PICARD SOL, a new ground-based facility for long-term solar radius measurements

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ABSTRACT

PICARD SOL is the ground segment of the PICARD mission to allow a comparison of the solar radius measured in space and on ground. PICARD SOL will enable to understand the influence of the atmosphere on the measured solar radius. The PICARD SOL instrument consists of SODISM II, a replica of SODISM Solar Diameter Imager and Surface Mapper), a high resolution imaging telescope, and MISSOLA (Monitor d’Images SOLaires Franco-Algériens), a high cadence solar limb imager allowing us to measure the spatio-temporal parameters of the local turbulence. Additional instrument consists of a Sun photometer, which measures atmospheric aerosol properties, a pyranometer to measure the solar irradiance, a visible camera, and a weather station. PICARD SOL is operating since March 2011. SODISM II provides wide-field images of the chromosphere and photosphere of the Sun in five narrow pass bands (393.37, 535.7, 601, 732.3, 1205.5 nm), spanning from the near ultraviolet (NUV) to the near infrared (NIR). This paper presents an overview of PICARD SOL instruments and some results obtained from observations performed at the Calern site of the Observatoire de la Côte d’Azur (OCA) since 2011. The SODISM II mean radius of 999.25 arcsec at 535.7 nm (with ±0.18 arcseconds) is deduced from measurements (between years 2011 and 2012).

INTRODUCTION

Solar diameter measurements performed from the ground for several decades seem to indicate a correlation or an anti-correlation between the solar diameter and the solar activity. However the interpretation of ground observations is controversial, ground-based measurements being affected by refraction, by atmospheric turbulence, and perhaps by atmospheric aerosol scattering. The only way to be free from atmospheric effects is to measure from space. This is the reason why, since the beginning of a space program and a ground component set up at the Calern observatory, PICARD-SOL comprises SODISM II, similar to the SODISM flight model, the turbulence monitor MISSOLA, and the additional instrumentation. The main objectives of the PICARD SOL mission are:
- To understand the influence of the atmosphere on the solar radius,
- To determine the relation between the turbulence parameters and the measured solar diameter and limb shape,
- To determine if the scattering by aerosol degrades the quality of the images,
- To compare the solar radius measurements obtained with SODISM II and ground based instruments (in order to identify possible biases and correct historical series),
- To continue solar radius measurements with ground based instruments.

SODISM II

SODISM II is a 257-m diameter telescope associated with a 2048x2048 pixel CCD detector. The SODISM II instrument is described in detail by Meftah et al. (2011). The instrument field of view and its angular resolution are about 35 arcminutes and 1.06 arcseconds/pixel, respectively. SODISM II observes the Sun in five wavelength domains by using interference filters. The Sun image is stabilized on the detector by the equatorial mount (Figure 1).

Preliminary results

SODISM II records full solar images at several wavelengths since March 2011. The solar radius is defined as the position of the reflection point of the Limb Darkening function (LDF). From the ground, the solar radius is obtained at several solar zenith angle. An evaluator of the solar radius measurement is shown in Figure 2 as a function of time for different wavelengths. They behave similarly, however providing different solar radius. Different effects can introduce a bias in the solar radius measurement. Major effects are: refraction, atmospheric turbulence, instrumental effects (PSF, thermo-optical effects, ...). Other effects have an impact, such as aberration and scattering of the solar light by aerosols, and the spatial domain of observation must be taken into account.

SODISM II solar radius measurement (357.7 nm), corrected from refraction (barbar) is shown in the Figure 5. Mean semi-diameter (solar radius) of 999.25 arcseconds (with ±0.18) is deduced from more than 11,000 measurements. Mean semi-diameter for all wavelengths is shown in the Table 2. We do two series of measurements to determine the angular resolution of the telescope (March 2011, and October 2012 – Figure 6). The two series provides slightly different values (1.0513 and 1.051 arcseconds/pixel). The angular resolution of the telescope is stable.

MISOLFA

MISSOLA (figure 7) A solar seeing monitor associated with a 4096x4096 pixel CCD detector. It is described in detail by Ibrah et al. (2012). The design (figure 8) is based on the statistical analysis of the entry angle fluctuations defined as the slope in each point of the wave front against the pupil. In the case of diurnal conditions, these fluctuations are shown by observations of the solar limb. Figure 9 shows an image Bk (by 128 arcseconds) of the Sun recorded on June 2, 2012 (transit of Venus).

Additional instrumentation

Solar measurements achieved from ground are perturbed by different phenomena, which are time dependent. The Earth’s atmosphere contains aerosols such as water droplets, dust and ice crystals generating scattering to which turbulence effects are added. A dedicated instrumentation will allow detailed atmosphere characterization for long-term studies.

CONCLUSION

PICARD SOL is the ground segment of the PICARD mission. The seeing monitor MISSOLA, and the solar diameter imager SODISM II have been observing the Sun together since March 2011. MISSOLA is a high cadence solar limb imager allowing us to measure the spatio-temporal parameters of the local turbulence. SODISM is a multi-wavelength full disk solar imager specially designed for metrological measurements. Additional instrumentation (photometer and pyranometer) are in operation since July 2011. The PICARD SOL photometer provides a quality index of pictures taken by SODISM II (aerosol optical depth). The PICARD SOL pyranometer measures the luminous flux received, and provides another quality index for SODISM II measurements. PICARD SOL is a new ground-based facility for long-term solar radius measurements. The mean value of the semi-diameter was measured at 999.25 arcseconds at 535.7 nm (with ±0.18 arcseconds).

The quality of the solar radius measurements can be improved (atmospheric turbulence, scattering of the solar light by aerosols, instrumental effects, ...). PICARD SOL preliminary results are very promising and the first solar radius measurements are in good agreement with those obtained on the same site with other instruments (Solar Astrolabe and Doraysol).