

# THEMIS solar telescope: a new era begins



Colloque scientifique de l'ATST, Biarritz, FR, 1-5 juin 2026

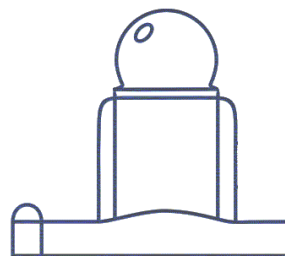


Étienne Pariat<sup>1,2</sup>, Bernard Gelly<sup>1</sup>, Richard Douet<sup>1</sup>, Didier Laforgue<sup>1</sup>,  
Saida Diaz Castillo<sup>1</sup>, Jorge Romero Castañeda<sup>2,1</sup>, Sofiane Mami<sup>3</sup>

<sup>1</sup> French-Spanish Laboratory for Astrophysics in Canarias (FSLAC), CNRS, IAC, La Laguna, Tenerife, Spain

<sup>2</sup> LPP, Sorbonne Université, École polytechnique, IPP, U. Paris Saclay, Obs. Paris-PSL, CNRS, Paris, France

<sup>3</sup> Ecole Polytechnique, France



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de la recherche

projet ANR-25-CE31-7416

- **Past**

- Present

- Future

# THEMIS Factsheet



## Main French solar telescope

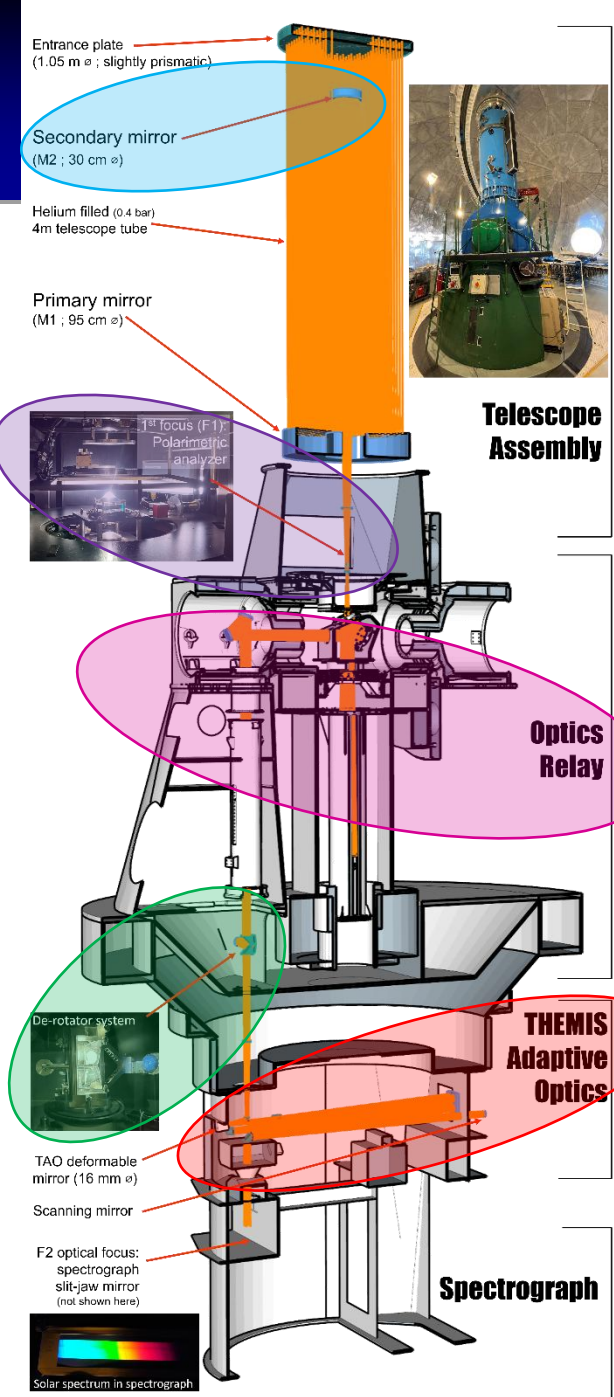
- Designed by J. Rayrole, P. Mein & M. Semel
- Located at Teide Observatory, Tenerife, Spain
- 1<sup>st</sup> light in March 1996, & commissioned in 1999



