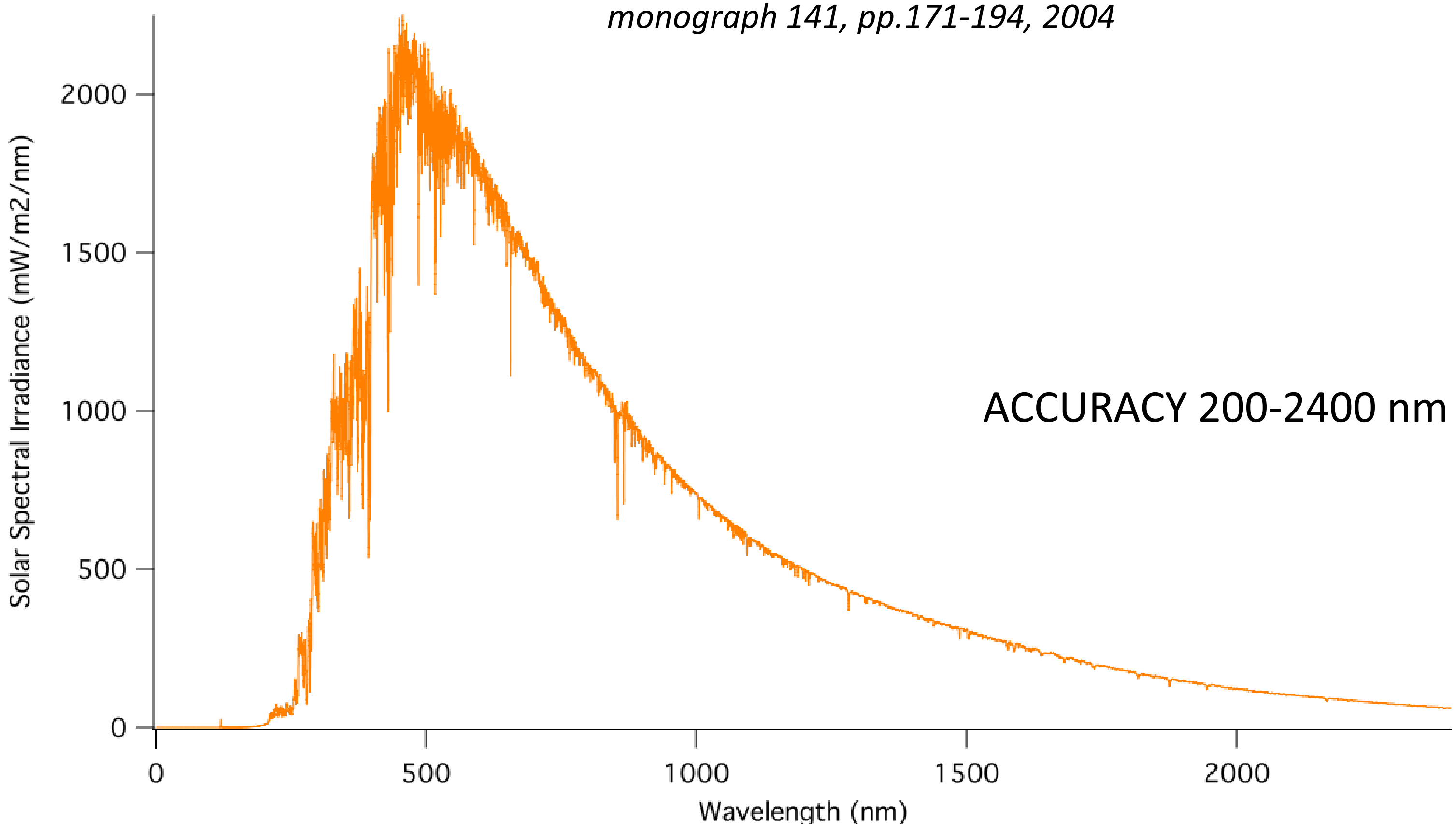
THE ATLAS COMPOSITE SPECTRA

Two composite spectra at two levels of solar activity as encountered during the ATLAS 1 and 3 missions covering the domain 0.5 nm to 2400 nm were built by using rocket data from 0.5 nm to Ly α from Woods et al. (1998), UARS (SUSIM and SOLSTICE), ATLAS 1-2-3 (SUSIM, SOLSTICE and SOLSPEC) data from Ly a to 400 nm, and SOLSPEC from 400 nm to 2400 nm from ATLAS and EURECA Missions.

Thuillier et al., Solar irradiance spectra, in Solar variability, AGU monograph 141, pp.171-194, 2004

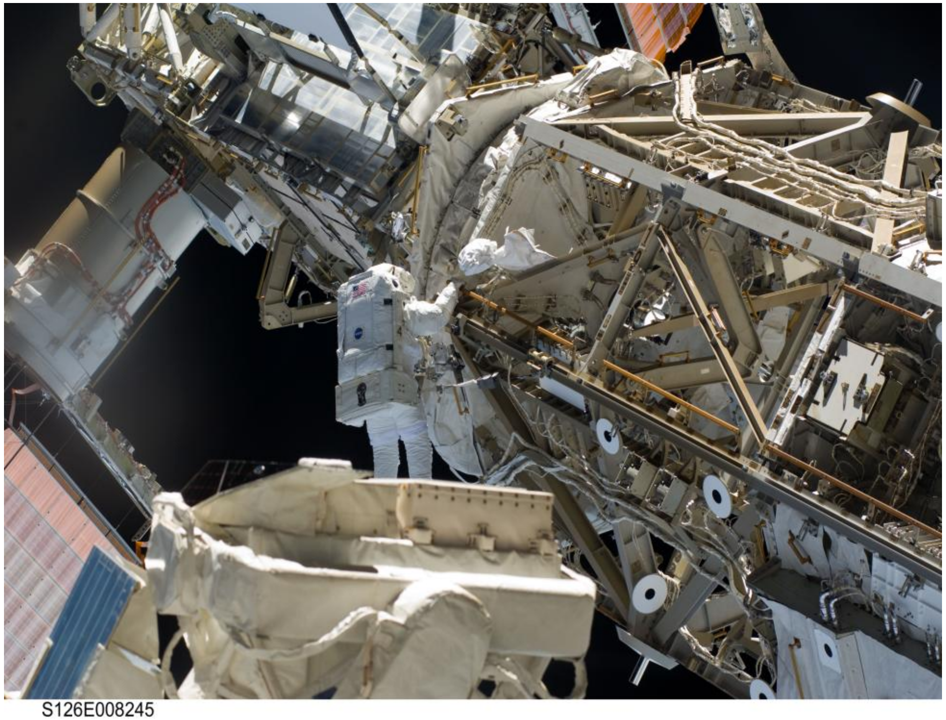


ACCURACY 200-2400 nm : 3%

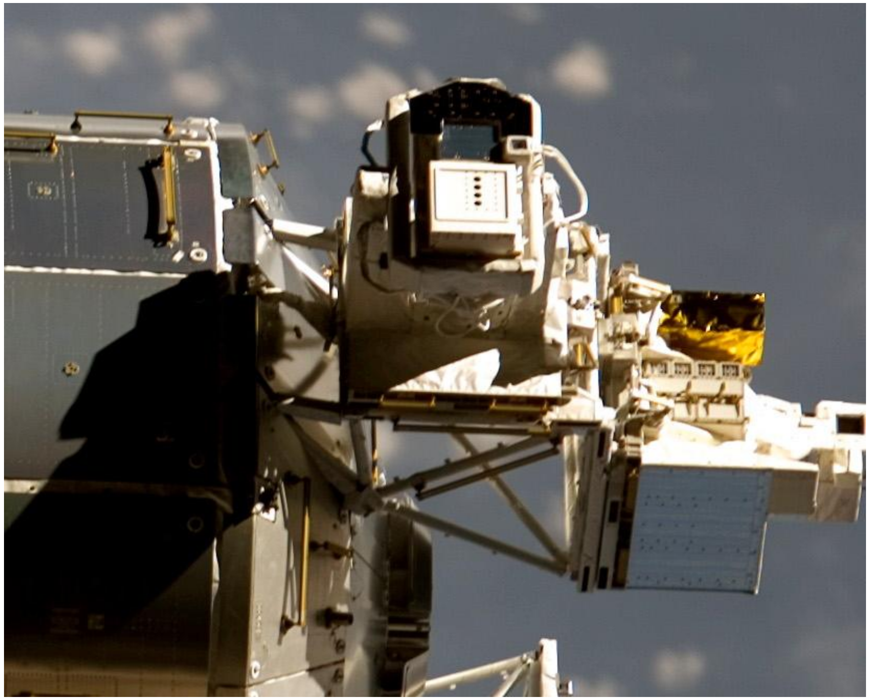
SOLSPEC MEASUREMENT OF THE SOLAR ABSOLUTE SPECTRAL IRRADIANCE FROM 165 to 2900 nm ON BOARD THE INTERNATIONAL SPACE STATION

G. Thuillier[1], D. Bolsee[2], T. Foujols[1], D. Gillotay[2]

1 LATMOS-CNRS, France
2 Institut d' Aéronomie Spatiale de Belgique



SOLAR on COLUMBUS Laboratory



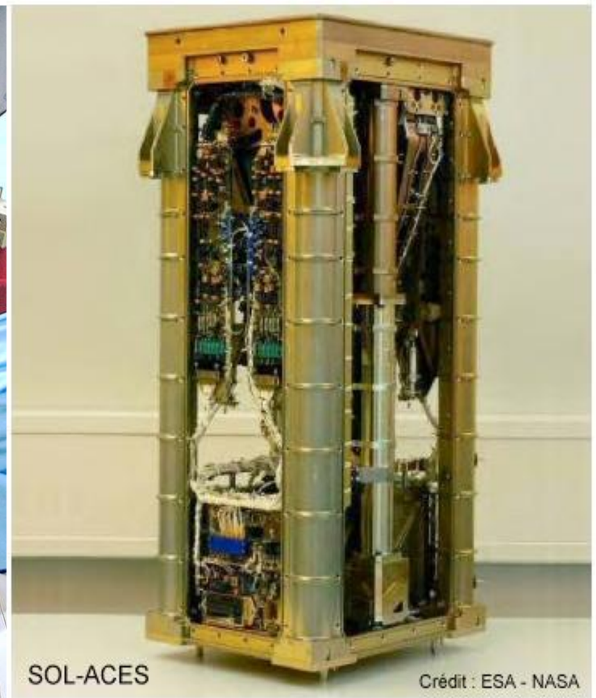
Launched on 7 Feb. 2008

INSTRUMENTS PRESENTLY IN SPACE: SOLAR (5/6)

SOLSPEC

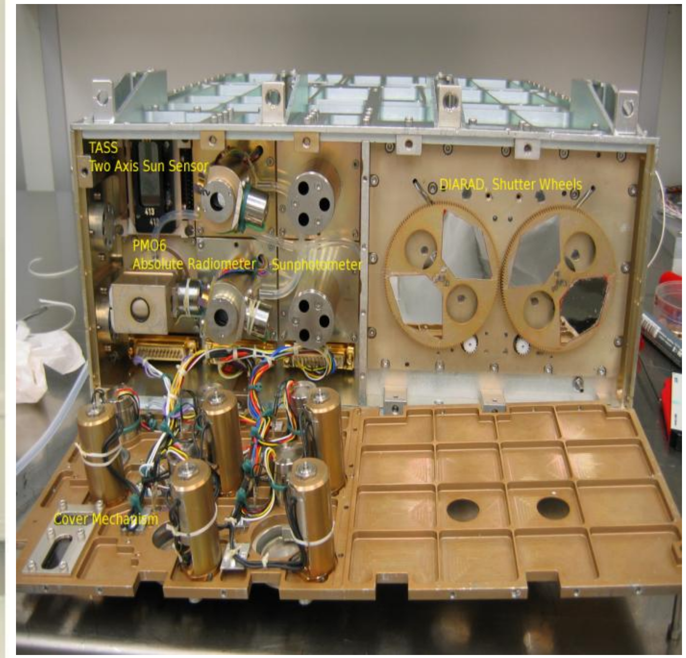
Triple double gratings spectrometer using D2, W, HC lamps. Range: 170 -3000 nm. Calibrated with the PTB blackbody. SOLSPEC was built in cooperation between **France, Belgium and Germany.**

