CENTRE NATIONAL D'ÉTUDES SPATIALES

The PICARD mission

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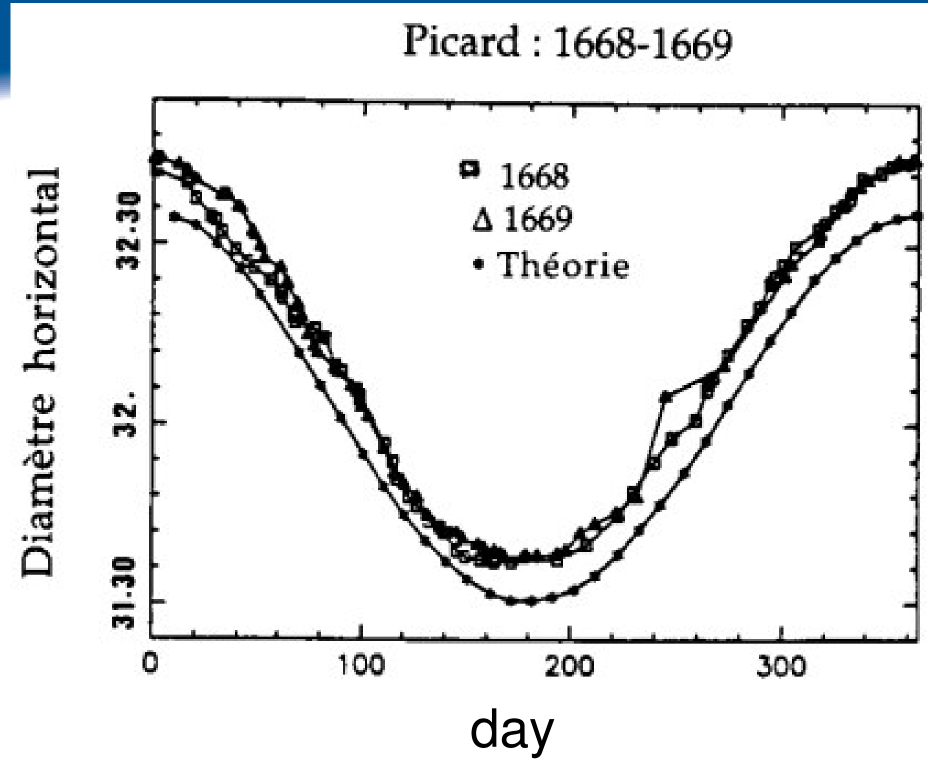
Presentation Outline

- An Historical Enigma
- The Scientific Objectives of the PICARD Mission
- The Instruments
- Mission Overview
- Accompanying Ground Activities
- Conclusion

THE PICARD MISSION GENESIS

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



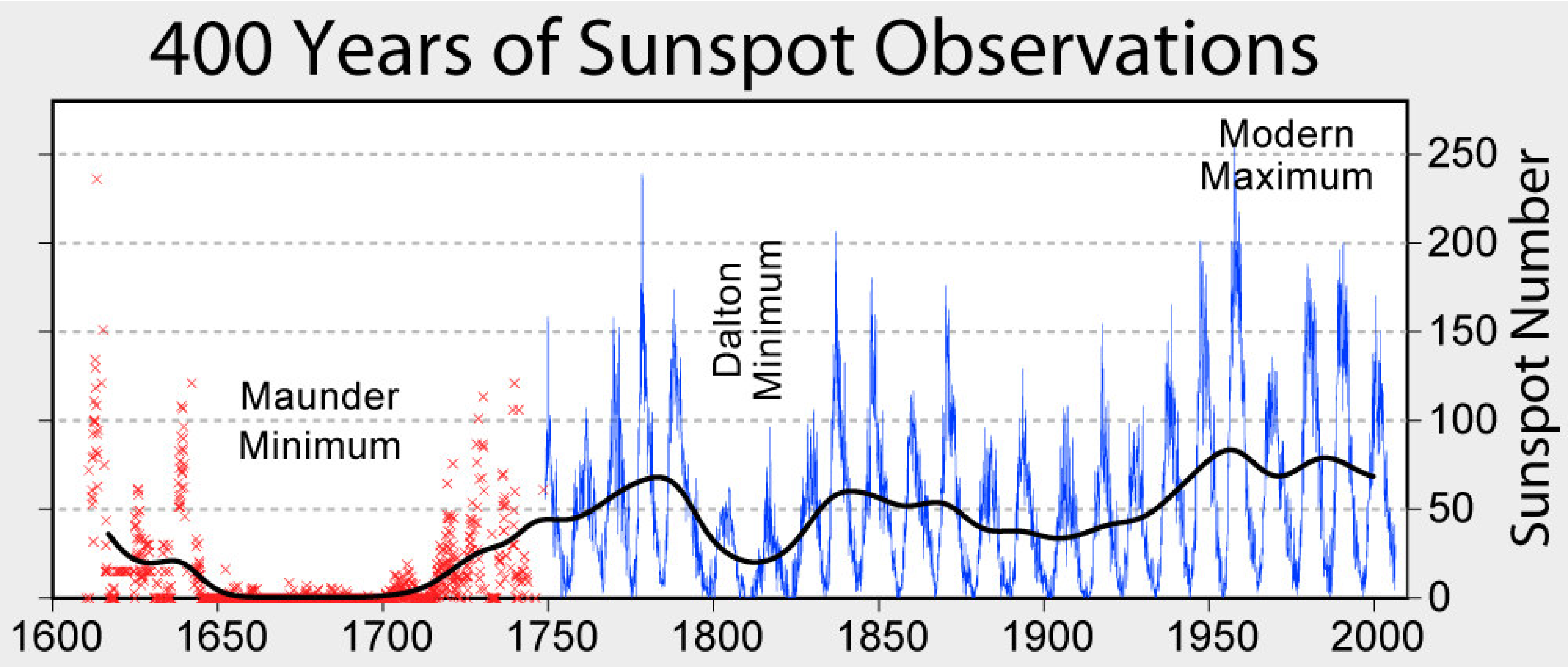
• Old data (and instrument) have been retrieved and analyzed (E.Ribes-1987)

