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METEOSPACE, SOLAR MONITORING AND SPACE WEATHER AT CALERN OBSERVATORY

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Abstract. METEOSPACE is a new partnership project between the Paris Observatory (OP), the Observatoire de la Côte d'Azur (OCA), the French Air Force and a service company (LUNA technology) for the development and operation of a set of small telescopes Hα / Ca II K / Ca II H / G band to be installed at on the Calern plateau (OCA). The objective is to monitor solar activity for both research and its applications in space weather through continuous optical observations of the dynamic phenomena that are visible in the chromosphere: eruptions, destabilization of the filaments triggering coronal mass ejections and associated Moreton waves.

Keywords: Sun, Chromosphere, Space-Weather, Hα

1 Introduction - Short history of solar monitoring at Calern and Meudon observatories

A long term solar monitoring program has started at Calern observatory in 1974 (Laclare 1975). It is dedicated to solar astrometry and aims to detect and monitor possible solar diameter variations. The first instrument hosted by this solar astrometric station was a visual astrolabe. Over the years the observer's eye was replaced by analogic and digital cameras and in 1999 a new instrument called DORAYSOL was built which included a variable prism in order to record transit data all along the day (Morand et al. 2010). In 2010 the CNES PICARD satellite was lauched with the SODISM telescope onboard which was fully dedicated to solar astrometry (solar diameter and shape) (Meftah et al. 2014b, 2016). In 2011, the qualification model of SODISM called SODISM-2 was installed at Calern (Meftah et al. 2014a) and a day-time turbulence monitor was developped that allows simultaneous record of the spatio-temporal parameters of atmospheric turbulence (Ikhlef et al. 2016). SODISM-2 is a multi-wavelength imager providing full-disk images of the photosphere in the continuum at 535.7 nm, 607.1 nm , 782.2 nm and 1025.0 nm, and of the chromosphere in the Ca II K-line at 393.37 nm. Since 2011 more than 138000 images have been recorded and distributed via our local server `https://solar-data.oca.eu/` and the Multi Experiment Data and Operation Center (MEDOC). Continuum wavelength avoiding Fraunhofer lines were specificaly chosen in order to avoid the influence of magnetic activity on diameter measurements. The Ca II K filter is a broadband filter (0.7 nm) that covers the whole chromosphere from the temperature minimum 500 km above the photosphere up to about 1800 km and the transition region. It is used to detect large scale activity features on the solar disk.

Observations at Calern are fully complementary to those performed in Meudon since 1909. The climate of Ile-de-France allows to get daily images (280 days per year) but it is impossible to perform there continuous observations and monitor solar activity with temporal resolution compatible with transient and fast phenomena as flares, filament disturbances and Coronal Mass Ejecta. Hence, the scientific objective at Meudon is to follow solar activity along the solar cycle, and for that purpose, daily images are sufficient. From another point of

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view, Meudon operates a spectrograph which provides full line profiles (of Hα, CaII K) over the full disk with 0.02 nm spectral resolution typical; profiles can be used for probing the solar atmosphere as they contain depth information. On the contrary, most instruments in the world operate with monochromatic filters, corresponding to only one layer in the chromosphere. Another spectrograph operates the same way in the world at Coimbra (Portugal): it is a copy of Meudon spectrograph.

2 METEOSPACE Scientific Objectives

The goal of the new project presented here is to install a set of small telescopes at Calern observatory dedicated to the continuous observation of the chromosphere. This project will benefit from the existing solar station equipment and staff at Calern observatory. Monitoring solar activity both in real time and in the long term are needed for both research and for applications in space weather through the detection of rapid and transient solar phenomena:

- instabilities in solar filaments, eruptive filaments being partly associated with the onset of coronal mass ejections (CME)
- solar flares, also associated with CME
- chromospheric Moreton wave, also associated with the coronal wave which also appears in the lower corona radio radiation and in the high corona coronographic observations (SOHO / LASCO).

The hydrogen Hα line is the most suitable line for monitoring solar phenomena from their birth, low in the solar atmosphere, the chromosphere, the root of solar eruptive activity. Images taken in narrow band filters of Ca II K and Ca II H lines will also complement these observations. These lines of singly ionized calcium are the strongest absorption lines in the visible solar spectrum and among the most sensitive indicators of the chromospheric structure and magnetic features of the Sun.

