The PICARD Scientific Mission
The operational aspects

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content

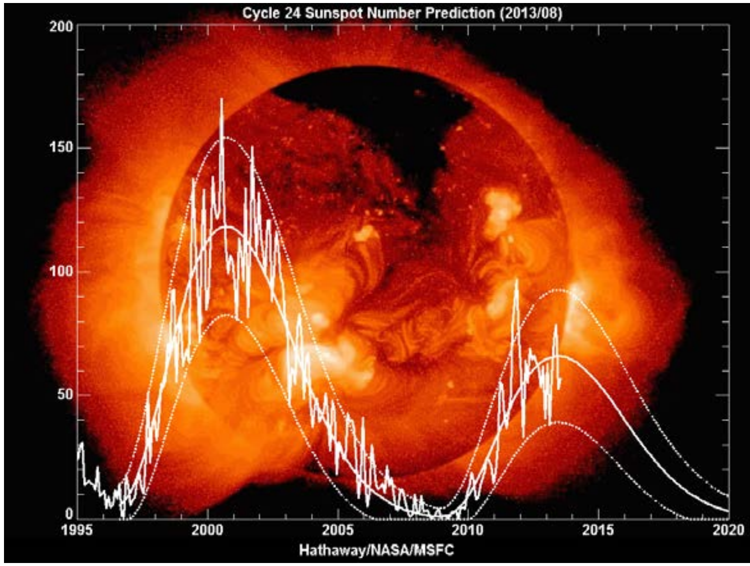
- The PICARD mission - Overview
- PICARD observational results
- Interpretation of the results – operational impacts
- Some Lessons Learned

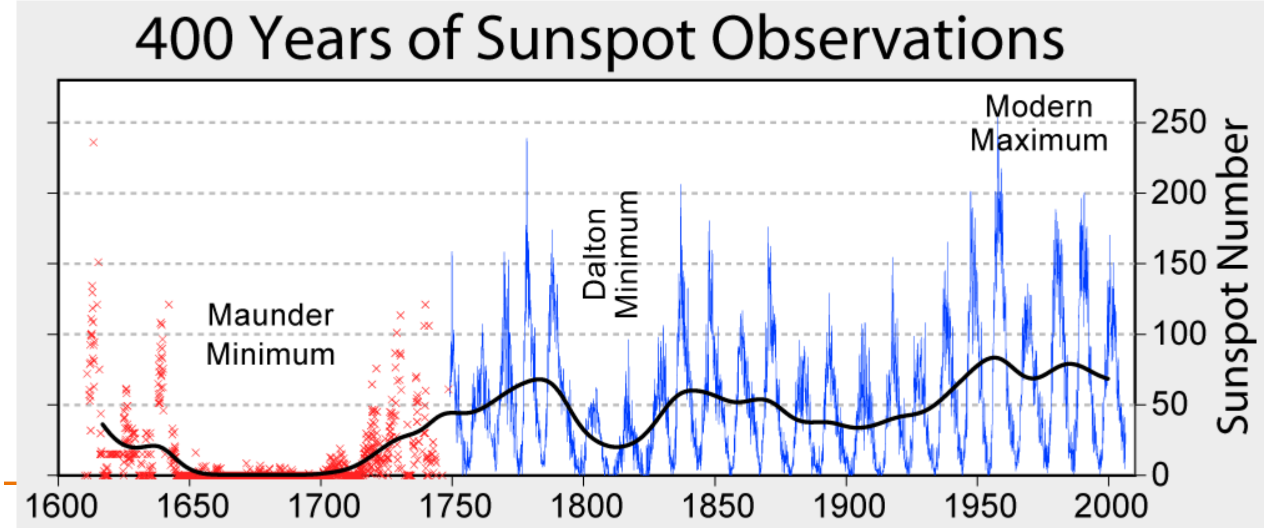
PICARD Scientific objectives

- **Objectives**
  - ✦ To reconstruct Total Solar Irradiance and Spectral Solar Irradiance
  - ✦ To determine the Sun diameter (10^{-6}) and shape,
  - ✦ To Sound the internal structure of the sun by helioseismology,

→ To determine if the solar parameters vary with solar activity

- **In order to:**
  - ✦ Improve the knowledge of the Solar Physics,
  - ✦ Study the impact of solar activity on Earth climate

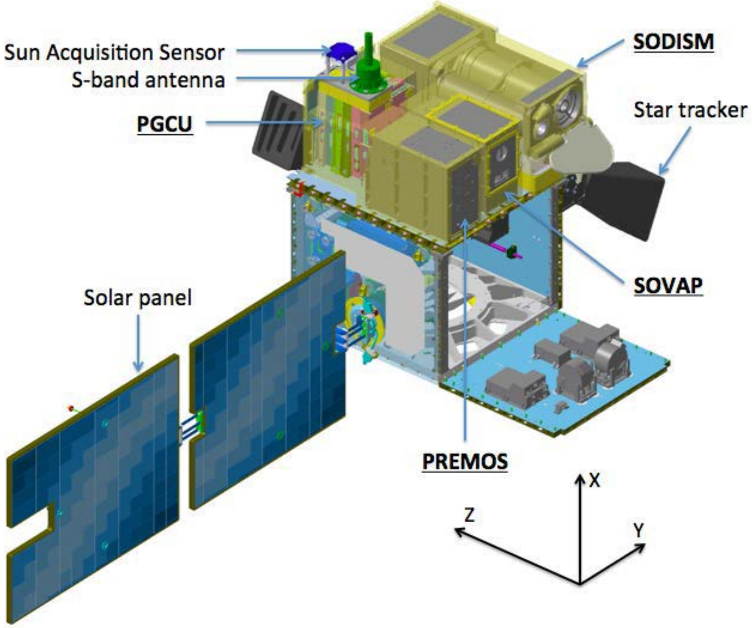




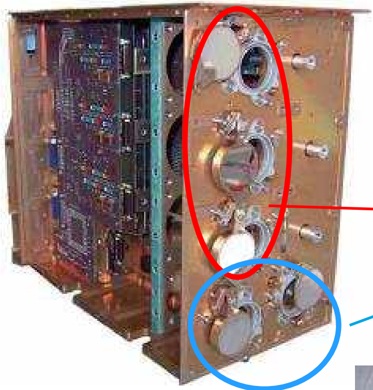
The PICARD satellite (1)

- The PICARD mission was named after the French astronomer of the XVIIth century Jean Picard (1620-1682) who achieved the first accurate measurements of the solar diameter.
- These measurements were especially important as they were made during a period when the solar activity was minimum characterized by a sun nearly without sunspots between 1645 and 1710.

