

THE PICARD MISSION

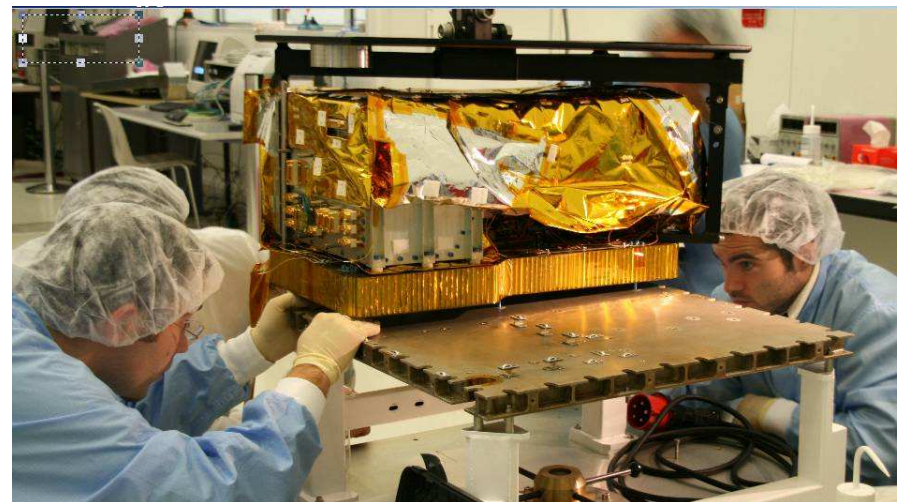
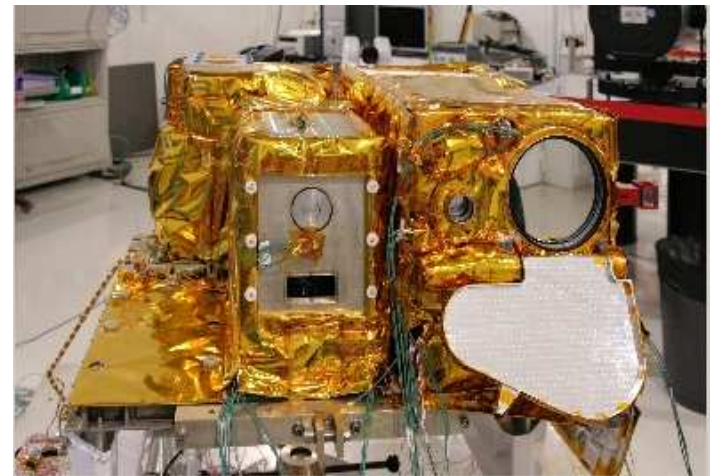
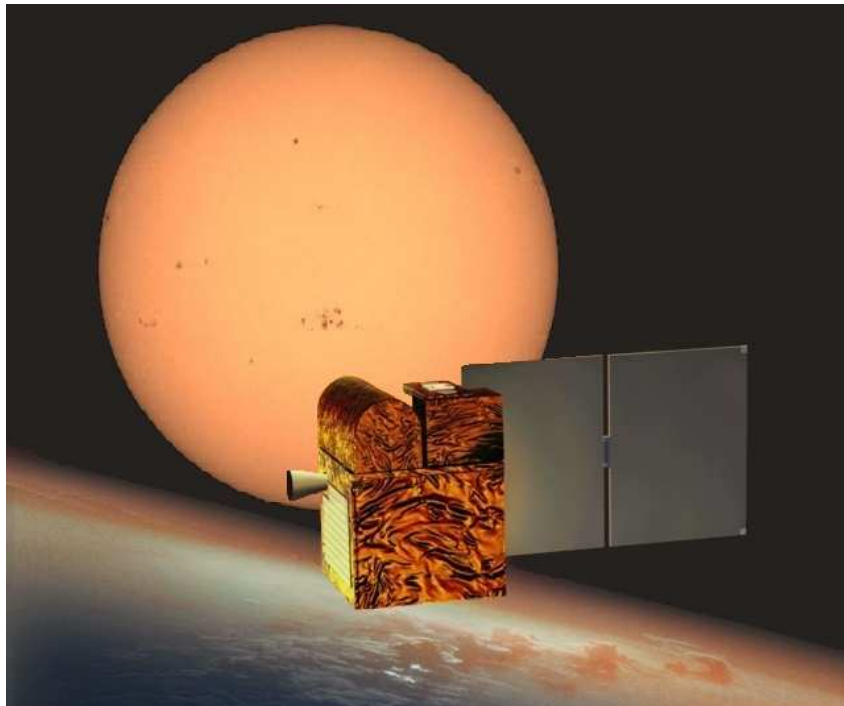
Gérard Thuillier,
Service d'Aéronomie du CNRS

and The PICARD Team

Bozeman, 6 June 2008

PICARD is a CNES led satellite mission to simultaneously measure key parameters necessary to understand the origin of the solar activity and its links with the Earth's climate.

Launch scheduled to June 2009

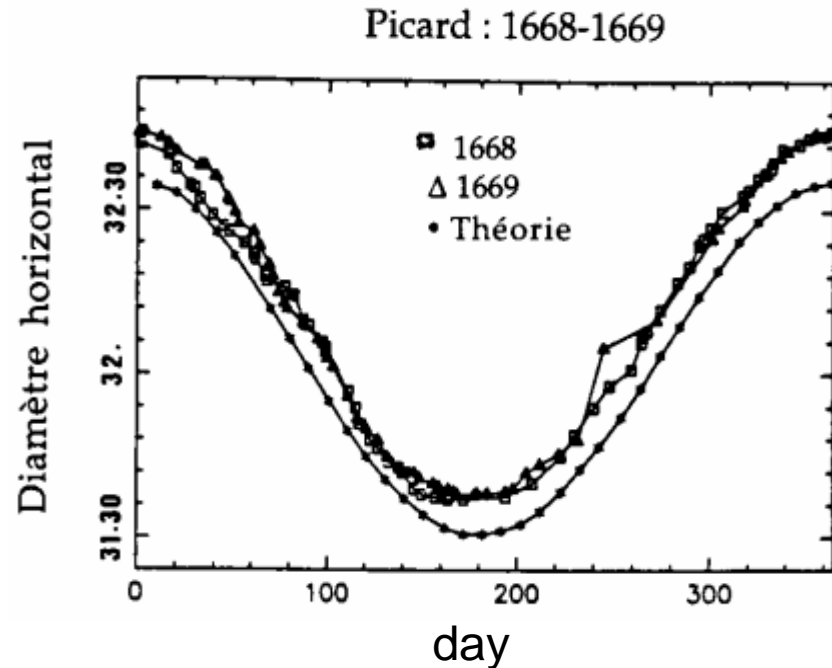


OUTLINE

- BACKGROUND
- MISSION SCIENTIFIC OBJECTIVES
- INSTRUMENTS
- MEASUREMENT
- BRUSSELS MISSION CENTER
- PRESENT STATUS OF DEVELOPMENT

THE PICARD MISSION GENESIS

Jean PICARD (1620-1682), a French astronomer measured the solar diameter as a function of the day of the year to determine the Earth's orbit eccentricity.



Ribes (1987) processed the data at one A.U. It appeared that the Sun was slightly bigger than today!

Furthermore, these measurements were made during the Maunder minimum, for which the TSI was lower than today. These two results opened an active debate about the anti correlation between diameter and luminosity.

After 20 years, this question remains open!!!

THE PICARD mission

SA (F)
IRMB (B)
PMOD (Ch)

OCA
Obs. Meudon
Nice University
IAS
LMD
DAPNIA-CEA



Jean PICARD (1620 - 1682)

Yale University
HAO
GSFC
JPL
NRL
CSA
Valencia U

ILWS

PICARD launch is scheduled for June 2009

FUNDAMENTAL SOLAR INPUTS

Parameters that are key constraints for validating the physics of solar interior models:

- **Solar diameter, limb shape, asphericity in the photosphere**
- **Total solar irradiance (TSI)**
- **Oscillation modes**
- **Temperature**
- **Solar spectrum**

and their variability

CURRENT SITUATION OF THE SOLAR MEASUREMENTS

Among the previous quantities, the solar diameter is **the least** reliable.

Several reasons may explain the discrepancies:

- Measurements on the ground, which contain the effect of the Earth's atmosphere.
- Instrumental effects (sampling, psf, wavelength domain...)
- Data processing (filtering effect)

SOLAR DIAMETERS

Photospheric diameter:

defined by the inflection point position of the limb shape determined by optical instruments.

Seismic diameter:

Determined from frequency oscillation modes by adjusting the solar radius to minimize the model/measurements difference (Antia et al. 1998). It is model dependent and corresponds to a region below the photosphere depending of I.

RESULTS FROM GROUND OBSERVATIONS

There are several optical methods (Mercury transits in front the Sun, solar eclipses, astrolabes, imaging telescopes) showing :

- in phase, or anti phase with the 11-year solar cycle, or none variation.

To explain the discrepancies, the role of the atmosphere is considered, however to which extend?

Given that the ground based observations constitute the longest series, within the variations, what part is of solar origin?

RESULTS FROM SPACE

MDI/SoHO images have been used to determine the radius variation as a function of time. The recent results show a maximum change of 15 mas from 1995 to 2004 (Kuhn et al., 2004).

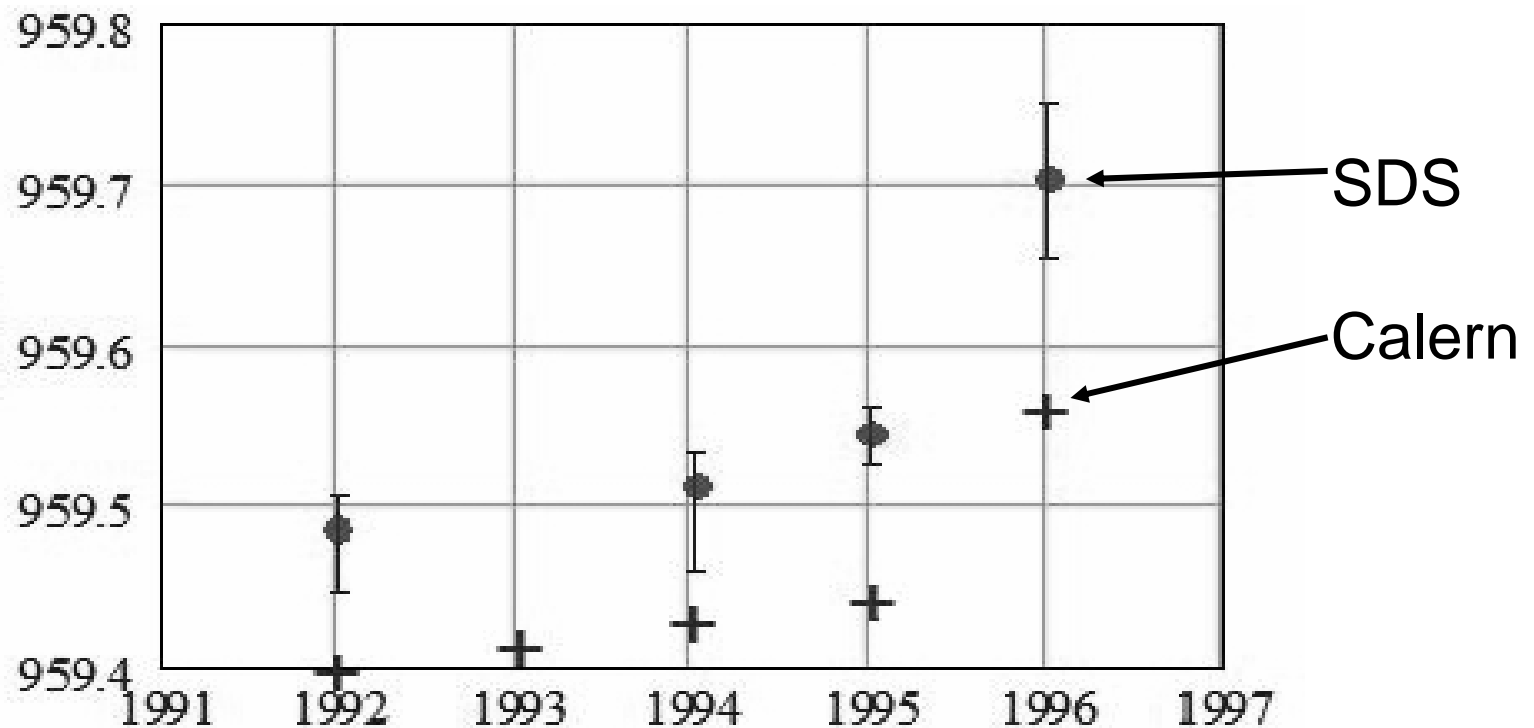
MDI has no internal means to check the instrument angular scale. Thermoelastic effects and ageing were carefully corrected by models. However, they can be questioned.

