SODISM-2
A ground based multi-wavelength full disk solar imager

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Plan

☑ 1 – Context : Why and How this instrument was developed
☑ 2 – Description of SODISM-2
☑ 3 – Other instruments of PICARD-SOL facility
☑ 4 – Observations – Calibrations
☑ 5 – First results for solar metrology
☑ 6 – Toward more science with SODISM-2 ?

22/04/2013 Synoptic Network Workshop (Boulder)
1 – Context: Why and How this instrument was developed

PICARD launched in June 2010
End of scientific mission Dec 2012

PICARD SOL installed at Calern Observatory

Link between Solar Irradiance and Radius Variations?

- Radiometers (SOVAP)
- Photometers (PREMOS)
- SODISM (full disk imager)

- SODISM-2
- Atmospheric Monitors
1 – Context: Why and How this instrument was developed

History of Solar radius measurements at Calern Observatory (1978-2006)

- 28 years of observations
- ~30000 measurements
- ~200 mas variations anti-correlated with Solar Activity
- Coherent with SDS balloon flights measurements but few points only.
- No confirmation from space observations so far

True solar variations?

Earth atmospheric effects (possibly triggered by Solar Irradiance variations)?

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1 – Context: Why and How this instrument was developed

SODISM-2 Development objectives

- A comparison of diameters acquired in space and on the ground to understand the influence of the atmosphere on the solar diameter

- To link space and ground measurements with the help of atmospheric parameters given by dedicated atmospheric and turbulence monitors (MISOLFA),

- To identify possible biases in historical series,

- To continue diameter measurements with ground based instruments at the end of the space missions with the results obtained from simultaneous observations from ground and space,

- To analyze possible anomalies noticed in orbit with the SODISM instrument,

SODISM II observe the Sun in the same wavelengths domain except in the UV domain where the 215 nm filter is replaced by another one (1025 nm filter).
2 – Description of SODISM-2

Environment SODISM II
- Pressure: less than $10^{-1}$ mbar
- Thermal regulation of the CCD (-30°C)
- Thermally regulated
- Weather station
- Pyranometer
2 – Description of SODISM-2

The instrument and its equatorial mount

*SODISM II built at CNES and LATMOS*

*Dimensions of SODISM II*

- Dimensions : 1300 (d) x 1065 (w) x 1065 (h) mm
- Dimensions de la cuve : 810 (d) x 460 (w) x 375 (h) mm
- Pression de la cuve : Inférieure 10 mbar
- Masse de la monture : Environ 500 kg
- Puissance de la monture : Environ 2000 W
- Pointage de la monture : +/- 15 arcseconds
2 – Description of SODISM-2

The instrument and its equatorial mount
2 – Description of SODISM-2

- 11-cm Ritchey-Chretien telescope with a CCD at its focal plane.
- Focal length of 2626 mm, an aperture of F/23 with a central obscuration of 40% in diameter (F/30 and 50% for the main channel).
- The Field of view is 36 36 arc-minutes.
- This design has some field curvature, the focus is adjusted at the Sun edge.
- Optical path: density filter (curved entrance window in silica (suprasil) back coated with a density filter), primary and secondary mirrors in zerodur, several interference filters on two filter wheels, and a CCD (2048^2 pixels of 13.5 µm (1.06”/pixel) side.)
The telescope thermal design
SODISM II requires a high level of thermo-mechanical stability to obtain the desired accuracy of solar radius measurements. A thermal control is implemented on the telescope and consists of
i. an efficient thermal protection (Multi Layer Insulation) of the overall telescope,
ii. a protection from solar illumination,
iii. the implementation of a heating system monitored by several thermal sensors.
Twenty heating lines are used to thermally stabilize the instrument at 20°C. The CCD is also thermally regulated at -10°C ±0.2°C to prevent any pixel size deformation and reduce its dark current, by using a Peltier element.

• The temperature of the interference filters is also regulated at 20°C ±1°C to ensure the stability of their spectral characteristics.
• The temperature of the entrance window is kept between 0 and 40°C in operating mode. Furthermore, the window is thermally insulated from the mechanical structure to avoid its deformations by thermal constraints.
• The whole instrument is kept in vacuum chamber placed on the equatorial mount.
• The mechanical parts on the optical path are black anodized
2 – Description of SODISM-2

4.1.2 Spectral domain of observation

Table 3 shows the main characteristics of the interference filters. All filters cleanliness complies with ESA PSS-51. Anti-reflection coating is used to limit the reflection between the CCD and the back area of the filter.

Table 3. SODISM II interference filters characteristics.

<table>
<thead>
<tr>
<th>Wavelength λ [nm]</th>
<th>Δλ [nm]</th>
<th>Transmission</th>
<th>Optical thickness</th>
<th>Exposure time</th>
</tr>
</thead>
<tbody>
<tr>
<td>393.37 ±0.1</td>
<td>0.7</td>
<td>6.2 to 10%</td>
<td>12.328 mm</td>
<td>1.70 s</td>
</tr>
<tr>
<td>535.7 (a) ±0.05</td>
<td>0.5</td>
<td>29.5 to 35.1%</td>
<td>12.297 mm</td>
<td>1.30 s</td>
</tr>
<tr>
<td>535.7 (b) ±0.05</td>
<td>0.5</td>
<td>26.3 to 32.8%</td>
<td>12.303 mm</td>
<td>8.90 s</td>
</tr>
<tr>
<td>607.1 ±0.1</td>
<td>0.7</td>
<td>33.5 to 42.8%</td>
<td>12.225 mm</td>
<td>1.28 s</td>
</tr>
<tr>
<td>782.2 ±0.2</td>
<td>1.6</td>
<td>29.7 to 37.6%</td>
<td>12.341 mm</td>
<td>1.43 s</td>
</tr>
<tr>
<td>1025.0 ±0.2</td>
<td>6.4</td>
<td>About 60%</td>
<td>12.080 mm</td>
<td>1.70 s</td>
</tr>
</tbody>
</table>
3 – Other Instruments of PICARD-SOL