- **PICARD is a space mission, which was successfully launched on 15 June 2010,**
- **PICARD Payload uses the MYRIADE family platform, developed by CNES and design for a total mass of about 120 kg**
- **Orbit:**
  - **Sun Synchronous Orbit**
  - **Ascending node: 06h00**
  - **Altitude: 735 km**
  - **Inclination: 98.29°**
- **Mission duration : 2 years**
  - **Extensions possible**

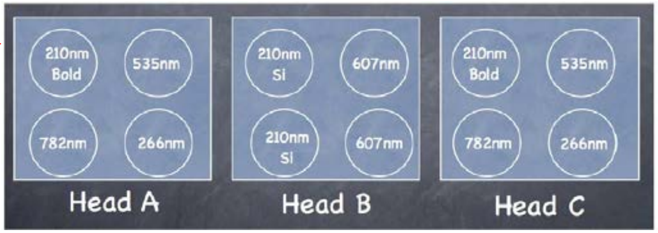


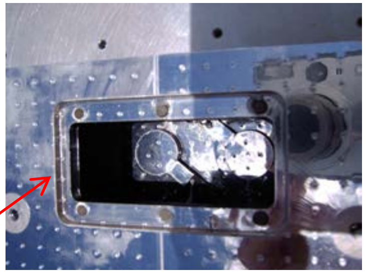
The PICARD Payload

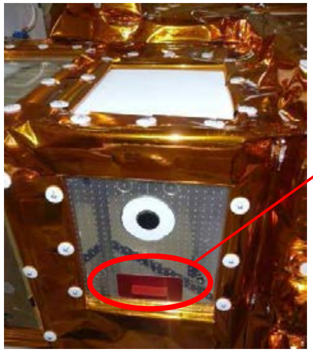


- **PREMOS** (PREcision MOnitoring Sensor) is made of four units: a set of 3 Sun photometers and the radiometer PMO6 as used on SoHO to measure the absolute Total Solar Irradiance (PMOD).

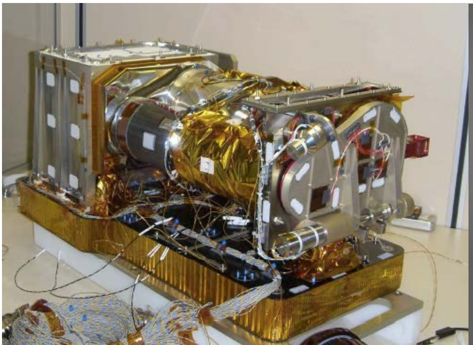
TSI PMO6 (A/B) absolute radiometer

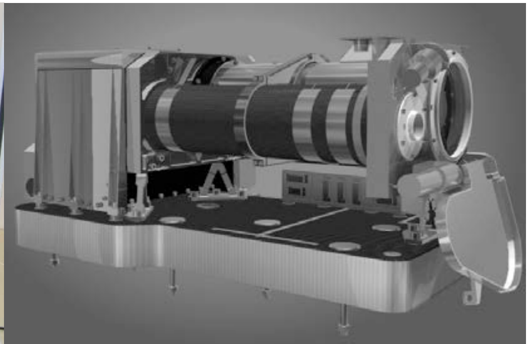






- **SOVAP** (SOlar VAriability PICARD) measures the absolute Total Solar Irradiance. This instrument is a radiometer of DIARAD type used in previous space missions, SOHO, and SOLCON on the Space Shuttle (IRMB).





- **SODISM** (SOlar Diameter Imager and Surface Mapper) is an imaging telescope measuring the solar diameter and limb, and performs helioseismologic observations to probe the solar interior.

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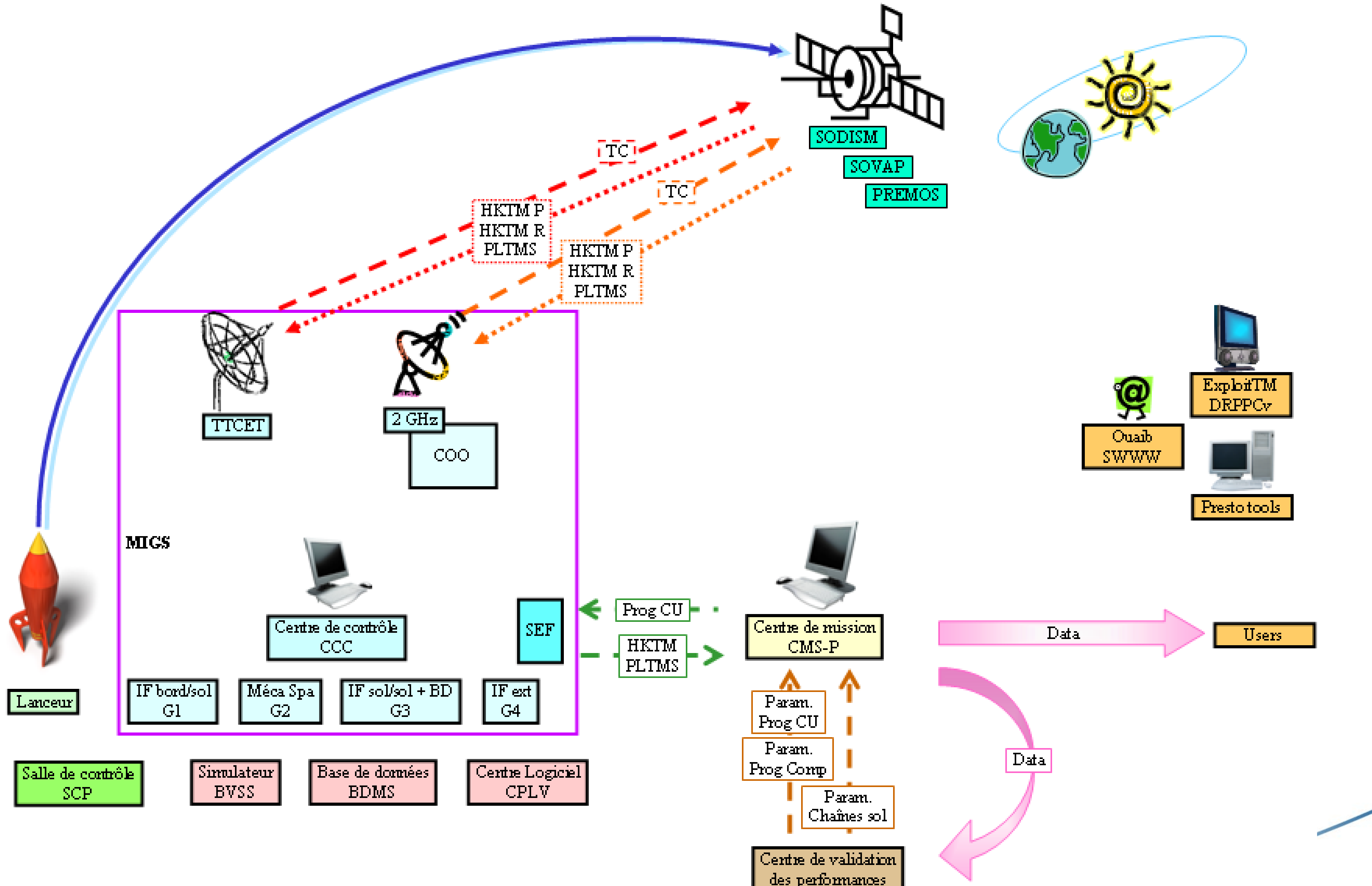
The PICARD ground segment



PICARD Images (393 nm, 535 nm)