The **Solar Disk Sextant (SDS)** has measured the diameter variability with an instrument carried by a stratospheric balloon. An anti correlation is found with the solar activity, however only based on four flights.

SDS has an internal angular scale to check the instrument *psf* in flight.

DIAMETER VARIATION FROM STRATOSPHERIC BALLOON OBSERVATIONS

Sofia et al. (1994) have built the Solar Disk Sextant (SDS) including an [angular reference](#). Operated on board a stratospheric balloon, four flights were achieved.



Results of four stratospheric balloons flights carrying SDS (Egidi et al., 2006) showing a diameter increase of 0.2" while the solar activity decreases.

PICARD MISSION MAIN SCIENTIFIC OBJECTIVES

- (1) Modelling of the solar machine
using simultaneous measurements of several fundamental solar properties and their variability.

Role of the magnetic field, on surface or deeper in the convective zone. Origin of the solar activity?

This is an essential objective.

- (2) Contribution to solar luminosity reconstruction
- (3) Long term trend using the solar diameter referred to stars angular distances
- (4) Understanding of the ground based measurements
- (5) Contribution to Space Weather

A strong synergy with several other solar missions is anticipated.

PICARD MEASUREMENTS IN ORBIT

Images:

- Diameter, limb shape and asphericity in the continuum (535, 607, 782 nm).

Diameter (215 nm)

Precision: 3 mas per single image

Diameters are referred to stars angular distances

- Activity (215 nm, Ca II)

Spectral irradiance:

- Several solar spectral channels with redundancy observing the same wavelengths as above.

Two channels dedicated to ozone measurements

Total Solar Irradiance:

- 2 independent radiometers as on SoHO, and one bolometric channel

SORCE-TIM: 5 W/m²?

Solar oscillations (535 nm):

- on limb, macropixels and spectral channels

Variability: of the above quantities as a function of time

HELIOSEISMOLOGY MEASUREMENTS WITH PICARD

- Limb is measured every two minutes.
- Macropixels:

Macropixels were initially sampled each **two** minutes using a 32 X 32 binning.

There are now sampled **each** minute using a 8 X 8 binning allowing to reach $I = 256$

The telemetry increase has been approved by CNES.

PICARD CONTRIBUTION TO LONG TERMS VARIATIONS:

- *A critical information for solar physics (Maunder minimum?),*
- *Climate simulations also require predictions over some decades time frame.*
- Theoretical approach: In depth understanding of the mechanism of solar variability
- New experimental method: PICARD will measure the solar diameter with an instrument geometrically calibrated on angular distances of several stars doublets (9) with the accuracy of 1 mas.

Advantage: these measurements can be resumed within 10 or 20 years with the same source for calibration.

Condition: The diameter variation needs to be corrected for the stars proper motions. This can be done by using positions measured by Hipparcos (1991) and GAIA (2012). GAIA will allow to calibrate diameter measurement in the absolute scale.

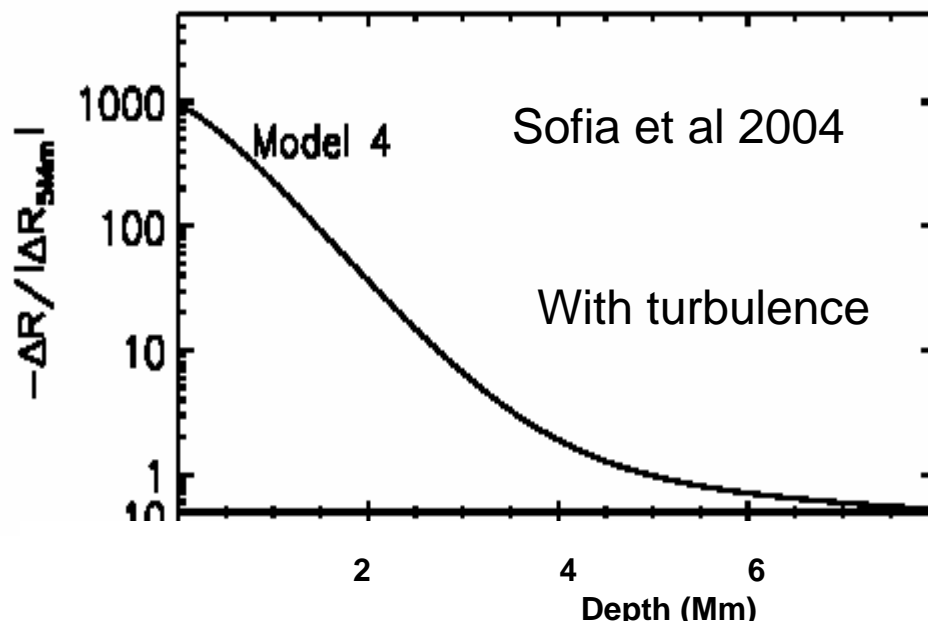
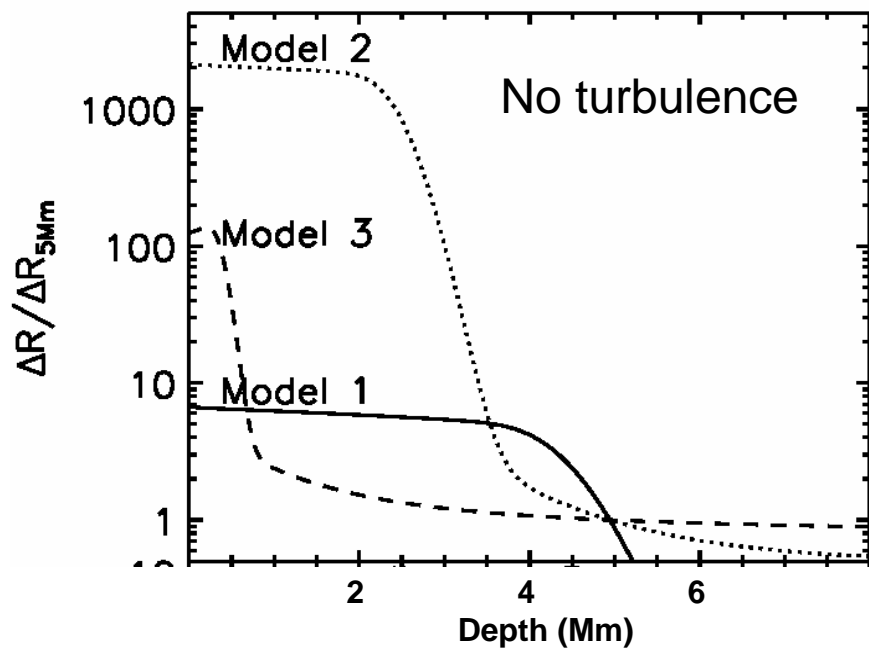
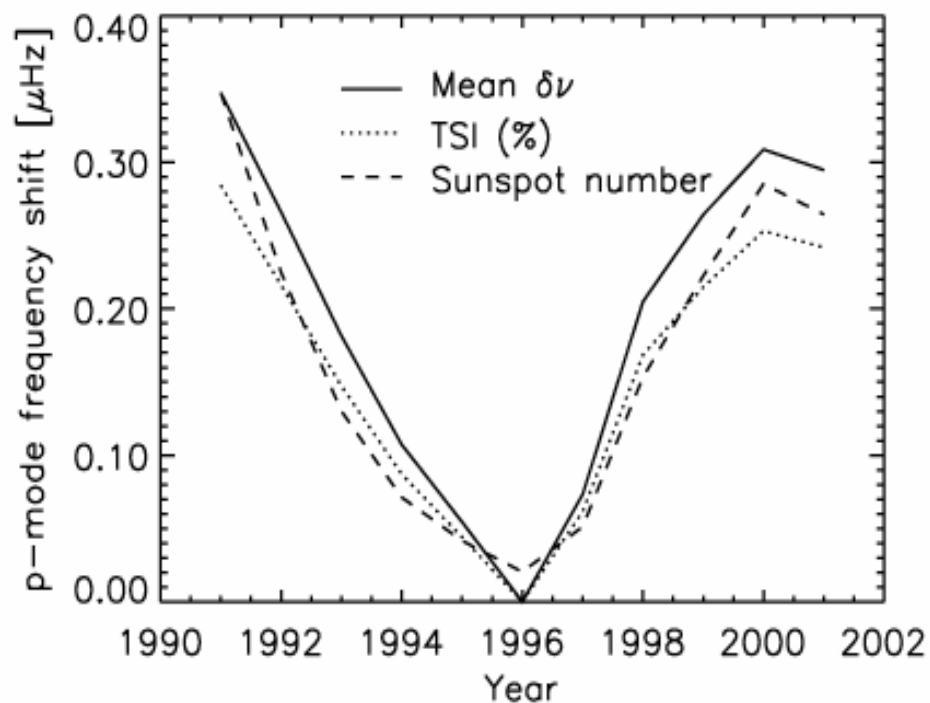
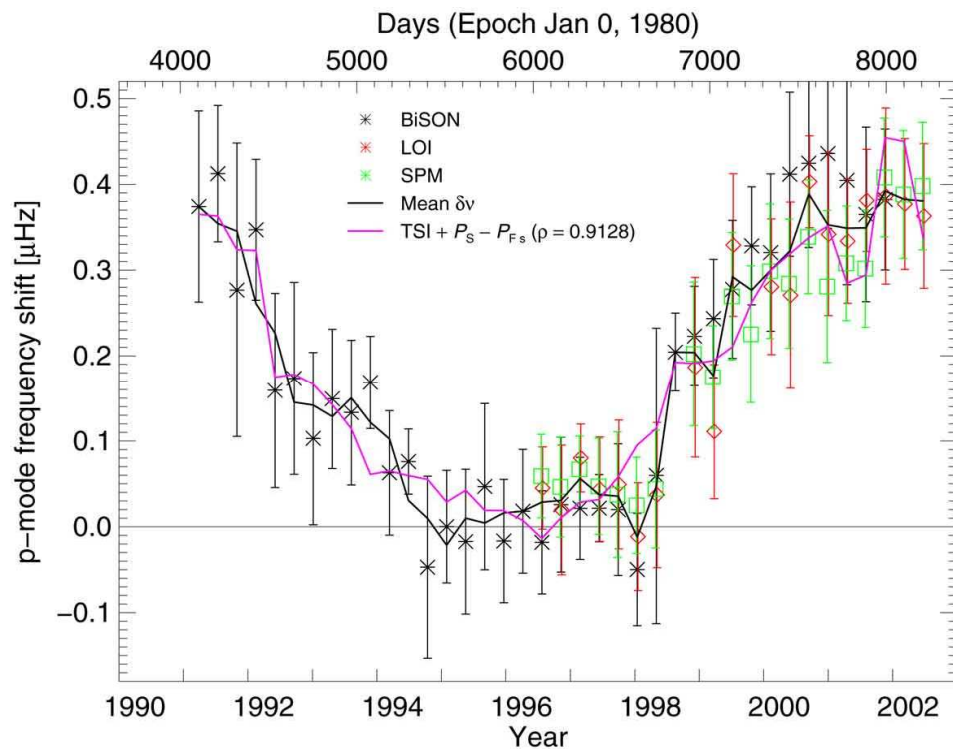
SOLAR MODELING WITH PICARD (1/3)