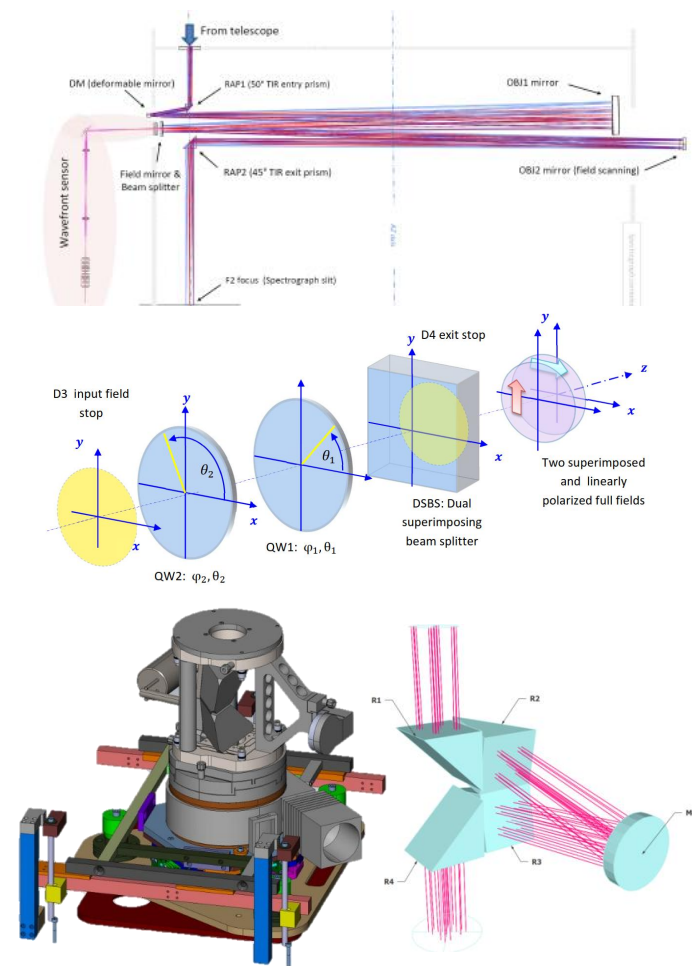
THEMIS @ OT in June 2025

- 1m-class solar telescope, with one the world “slowest” optical design:
  - Aperture: 92 cm ;
  - Effective focal length: 57m
  - Effective focal ratio: f/62
  - 60”x60” to 120”x120” square field-of-view
- **MULTI Ray spectrograph (MTR2): ideal for high-spectral resolution spectropolarimetry:**
  - Working spectral range: 4000 - 11000 Å
  - **Polarization calibration free**
  - **Ultra-high spectral resolving power:**
    - $R \sim 200\,000 - 300\,000$
  - **Simultaneous observations of user-defined set of up to 6 spectral ranges:**
    - $\sim 6-7 \text{ \AA}$  spectral range
    - $\sim 25 \text{ m\AA}$  spectral resolution

# “Total makeover” : 2016 → 2021



- **THEMIS has been widely renewed and redesigned**
  - Thanks to EU funding: ~1M€ from 2 SOLARNET programs
- **M2 mirror re-aluminising** (WHT & THEMIS team)
- **Themis Adaptive Optics:** “classical” single-DM adaptive optics based on innovative wavefront sensing and mirror commanding concepts (AIRI@CRAL & THEMIS teams)
- **Superimposed dual-beam polarimetric analysis** without field limitation (M. Semel, A. Lopez, C. Le Men C. & THEMIS team)
- **“Polarization- friendly” complete redesign of the whole transfer optics (M3, M4 & M5)** (C. Le Men & THEMIS team)
- **New de-rotator system** (THEMIS team)
- + new context, broadband and spectral cameras.