3 National and international context

Because Hα images of the Sun are potentially very useful for predicting eruptions, observatories around the world observe the sun at that wavelength for both the scientists and space-weather applications. This led to the Global High Resolution Hα Network `http://swrl.njit.edu/ghn_web/` but also to the Hα program of the Global Oscillation Network Group (GONG) `http://halpha.nso.edu/` which, in addition to its helioseismology products, provides since 2012, in real time, Hα images throughout its network for civilian and military applications.

The FEDOME* project managed by the French Air Force that aims to gather observations useful for space-weather prediction has already signed agreements with the Nancay station for radio observations (ORFEES† antenna) and the 'Institut de Physique du Globe de Paris' (IPGP) for their magnetometric data. It also uses optical data from CLIMSO‡ (Koechlin 2015) which is an associative operation led at Pic du Midi Observatory under the Research Institute in Astrophysics and Planetology (IRAP) scientific supervision. CLIMSO comprises 2 telescopes and 2 coronographs on the same equatorial table. It provides images of the solar disk in Hα and Ca II, and images of the low corona in Hα and singly ionized helium (He II) when the weather allows.

Meudon observatory provides Hα and Ca II spectroheliograms at low cadence, typically a single image of each type per day suitable for studies at the scale of the 11 year solar cycle. Because of climate, this site does not allows monitoring solar activity continuously. The only European station conducting continuous observations in H-alpha is GONG station on the Canary Islands with a cadence of one image per minute. The Kanzelhöhe observatory in Austria and the Royal Observatory of Belgium also have an Hα observation program and their images are made available through the space weather web portal of the European Space Situational Awareness (SSA) program `http://swe.ssa.esa.int/swe`.

From space, the Hinode/SOT instrument (Tsuneta et al. 2008) provides high resolution images with a limited field of view of the chromosphere notably in Hα and Ca II H. It also provides photospheric network diagnostic through the CH molecular G-band. The Solar Dynamic Observatory instruments continuously provide full

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†Observation Radio Fréquences pour l'Etude des Eruptions Solaires
‡ Christian Latouche IMageur Solaire.

images of the photosphere and corona at different heights (Pesnell et al. 2012). The only channel covering partially the chromosphere is the one of He II line in extreme ultraviolet (at 30.4 nm) which probes the upper chromosphere and lower transition region.

4 METEOSPACE Instruments

METEOSPACE will propose several 80 mm or 100 mm aperture small telescopes operating either in spectral lines as Hα, CaII K, CaII H or G band (4 instruments maximum). Hα will be provided by a Fabry Perot from DayStar Filters (USA) with 0.05 nm bandwidth. CaII K and H will be obtained using Barr Associates narrow interference filters (0.15 nm). G band will use a 0.8 nm Andover filter. The telescopes will be mounted in a box maintained at 25 degrees temperature (active heating, passive cooling). The CCD cameras use interline Sony sensors of 2750 x 2200 pixels (4.54 microns and 20000 electrons full well capacity) with electronic shutter. The pixel size will be 1 arc sec on the sun. The temporal resolution will be 10 s for Hα and 60 s for other lines. Data will be provided in FITS format after data treatment using an automated pipeline. Real time data will be available for operational purposes for solar weather forecasting. Several gigabytes will be produced every day. The instruments will run in automatic mode. The equatorial mount is made by Valmeca (France). The computer will drive the mount, filters and cameras and will direct raw data towards the Calern server. The pre-processing will be done automatically at Calern before transfer do the database in Nice. A small part will be directed daily to the national solar survey archive BASS2000 `http://bass2000.obspm.fr/`. The telescopes (~350 k€) and the building (~50 k€) to host them at Calern are already financed by Direction Générale de l'Armement with contributions from Observatoire de Paris and Région Ile-de-France. However, to be successful and to have a chance to join the existing international programs gathering data for space-weather from ground-based observatories, the project needs to be totally automated and to be able to handle the real time processing of the images. For this we need to have an automatized roof for the building, to control the environment (weather station, rain sensor, wide field camera) and to insure the continuity of the observations by provisioning spare cameras and computers. Several funding requests are underway for these aspects.