Image Pleine RS393 du 2012-03-09 06:27

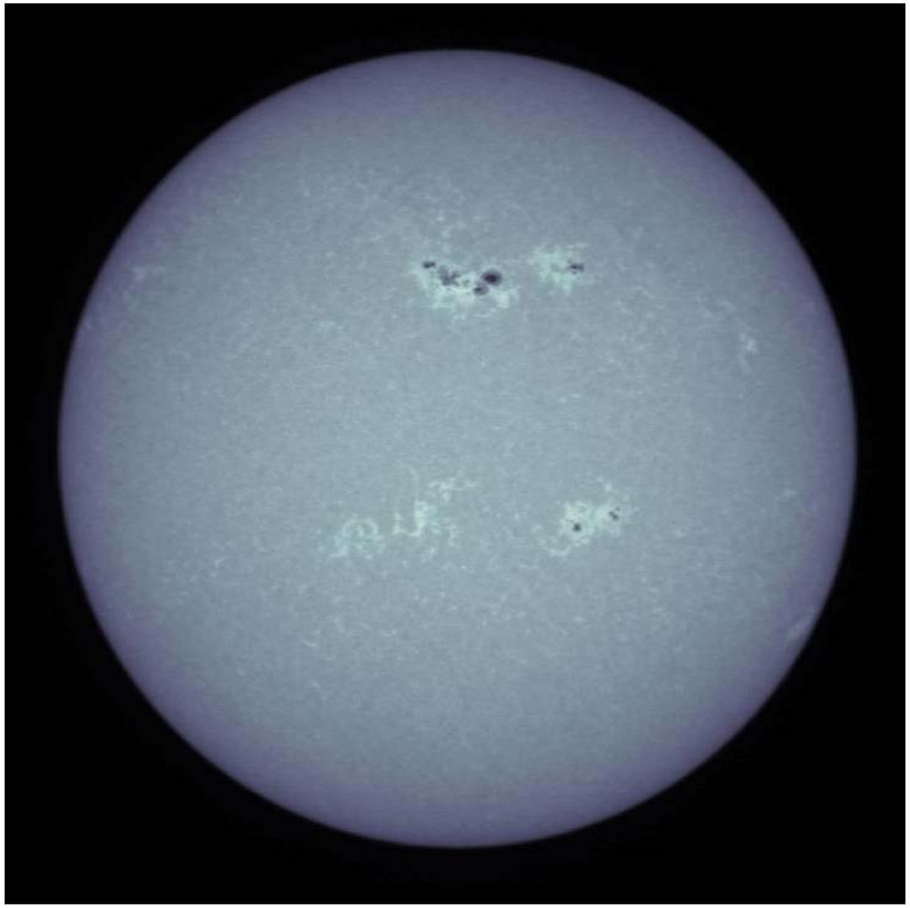
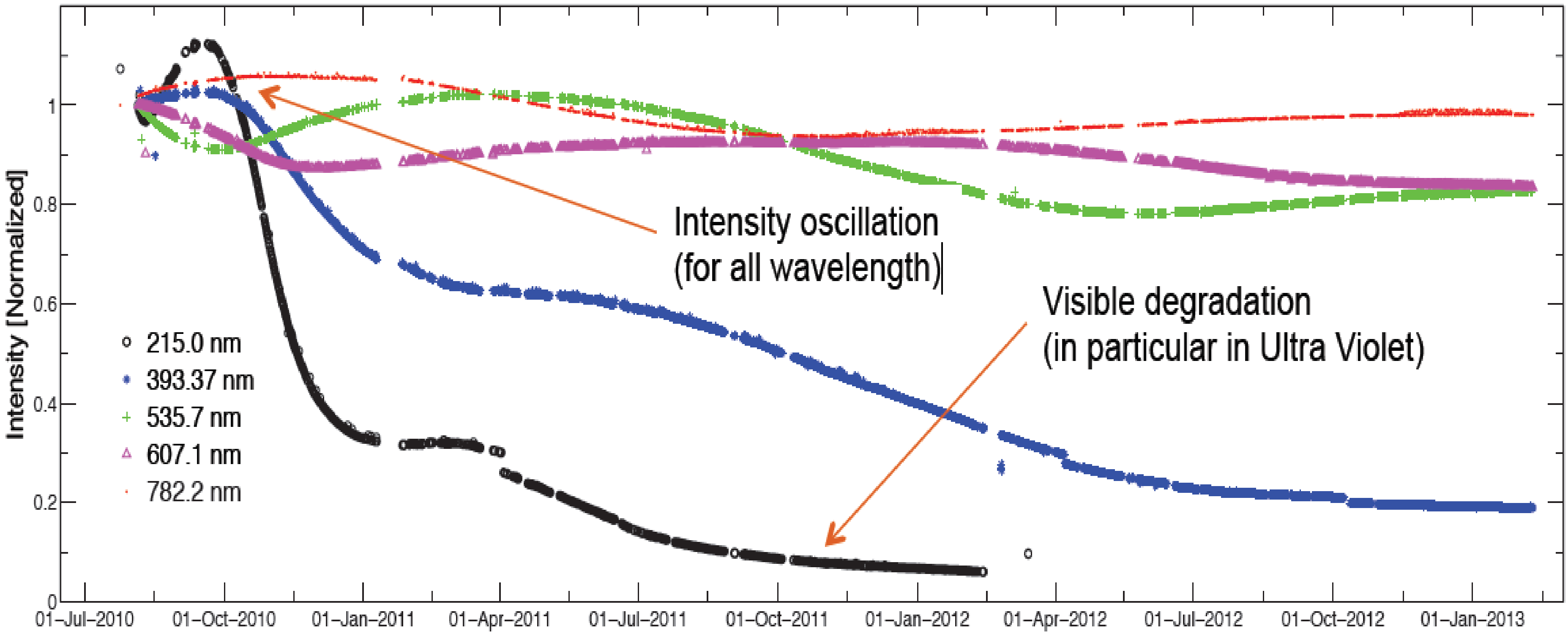


Image Pleine RS535 du 2012-03-09 16:51

SODISM observational results (1)

Intensity

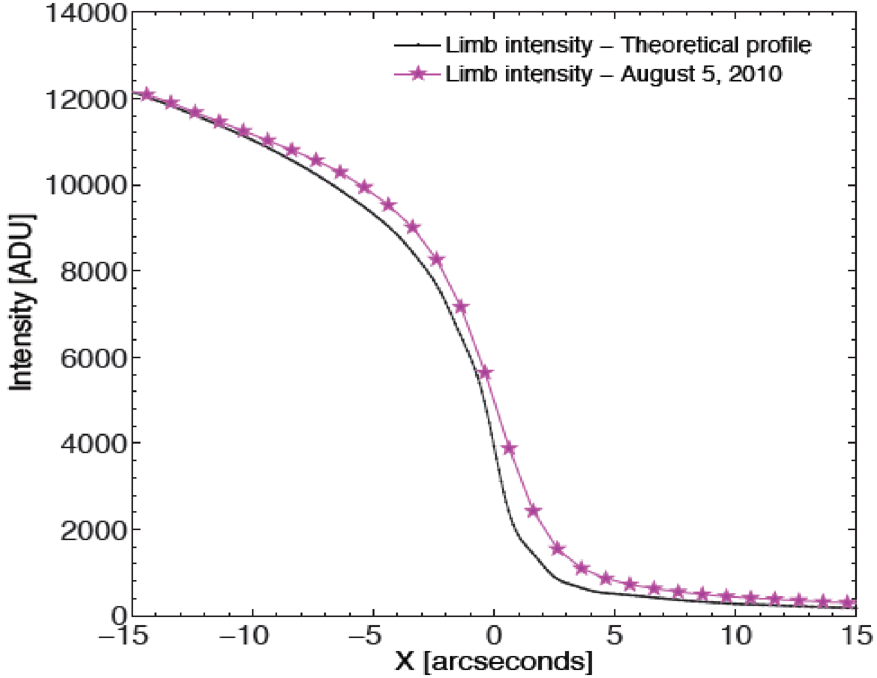
- Evolution of the integrated intensity in SODISM images at all wavelengths.
- UV channels are seen to experience degradation. By early 2013, the “215” channel has lost more than 90%, and “393” about 80%.