SOL-ACES



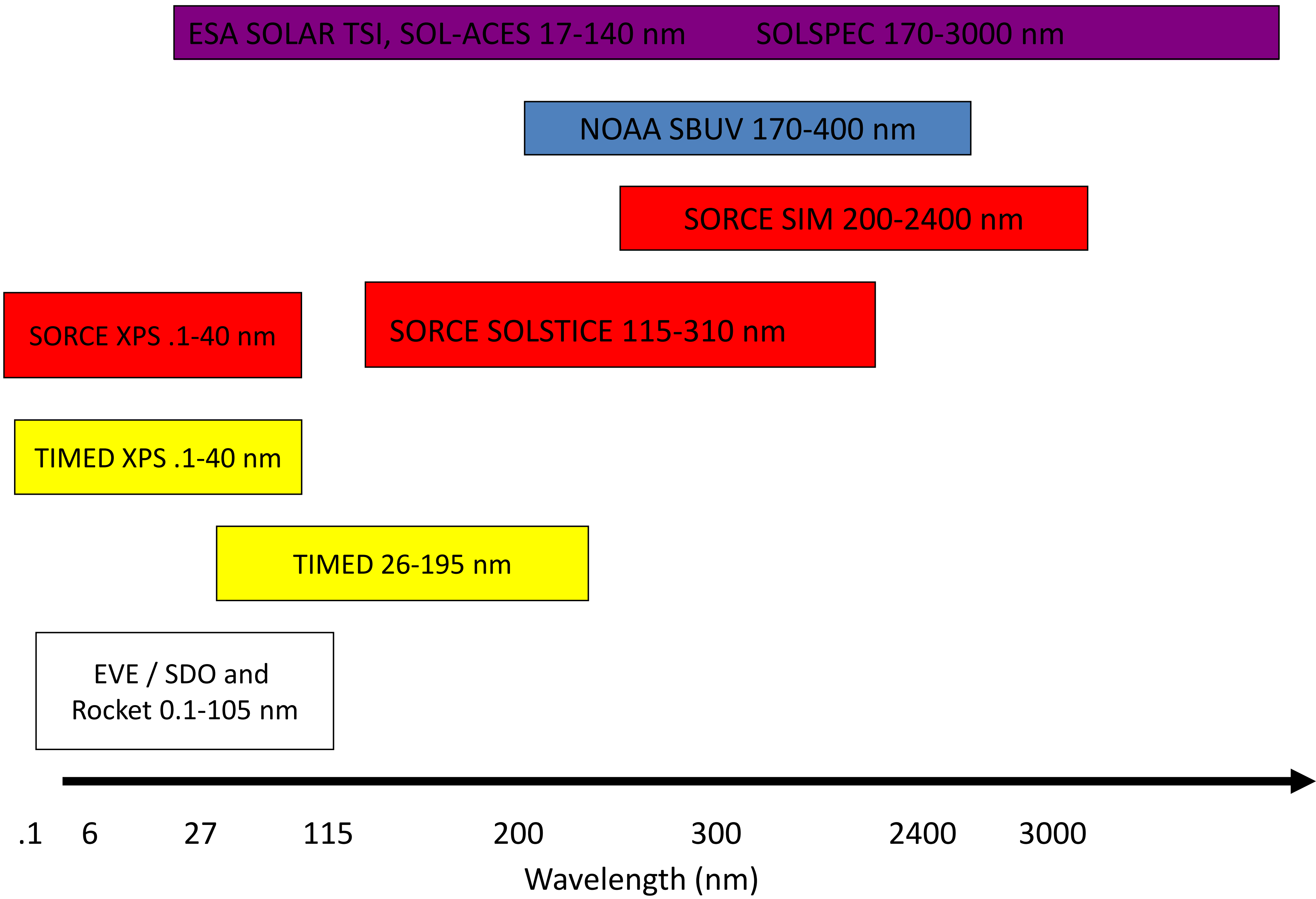
SOL-ACES (G) is a-4 grazing incidence grating spectrometers plus two three-ionization chambers with exchangeable band pass filters to determine absolute fluxes from 17 to 140 nm.

SOVIM



Four absolute radiometers (PMO6 (Ch) and DIARAD (B) as on board SoHO, and two sunphotometers.

PRESENT SOLAR SPECTRAL IRRADIANCE MEASUREMENTS (2/6)



METHODS OF CALIBRATION

Instruments	Missions	Laboratory absolute calibration	In-space control
SIM	SORCE	Characterization	2 twin instruments
SOLSTICE	SORCE	Surf[1] and D_2 lamps	Stars
SEE	TIMED	Absolute detectors	
SOL-ACES	SOLAR-ISS	SURF[2]	Absorption cells
SOLSPEC	SOLAR-ISS	PTB blackbody and D2 lamps calibrated by PTB	D2,W, HC lamps
EVE	SDO	Surf[1]	Led (flatfield)

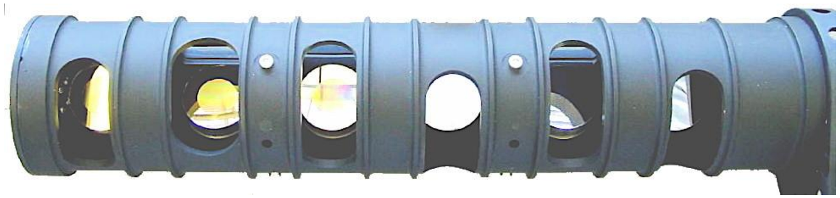
The different techniques contribute to minimize the systematic uncertainties. Agreement between data sets gathered by instruments based on different concepts also ensure that measurements are achieved in the absolute scale.

SURF: Synchrotron UltravioletRadiation Facility. 1= NIST; 2= PTB

Principle of the SOLSPEC spectrometer (1/2)

- 3 double-monochromators (UV, VIS, IR) allow to cover the range 165-3080 nm

- The six gratings simultaneously rotate



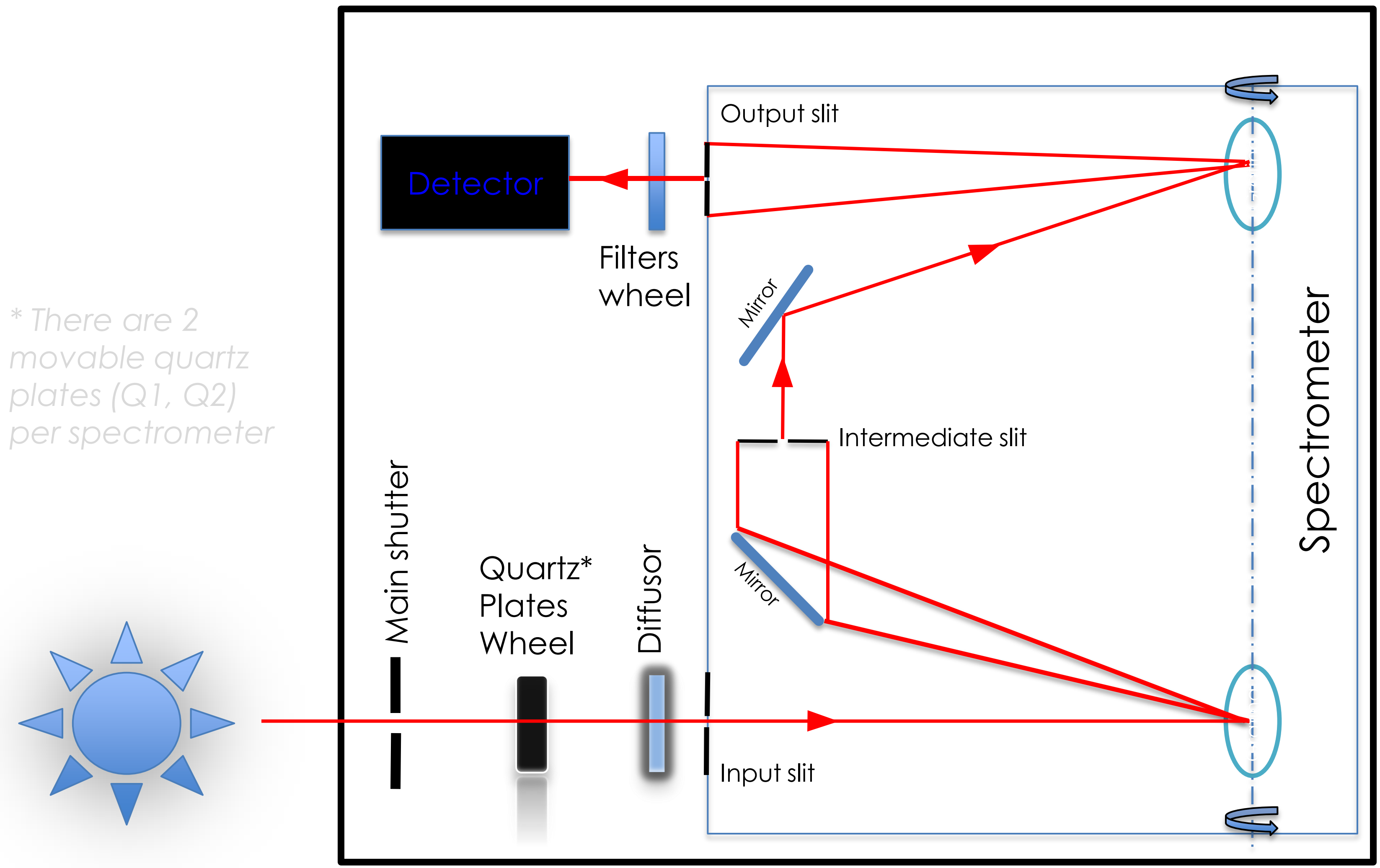
- References on board:

  - One hollow cathode lamp (HCL) providing lines from Argon, Zn and Cu to measure the slit function and the dispersion law.
  - Four tungsten ribbon lamps for the VIS and IR spectrometers calibration
  - Two deuterium lamps for the UV spectrometer calibration

- Entrance slits are covered by diffusors

- Quartz plates and a hole are carried by a wheel. The plates can be placed in front of the entrance diffusors to ensure their protection.

- A sensor measures the Sun position/platform axis.



* There are 2 movable quartz plates (Q1, Q2) per spectrometer
Detector
Filters wheel
Output slit
Mirror
Intermediate slit
Mirror
Spectrometer
Main shutter
Quartz* Plates Wheel
Diffusor
Input slit

Principle of the SOLSPEC spectrometer (2/2)

Detectors: PMT in UV and visible domains, PbS cell in IR.
Vis and IR detectors are cooled.

Signals: Counting for PMT's, synchronous detection in IR (16 bits, 3 gains)

PMT's data acquisition works with two modes

- at fixed integration time
- at fixed counts (fixed precision)

Spectral characteristics:

Total spectral range: 165-3080 nm

UV spectrometer: 165-380 nm, spectral width: 1 nm, sampling 0.1 nm

VIS spectrometer: 300-980 nm, spectral width: 1 nm, sampling 0.25 nm

IR spectrometer: 800-3080 nm, spectral width 9 nm, sampling 1 nm

HOW TO LIMIT AGEING AND HOW IT CAN BE MONITORED?

- Sampling has to be minimum to achieve the scientific objectives
- Keep warm the optical entrance pupille
- Protect the instrument entrance by a tight shutter able to be open and close without limitation

- There are several exchangable entrance windows for each spectrometer:

The same window is usually used (Q1), the second window (Q2) is used from time to time. We periodically measured the ratio Q1/Q2 as well as the absolute transmission of both Q1 and Q2.