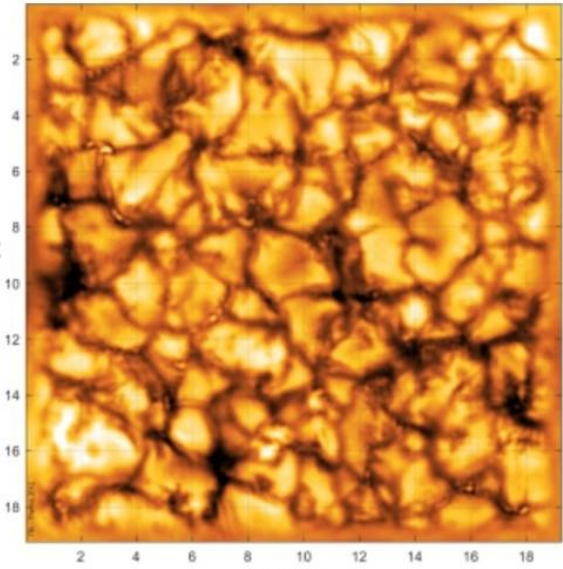
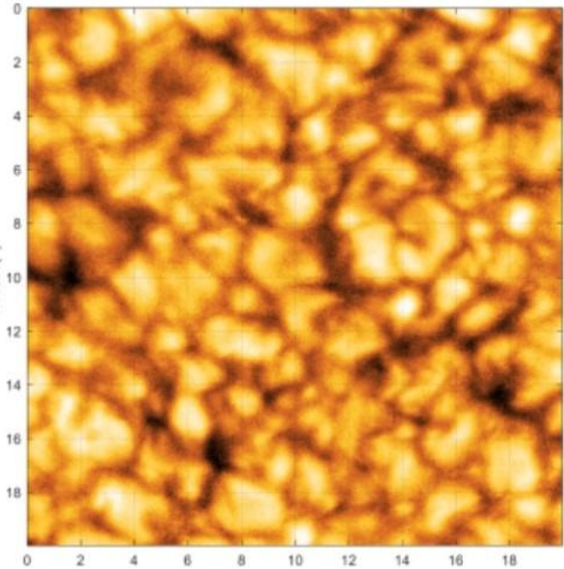
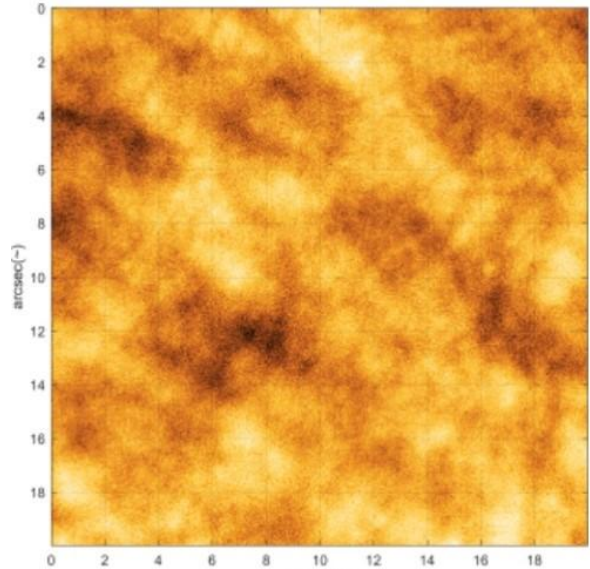
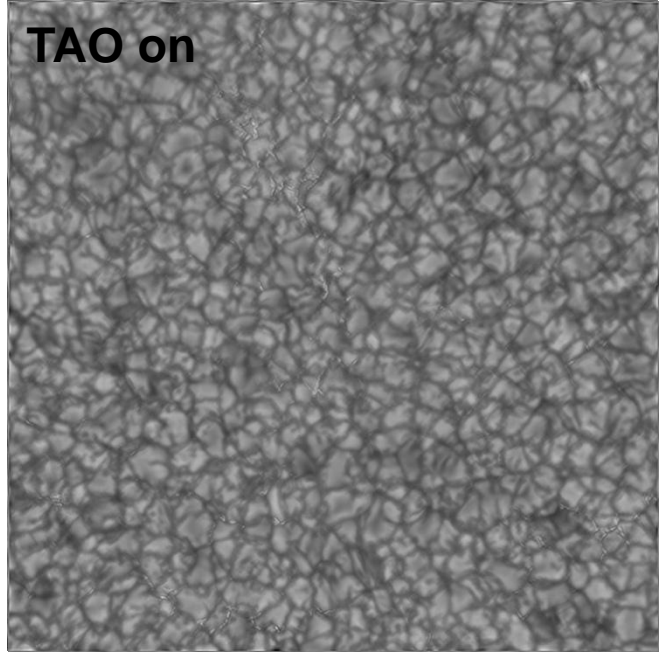