• After normalization to 1 AU, it appears that the Sun was slightly larger than today!

• These measurements were made during the Maunder minimum, for which the TSI (Total Solar Irradiance) was likely lower than today (no sunspot has been observed from 1650 to 1715).

• Is there any (anti) correlation between diameter and luminosity ?

THE MAUNDER MINIMUM



1609 First systematic observations of the sunspots by Christopher Scheiner

The Little ICE AGE of the XVIIth Century

Had the Sun a weaker activity than today?

There are several clues:

- While technology of telescope was improving, the number of reported sunspots decreased

- Aurora were unfrequent,

-During solar eclipses, the corona is usualy easily observed nowadays. The first report of the corona presence is for the 1715 eclipse,

- Cosmogenic abundance is inversely correlated with solar activity. 10Be and 14C show a weak activity in this period,

Key Parameters of the Sun

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

Solar variability is as its maximum during the ascending phase of the solar cycle, which is expected from 2010 to 2013 for the coming cycle 24

Why Measure the Solar Diameter ?

The Sun is a variable star :

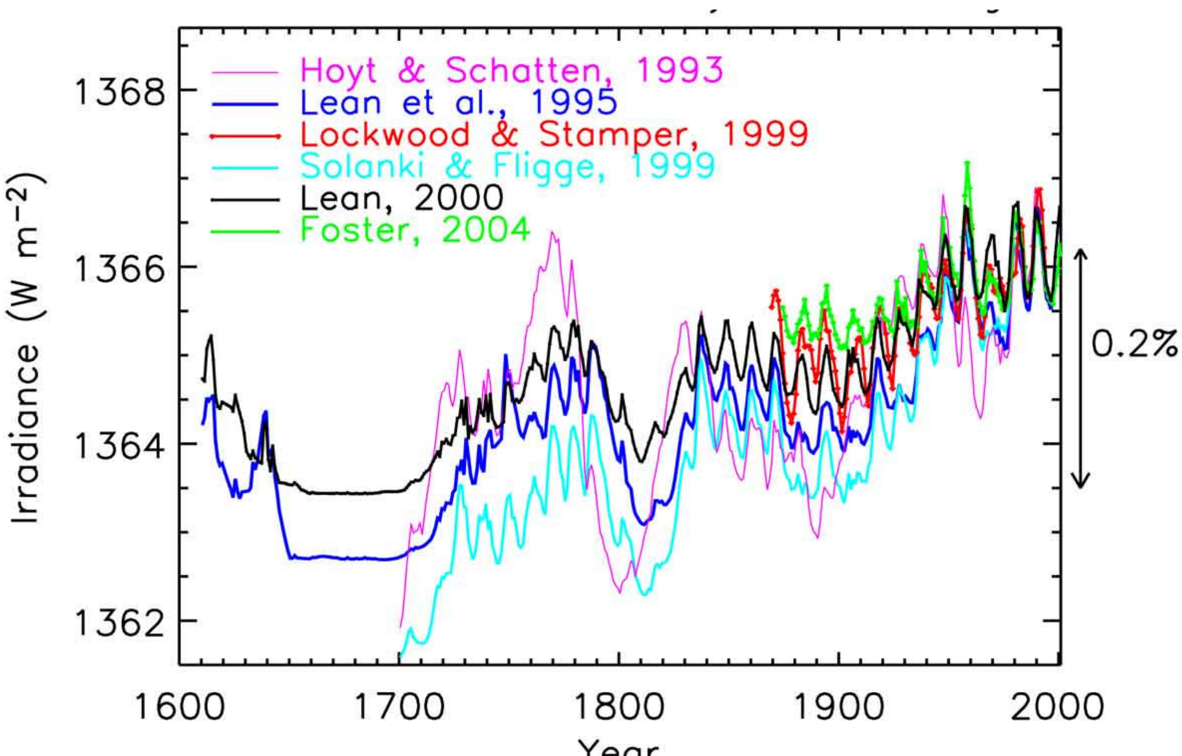
A change in its diameter would suggest a change in its internal features likely in the convective zone (magnetic field, differential rotation, convection and turbulence of the plasma)

