Solar Activity Monitoring at Calern Observatory: High-Cadence Chromospheric Surveillance

T. Corbard, F. Morand, F. Guitton, S. Flament, G. Verbiese (OCA)
J.-M. Malherbe, G. Barbary, C. Collin, D. Crussaire, J. Aboudarham (OP)

METEOSPACE Instrumentation

Observatoire de la Côte d'Azur and Paris Observatory developed the METEOSPACE project to provide continuous high-cadence observations of the solar chromosphere with a dual objective: fundamental research on solar eruptive activity and space weather studies (processing/dissemination of real-time data). The instrument is installed at the Calern observatory site (1270 m altitude) in southeastern France and operates automatically with near real-time processing capabilities.

Scientific Motivation

High-cadence Hα surveys are essential for observing rapid chromospheric phenomena associated with solar activity:

- Solar flares
- Filament eruptions
- Moreton waves
- Precursors of coronal mass ejections

Historical Hα heliographs operated at Meudon and Haute-Provence observatories between 1956 and 2004 produced more than 6 million images, demonstrating the scientific value of systematic chromospheric monitoring. METEOSPACE continues and modernizes this legacy using automated digital instrumentation.

Instrument Architecture

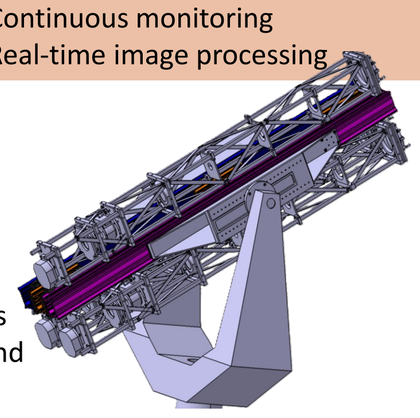
The METEOSPACE instrument consists of **three synchronized telescopes** telescopes with an equivalent focal length of 983 mm dedicated to chromospheric observations in:

- Hα (656.28 nm and 656.23 nm)
- Ionized calcium spectral lines (Ca II)

The use of multiple wavelengths allows observations at different heights in the chromosphere. Two Hα channels are centered at slightly different wavelengths to simultaneously observe filament structures at different chromospheric heights, improving detection and characterization capabilities.

The instrument is optimized for:

- Full-disk solar imaging (<1"/pixel)
- High temporal cadence (10s)
- Automatic operation
- Continuous monitoring
- Real-time image processing



Optical Design

Hα Channels: The two Hα channels use 80 mm and 100 mm aperture telescopes with Takahashi TSA102 objectives (816 mm focal length) followed by a 1.2x afocal chamber. This setup places narrow-band DayStar Quantum Pro Fabry-Pérot filters directly into the F/30 pupil plane and incorporates a two-lens field corrector to compensate for field curvature at the final detector.

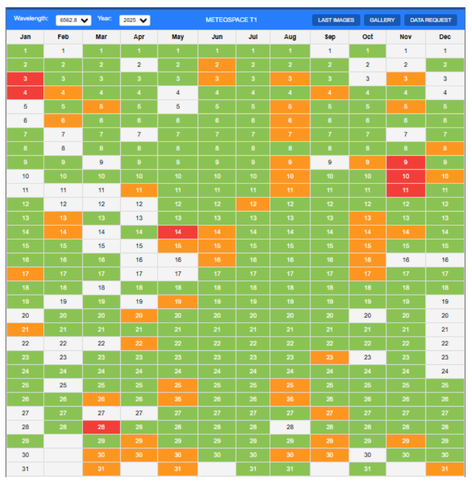
CaII K Channel: This channel utilizes an 80 mm aperture telescope built around a Takahashi FS102 objective lens (820 mm focal length) paired with a 1.2x magnifying chamber to house its broad-band interference filters within the F/12.3 image plane.

Simulated via Zemax, the entire configuration achieves a near-absence of optical distortion, delivering high Strehl ratios of 88% for the CaII K channel and 93% for the Hα channels.