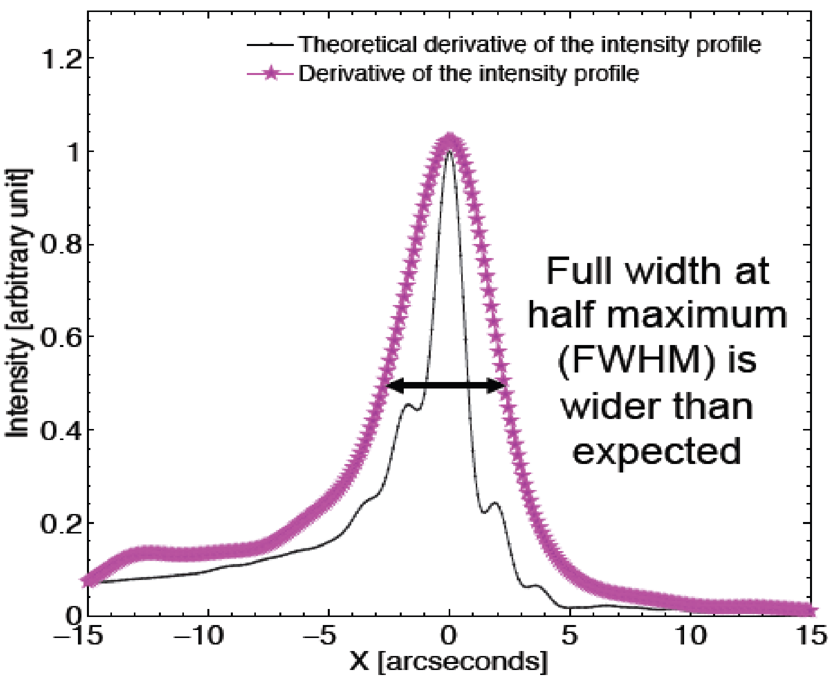


SODISM observational results (2)

Image Pleine RS535 du 2012-03-09 16:51

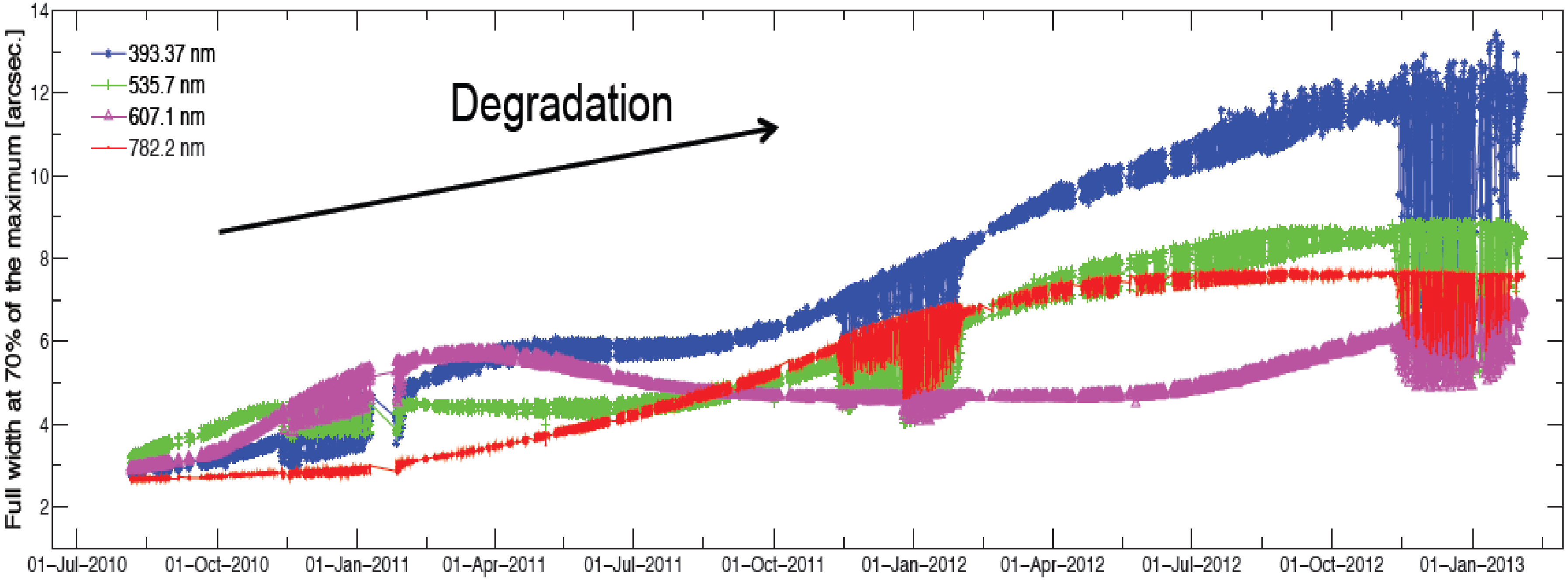
- **SODISM image shape evolution**
  - We observe that the solar limb recorded with SODISM is wider than the spread expected from the model
    - → Misalignment of the optical elements (initial position of the CCD) combined with thermo-optical effects).
    - → But it would have to be time invariant (constant during the entire mission).





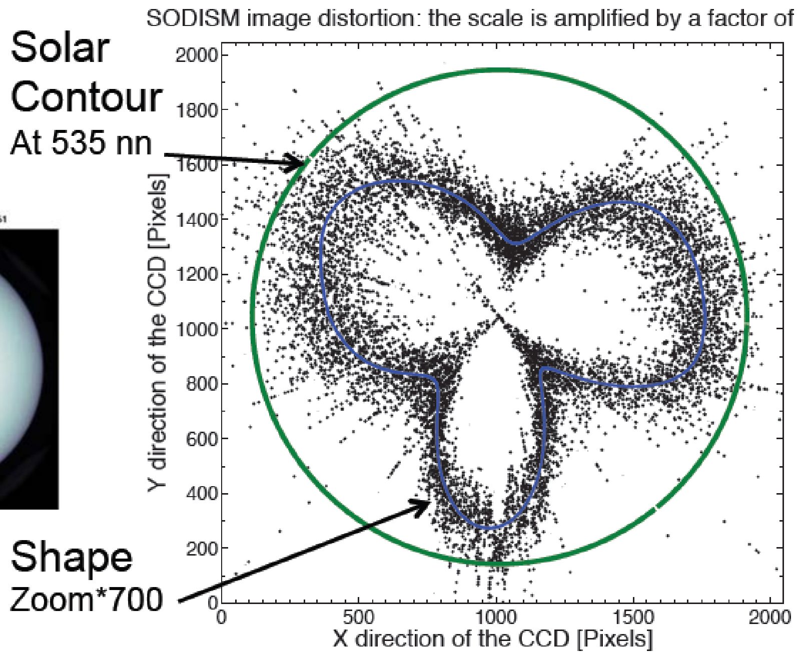
SODISM observational results (3)

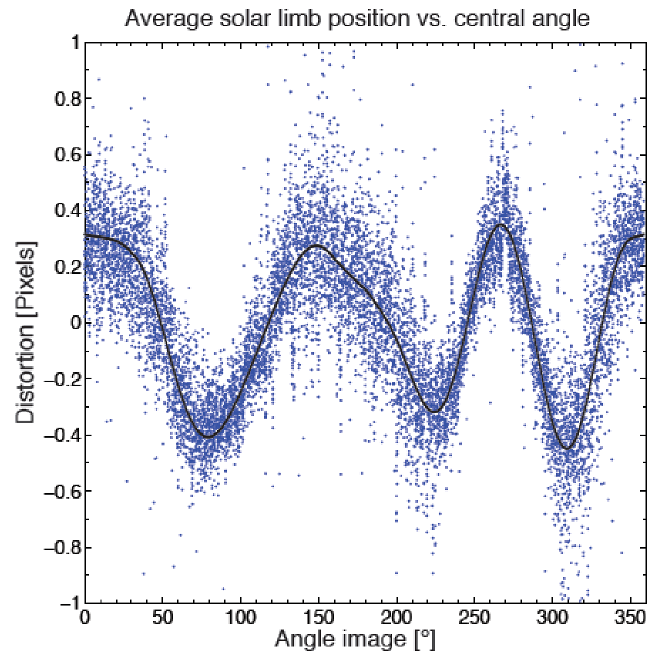
- The limb width (or FWHM : Full width at half maximum) varies with time:
  - modulation in phase with the orbit,
  - long term trend toward worsening.