After PICARD has established a relationship between Diameter and TSI (« solar constant »), ground telescopes, airborne instruments or observation during eclipses will contribute to

- the reconstruction of the past solar activity
- the long term monitoring of the solar variabilty

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 increasingly towards the past.



After PICARD has allowed to determine the diameter/luminosity relationship, the best historical diameter determination as provided by eclipses, will be used, in particular the eclipse of 1715 rigorously observed by Edmond Halley.

Climatology of the Sun and of the Earth

Solar activity prediction present capability: a few year

Analyzing observations from the past is essential for improving Sun models and Earth climatology models

Given the GHG (Greenhouse Gas) increase, climate predictions are required over some decades time frame.

The assessment of the relative importance of the solar forcing is a key issue when considering global change

Considering solar variability as an input for climate modelling is gaining ground

Scientific Objectives for PICARD

• Determine the variability of several global solar properties. In particular, whether the solar diameter varies or not with solar activity

=> Test of hypothesis

• Contribute to the modelling of the solar machine and in particular about the role of the magnetic field (on surface or deeper in the convective zone)

=> Solar models

• Contribute to solar luminosity reconstruction

=> Earth climate models

• Provide reference data for long term observations of the solar variability

=> Stellar model of the Sun

• The space mission (2 to 3 years) will be used to validate ground observations. This will allow to pursue solar diameter metrology in the future

=> Solar monitoring

Measurements

in orbit (3 instruments) :

- Diameter, limb shape and asphericity in the continuum
- 5 spectral channels (215,393, 535, 607, 782 nm)
- Activity (images at 215 nm and Ca II)=> space weather
- Solar oscillations
- TSI (x2)
- UV Irradiance in 3 channels

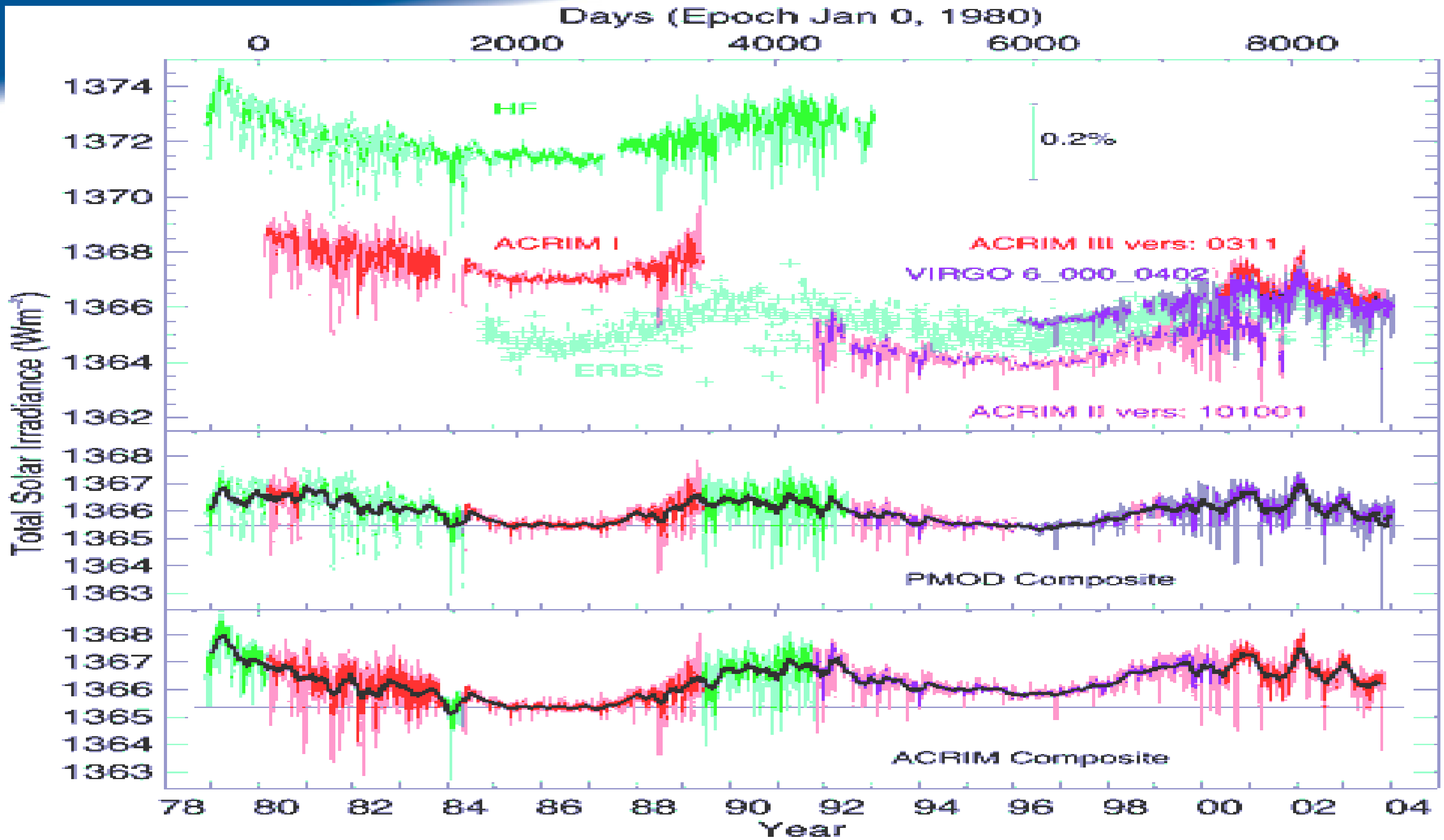
from balloons :