Data access

https://solar-ftp.oca.eu/pub/DEPOT/MTS_CALENDAR.html

(Old version)



Meteospace calendar. White days indicate no observations, whereas orange and red days indicate that at least one M-class or X-class flare occurred during the observing period.

https://solar-db.oca.eu/

(New β version)

FTP server and real-time QuickLook

Level 1 data are publicly available in near real time via a dedicated FTP server. A quick-look interface enables the selection and visualization of image sequences around events of interest, while also providing access to several indicators (e.g. Intensity level, contrast, cloud cover, GOES X flux).

BASS2000

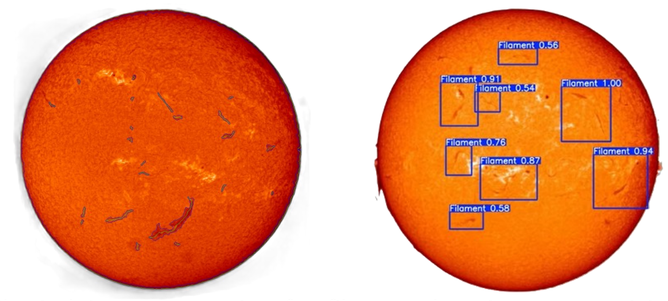
One image per hour and per channel and daily movies are made available via BASS2000 solar data center.

Virtual Observatory access

We have deployed a new DaCHS server for SolarData on the OCA infrastructure. Rather than maintaining a local database, the server directly accesses the project's TimescaleDB database. The service has been declared and registered within the IVOA registry in order to fully comply with EPN/IVOA standards and to make the service visible in VESPA in the near future.

Solar Filament Tracking Using Artificial Intelligence

Building on classical methods (image processing and mathematical morphology) for the detection and characterization of solar filaments developed by Fuller et al., an R&D project carried out by students from the École des Mines d'Alès has developed a training dataset for an AI-based detection method.

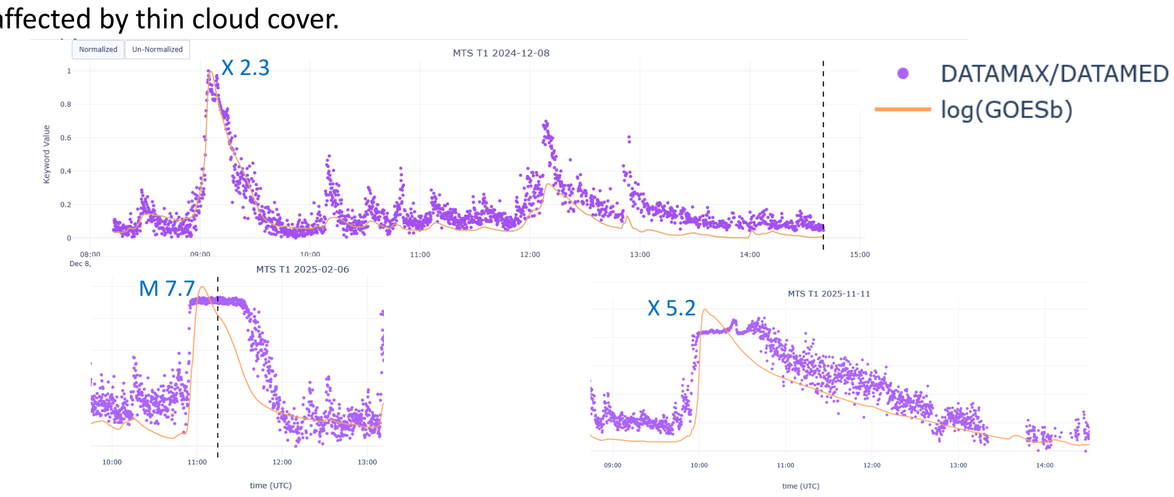


Classical image processing for filament detection on a training dataset (left) and AI detection with associated probabilities on new images (right)