- The set of lamps D2 and tungsten ribbon lamps allows us to check the instrument reponsivity. For redundancy, two lamps of each type are foreseen.

- The HC lamp allows measurements of the dispersion law, the instrument *psf*.

- It also allows to monitor the ageing by a new method.

INSTRUMENT CALIBRATION

	Ground	Orbit
Absolute photometry	X	
Relative photometry	X	X
Linearity	X	≈X
Slit Function	X	X
Dispersion law	X	X
Scattered light	X	X
Flatfield	x*	X
Second order contribution	X	X

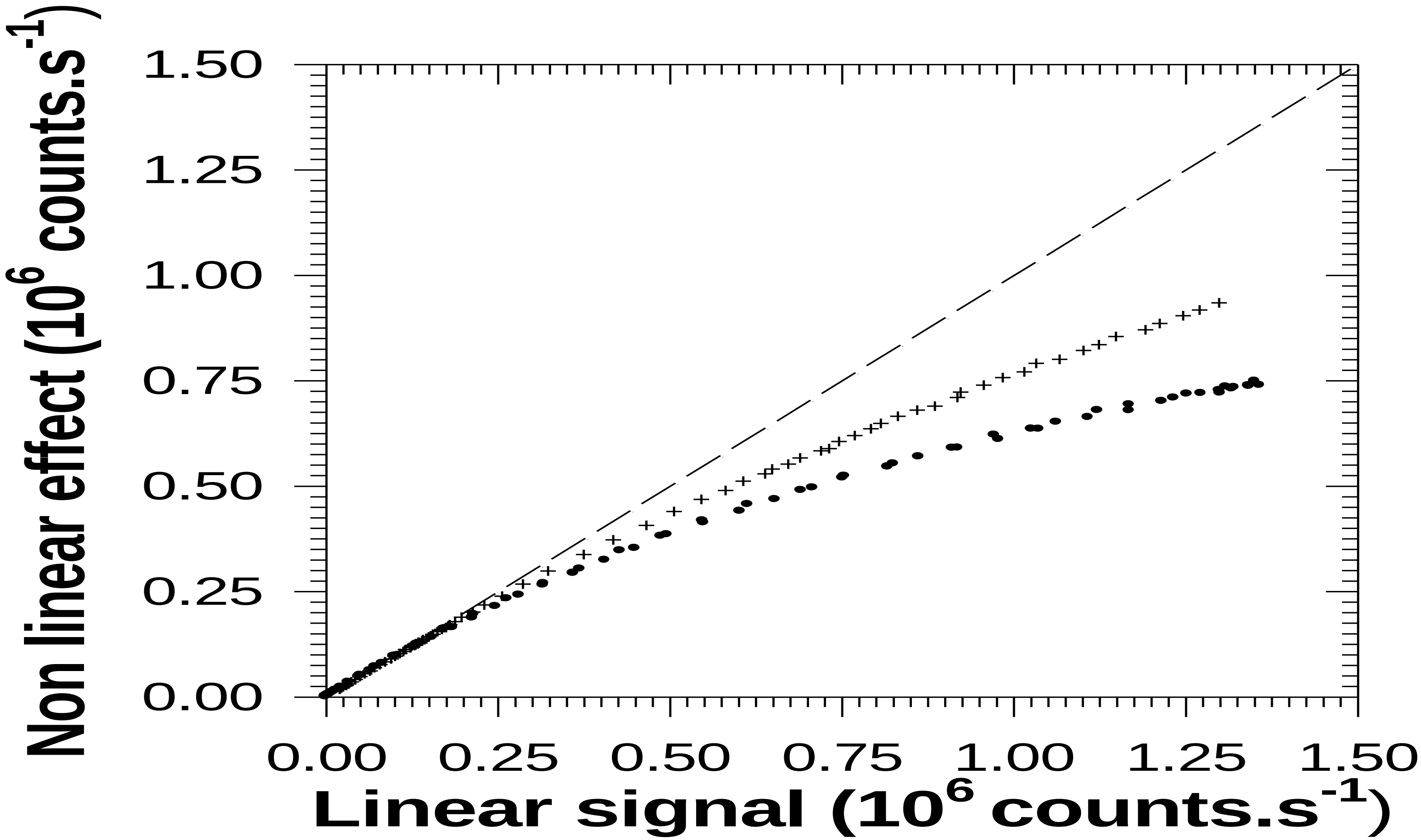
* More precise in space

CALIBRATION MEASUREMENTS ONLY ACHIEVABLE ON GROUND

- Absolute photometric response

- Linearity can be easily achied on ground, with more difficulties in orbite.

INSTRUMENT LINEARITY



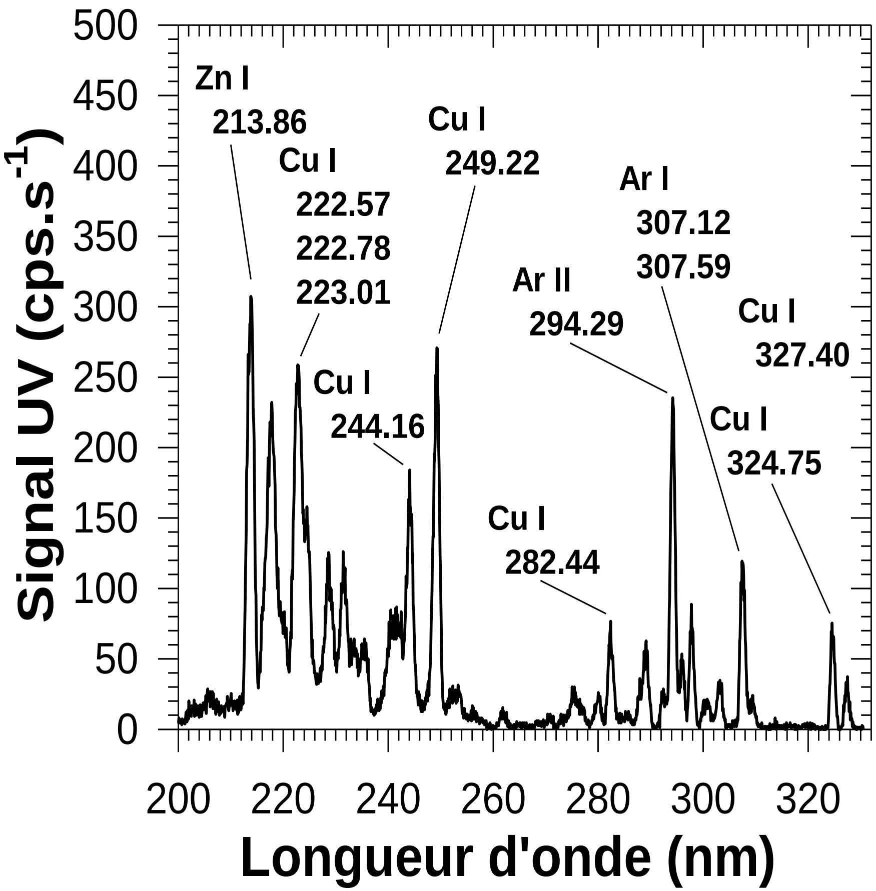
The Sun will not generate a signal greater than 10^5.

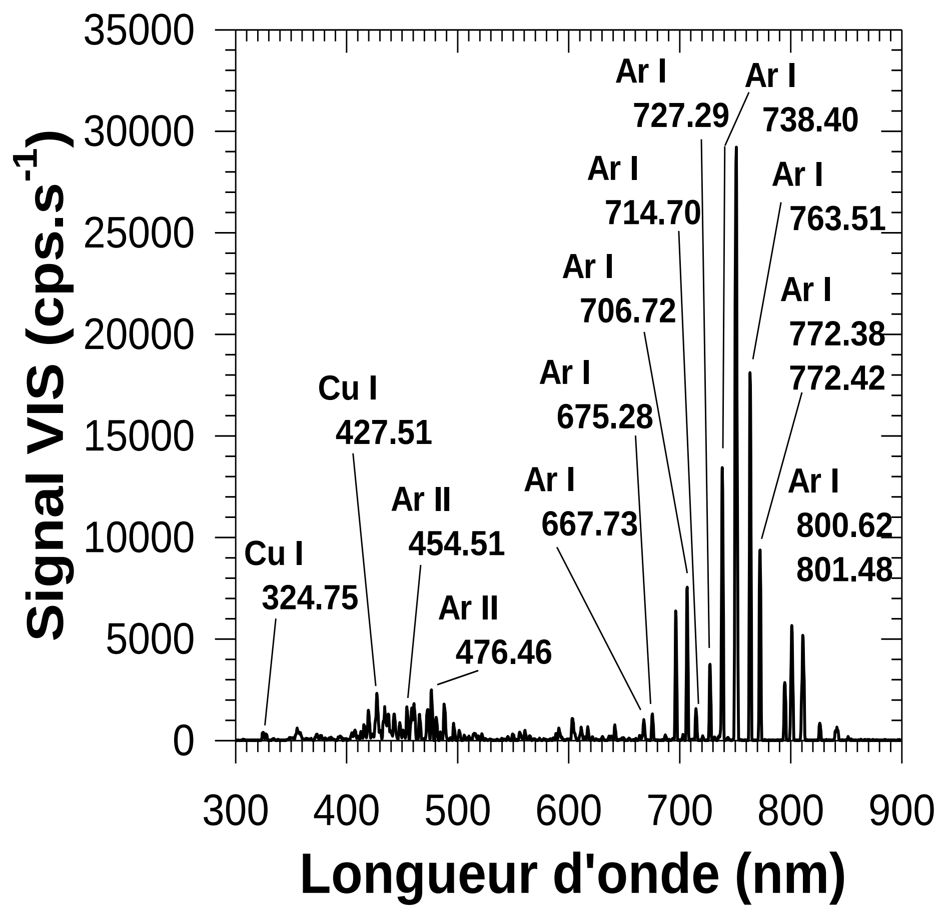
HOLLOW CATHODE LAMP

Role:

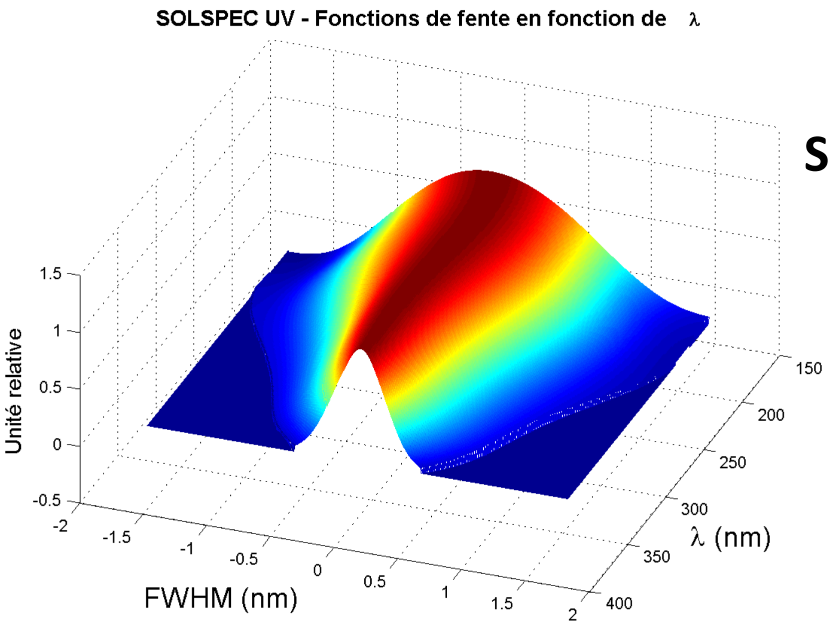
- Measures in orbit the slit function
- Measures in orbit the dispersion law
- Used as reference source

