Proc. of SPIE Vol. 7794 77940B , 2010

Solar Orbiter SPICE proposed design



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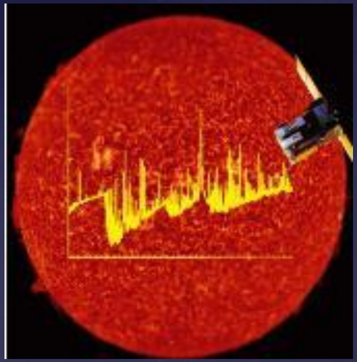

Contamination control equipment

- particle counters
- inspection lamps: UV lamp, bright spot lamp
- bakeout oven with vacuum pump and purge gas supply
- QCM – quartz crystal microbalance
- witness samples, PFO samples

MPS
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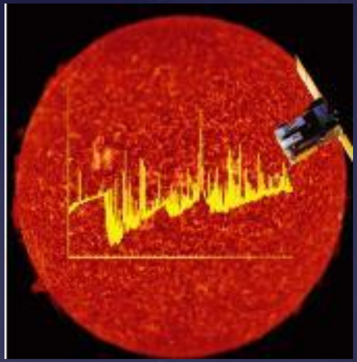

Literature

- For further information read the book:

  “The Radiometric Calibration of SOHO“,
  ISSI Scientific Report SR-002, in press, 2002,
  (eds. A. Pauluhn, M.C.E. Huber, and R. v. Steiger)

The book is online at:
http://www.issibern.ch/PDF-Files/soho_cal.pdf

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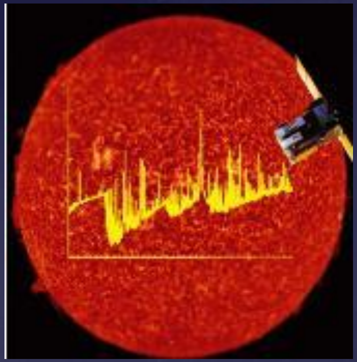

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- "Cleanliness and Calibration Stability of UV Instruments on SOHO", U. Schühle, in *Innovative Telescopes and Instrumentation for Solar Astrophysics*, S. L. Keil, S. V. Avakyan (Eds.), *Proc. SPIE*, 4853, 88 - 97, 2003
- "The cleanliness control program for the SUMER/SOHO experiment", U. Schühle, in: *UV and X-Ray Spectroscopy of Astrophysical and Laboratory Plasmas*, E.H. Silver and S.M. Kahn, (Eds.), Cambridge University Press, 373-382, 1993

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