Limb shape and diameter measurements, and model predictions:

- Solar diameter as a function of wavelength
- Solar diameter with chromospheric lines contribution
- Limb shape as a function of wavelength

SOLAR MODELING WITH PICARD (2/3)

- Effect of solar variability on the diameter, on p-mode frequency, limb shape and TSI.
- Photospheric/seismic diameters: how do they compare?
- TSI, p-mode frequency and solar diameter variations: how these results are comparable to the theoretical modeling predictions (e. g. Sofia et al. 2005)



ATMOSPHERE AND CLIMATE MODELING WITH PICARD (3/3)

- Development of four different chemistry-Climate models to study the coupling of the stratosphere-troposphere by including the solar forcing:

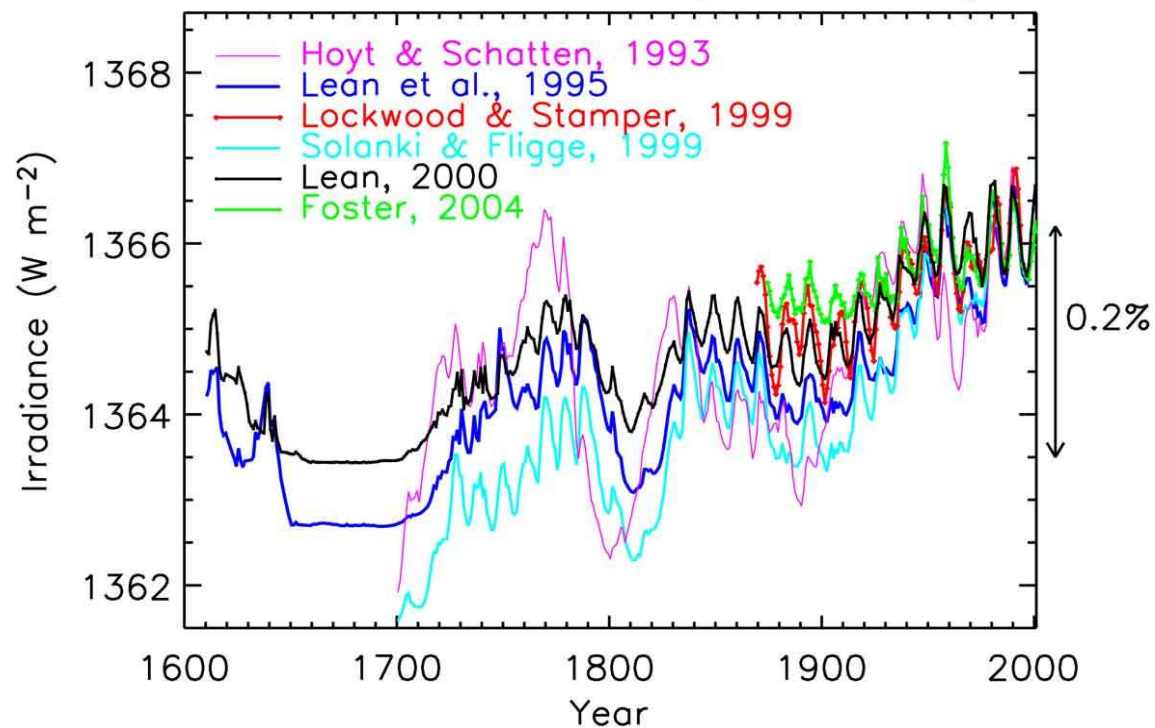
- *France: LMDz-REPROBUS (Service d'Aéronomie),*
- *Canada: CMAM (CSA, UofT, YorkU), IGCM-FASTOC (McGill)*
- *Switzerland: PMOD model.*

A collaborative approach to optimise efforts and increase the robustness of the results.

- Validation of the CNRS model to correct the effect of the atmospheric turbulence on images recorded by the ground compared with images from space obtained using the same instrument.

LUMINOSITY RECONSTRUCTION

Reconstructions are based on different hypothesis (stellar evolution,) and different data sets (sunspots, length of the cycle, cosmogenic concentration variations,). Reconstructions disagree at certain periods and disagreements increase towards the past.



If PICARD determines the diameter/luminosity relationship, the best historical diameter determination as provided by eclipses, will be used. Eclipse of 1715 presents an important opportunity.

INSTRUMENTS FOR THE PICARD MISSION

In orbit:

Two radiometers of different type allow to discriminate between variations of instrumental and of solar origin. PICARD uses the same configuration as SoHO with the instruments DIARAD (IRMB) and PMO6 (PMOD-Ch).

- **SOVAP**: radiometer and bolometer, PI: Dr S. Dewitte (IRMB)
- **PREMOS**: radiometer and 3 sunphotometers, PI: Dr. W. Schmutz (PMOD, CH)
- **SODISM** : metrological imaging telescope, SA(F)

Instruments design takes into account the heritage of instruments previously designed for these measurements.

On the ground:

At Plateau de Calern, **SODISM II** measures the solar diameter, and limb shape. **MISOLFA** measures the local turbulence.

A collaboration with the PSPT network and Observatoire de Meudon is foreseen.

SODISM DATA

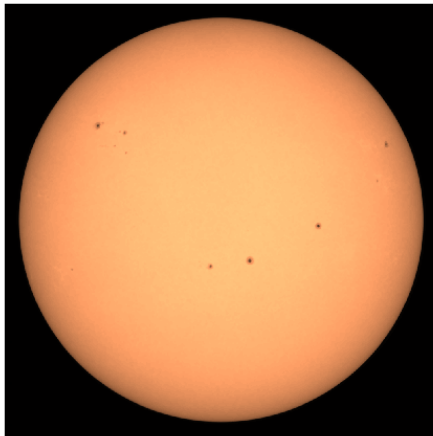
THREE TYPE OF IMAGE:

1) Helioseismology measurements:

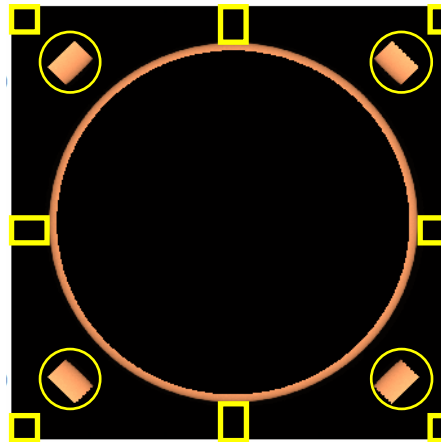
- Limbs 22 pixels width ($1/2M_N$ at $\lambda = 535$ nm)
- Macropixels (8 x 8) each minute

2) Full Images ($1/\text{orbit}/\lambda$; $\lambda = 215, 393, 535, 607, 782$ nm)

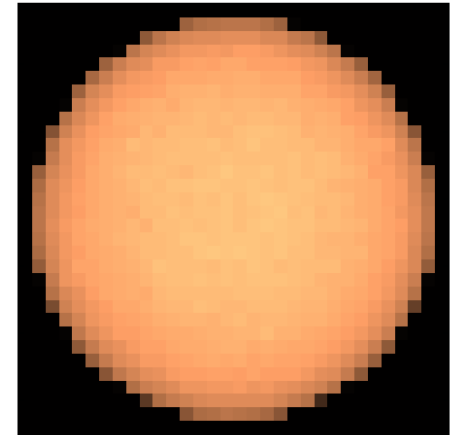
3) Diameter measurements: Limb 40 pixels width ($2/\text{orbite}/\lambda$)



Full Image



Limb and reference



Macropixel image

Other: Images DK & Flat Field ($1/d/\lambda$); monthly stars couple;
Instrument characterisation: internal scale, scattered light, DK

DATA PROCESSING

In Brussels a Center for PICARD data processing, named CMS-P will have the following functions:

- generate commands to carry out specific measurements (e. g. stellar observations, Flatfield, optical distorsion by spacecraft rotation....)
- process data up to level 2A allowing:
 - ❖ validation
 - ❖ preliminary scientific analysis

Level 2B will be produced by the participating institutes after corrections such as flatfield, optical distorsion, ageing, thermal corrections by model

SYNERGY WITH OTHER SOLAR MISSIONS

Solar Dynamics Observer (SDO): scheduled for the end of 2008

SORCE and/or its successor (GLORY?):

- TSI (5 W/m^2 ?)
- Solar spectrum from 12 to 2500 nm.

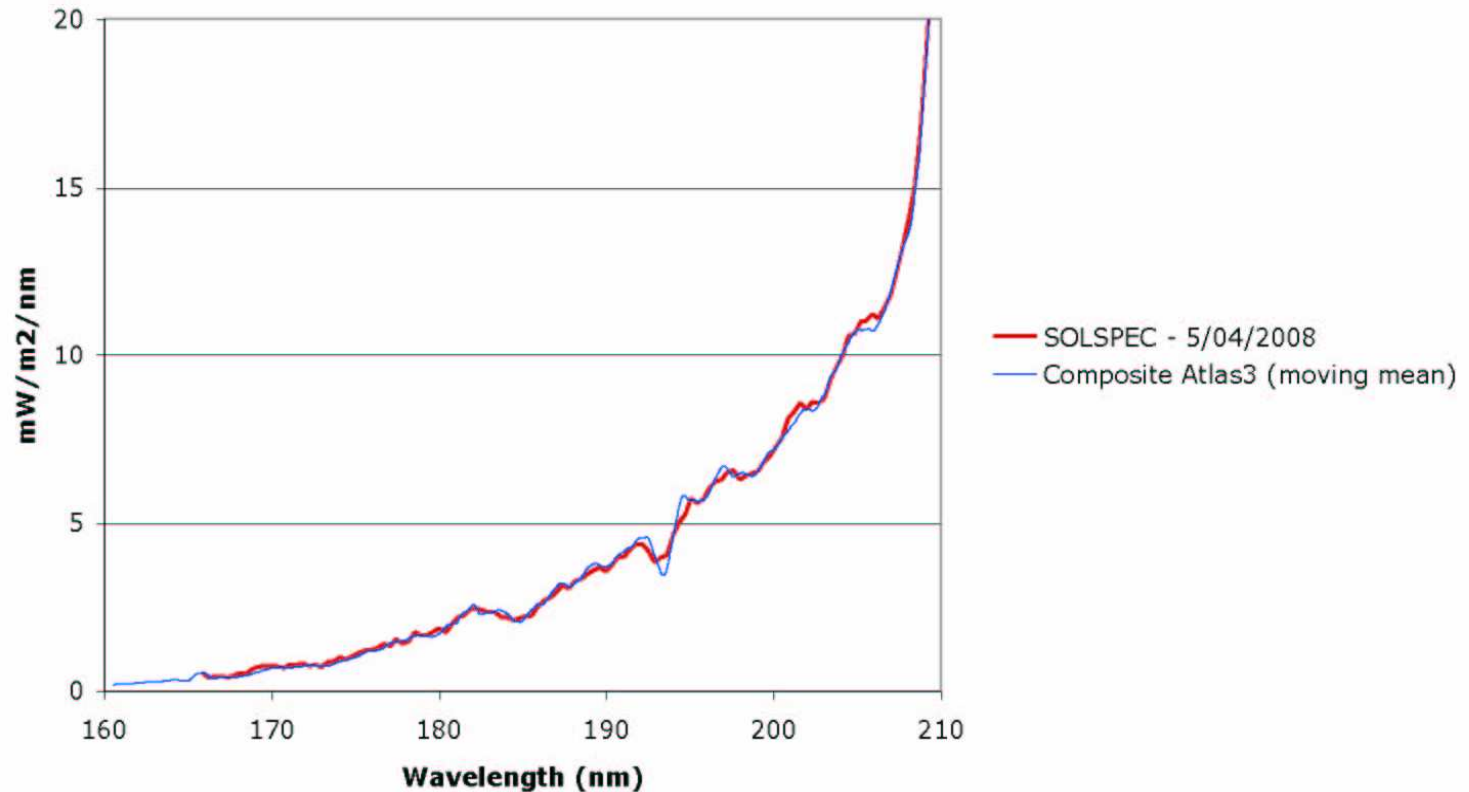
SOLAR on International Space Station, launched on 7 Feb. 2008:

- TSI (same instruments as on PICARD)
- Solar spectrum from 17 to 3000 nm. SOLSPEC measures from 165 to 3000 nm. Pointer and instruments are still in commissioning phase.