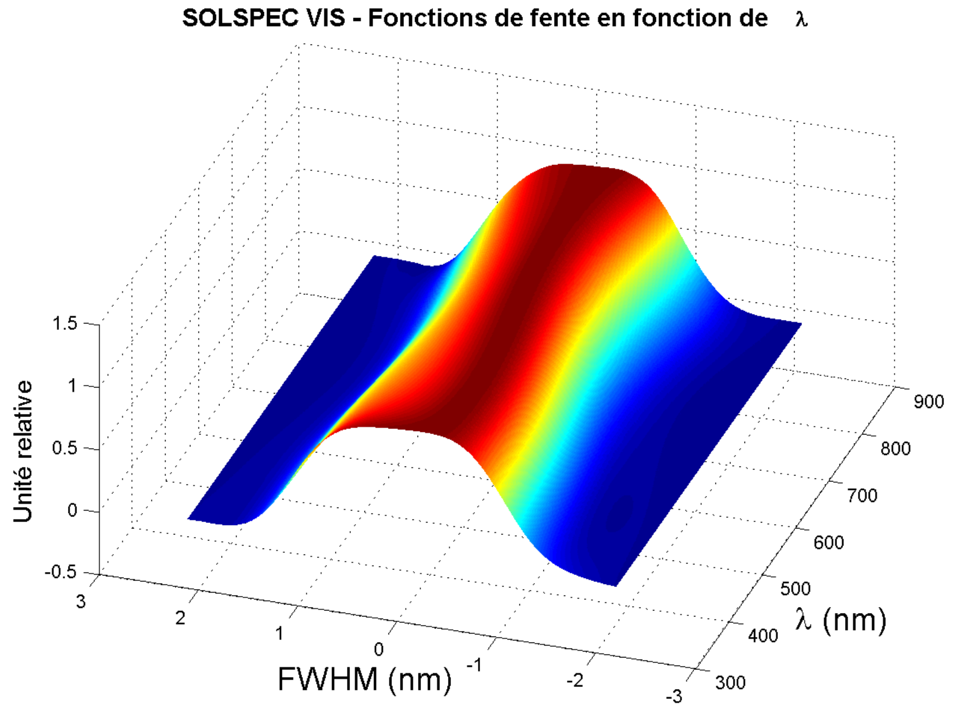
LINES PROVIDED BY THE HOLLOW CATHODE LAMP

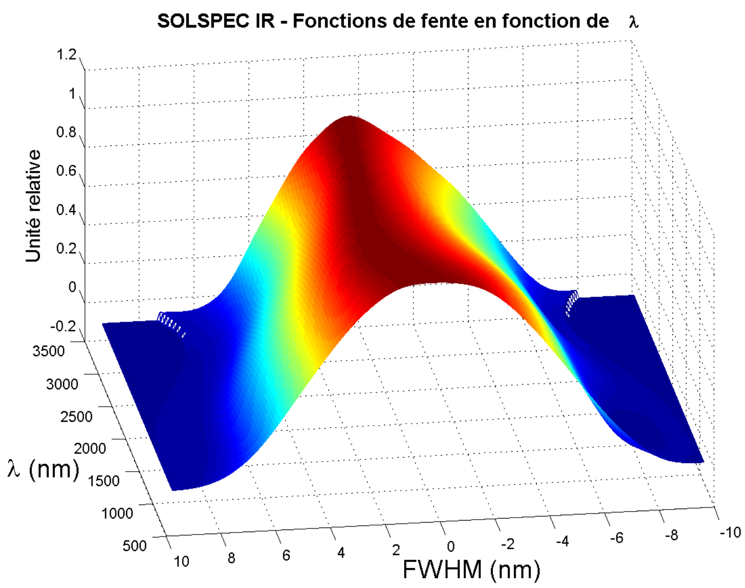




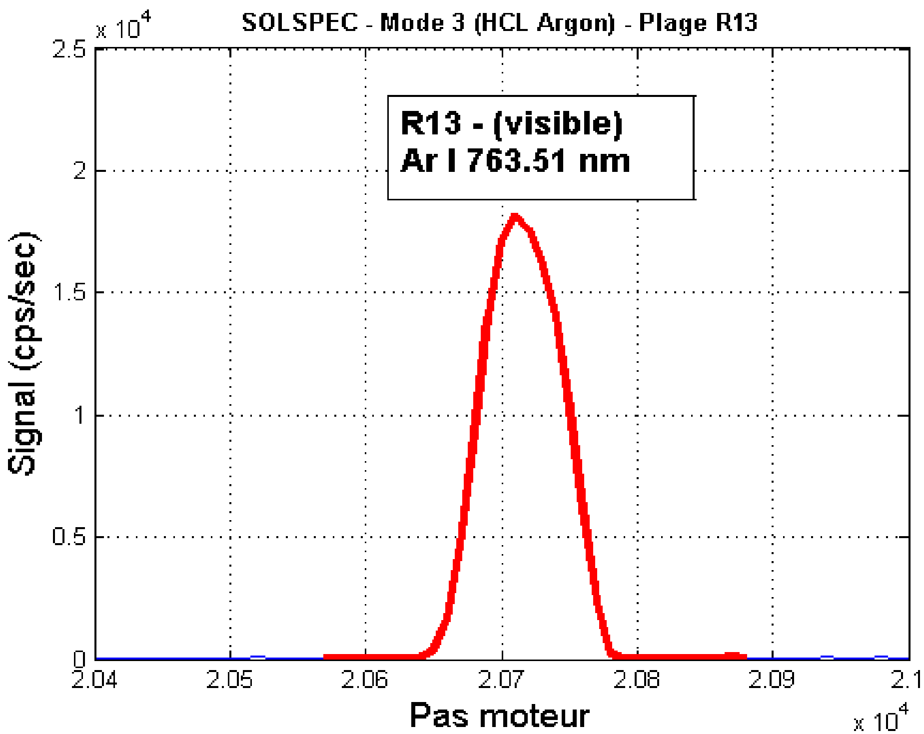
Spectrometers Slit Functions in UV, VIS, IR



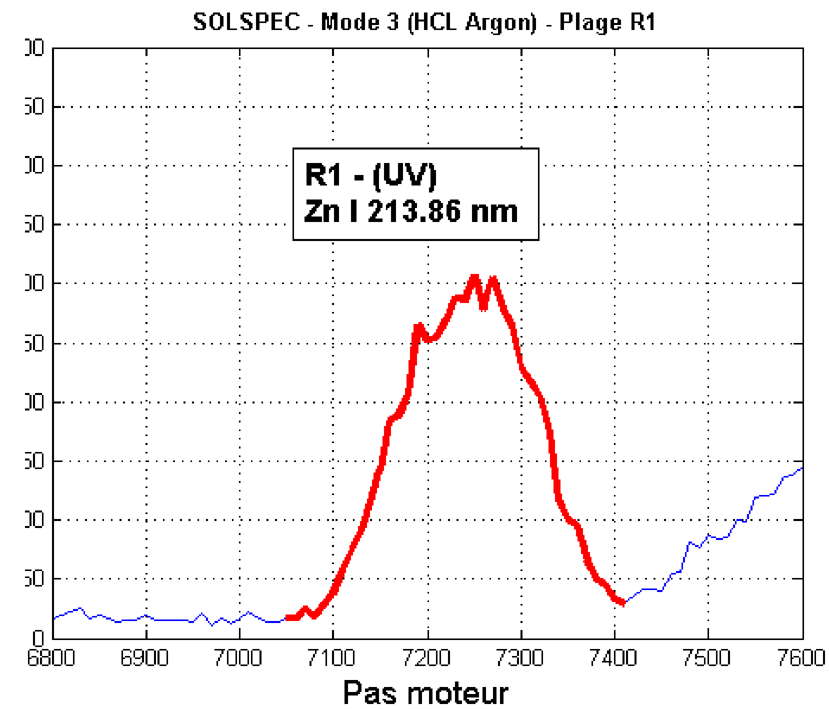




SLIT FUNCTION

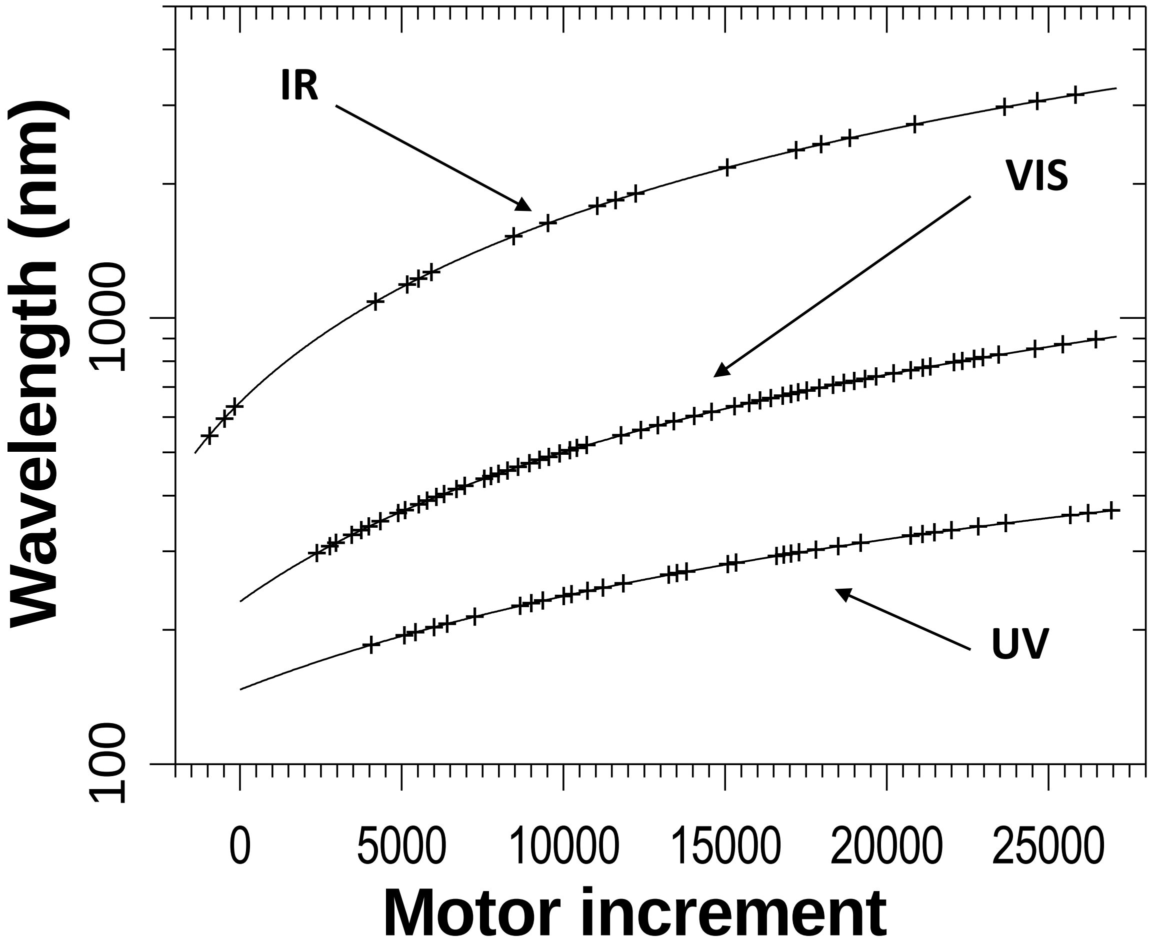


With an isolated line



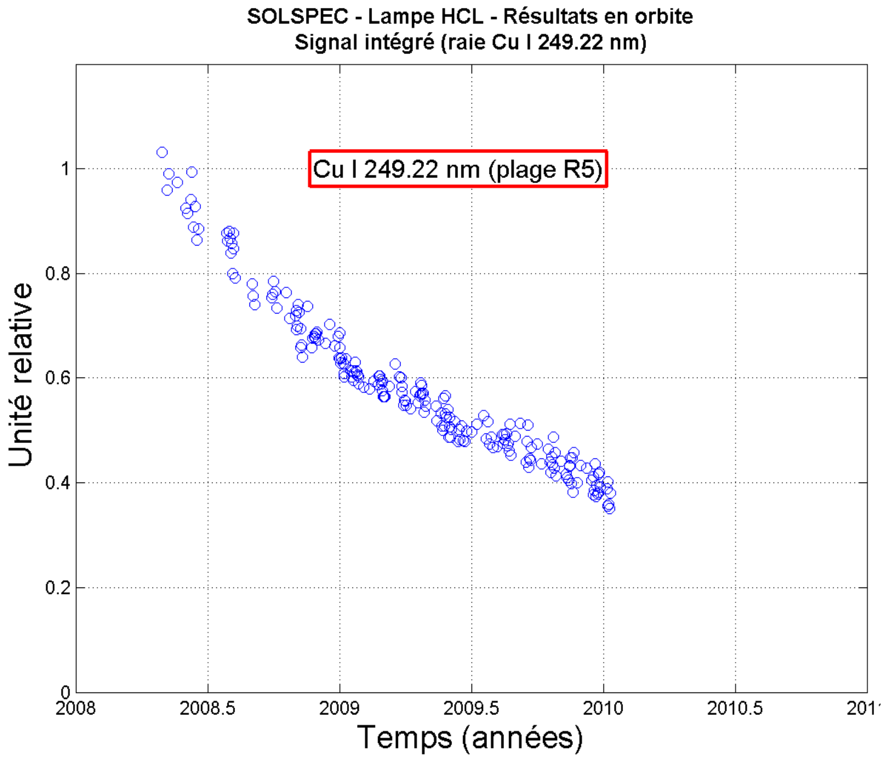
When two lines are adjacent in the slit function