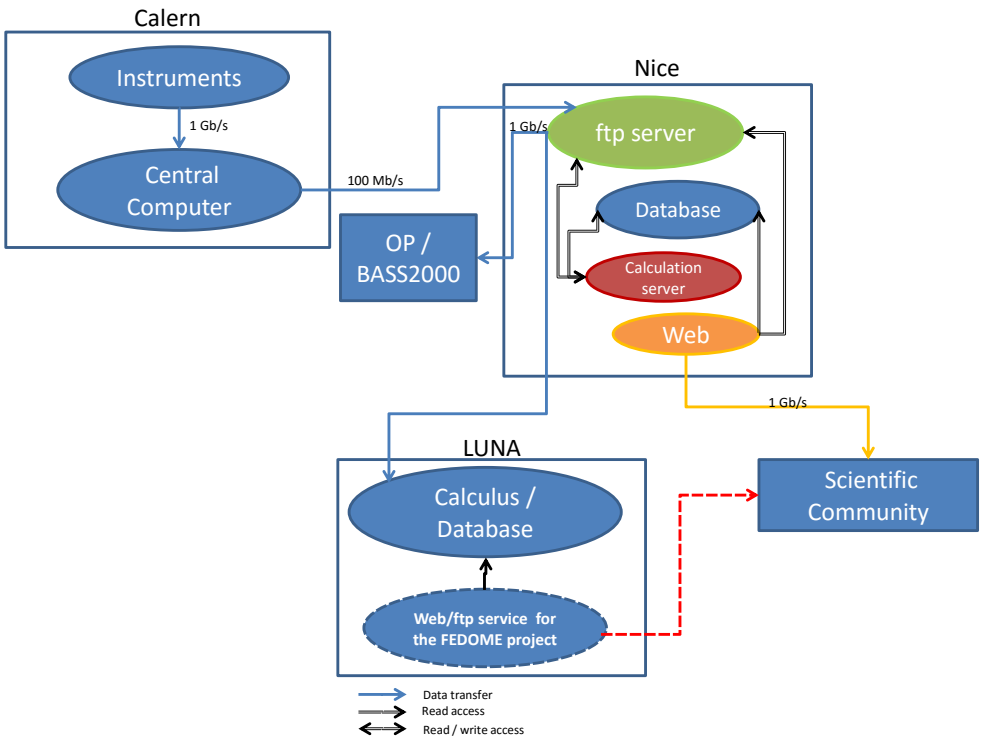

Fig. 1. Data acquisition, reduction and distribution system

5 Data processing and distribution

Data will be processed and distributed in near real-time. The system shown on Fig. 1 is made of three main units: a central computer close to the instruments at Calern observatory, a cluster located in Nice with nodes for computing, hosting a database ftp and web servers and a cloud service developed and maintained by LUNA for operational space weather applications and its use by the FEDOME project. The central computer reads raw data from the instruments, build level 0 FITS files and quick-look jpeg files and continuouly transfers these data to the cluster in Nice. The computing nodes of the cluster will implement real-time data selection, build the level 1 (calibrated) data when relevant, run the real time solar features extraction codes and populate the database. Automation of the filament tracking was previously developped in the framework of the HELIO project (Bonnin et al. 2013) and will be adapted for these new data. The ftp server is dimensioned to serve 5 TB per year and uses redundant array of independent disks (RAID 6) for insuring raw data security. Data will remain accessible on the server for three years after which a long term archive possibly hosted by BASS2000 should be developped and used. The web interface to the database and ftp server will be developped in collaboration with LUNA and made fully open to the scientific community and general public. All data will be fully open and made accessible as soon as they are produced without any retention period. A service for space-weather applications developped by LUNA for the FEDOME project will gather data from these servers. Part of the tools developped for this service will also contribute to the pipeline hosted by the Nice cluster.

6 Conclusion

The possibility of installing this instrumentation at the Calern station of OCA with local scientific and technical team on an existing platform of solar observations is a unique opportunity in continental Europe in complementarity with Nançay for radio astronomy and solar coronography at Pic du Midi. The METEOSPACE project will provide unique high cadence images of the chromosphere to the community and our goal is to join and contribute to the major international networks distributing optical ground-based solar data for both the fundamental study of chromospheric activity and space-weather applications. A workshop is held in Nice[§] to discuss and gather community input on science requirements and to discuss the existing and futur instrumentation for ground-based solar observing programs in the framework of space-weather studies and applications.

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[§] `http://meteospace.sciencesconf.org`

[¶] Environnement Spatial de la Terre : Recherche et Surveillance `http://esters.obspm.fr/`