- diameter, limb shape and asphericity,

from the ground :

- diameter, limb shape and asphericity,
- local atmosphere turbulence

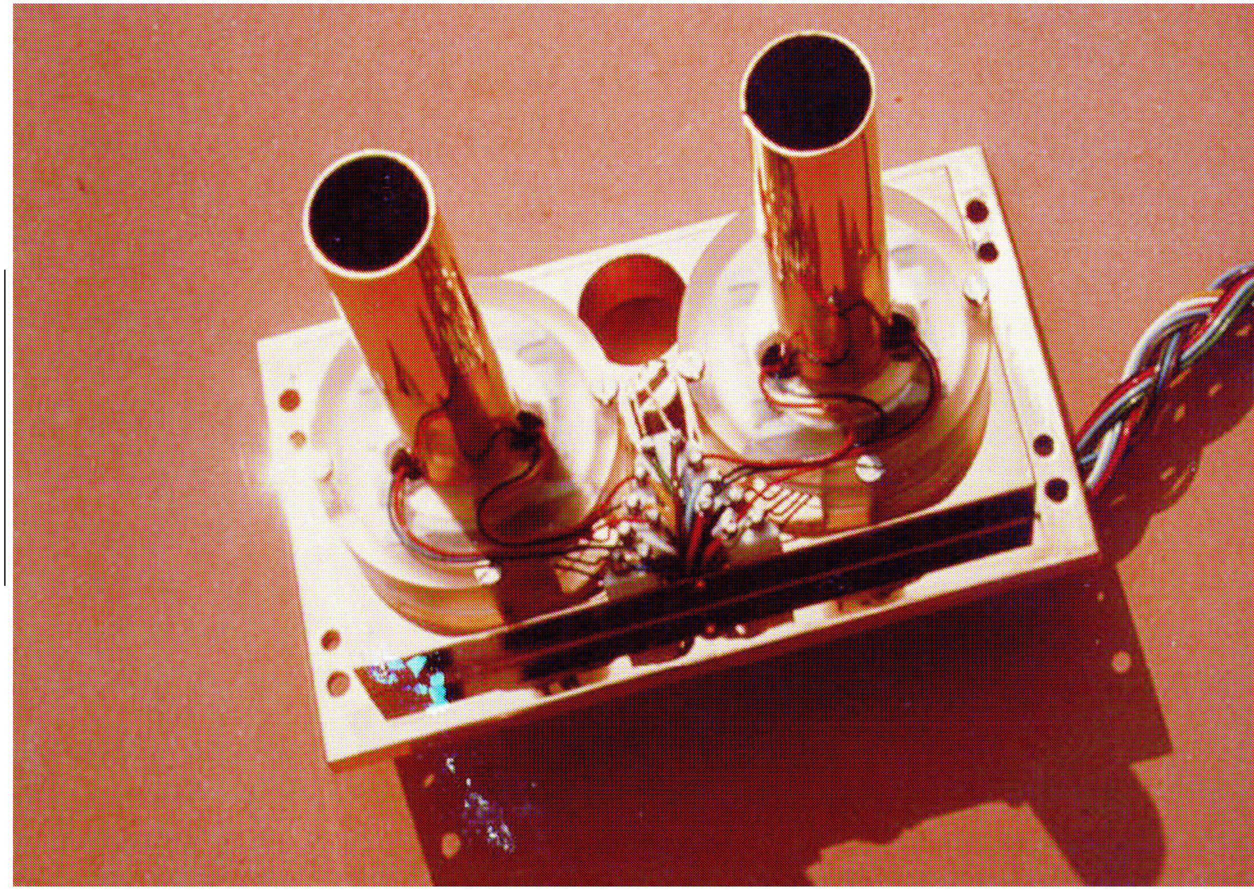
TSI Reconstruction Problem



- The reasons for the discrepancy are twofold:
  - insufficient period of overlap
  - difficulties for assessing the instrument ageing (sensitivity changes)