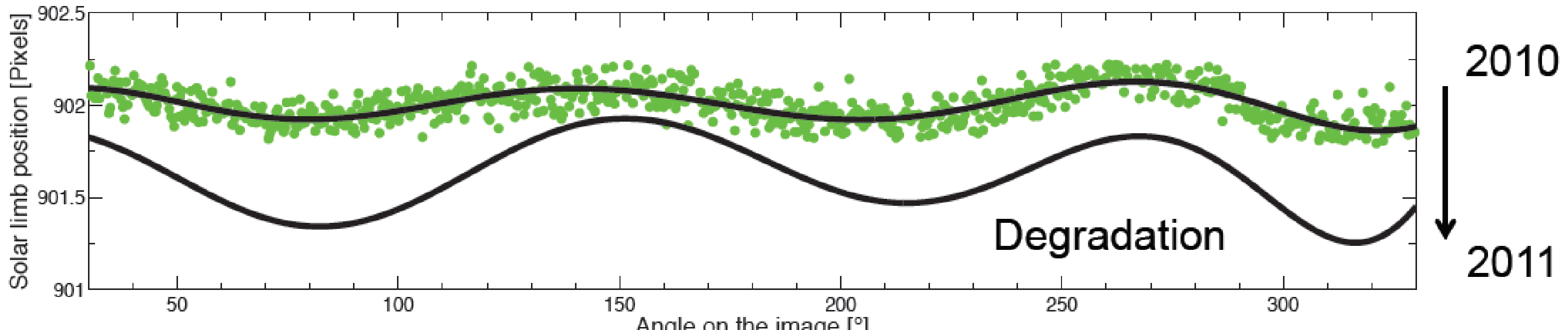
SODISM observational results (4)

- The shape of the solar figure departs more and more from perfect circularity. The residual pattern reveals a triangular “trefoil” outline.