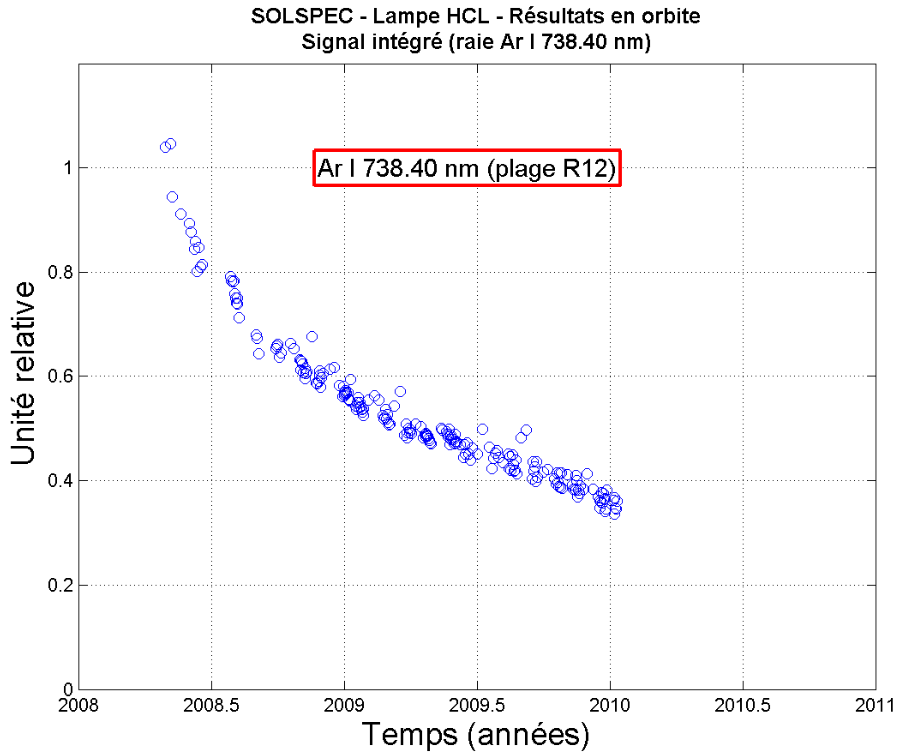
INSTRUMENT DISPERSION LAW



The line wavelength associated to the corresponding step number allows to derive the dispersion law. It is consistent with the theoretical law.

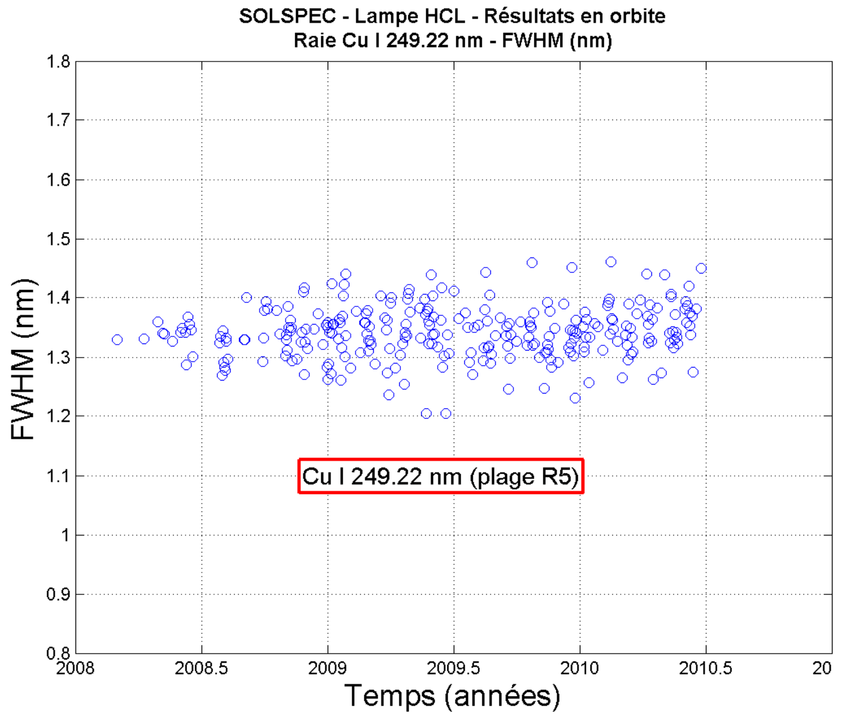
BEHAVIOR OF THE HOLLOW CATHODE LAMP IN SPACE

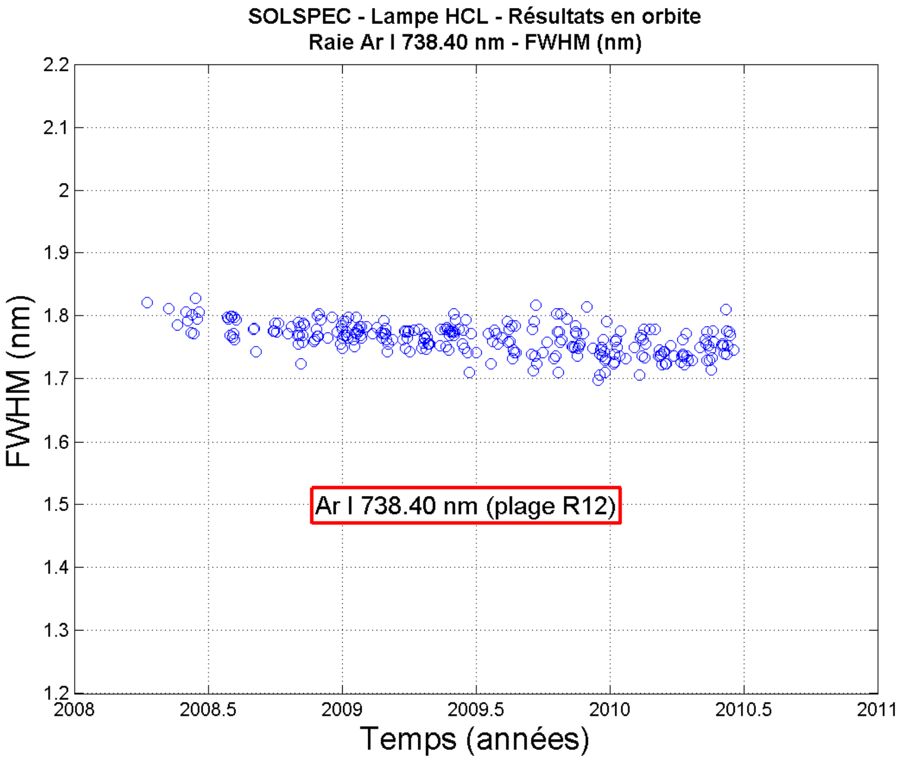




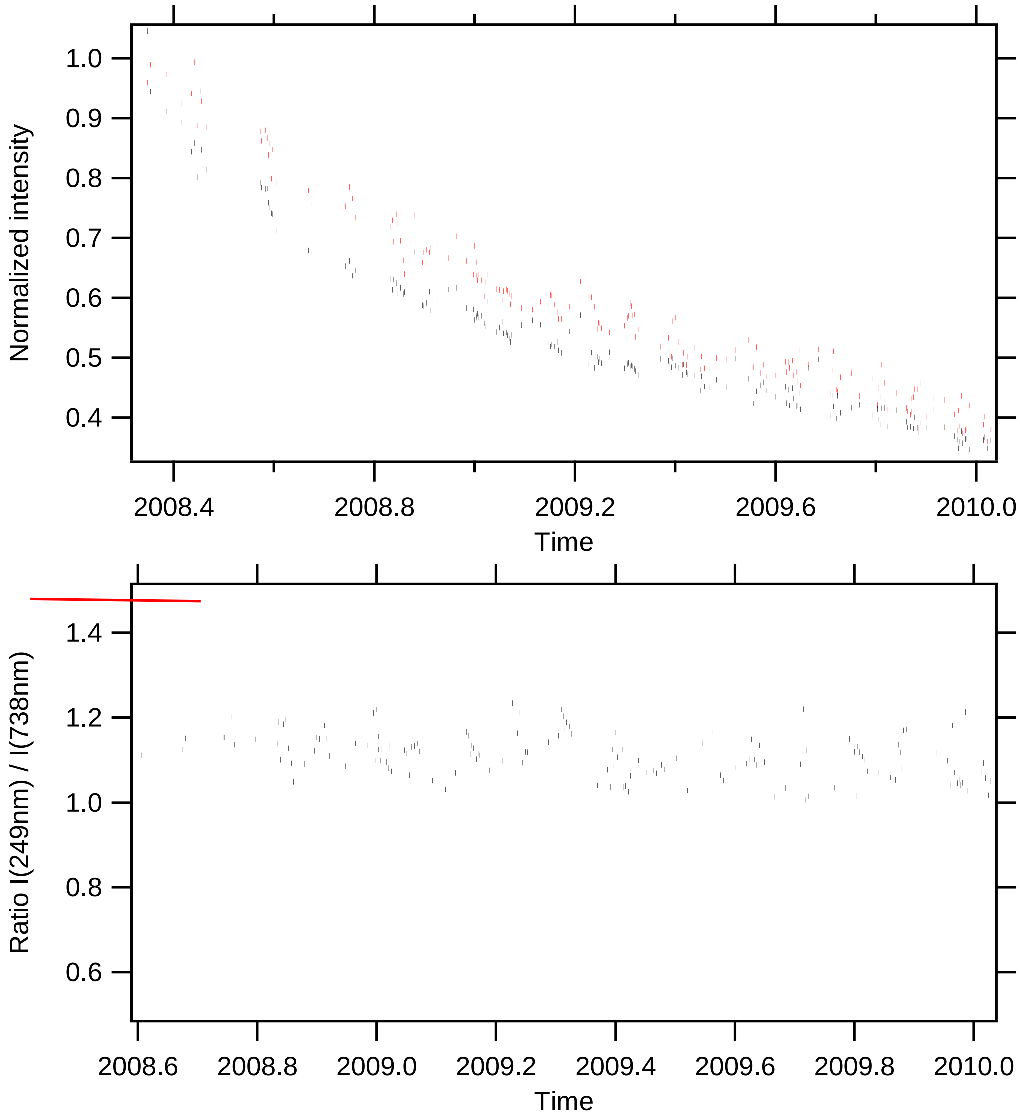
The s/n ratio remains acceptable.