- Past

- **Present**

- Future

# THEMIS Adaptive Optics (TAO): results on granulation



**TAO OFF**

- seeing “daytime bad” :  $r_0 \approx 3-4$  cm
- granulation contrast: 1.6 %

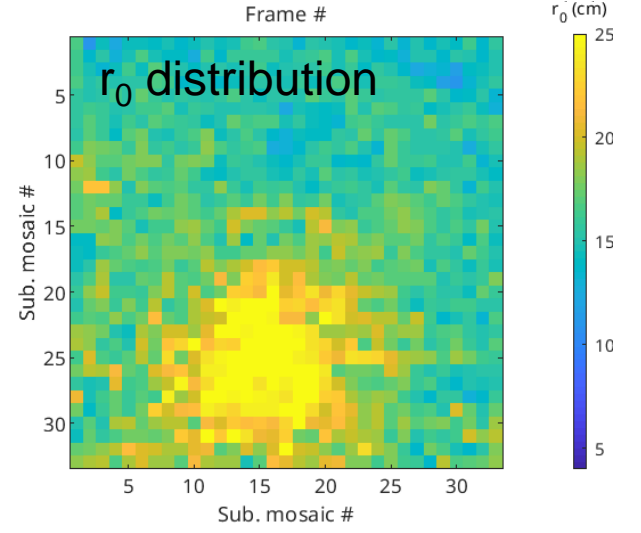
**TAO ON**

- seeing “daytime bad” :  $r_0 \approx 3-4$  cm
- granulation contrast: 4.2 %

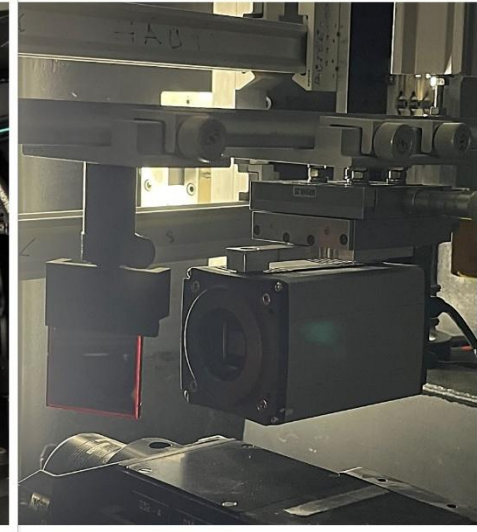
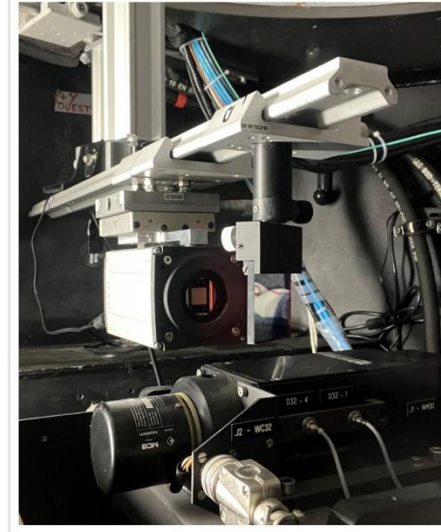
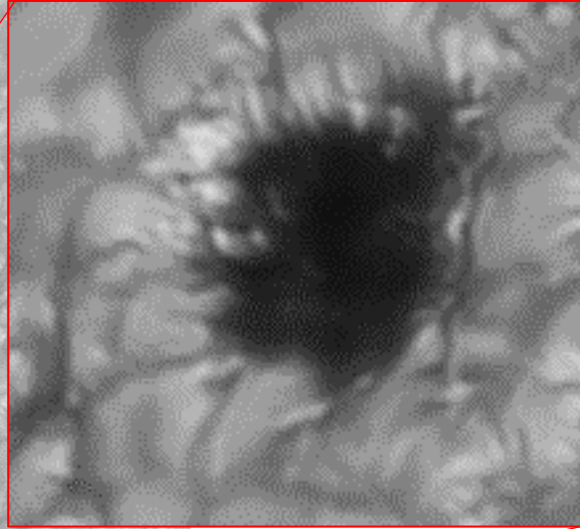
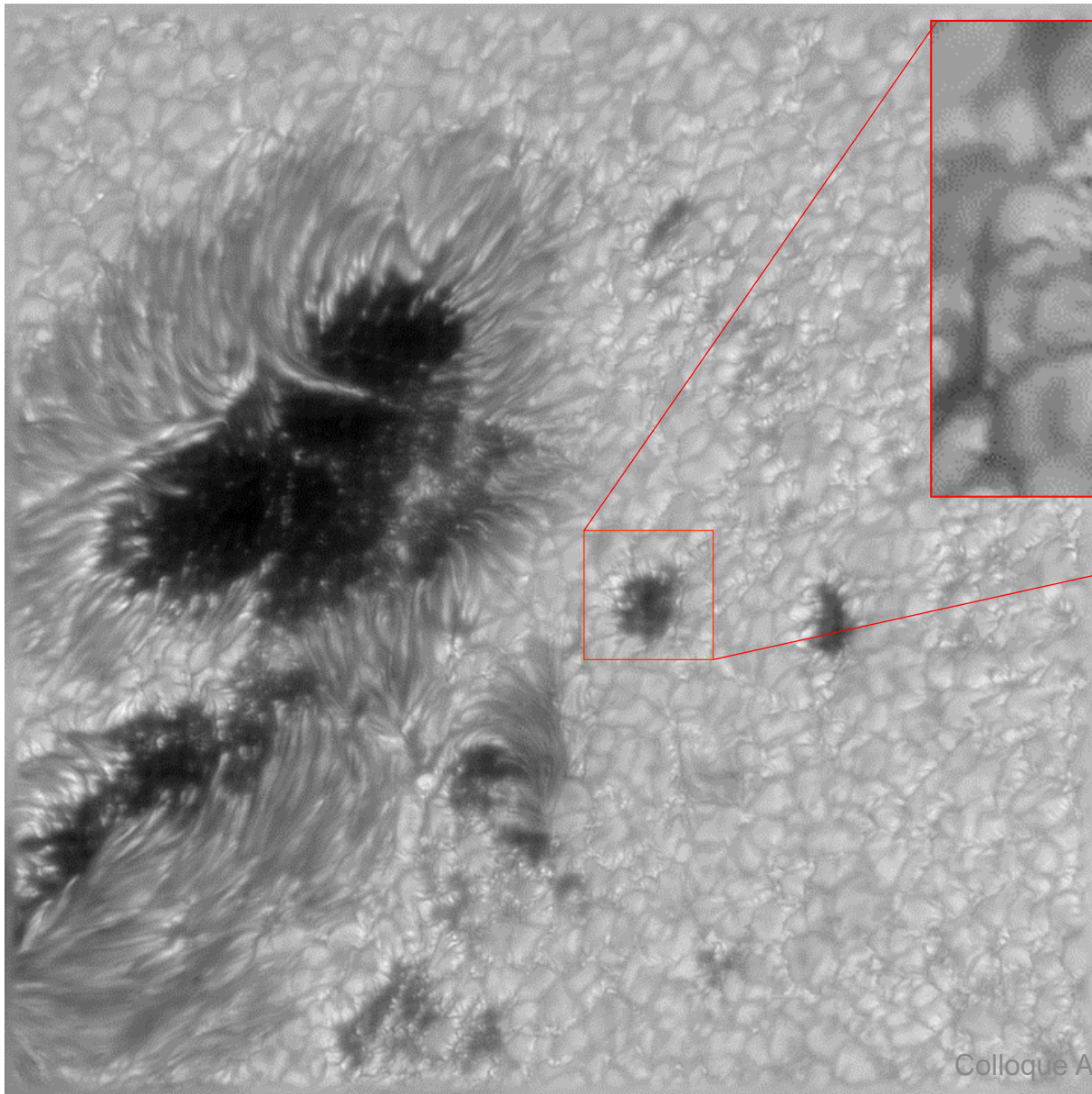
**TAO ON + Knox-Thompson reconstruction (100 frames)**

- granulation contrast: 9.6 %

- **TAO permits significant quantitative image quality gain:**
  - **in effective seeing:** Fried's coherence length from  $r_0 \sim 7$ cm (ave. seeing)
    - $\sim 25$ cm at TAO focus
    - $\sim 17$ cm on rest of FOV, away from isoplanatic patch
  - **in granulation contrast:** from  $\sim 1-2\%$  (bad seeing)
    - to  $\sim 10\%$  (with image reconstruction)



# THEMIS at diffraction limit: NOAA 12975



## THEMIS Broadband Imaging (BBI)

- NOAA 12975 on 2022/03/31 observed @  $\sim 630\text{nm}$  with 1nm broadband red filter
- 100 BBI acquisition @ 40 frames/s with a 55"x55" FOV
- Knox-Thompson (speckle) image post processing
- **$\rightarrow 0.17''$  resolution ( $0.035''/\text{pixel}$ ) near THEMIS theoretical diffraction limit of  $0.15''$** 
  - **$\sim 125$  km resolution on the Sun photosphere**