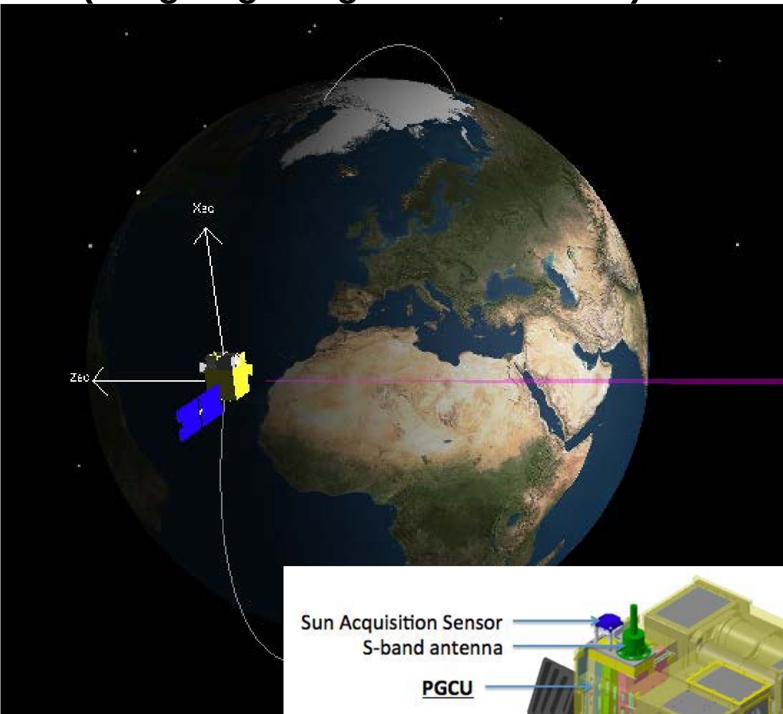


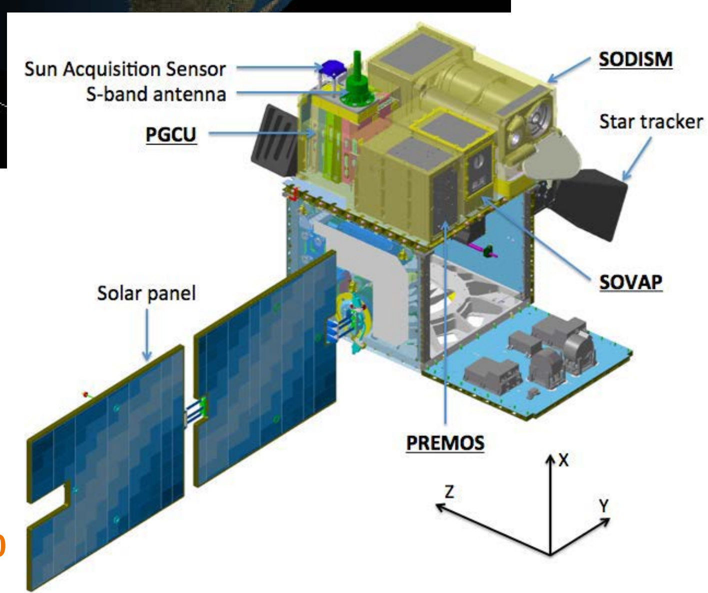
July 2011

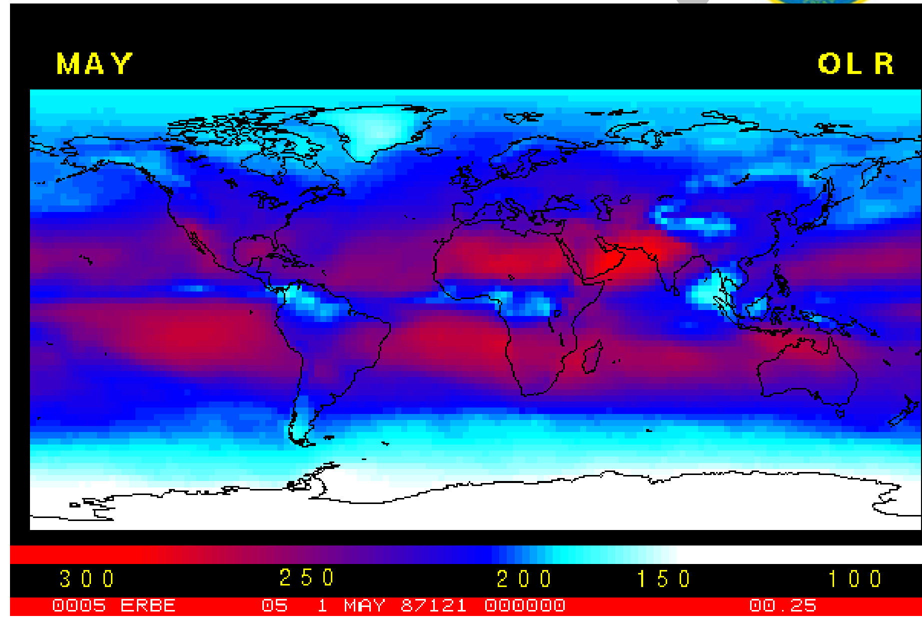


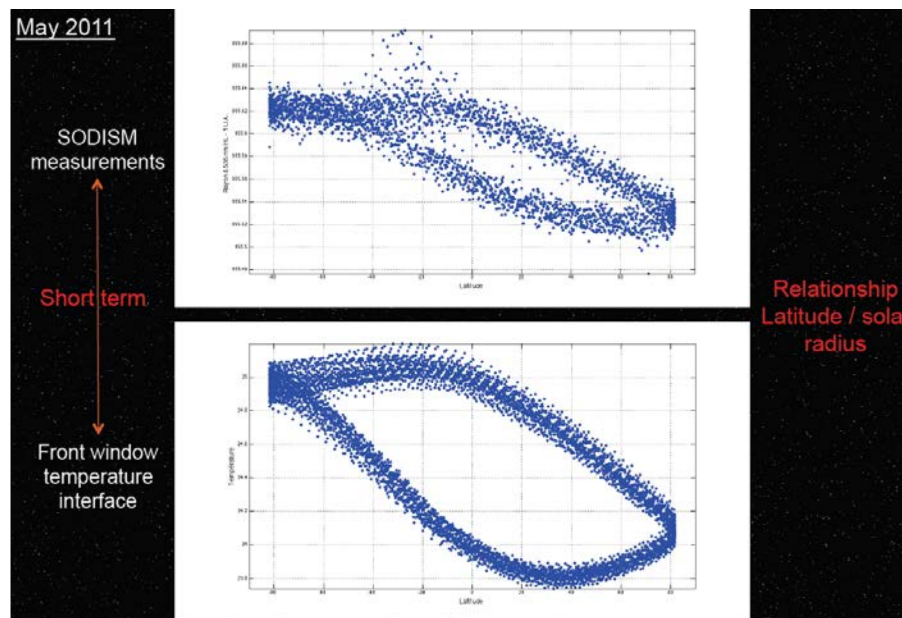
SODISM observational results (5)