BEHEVIOR SPECTRAL CHARACTERISTICS IN SPACE AS A FUNCTION OF TIME



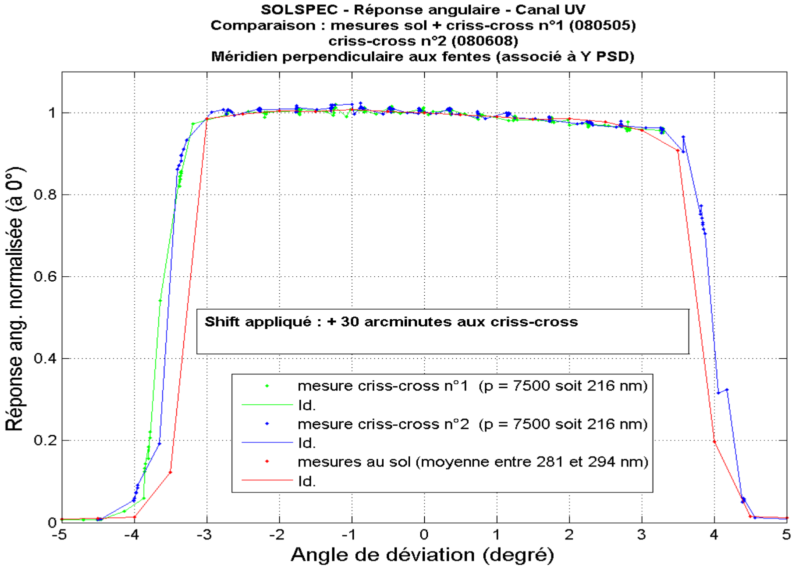


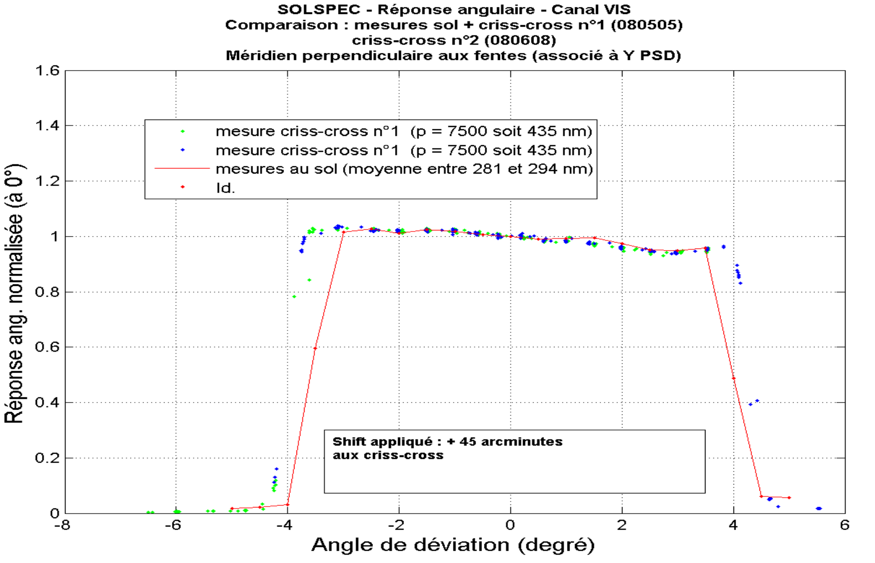
THE LINE INTENSITY COVARIANCE

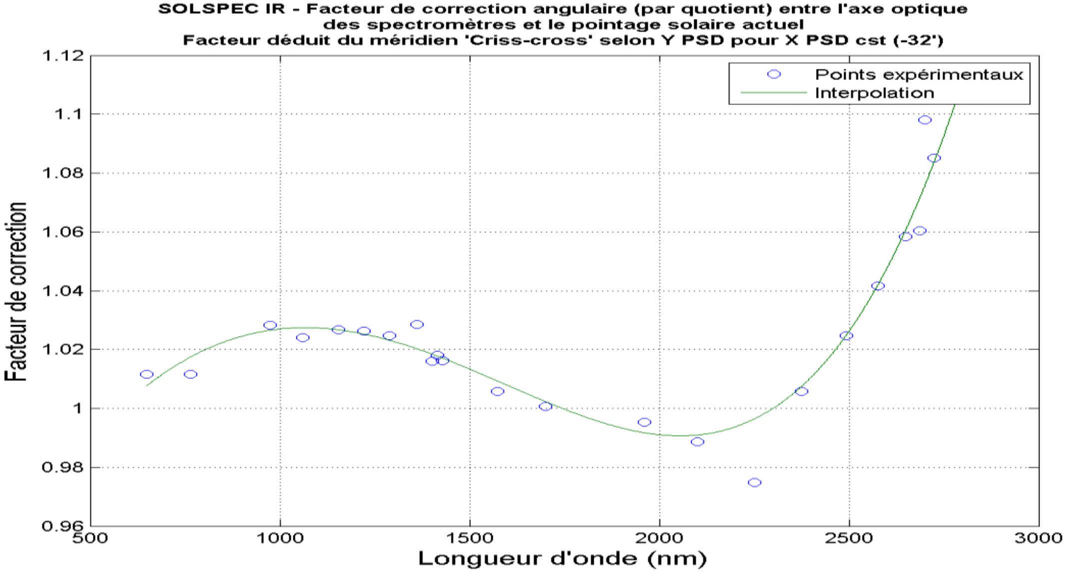


Line 249 nm (red)
Line 738 nm (black)

FLATFIELD MEASUREMENTS IN ORBIT







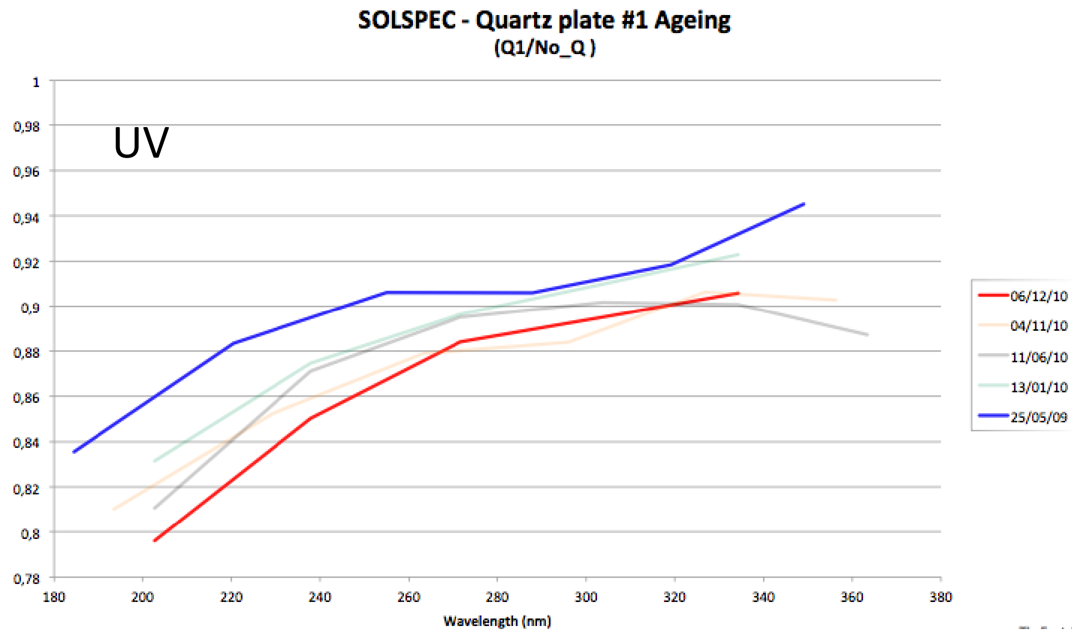
STRATEGY OF QUARTZ PLATES USE

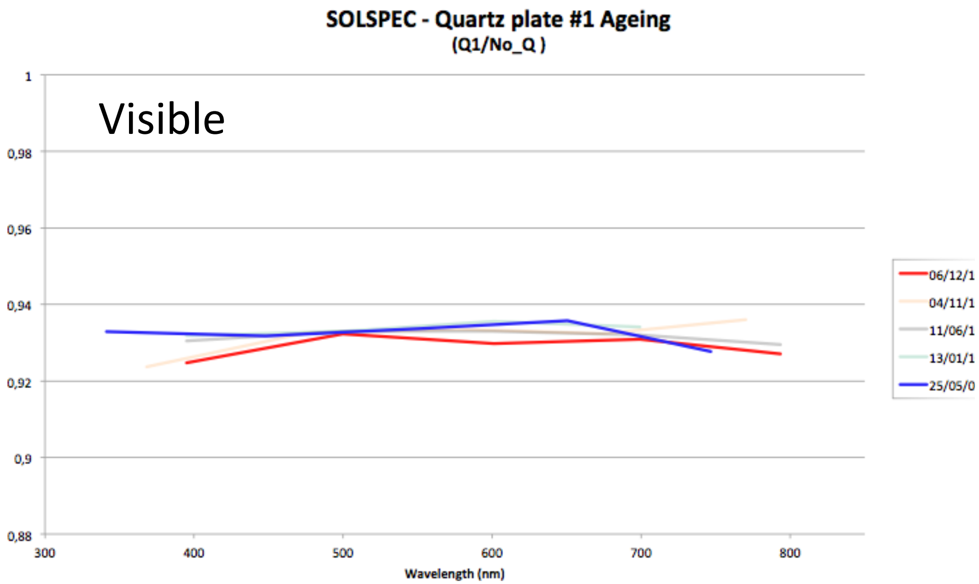
Each spectrometer is equipped by two quartz plates.
They are set on a wheel together with a hole. They allow to protect the entrance diffusors from the hard radiation.

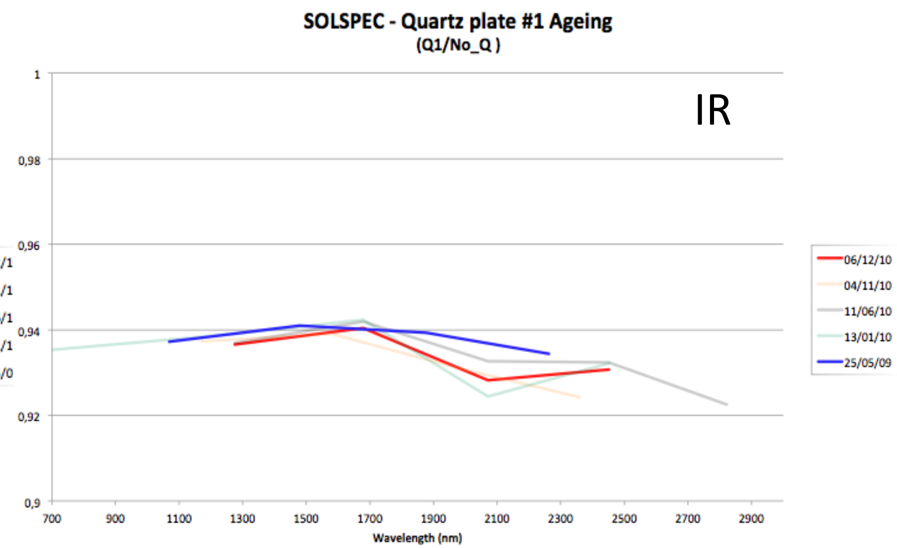
Operations:

- Solar measurements are daily made with Q1
- Once per month, Q2 is exposed to measure the transmission ratio Q1/Q2
- Q1 transmission is also measured by measuring the ratio Q1/hole.