Automatic photometer (Aerosol RObotic NETwork)

Pyranometer (Irradiance) and Wide field Camera (nebulosity)

<table>
<thead>
<tr>
<th>Wavelengths $\lambda$ [nm]</th>
<th>$\Delta \lambda$ [nm]</th>
<th>Exposure time</th>
</tr>
</thead>
<tbody>
<tr>
<td>340, 380, 440, 500, 675, 870, and 1020</td>
<td>10</td>
<td>10 s</td>
</tr>
</tbody>
</table>
3 – Other Instruments of PICARD-SOL

MISOLFA (Generalized Turbulence Monitor)
MISOLFA (Generalized Turbulence Monitor)

Cassegranian, D=25cm, f=10m
Alt-Az mount + derotating system

Allow us to record the spatio-temporal characteristic of local turbulence ($r_0, L_0, \theta_0, \tau$)

4 optical fibers guide the light to 4 diodes @ 2 KHz

32 im/s 480x660
0.2"/pix
1.5 mn sequences
4 – Observations and Calibration MISOLFA
4 – Observations and Calibration SODISM2 Alignment using P-angle
Black SOD2  17/05/2011 11:04  Red SOD1  17/05/2011 10:21 (ADU / 2.1)
4 – Observations and Calibration SODISM/SODISM2

Black SOD2  17/05/2011 11:04    Red SOD1  17/05/2011 10:21 (ADU / 2.1)
Flat Field at 782nm using Kuhn and Lorantz (1991) method and a sequence of shifted images acquired by moving M1 mirror.

=>$\text{Need a long sequence of images for each filter and excellent and stable atmospheric conditions.}$
4 - Observations and Calibration SODISM2
Flat Field Correction

782 nm raw

782 nm Flat Field Corrected
4 – Observations and Calibration SODISM2
Flat Field Correction
Alternate method using contrast images (Limb Darkening Function removed)
Under study …
Additional Calibrations:

• *Atmospheric Refraction*

• *Plate Scale estimation from star doublet pointing*

• *Turbulence correction using MISOLFA data*

• *Influence of extinction or Aerosol small angle scattering?*
5 –First Results SODISM2

Figure 15. SODISM II solar Semi-Diameter measurement (Refraction correction).

σ~0.2” but some calibration steps and especially turbulence corrections and global MTF estimates are still underway
=> Excellent instrumental stability over 2 years of observations
6- Toward more Science with SODISM2 ?

• SODISM2 was developed with the CNES support in the framework of PICARD space mission

• While SODISM showed a strong anomaly, SODISM2 is very stable and showed excellent stability.

• We focused so far on astrometric measurements for which photometric calibration was not the priority.

• We would like now to explore our capacity in having good photometric calibration and potentially join on going work / synoptic network for ground based irradiance studies (PSPT ?) => Changing the CCD (bad lines)

• We need to demonstrate that a larger community is interested and involved in order to keep minimum support from French National Sun-Earth connections Program.

• After its qualification on Calern site, SODISM2 (or PICARD-SOL) could also move to a better site. This would also require substantial financial support.
5 - Les premiers résultats (5.5/10)

Mesures : MISOLFA
- Statistique r0: médiane 3,86 cm
- Premiers résultats voie pupille

Ikhlef et al. 2012
Irbah et al. 2011
5 - Les premiers résultats (5/10)

Mesures : SODISM II, MISOLFA, Photomètre et Pyranomètre
5 - Les premiers résultats (7/10)

La visée stellaire

- Validation de la valeur du facteur d’échelle du télescope (mesures et calculs optiques)
- Limitation du nombre de couples possibles (hauteur d’observation, magnitude des étoiles, distance entre étoiles, …)
- Correction du mouvement propre des étoiles, de la réfraction, …
- Calcul de la distance entre les étoiles en utilisant un photocentre ou par inter-corrélation (résultats différents) → convergence en cours concernant la méthode à utiliser

Difficulté: prise en compte de la configuration différente entre visée stellaire et solaire.

Exemple de couple d’étoiles visé en aout 2011

<table>
<thead>
<tr>
<th>Couple</th>
<th>Identifier</th>
<th>Nom</th>
<th>Flux</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIP10644</td>
<td>* del Tri</td>
<td>V 4.900</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HIP10670</td>
<td>* gam Tri</td>
<td>V 4.000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>HIP17702</td>
<td>Aleynone</td>
<td>V 2.873</td>
<td>Sept.</td>
</tr>
<tr>
<td></td>
<td>HIP17573</td>
<td>Maia</td>
<td>V 3.871</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>HIP20877</td>
<td>* 75 Tau</td>
<td>V 4.971</td>
<td>Oct., Nov.,</td>
</tr>
<tr>
<td></td>
<td>HIP115033</td>
<td>V* psi02 Aqr</td>
<td>V 4.400</td>
<td></td>
</tr>
</tbody>
</table>
La visée stellaire

**5 - Les premiers résultats (8/10)**

**Inter-corrélation :**

- Photocentre :
  - 1695.33 +/-0.31
  - 1694.64 +/-0.39

- 313.654 +/-0.33
  - 312.37 +/-0.31

22/04/2013

*Synoptic Network Workshop (Boulder)*