PROBA: to be launched by end of 2008.

PRELIMINARY RESULTS : UV SPECTRUM

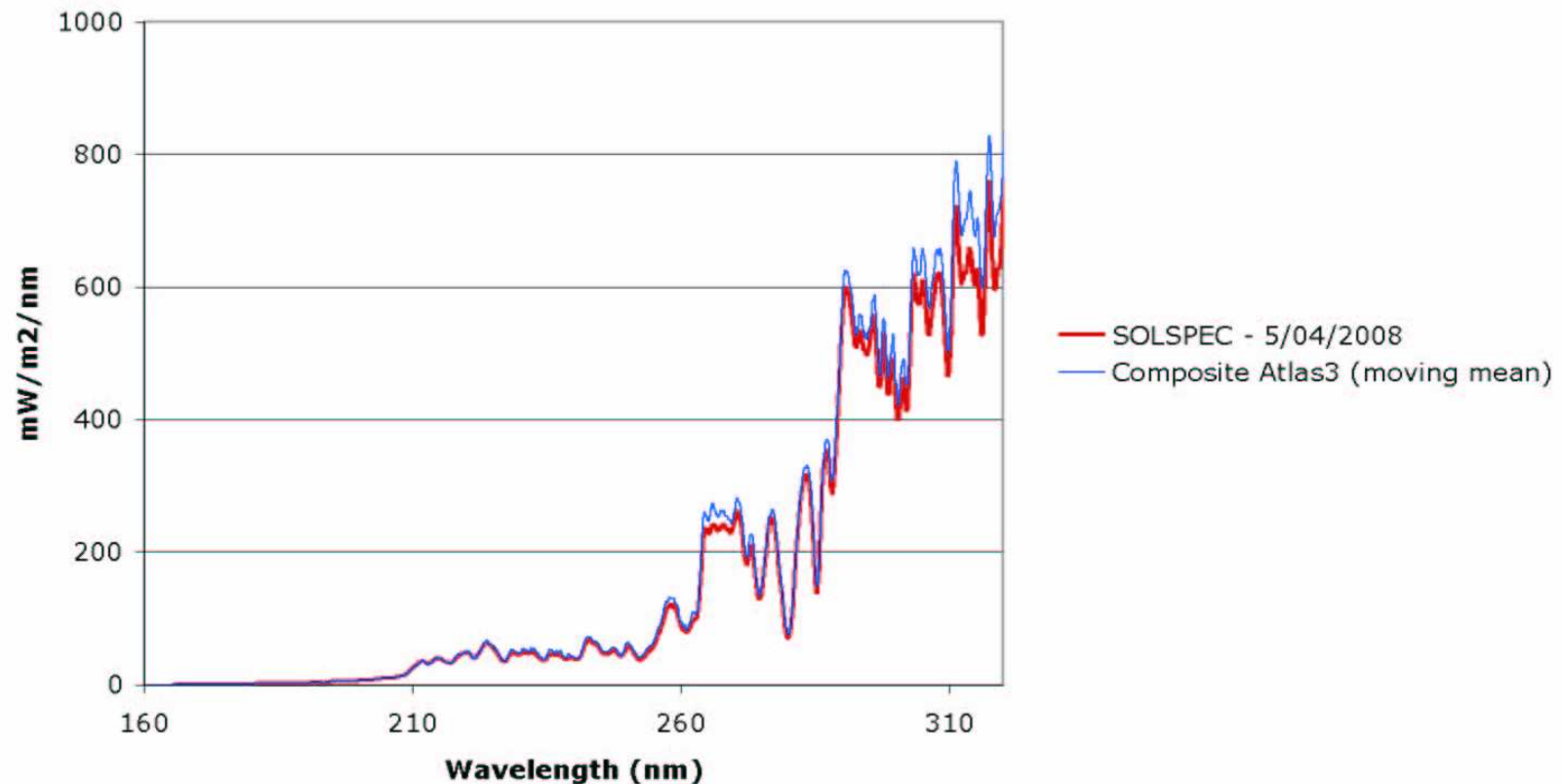
SOLSPEC - Solar Measurements Comparison



The first solar observation took place on 5 April 2008 with a pointer in commissioning phase. Data are shown without taking into account pointing and internal lamp data.

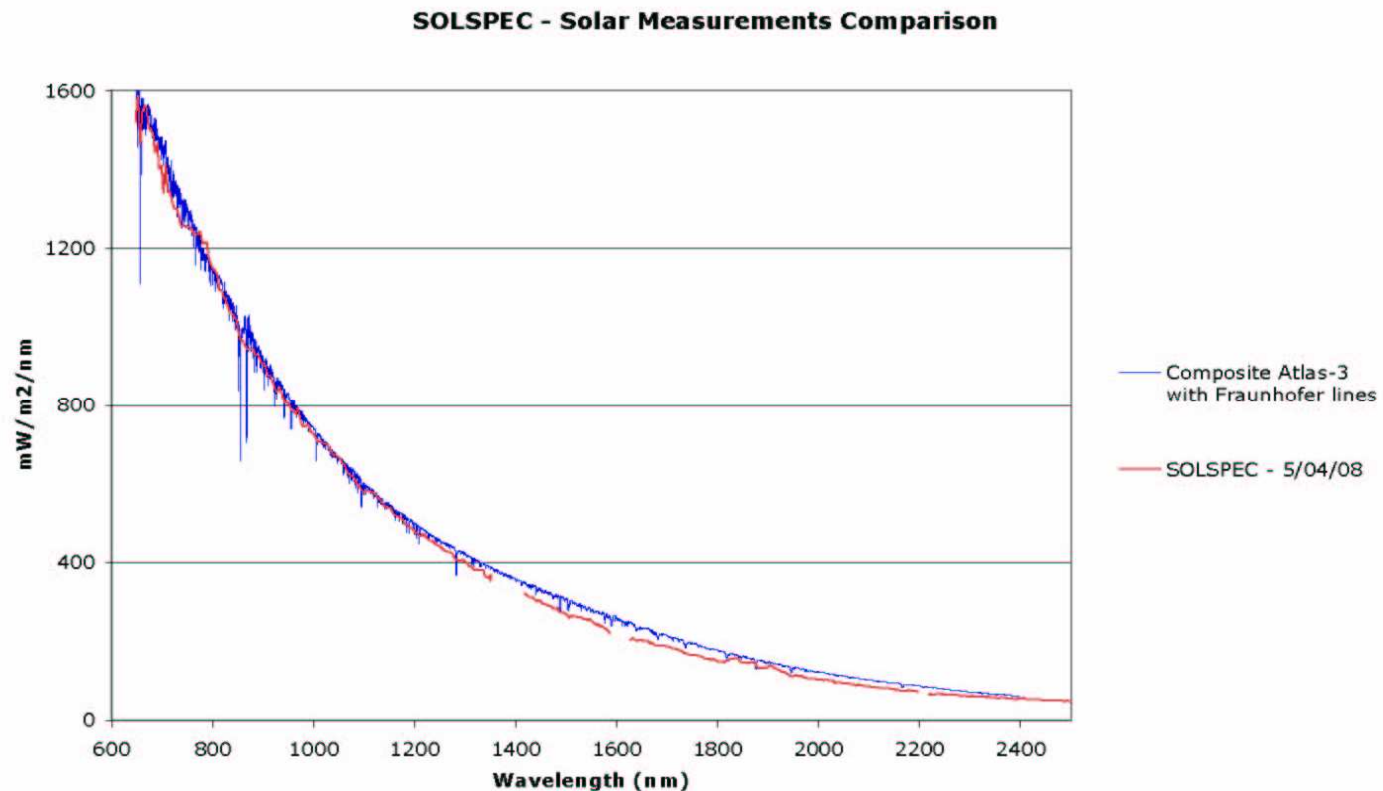
PRELIMINARY RESULTS : UV SPECTRUM

SOLSPEC - Solar Measurements (5/04/2008)



The first solar observation took place on 5 April 2008 with a pointer in commissioning phase. Data are shown without taking into account pointing and internal lamp data.

PRELIMINARY RESULTS : IR SPECTRUM



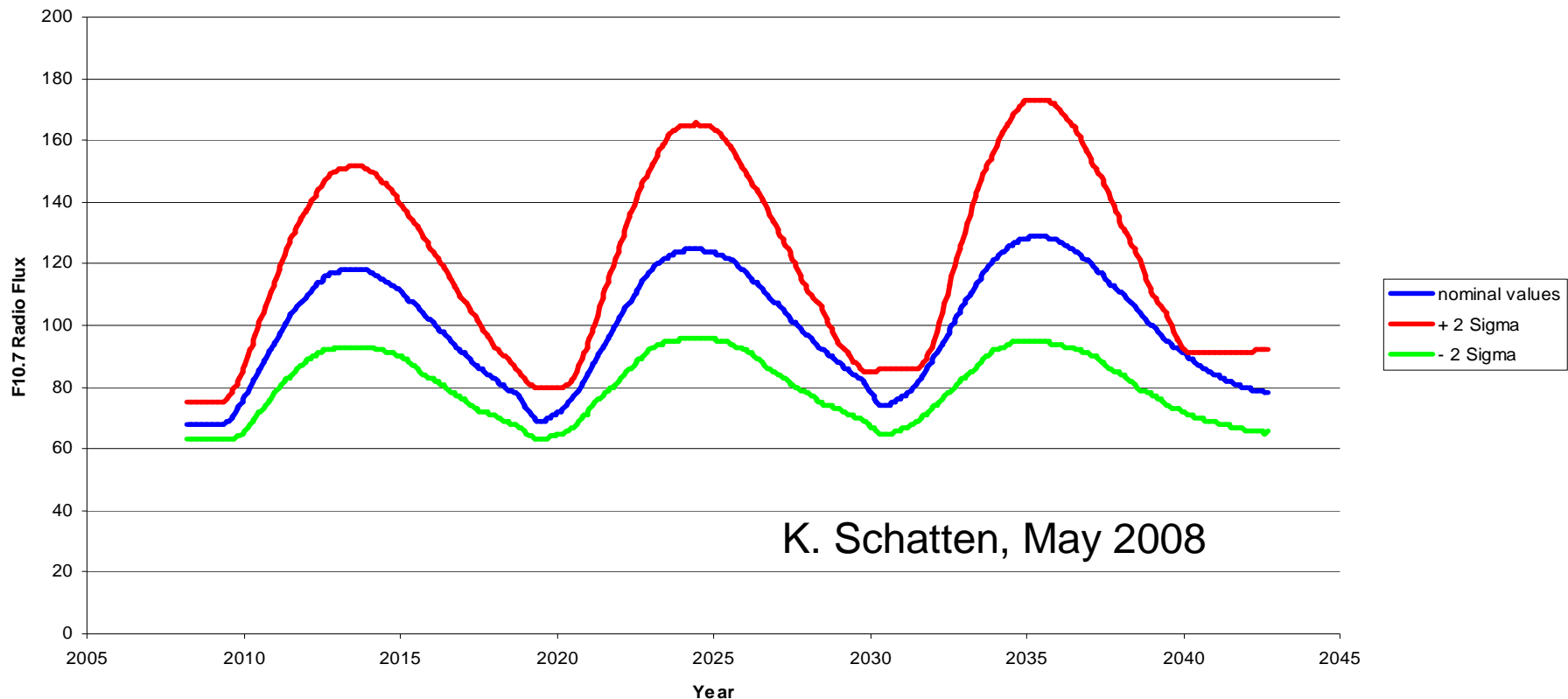
The first solar observation took place on 5 April 2008 with a pointer in commissioning phase. Data are shown without taking into account pointing and internal lamp data.