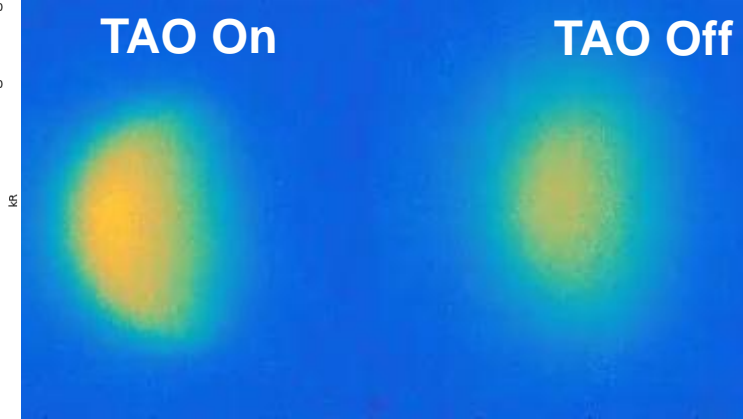
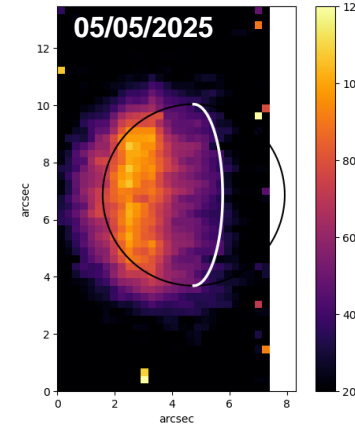
# Mercury observations

- **THEMIS one of the best-suited telescope for Mercury**

- Work in daytime → extended observation period
- Handle low contrast of hermian emission % to the diffuse sky
- THEMIS FOV & resolution suited for Mercury (Mercury disk: ~6")

- TAO successfully running for Mercury observations

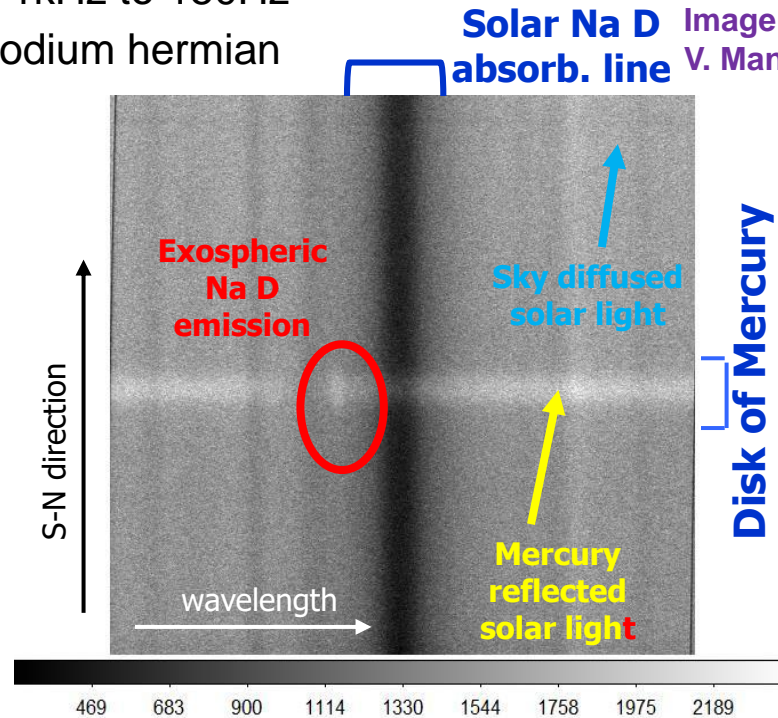
- Hardware and software identical to solar obs.
- Requires slowing down AO from 1kHz to 150Hz
- → Sub-arcsecond mapping of Sodium hermian exospheric emission