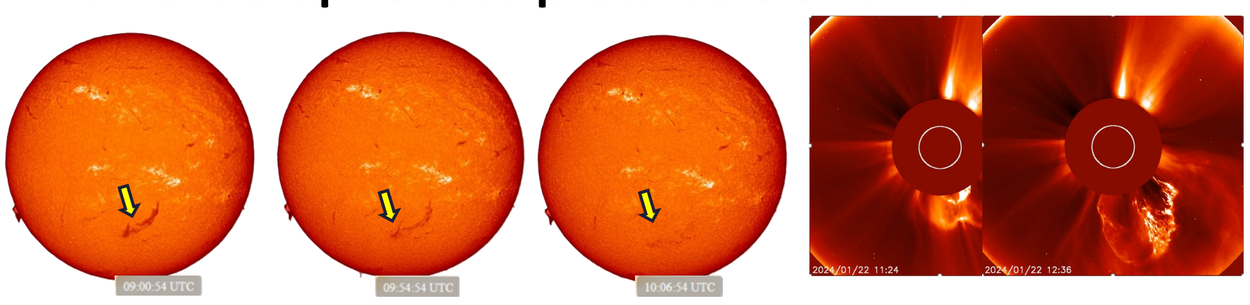
This approach has been successfully applied to a new series of images, significantly reducing the time required for analysis. It enables continuous monitoring of filaments and real-time detection of filament destabilization, which can sometimes be precursors of coronal mass ejections (CMEs).

Correlation Halpha intensity / GOES X flux

We have found that the ratio between the maximum intensity and the median intensity in H-alpha images provides a very good proxy for the X-ray flux measured in the GOES 0.1–0.8 nm channel.
A strong correlation is observed between this proxy and the logarithm of the X-ray flux, both during the typically short rising phase and during the decay phase, which can last several hours. However, the proxy may saturate under very clear sky conditions (lower left figure) and can also be affected by thin cloud cover.



Filament eruptions as precursors of CMEs

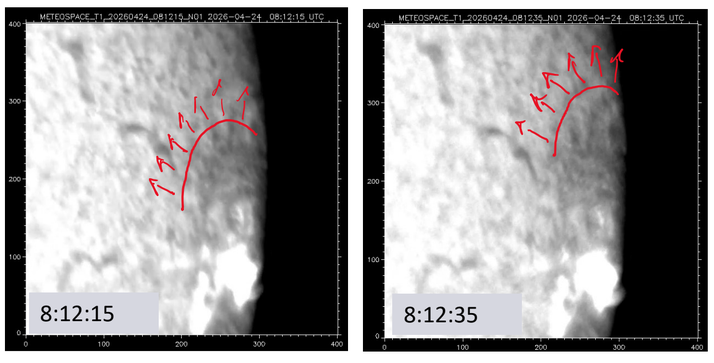


This example of a filament eruption captured on 22 January 2024 by Meteospace (3 images left) shows that the eruption is fully developed in the H-alpha images approximately one hour before the associated CME becomes visible in SOHO coronagraph observations (2 images right).

Link to the filament eruption sequence

Moreton wave detection

On 24 April 2026, a Moreton wave was detected following an X2.4-class flare observed near the eastern limb. Moreton waves are large-scale disturbances propagating through the solar chromosphere, typically visible in H-alpha observations as rapidly expanding wave fronts associated with powerful flares and coronal mass ejections (CMEs). They are interpreted as the chromospheric signature of a coronal shock wave.
Our preliminary analysis of this event indicates a propagation speed of approximately 1200 km/s. However, the signal remains weak and could not be identified directly in the quick-look image sequences. In addition, difference imaging between the line-core and blue-wing channels did not enhance the signal as effectively as initially expected.



Link to the Moreton wave sequence

References

- Fuller, N., Aboudarham, J., & Bentley, R. D. (2005). **"Filament recognition and image cleaning on Meudon Hα spectroheliograms"** *Solar Physics*, **227**, 61–75
- Malherbe, J.-M., Corbard, T., Barbary, G., Morand, F., Collin, C., Crussaire, D., Guitton, F. (2022). **"Monitoring fast solar chromospheric activity: the MeteoSpace project"** *Experimental Astronomy, 53, 1127*
- Malherbe, J.-M., Corbard, T., Dalmasse, et al. (2019). **"MeteoSpace, a New Instrument for Solar Survey at the Calern Observatory"** *Solar Physics*, 294, 177.
- Pacault, G., Schreiber, H., Lee, X. Y., ("**Solar Image Analysis for Solar Flare Prediction using the MeteoSpace Telescope at Calern**", R&D report 2025, Ecole de Mines d'Alès

Observatoire de la CÔTE d'AZUR · UNIVERSITÉ CÔTE D'AZUR · LAGRANGE · Observatoire de Paris | PSL