LAUNCH DATE and PREDICTIONS

Greater solar variability is expected during the ascending phase of the solar cycle than during the descending phase.

PICARD took advantage of a late start of cycle 24. A launch by May/June 2009 will provide appropriate variability for the measurements.

Nominal, Plus and Minus 2 Sigma March 08 forecast



CONCLUSION

PICARD is centred on a key question, which is the origin of the solar activity.

Data will be used for modeling the solar machine.

Climate modeling is part of the PICARD program.

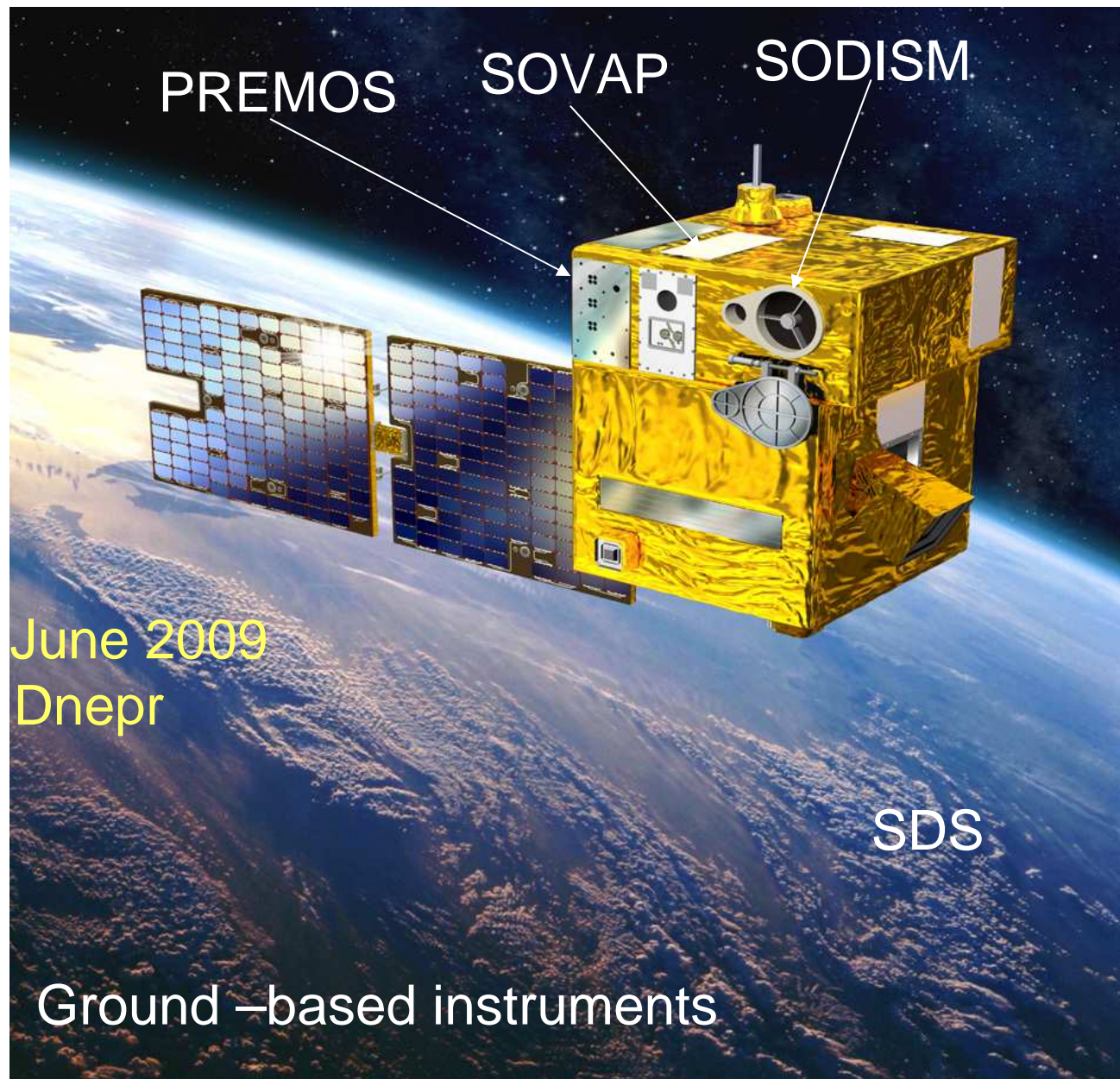
Given the today solar activity predictions, the launch must be achieved no later than **June 2009**.

Furthermore, synergy with other solar missions also requires no further delay

The schedule for instruments development is tight. Presently, testings and optical checks are made on the FU in CNES Toulouse.

Data processing and mission center design are on time.

Ground based instruments are on time.

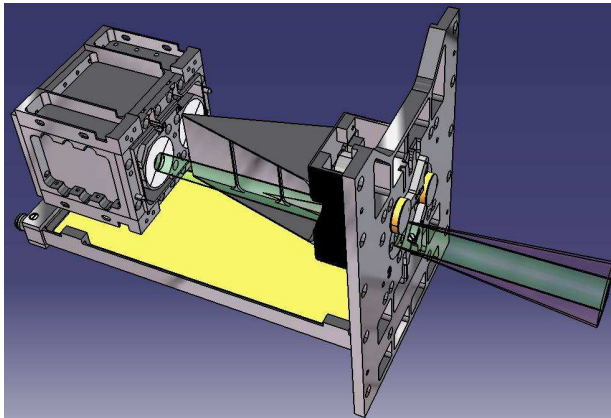
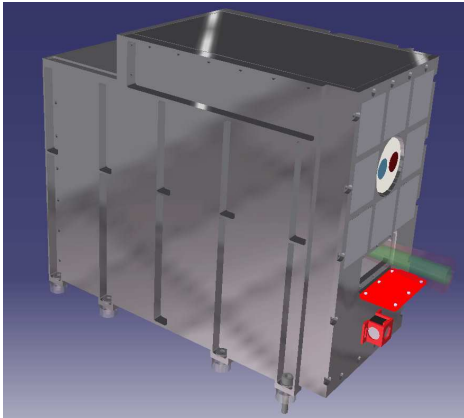


Launch: June 2009
Launcher: Dnepr

Ground-based instruments

Institutes providing instruments: CNRS, RMIB, PMOD-WRC, OCA
<http://smc.cnes.fr/PICARD/Fr/>

The SOVAP radiometer



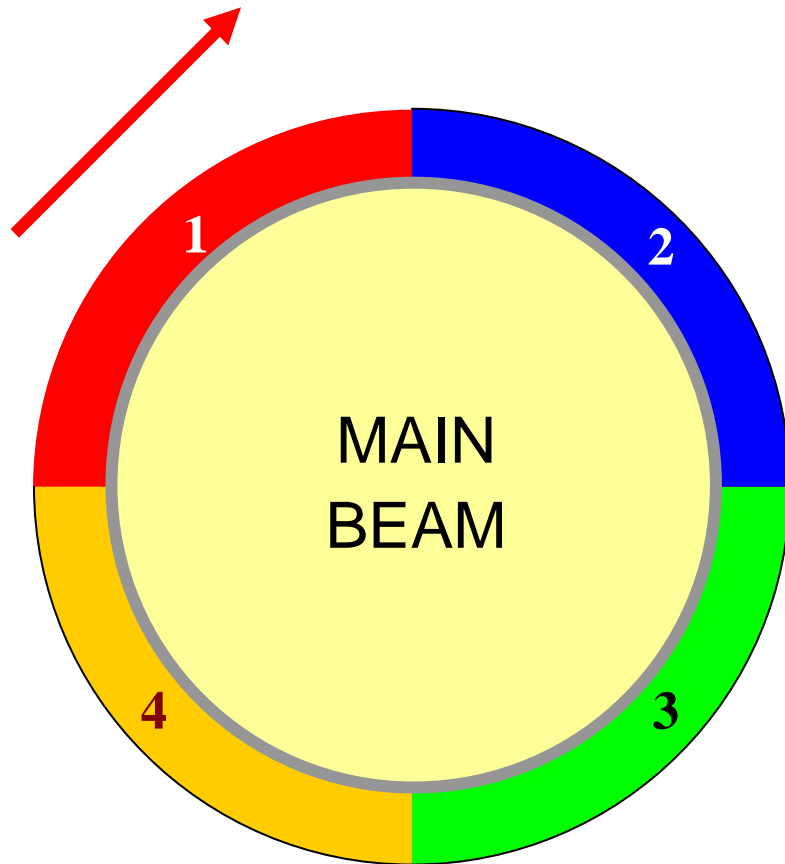
- Absolute Total Solar Irradiance radiometer
 - Sampling period: 3 minutes
 - Accuracy: 1 W/m²
 - Stability: +/- 0.1 W/m²
- Bolometric Oscillation Sensor
 - Sampling period: 10 seconds
 - Noise level: 0.01 W/m²