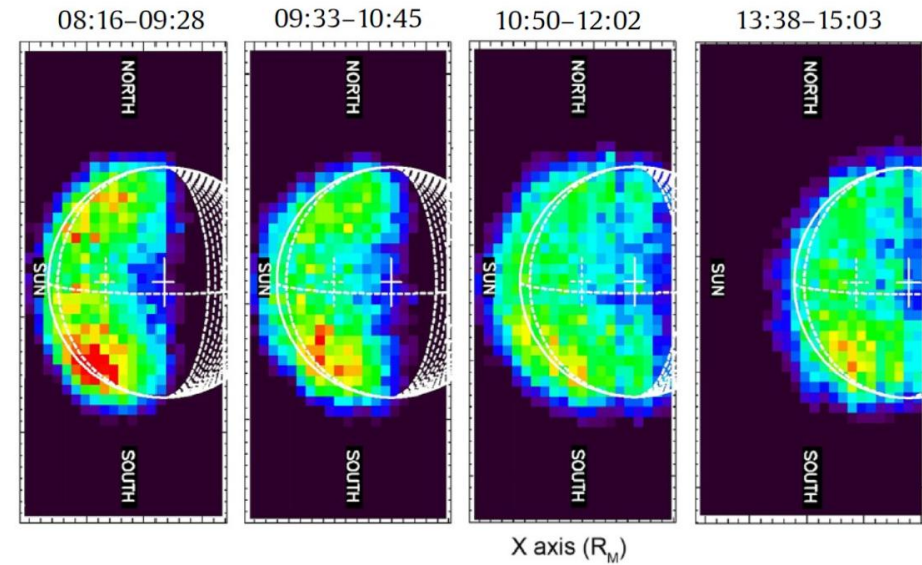
White light broadband imaging

- **Study hourly dynamics of hermian Na D emission distribution due to space weather** (e.g. Leblanc et al. 08; Mangano et al. 13; Orsini 24)

- Varying SW particles penetrating exosphere and flowing to the hermian surface inducing Na emission