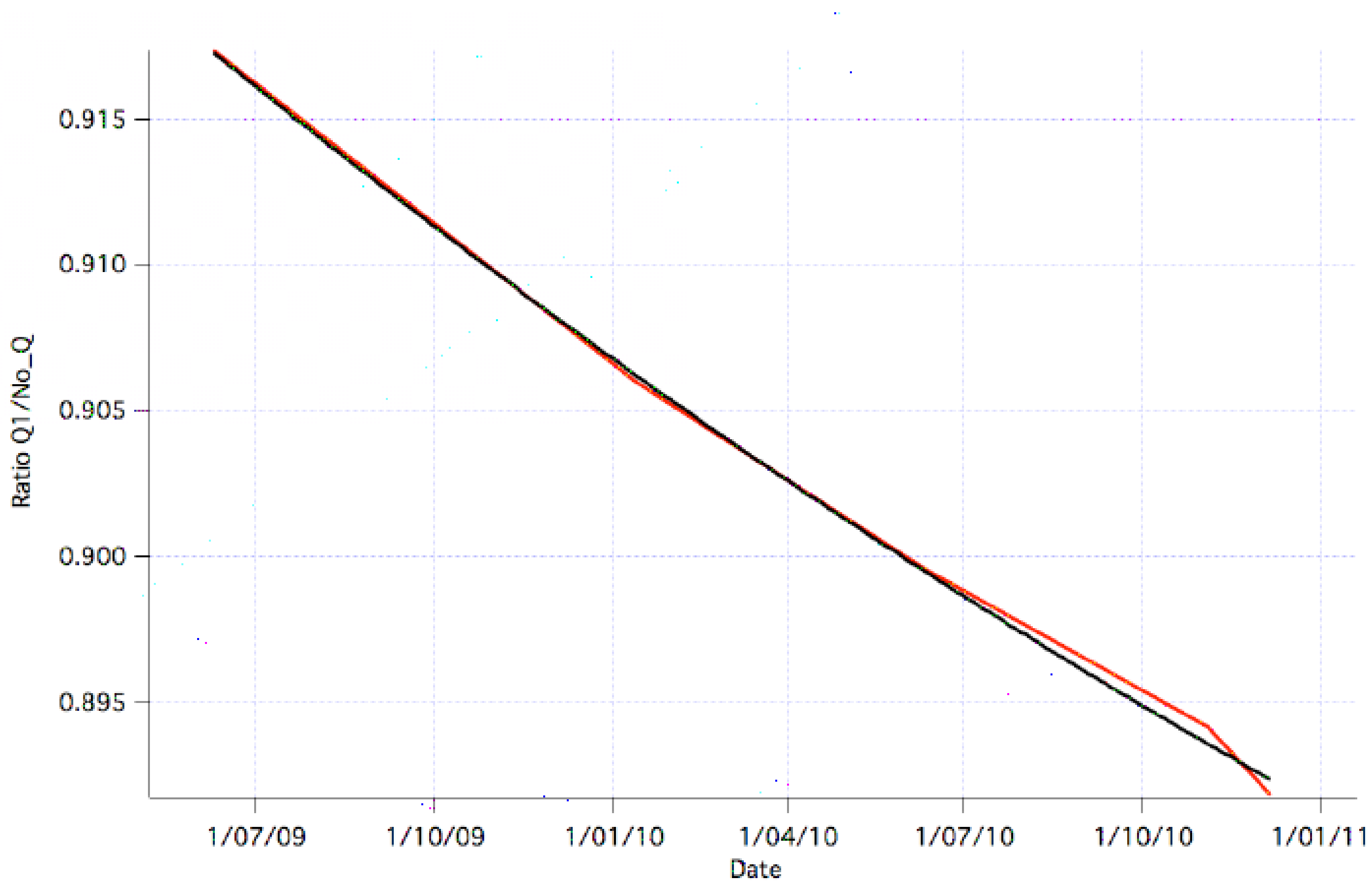
BEHAVIOR OF QUARTZ PLATES IN ORBIT





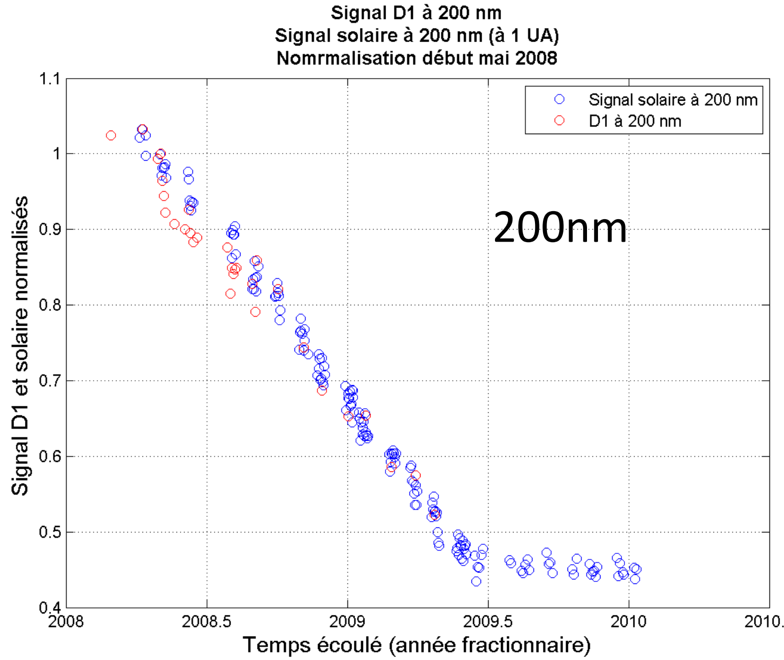


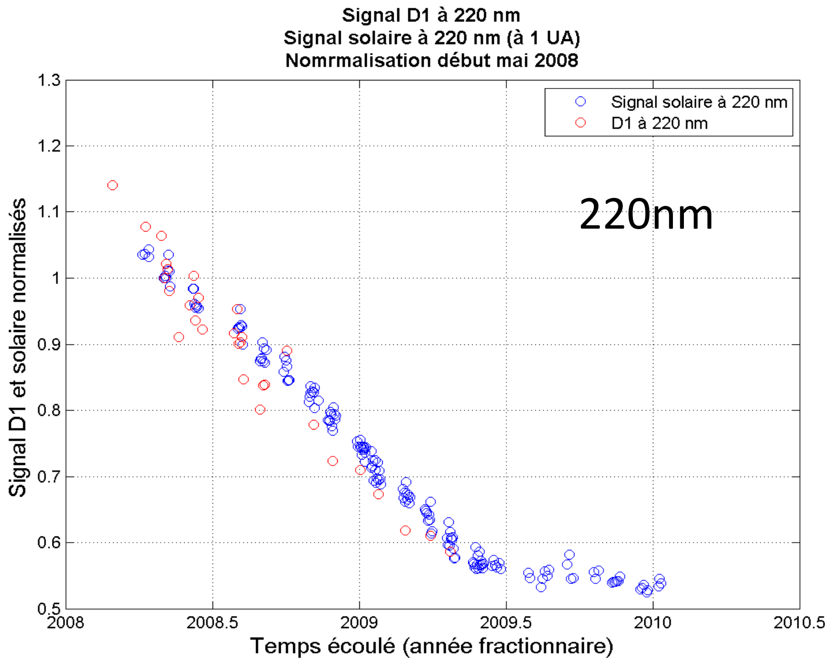
QUARTZ Q1 AGING AT 288 nm

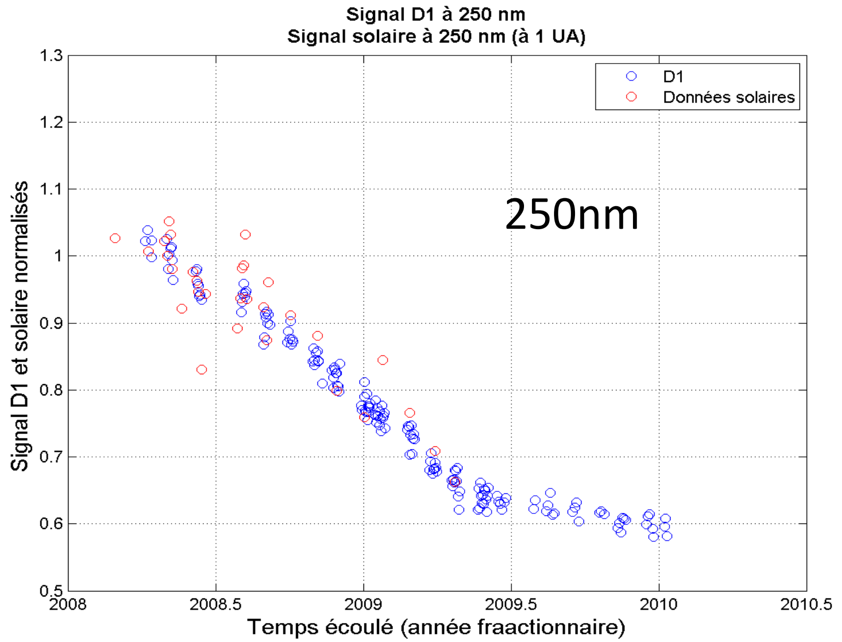


Q1 is the most frequently used quartz plate.

BEHAVIOR OF D2 LAMP IN ORBIT







D2 LAMPS POWER SUPPLY

It failed. Then, no D2 can be activated.

How to solve this problem?

We use the following facts:

- the aging in visible and IR is very small and furthermore it is controlled by use of the two tungsten ribbon lamps,
- the covariance of the lines hollow cathode lamp allows to monitor the line intensity in UV.

This procedure has been validated for the period where the D2 were still working.

CONCLUSIONS

Instruments in space are exposed to several sources of ageing: contamination, particles, EUV.

Adding on board means (7 lamps, ….) with redundancy, which imply a more *complex* instrument (7 motors, 3 shutters, optical fibers, …) allows to perform many controls (scattered light, psf, …) and generate *specific* data to monitor the ageing to perform the corrections.

On board, many types of calibration can be run (scattered light, quartz transmission, FF, wavelength scale, psf, …).

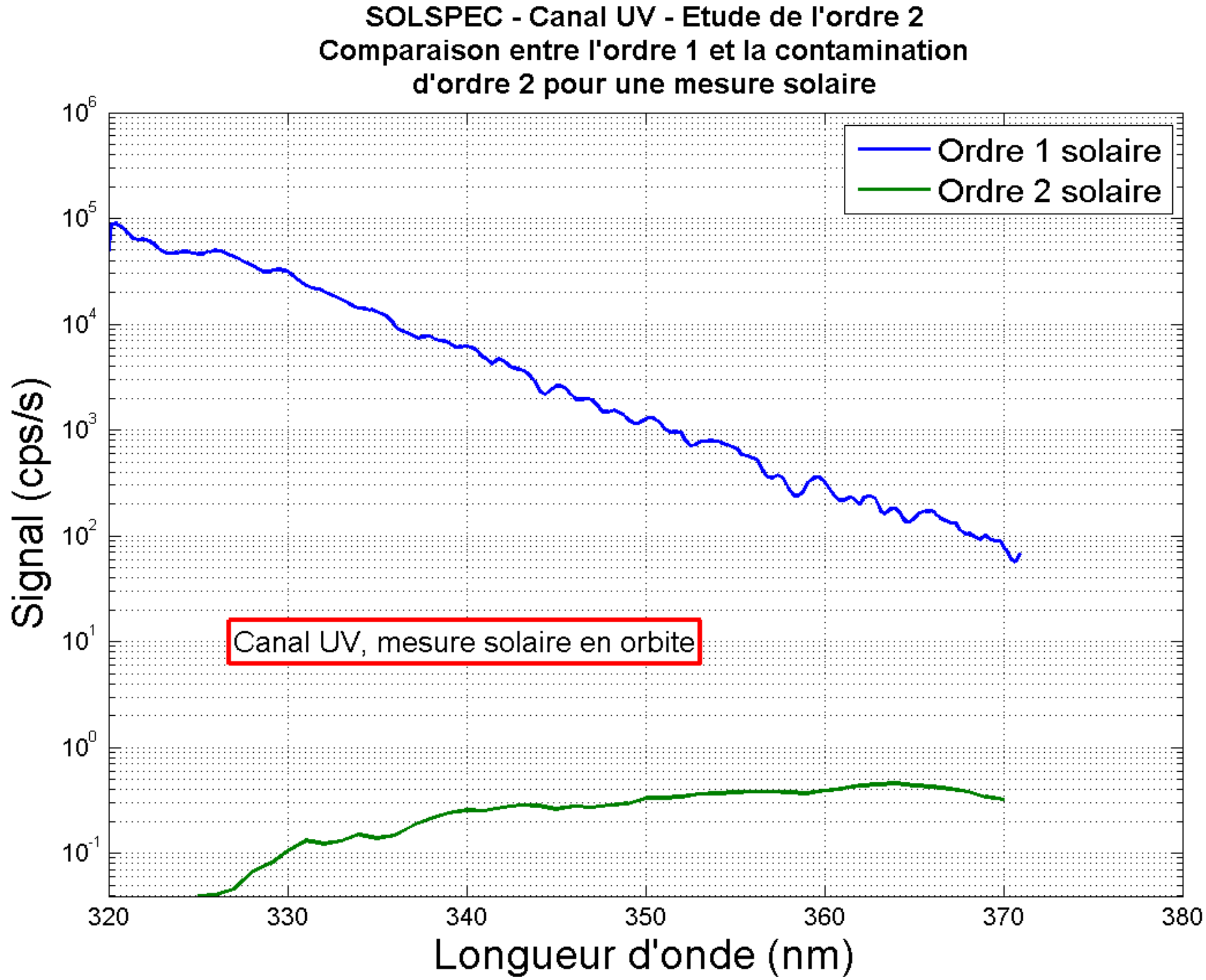
Quasi no aging exists in visible and IR. In UV, it is monitored and corrected by use of the aboard lamps (D2, then HCL).