- There will be two absolute radiometers onboard PICARD

SOVAP (IRM)



SOVAP radiometer measurements:

- Sampling period = 3 minutes
- Absolute accuracy of 500 ppm (0.7 W/m2)
- Long term repeatability of 70 ppm (0.1 W/m^2)

Bolometric Oscillation Sensor (BOS):

- Sampling period = 10 s (true average)
- Noise level = 10 ppm

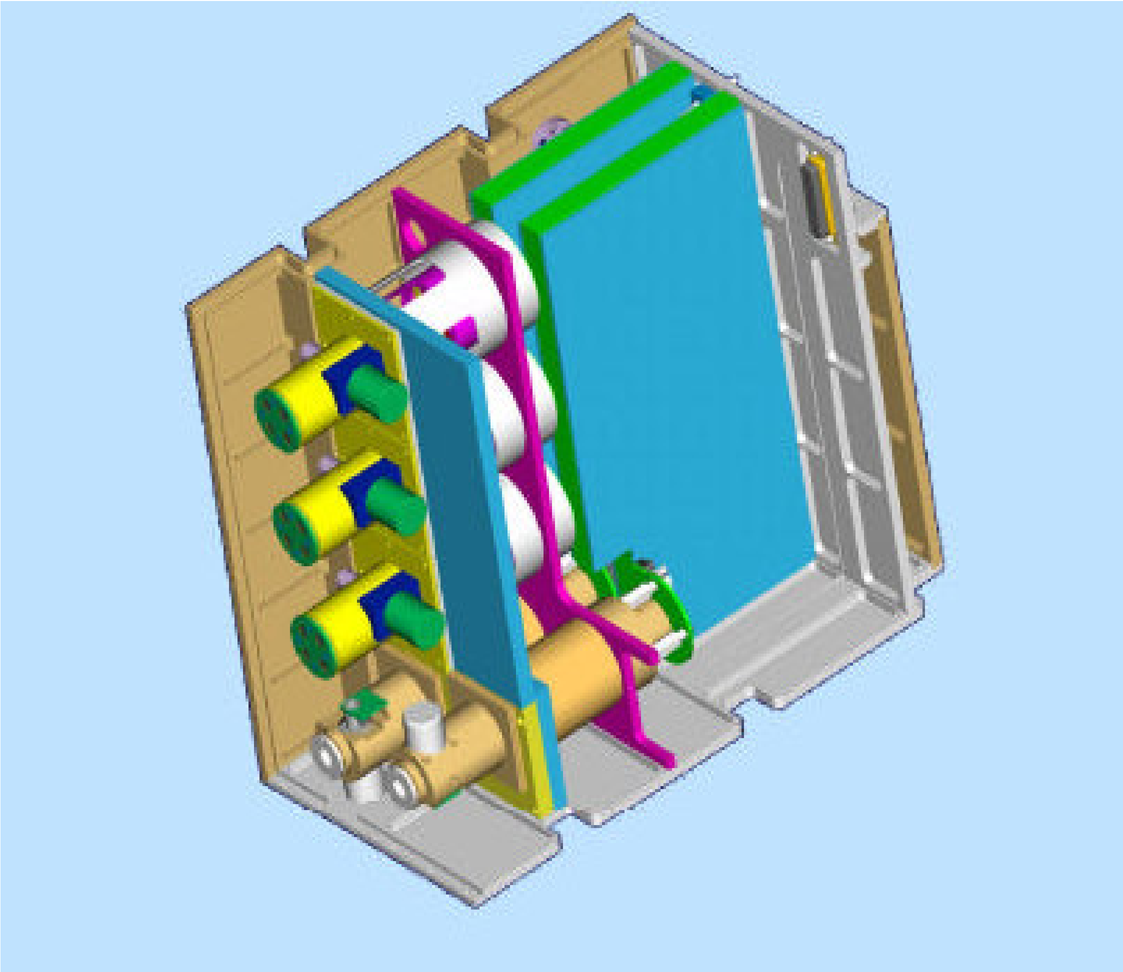
Belgium contributes on PICARD also through the Science Mission Center in Brussels