PI: Dr. S. Dewitte

MAIN IMAGE - AUXILIARY IMAGES

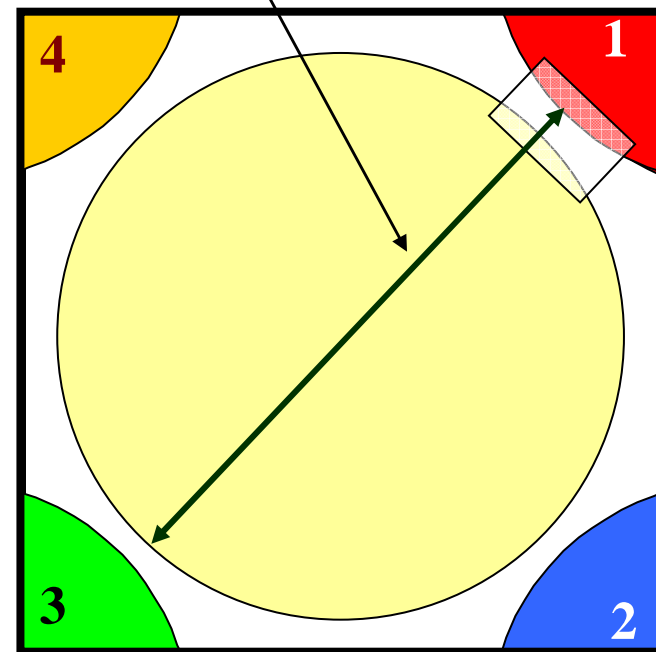


Prism dispersion

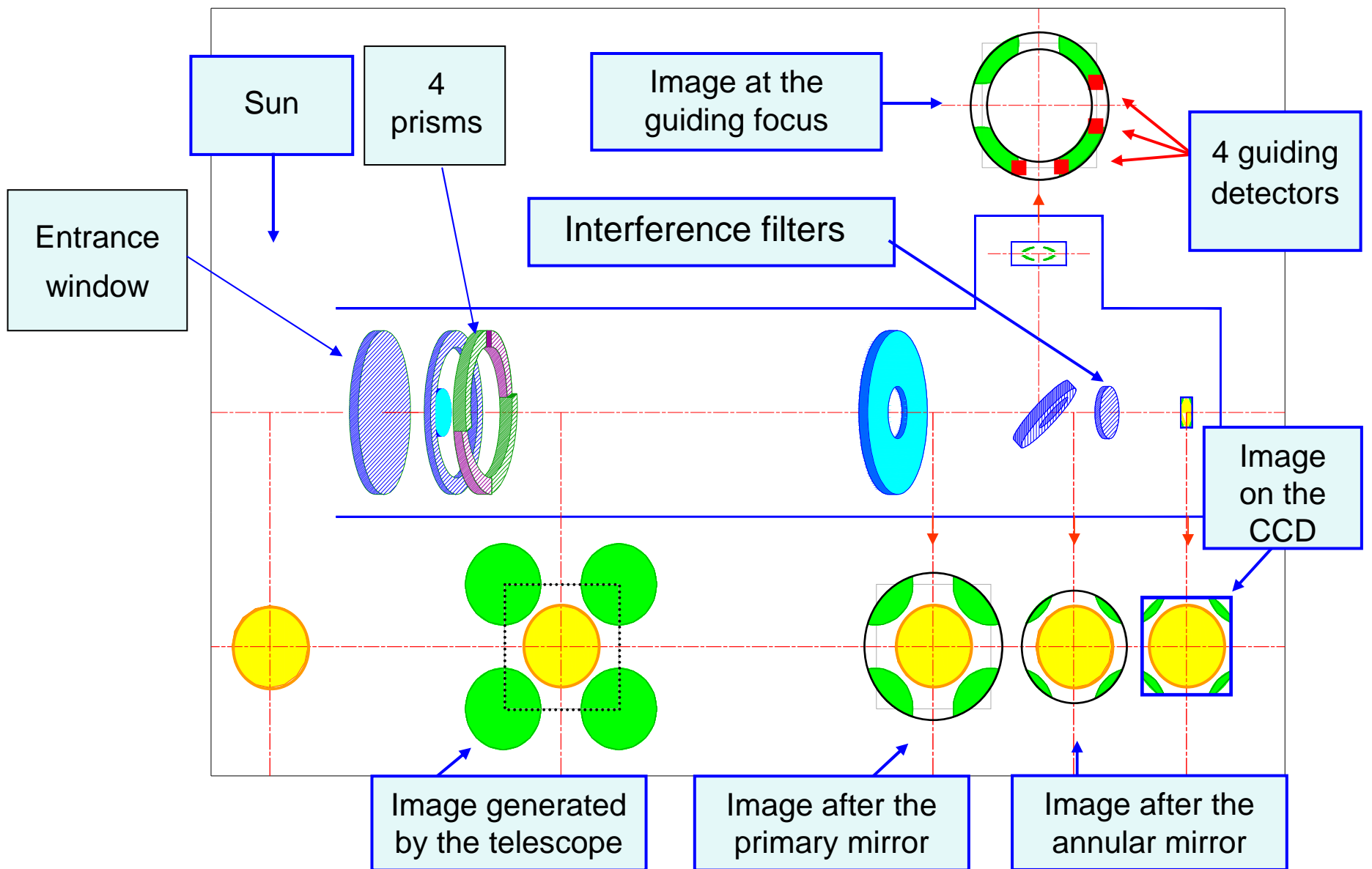


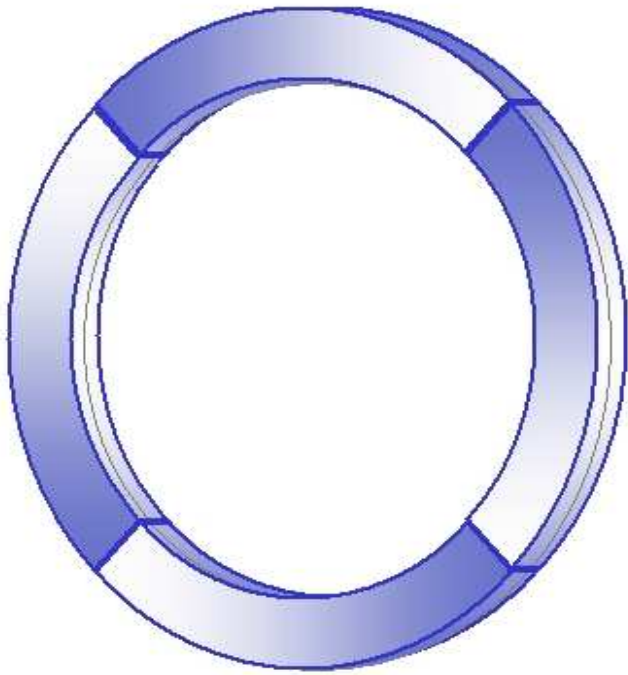
PUPIL PLANE

calibration distance

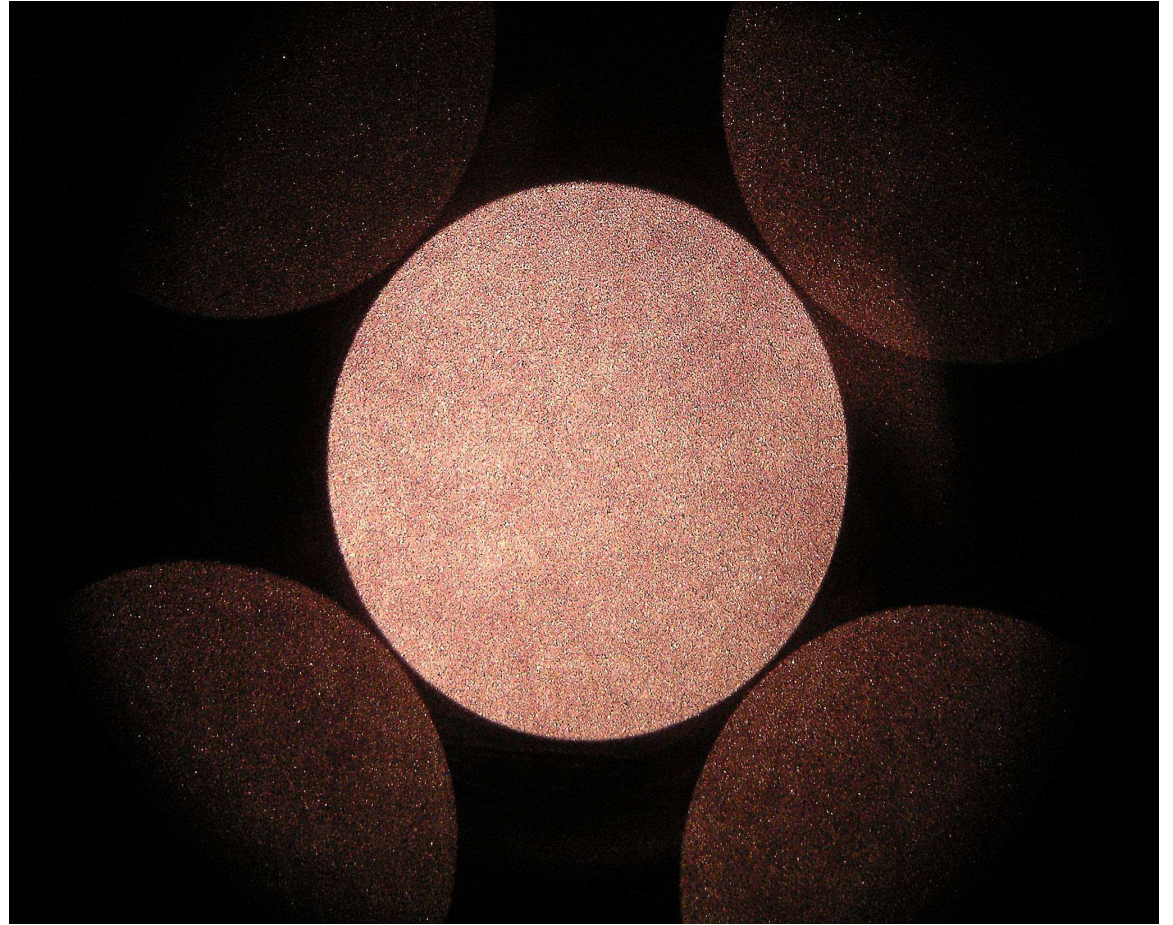


CCD PLANE



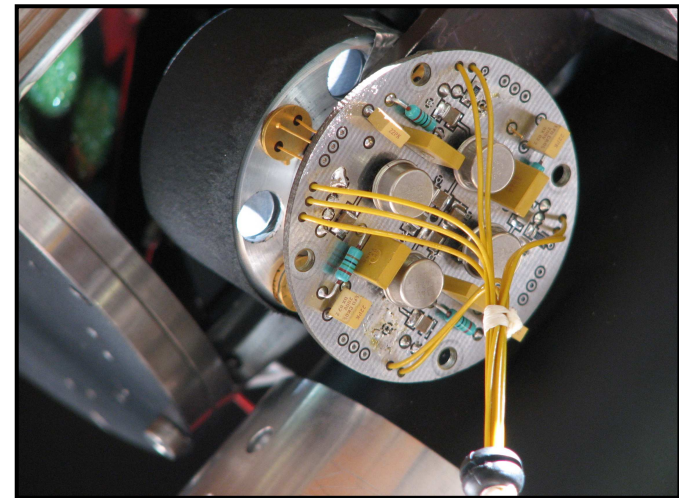
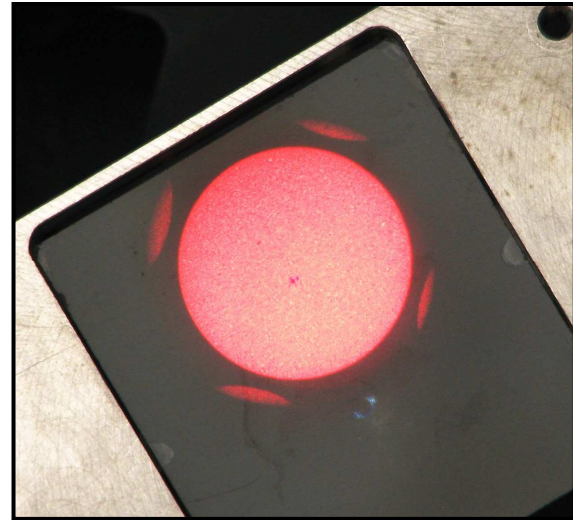
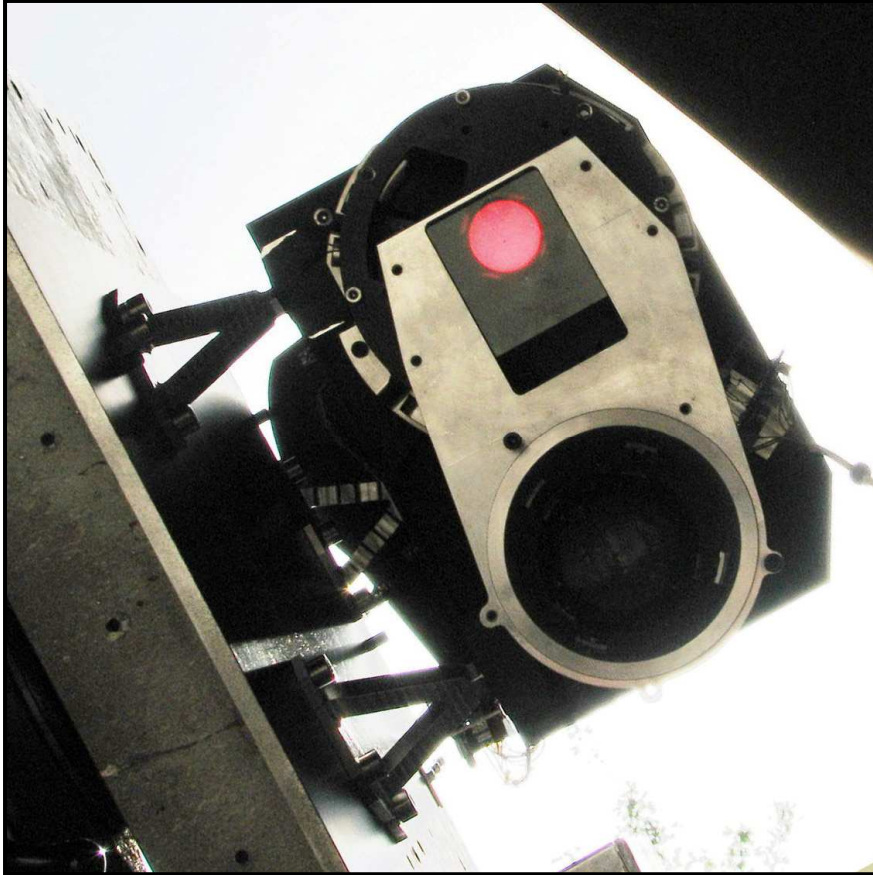