Consequently, the instrument responsivity change in time is recovered.

Finally, SOLSPEC is a solar spectrometer associated with a set of means to generate characteristaion data in orbit.

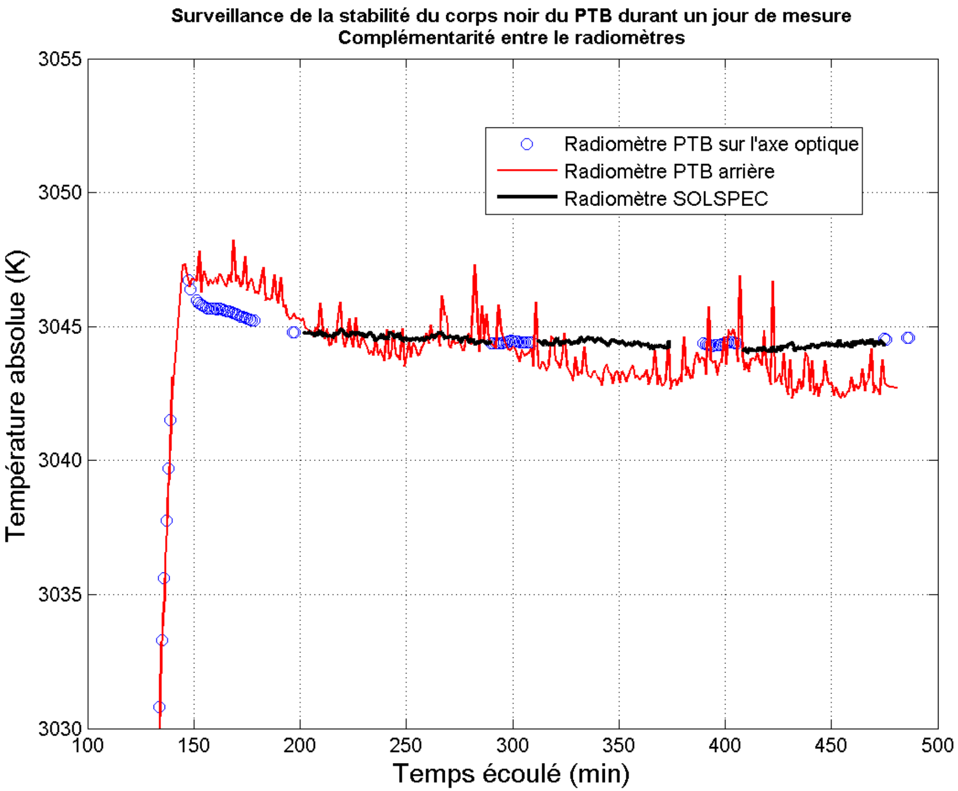
SOLSPEC = a Solar spectrometer + a space laboratory

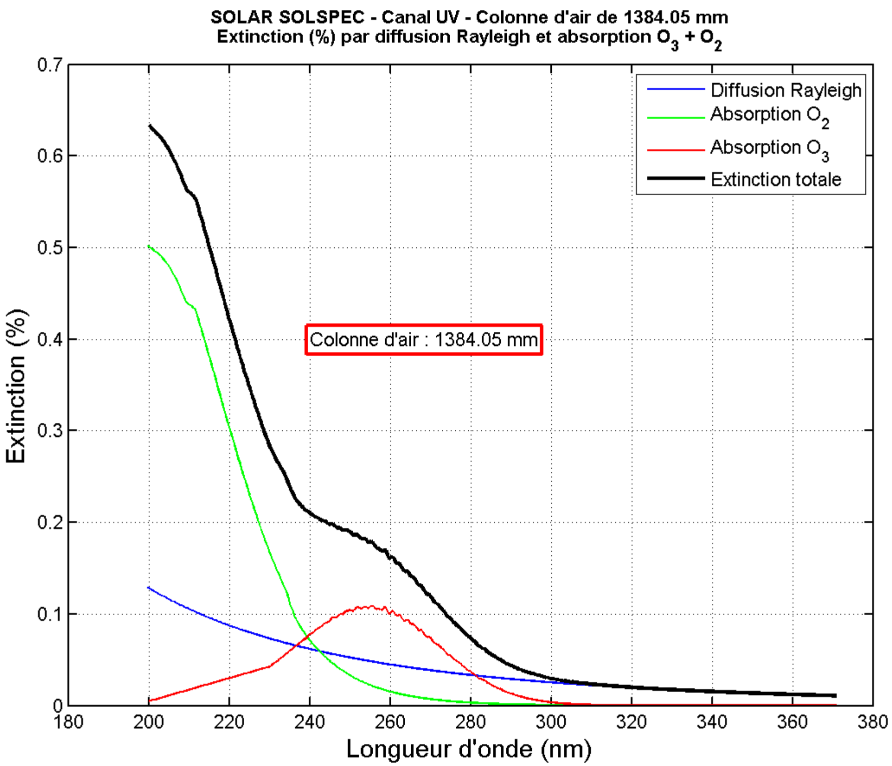
SECOND ORDER EFFECT



ABSOLUTE CALIBRATION AT PTB

We use the Blackbody at PTB (Braunscheiwg, Germany)
NIST FEL lamps and a D2 lamp (V0132 calibrated by PTB below 250 nm

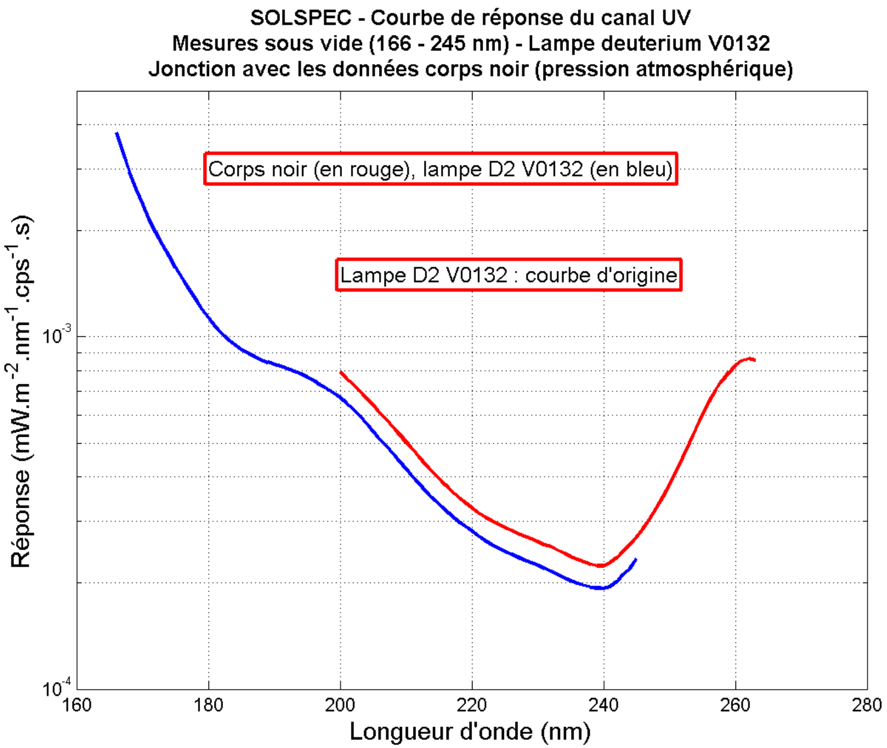


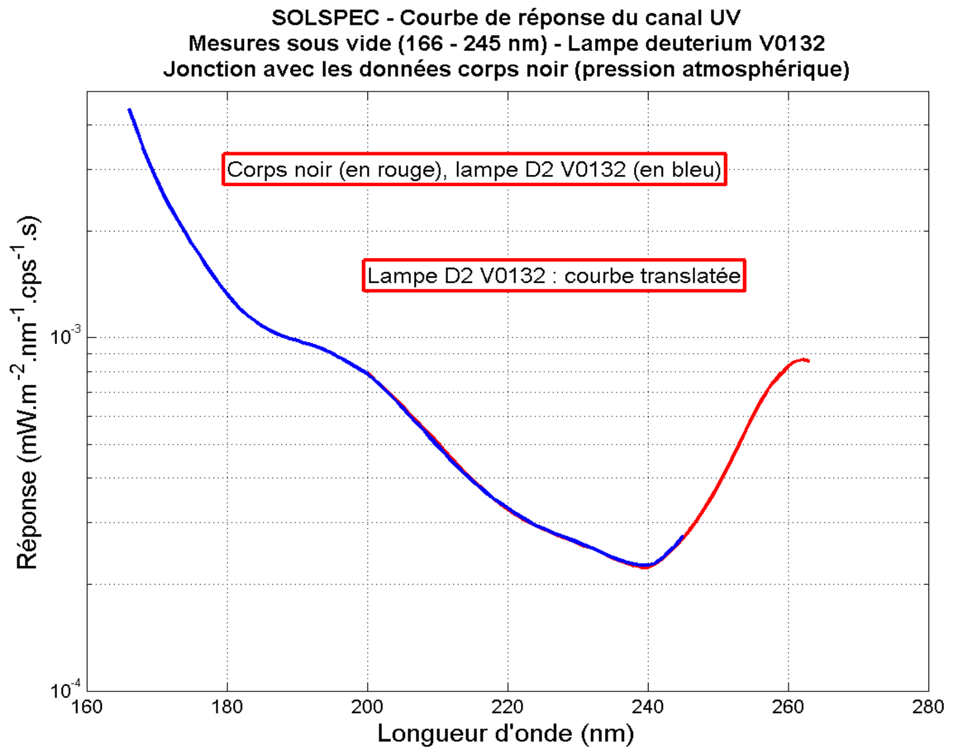


Temperature is recorded by three radiometers: at rear of BB for control (red, PTB),
In front (blue, PTB), in front (black, SOLSPEC).

PTB ensures an absolute temperature at 0.44 K accuracy.

UV Spectrometer calibration using PTB BB and NIST D2 lamps





SOLSPEC responsivity using BB: in red. As the BB is not usable below 200 nm, a D2 lamp was used (blue) calibrated by PTB in vaccum. This lamp and SOLSPEC were set in a vaccum chamber. Given the dimension of the chamber, the distance Instrument/lamp was very short → scattered light. After taking into account this effect, an agreement was found in the overlapping region.