- **Orbital effect on the solar radius and OLR (Outgoing Longwave Radiation)**

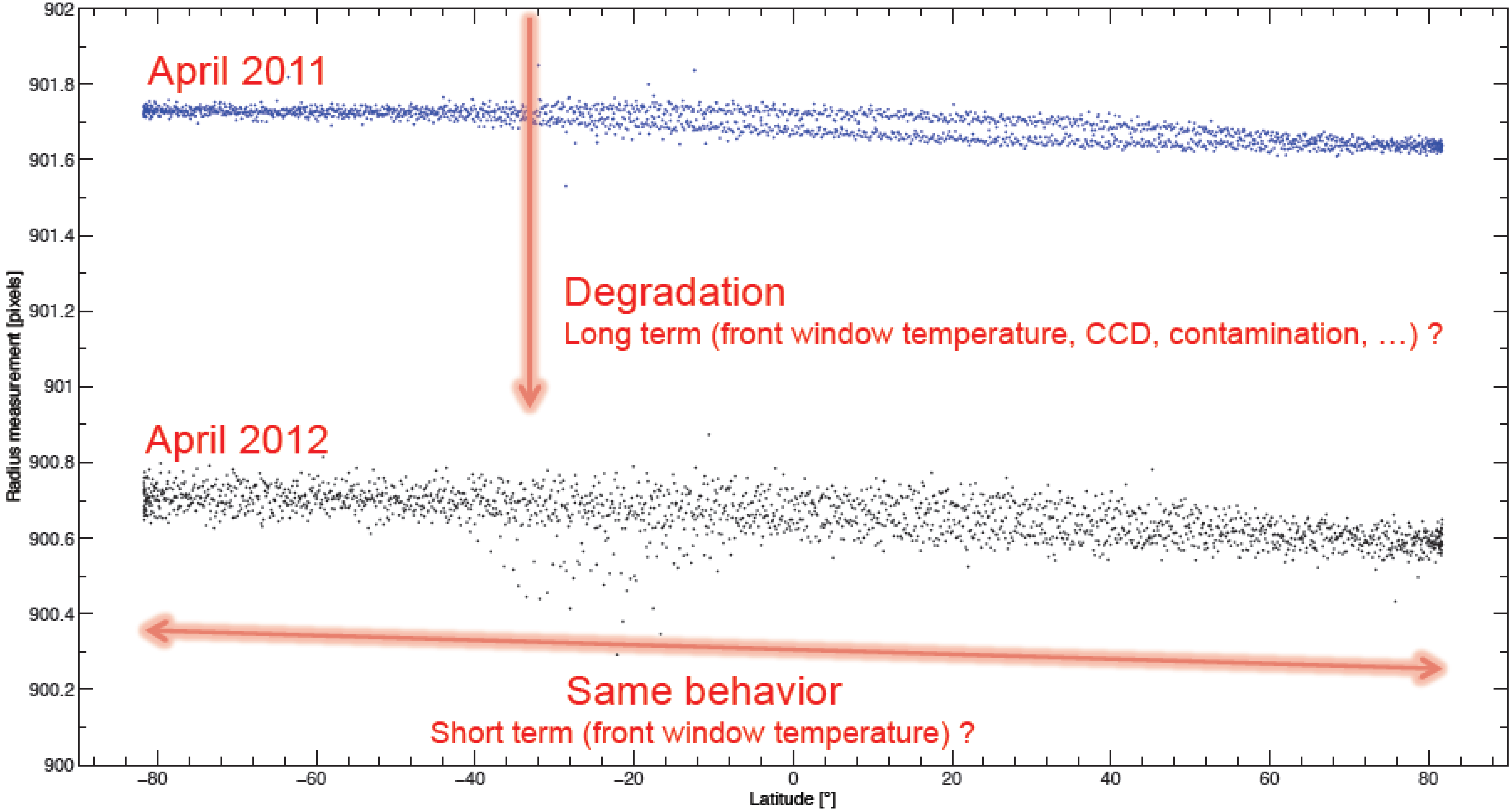




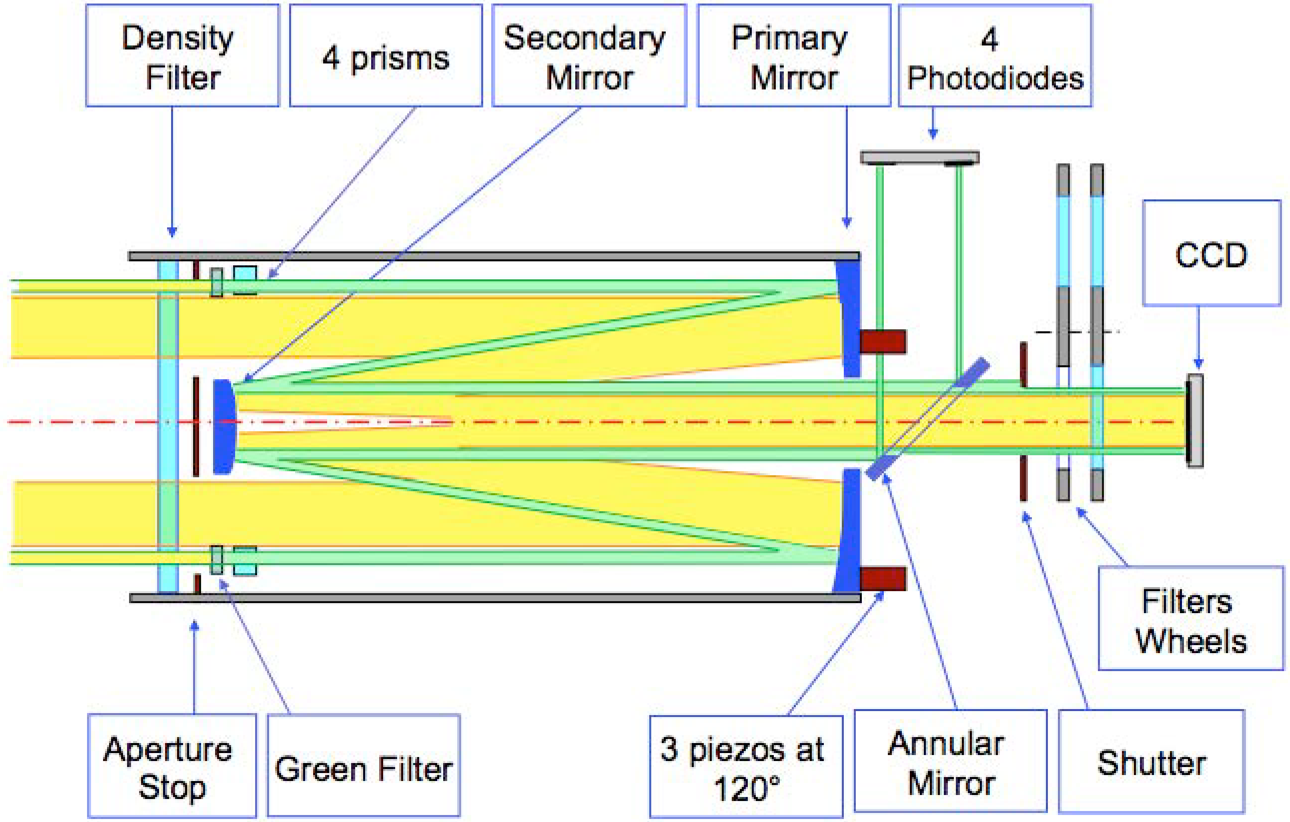




SODISM observational results (6)



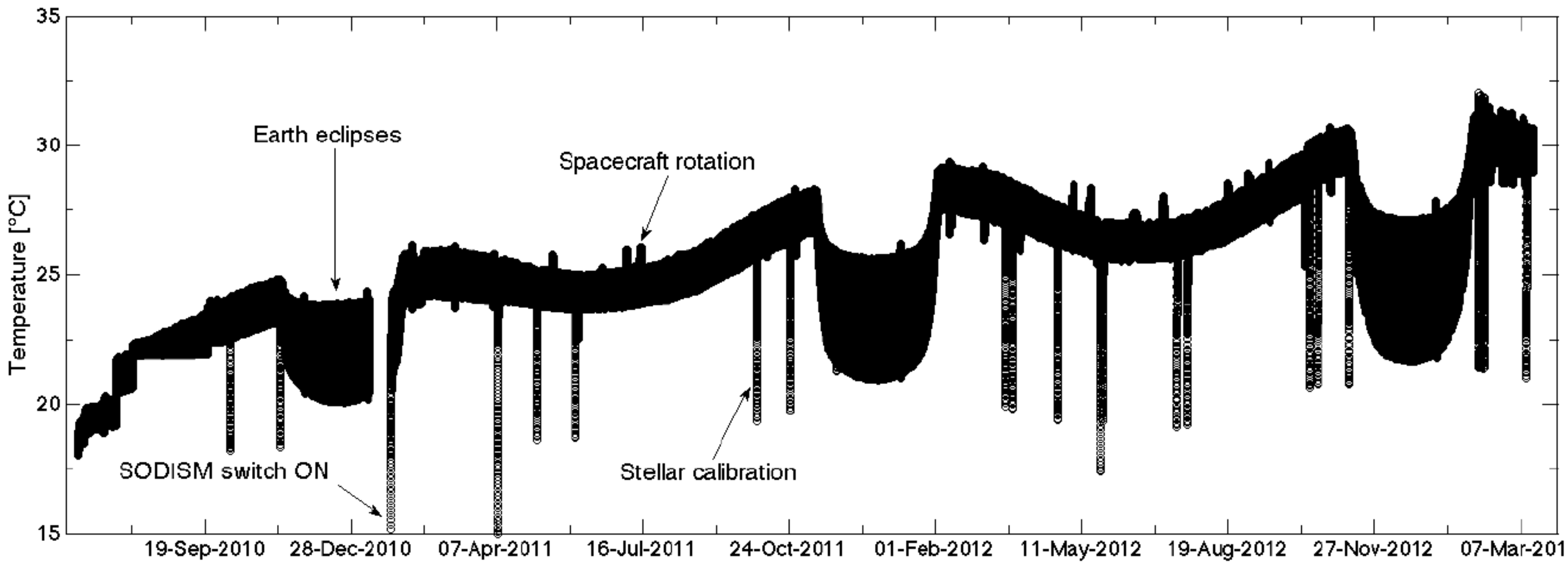
SODISM optical path



Interpretation of observational results (1)

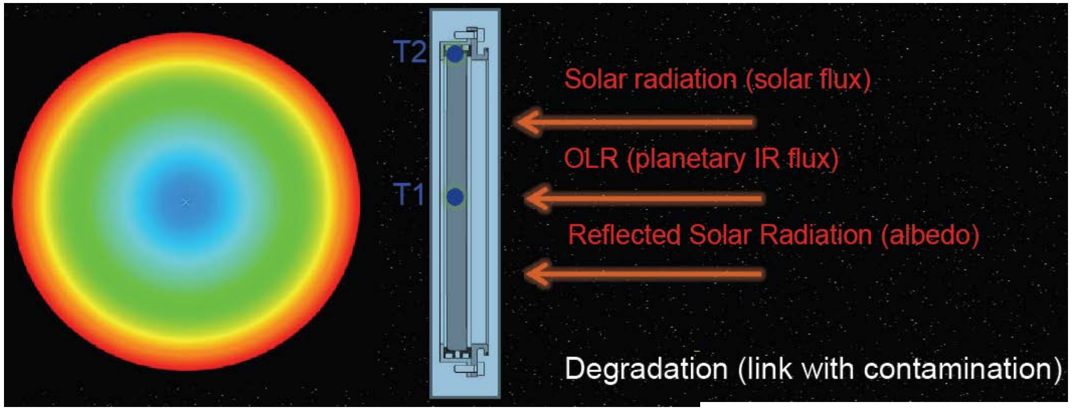
- **Intensity :** SODISM front window has suffered substantial degradation that can cause polymerization of organic material (origins: integration, test, launch, separation, …) and, subsequently, irreversible deposition of this material on internal and external surfaces of the glass,
  → **The simulations show the credibility of this scenario**

- **FWHM evolution, SODISM image shape evolution :** Solar absorptance degradation of the front face of the telescope (front window, MLI, …) and SODISM front window temperature evolution,