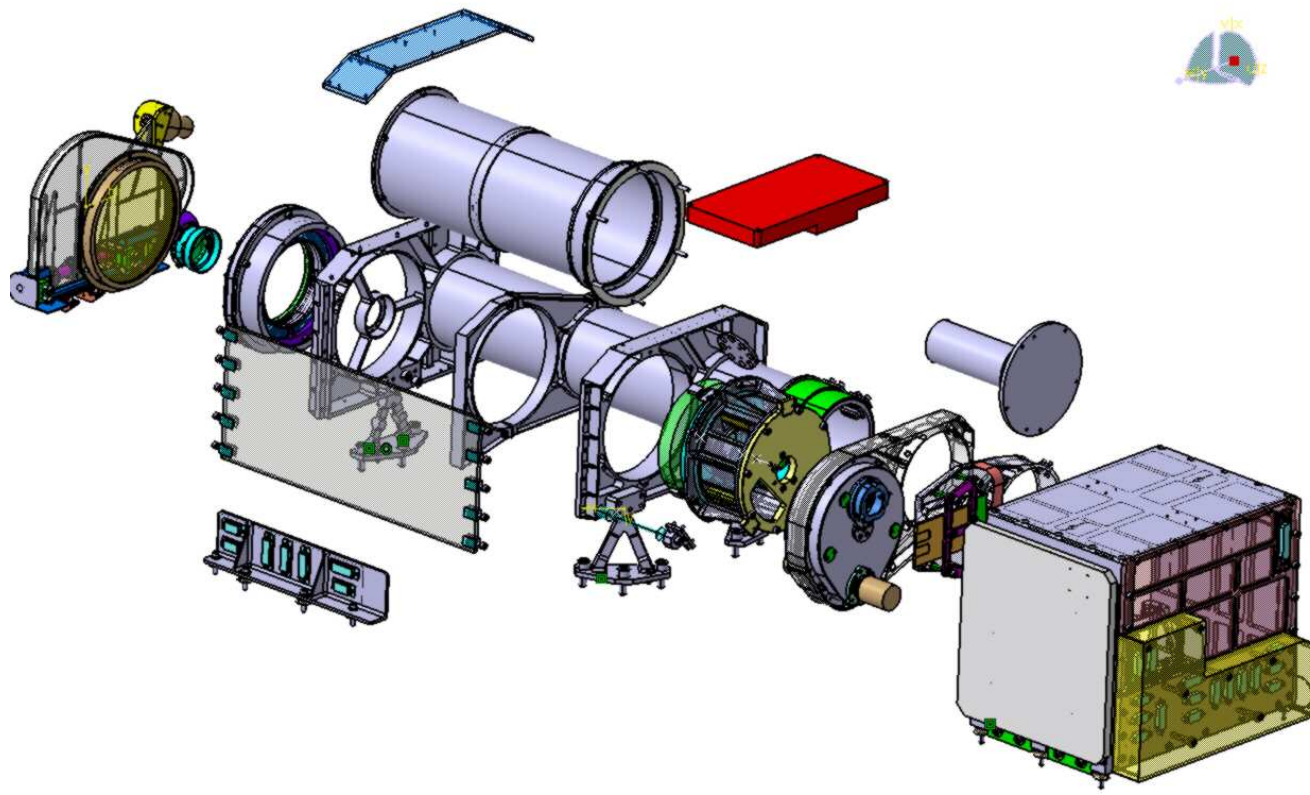
The 4-prism system



Images in the focal plane

TELESCOPE LOOKING TO THE SUN

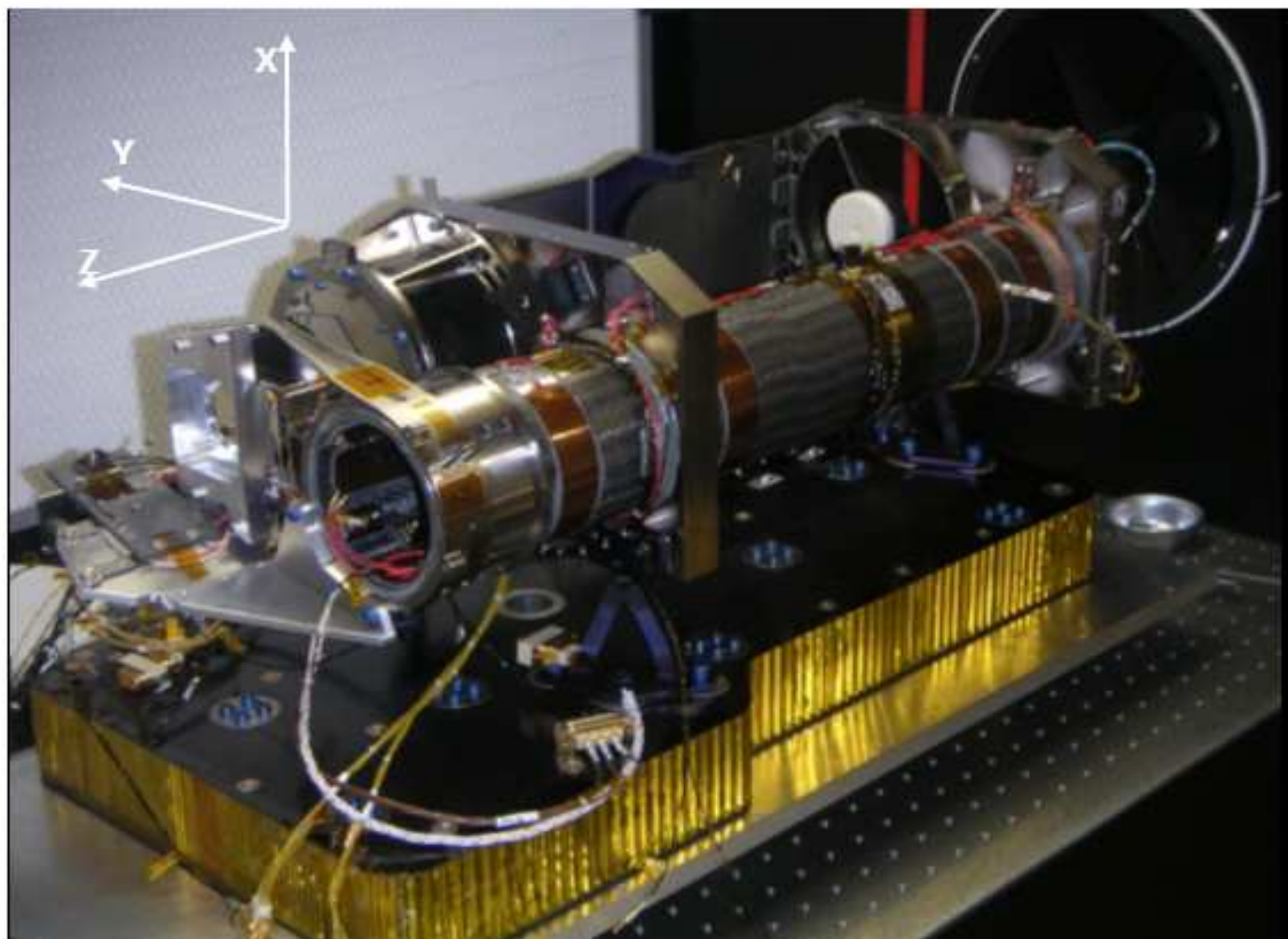


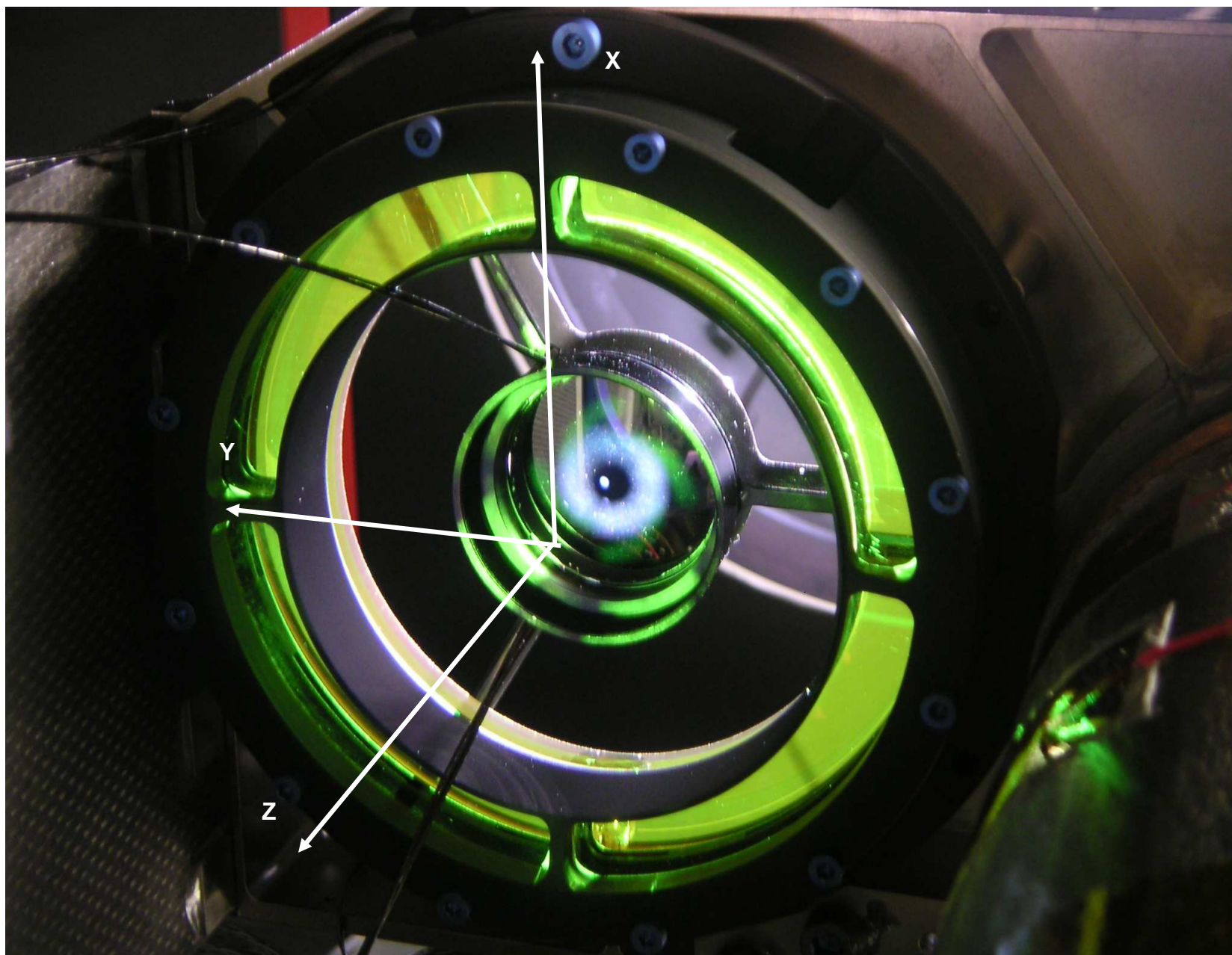


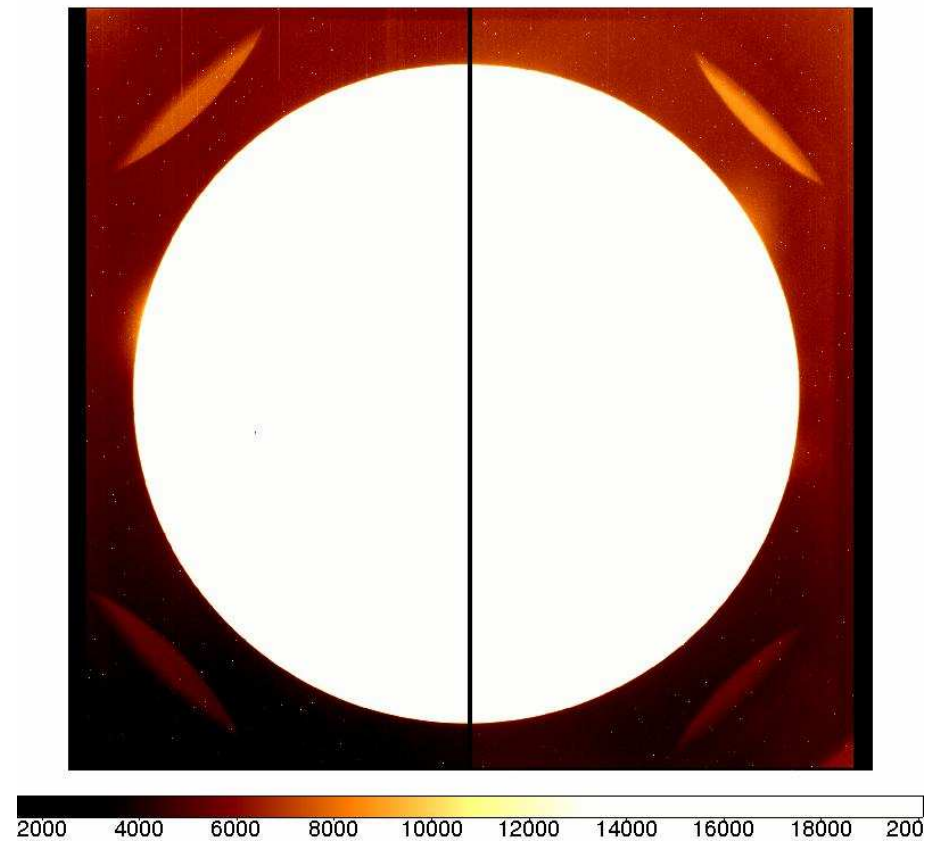