PREMOS 2

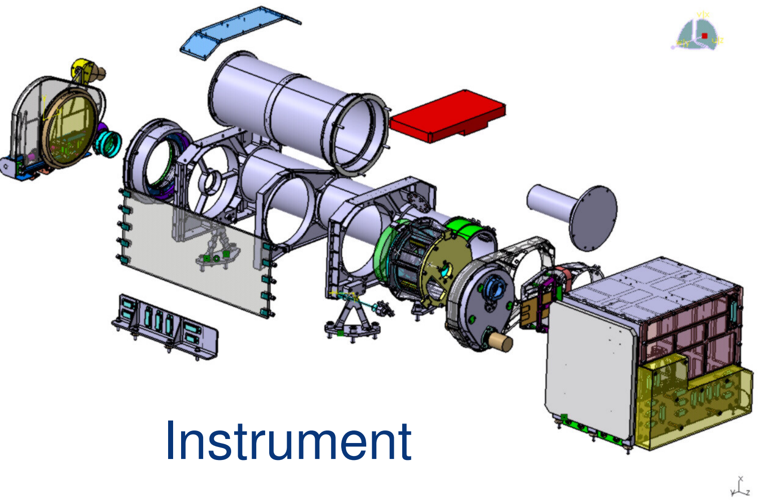
- 2 absolute radiometers
- 3 filter radiometers

Spectral solar irradiance at
215, 268, 535 and 782 nm
Total Irradiance with 2 Radiometers
PMO6-V (type „SOHO/VIRGO“)

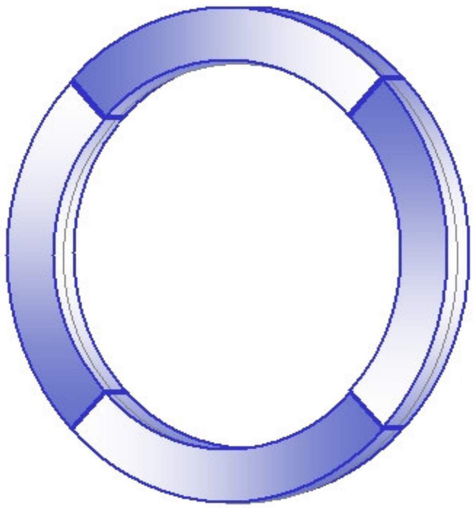
Instrument provided by PMOD (Davos)



SODISM (LATMOS)



Instrument



4-prism optics

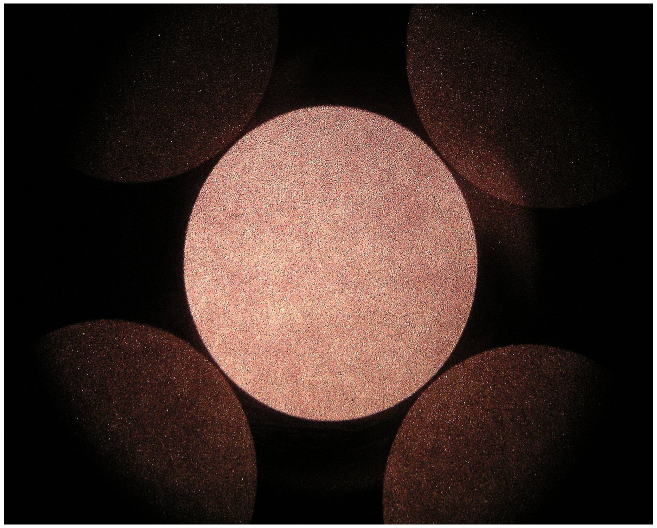


Image in the focal plane

Diameter data processing:

- Instrument geometry calibrated on angular distances of several star doublets
- The proper motion of the calibration stars determined from Hipparcos/GAIA
- Absolute measure of the solar diameter available after GAIA
- Target: Solar diameter : 3 mas per image
  Oblatness: 1 mas

The Complete Payload

PICARD Mission Main Features

- Sun synchronous orbit 6h/18h altitude 710 km
- No propulsion
- Spacecraft bus of the MYRIADE family
- S- Band telemetry
- ~2 Gbit/day
- Launch by a DNEPR, late 2009/early 2010
- Science Operation Center in Belgium
- Minimum mission duration 2 years
- Possible extension to 3 years