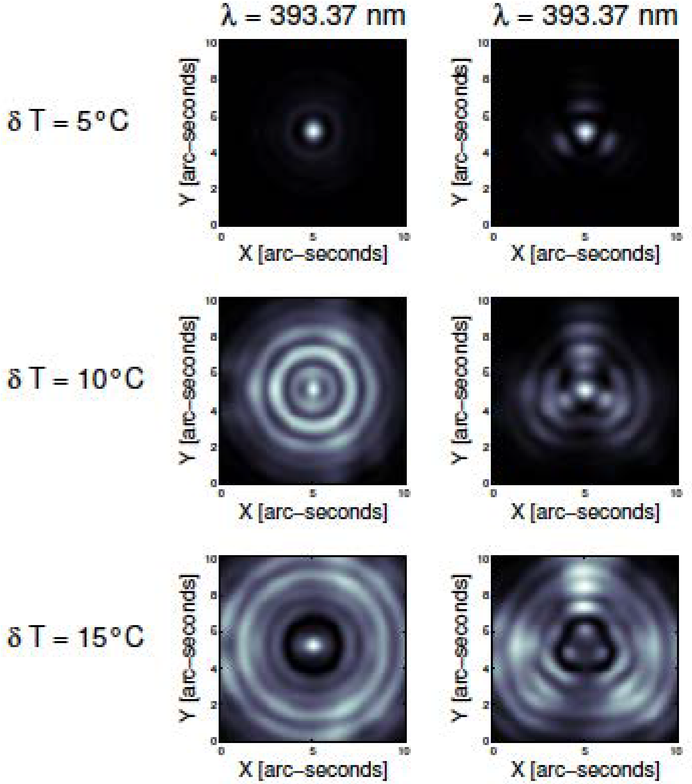


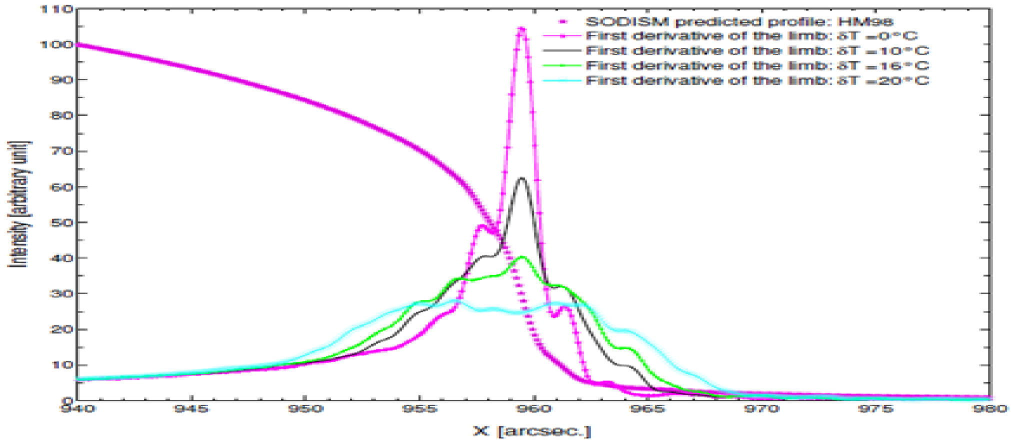
Interpretation of observational results (2)

SODISM front window temperature evolution



SODISM front window temperature gradient : it changes over time from -7°C to -12°C.





- **SODISM front window temperature gradient** :
  - → Significant defocus of the instrument
  - → PSF (point spread function) evolution
  - → Interpretation of FWHM (Full Width at Half Maximum) evolution
- **…and thermal gradient on the mirrors.**

The data processing (1)

- Data processing at CMSP (PICARD Scientific Mission Center) in Brussels, Belgium

- L0 product = FITS image
  - Raw (only reformatted from TM)
  - Header = all relevant information available at L0 creation
    - HK info (e.g. T° CCD), CMSP info (e.g. version #), CCC info (e.g. PICARD longitude)

- L1 product = FITS image
  - Instrumental effects addressed at level 1 (and only at level 1)
  - L1 image = corrected L0 images
    - Directly into L1 image if univocal correction estimation 'L1X'
    - Otherwise, 'L1Z' auxiliary file available for ulterior optional correction (e.g. PSF) [Required correction precisions depend on exact application]
  - L1 header
    - Propagation L0 info, + Information necessary to L2 production (e.g. R_sol) [Can be crucial to subsequent exploitation!]

- L2 = astrophysical information
  - L2 data computed from L1 products

- Higher levels (L3, L4) could be defined

The data processing (2)

N1 sublevel definition

Réf.	Title	L1 A @ CMSP	L1 B « Best effort »	L1 C « Confirmed »	L1 D « Definitive »
WP-1a	Offset	Yes	Yes		
WP-1b	Dark current	Preliminary	Target		
WP-1c	Persistence	No	If possible	Target	
WP-1d	CRH	No	Yes		
WP-2	CCD CTE	No	No	If possible	Yes
WP-3	Flatfield	Preliminary	Target		
WP-4	Point Spread Function – PSF	No	No	Target	
WP-5	Ghosts	No	Crescent ghost	Annular ghost	
WP-6	Distortion	No	No	Target	Yes
WP-7	Scale factor	No	No	If possible	Target
WP-8	QE & radiometric corrections	Preliminary	No	No	Target

- SODISM data re-processing was needed during the mission…
- … But the initial CMSP system did not allow reprocessing of the data (not included in the CMSP specifications : only one reprocessing at the end of the mission foreseen…),
- Modification of CMSP reprocessing system : “BEST EFFORT” (i.e. with the existing hardware)

Some Lessons Learned (1)

- The "no-nominal" functioning (degradation) of the SODISM instrument leads to :
  - Reconsider operational activities,
  - Develop new tools (modelisation, etc..)

  → The perturbation of the "routine" not optimal for a good knowledge of the long term functioning of the instrument(s) (aging, etc…)

- Further to the PICARD experience feedback, the need to anticipate the operational implementation from the beginning of the detailed definition of the system was recommended for the MICROSCOPE project (Fundamental Physics – Equivalence Principle - same MYRIADE family) :
  - to develop an operational concept of exploitation of the satellite and the mission,
  - to clarify the operational organization,
  - to optimize the distribution of the functions and to insure the acceptance of the concept by the involved entities.

Some Lessons Learned (2)

- Pre-flight calibration & simulations are very important (plate scale, PSF, distortion, …),
- Avoid low orbits for solar missions, and avoid micro-spacecraft with low mass (for metrology mission),
- Testing of space optics (UV filters, mirrors, front window) should be as representative as possible to the environment they will be exposed,
- Assess risk and impact of contamination of space optics (solar UV missions),
- Provide systems for refocusing (correction of the instrumental degradations),
- For “similar” instruments, the front window should be integrated in a controlled temperature enclosure (with temperature change for modify the focus).
- Low Temperature of the CCD (reduction of dark current, …) is very important (less than -20°C). Avoid micro-satellite with low power (Bake-out at more than 40°C is advisable).
- Re-processing capacity needed….
- The need to anticipate very early in the project the operational aspects.

Additional information

- PICARD data available to the scientific community (http://picard.busoc.be/sitools/index.jsp)
- Numerous published scientific results,
- PICARD Workshop on 25-26 September, 2013 (CNES – Paris)
- "The sun and the climate : contribution of the PICARD mission", Symposium in 2014
- http://smsc.cnes.fr/PICARD

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THANK YOU