SODISM imaging telescope

Solar diameter : 3 mas per image

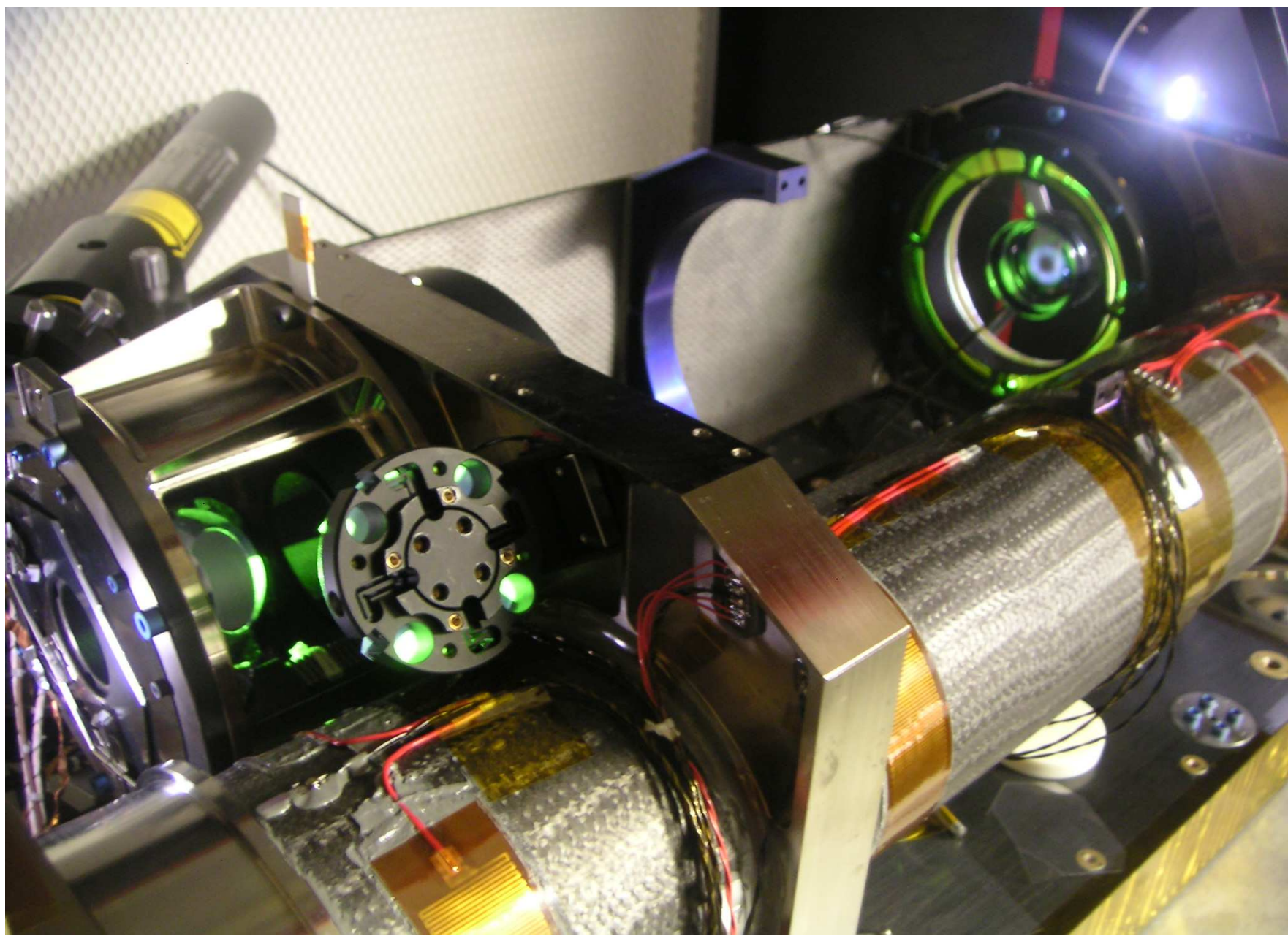
Oblatness: 1 mas





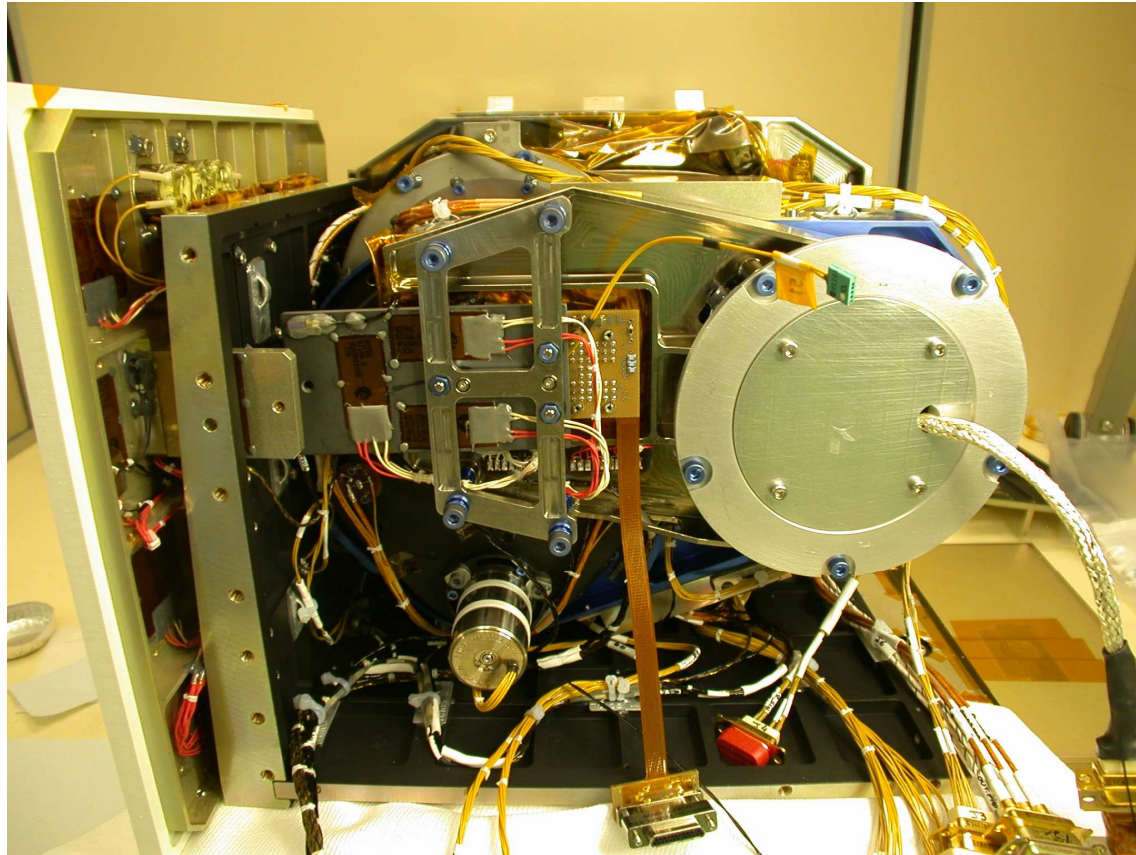


mv





FLIGHT UNIT: Front view



FLIGHT UNIT: Rear view