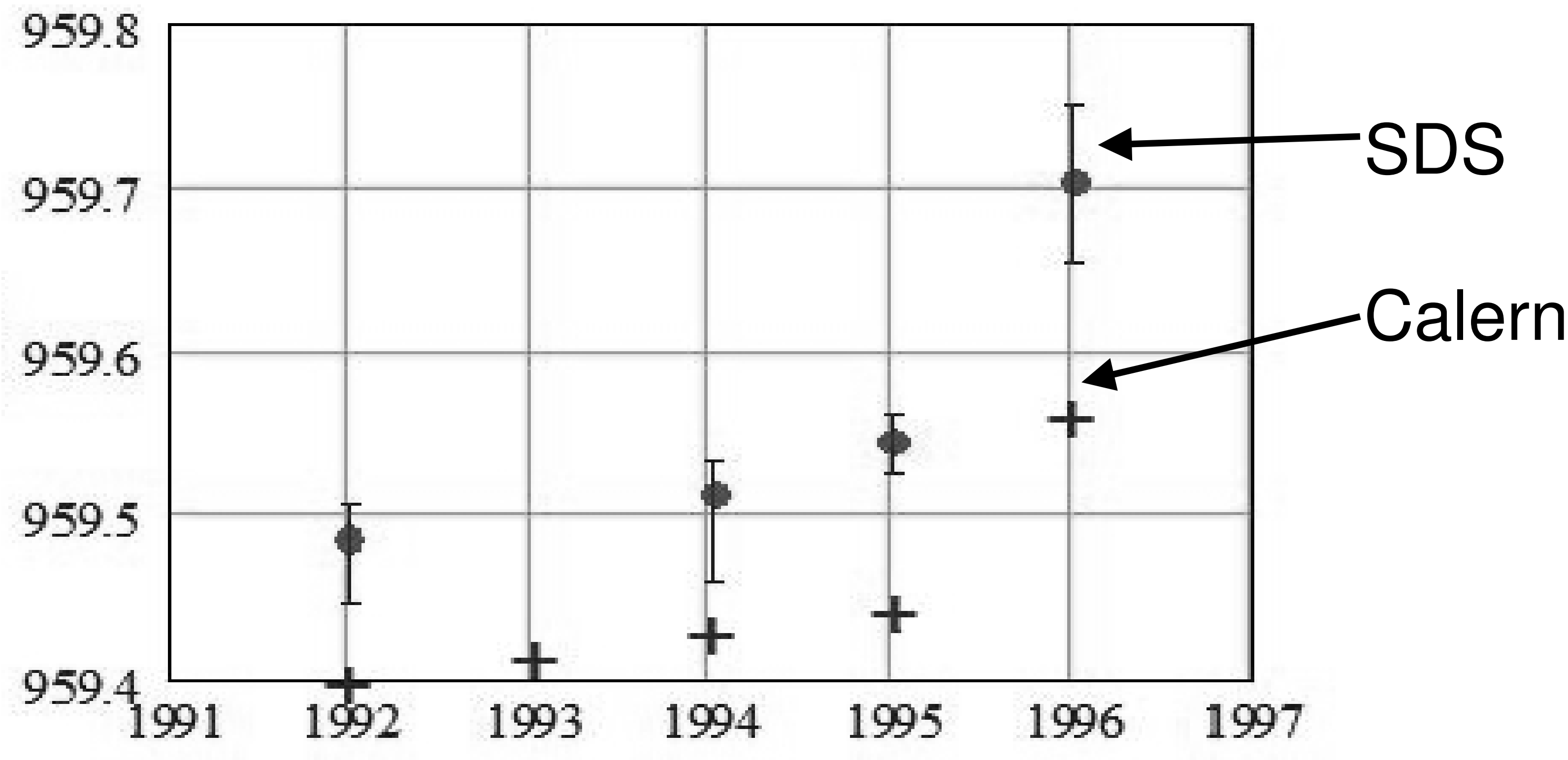
PICARD SOL

PICARD – Bâtiment SODISM II et MISOLFA – Observatoire du CALERN –

A seeing monitor MISOLFA (Moniteur d'Images Solaires Franco-Algérien) observing at the same instants with the solar experiments has been developed to give access to the atmospheric parameters.

Diameter Variation from Stratospheric Balloon Observations

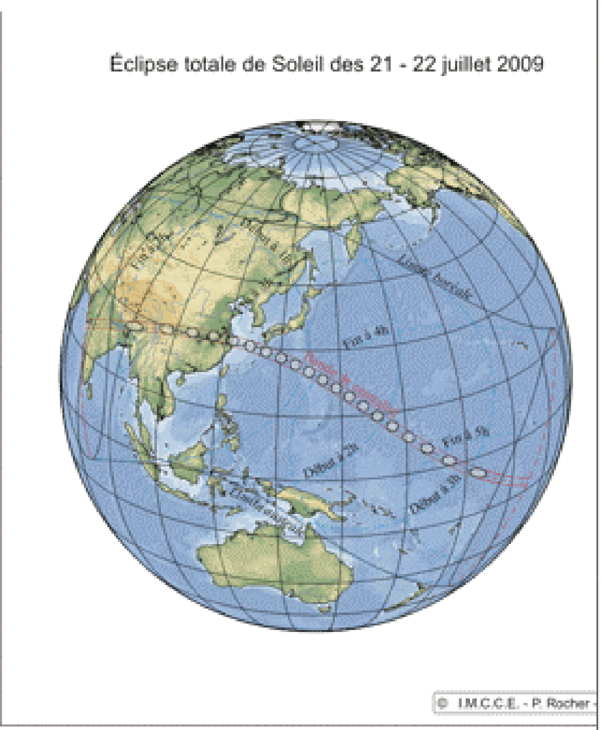
Sofia et al. (1994) have built the Solar Disk Sextant (SDS) using an angular reference. Operated on board a stratospheric balloon, several flights were achieved.

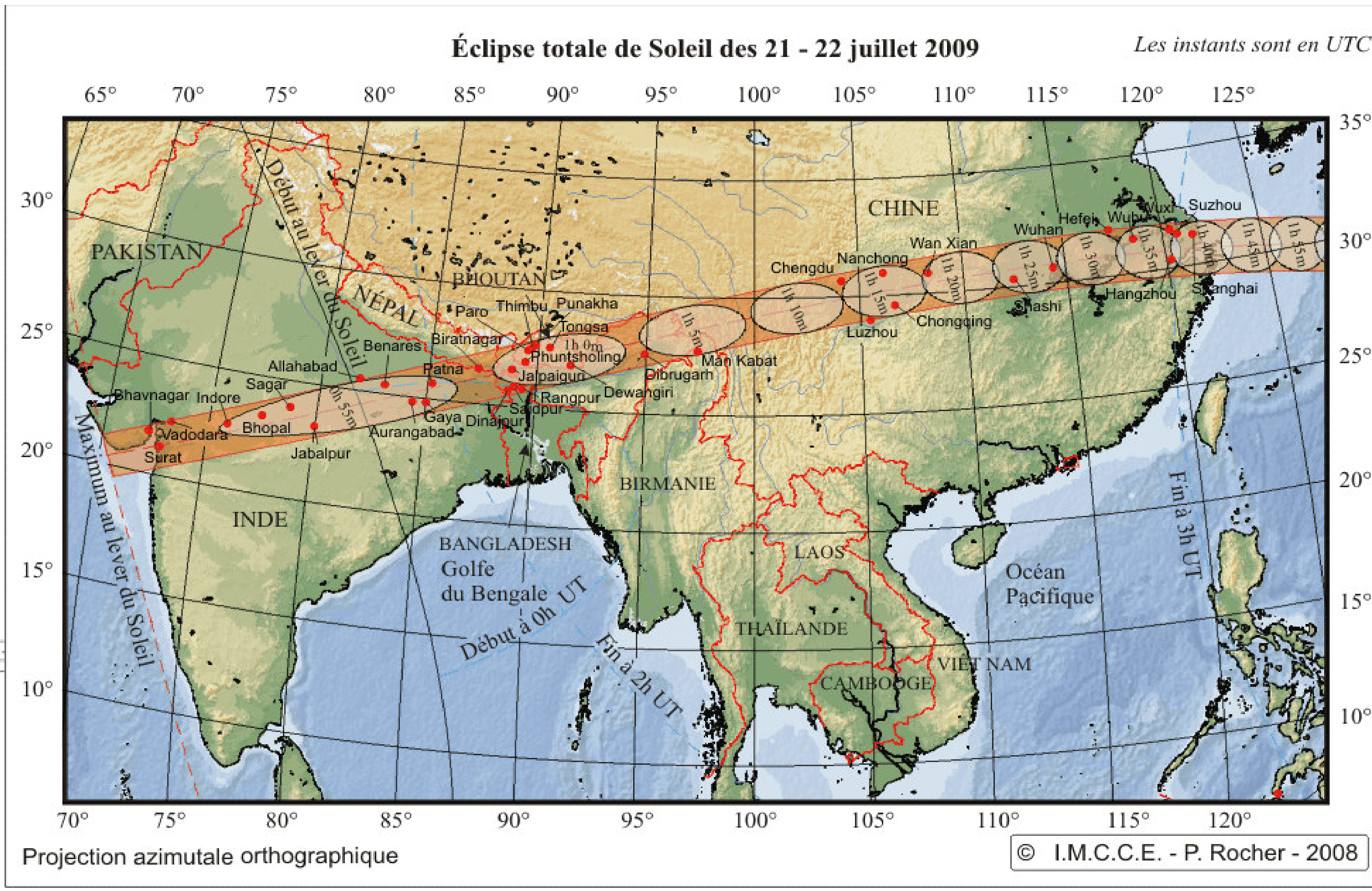


Results of four stratospheric balloons flights carrying SDS (Egidi et al., 2004) showing a diameter increase of 0.2“ while the solar activity decreases.

Solar Eclipse Timing

Solar eclipse timing allows to derive the solar diameter with an increasing precision due to the improvement of the figure of the Moon.





Edmund Halley's Broadside for the 1715 May 3rd Total Solar Eclipse

Conclusion

PICARD is a high technology mission that will allow

- to improve the present models of the Sun and the Earth climates
- to revisit historical data from J.Picard and E. Halley
- to pave the way for long term monitoring of the solar variability

All data will be publicly available 2 years after they have been validated

A Guest Investigator Program with a worldwide open AO will be released by CNES soon after the launch

Jean PICARD (1620 - 1682)