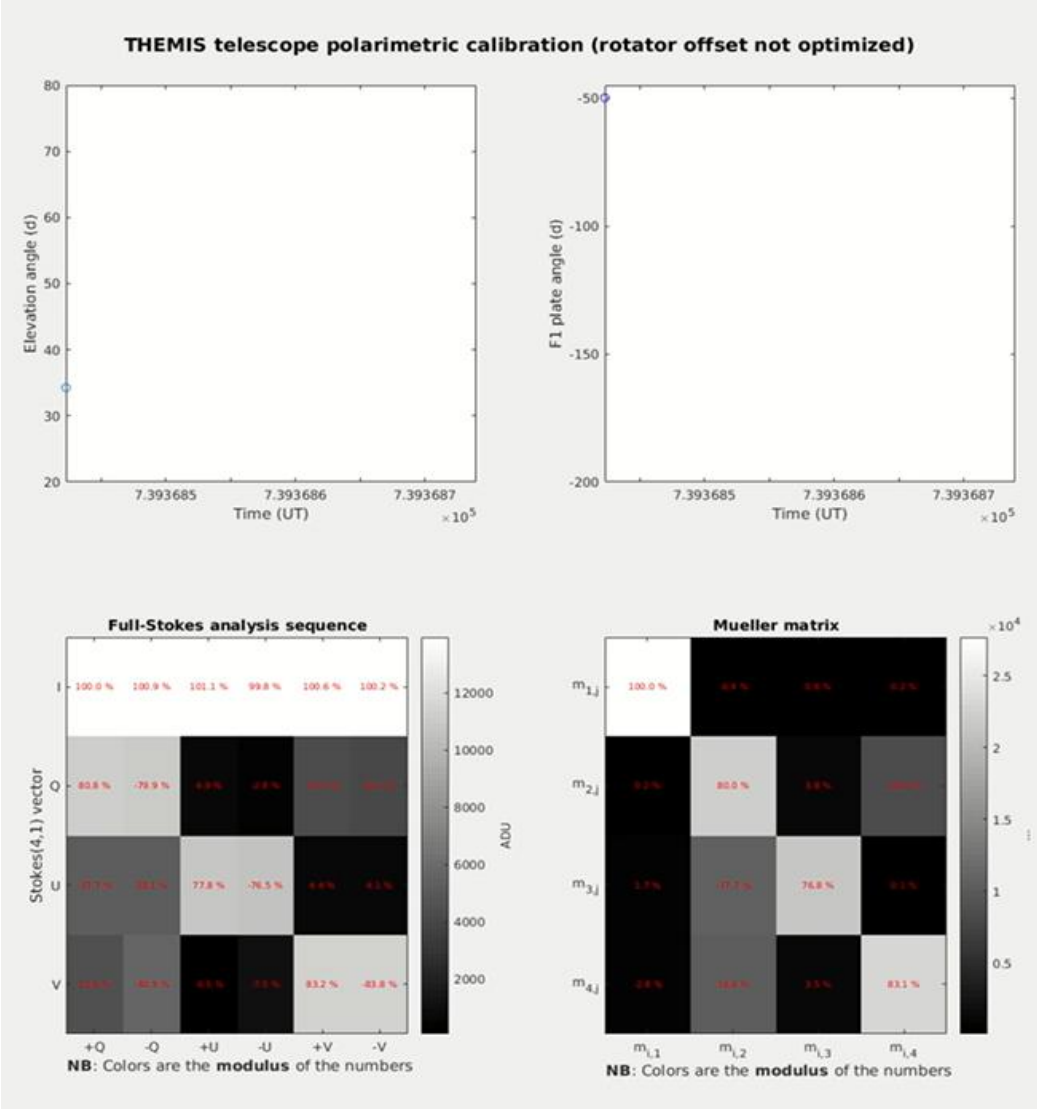


Solar Na D absorb. line Image courtesy of V. Mangano (INAF)



Mangano et al. 2013

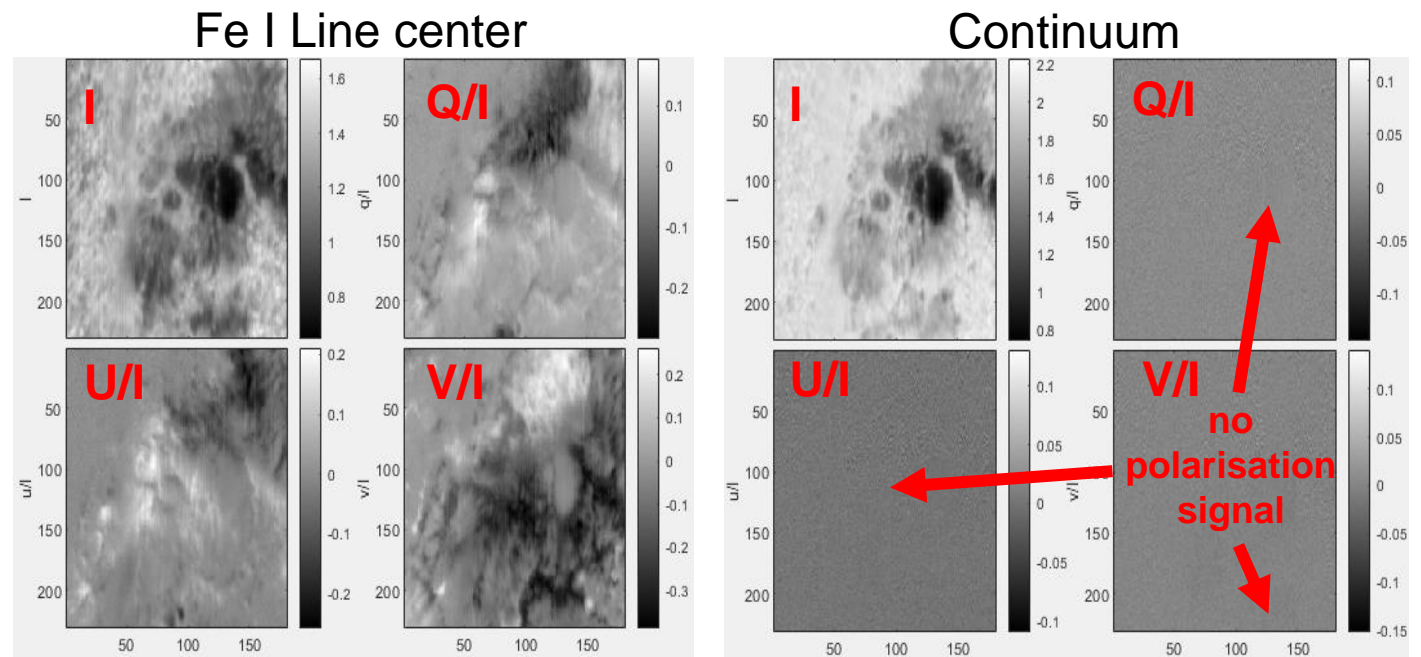
# THEMIS polarization analysis



• **New “polarization friendly” AO-compatible optical path: THEMIS remains a strongly polarization-calibration-free telescope, ideal for excellent spectropolarimetry**

- THEMIS Mueller matrix:
  - Averaged over one full day
  - Includes changing elevation axis and field derotation
  - Quite constant along one day

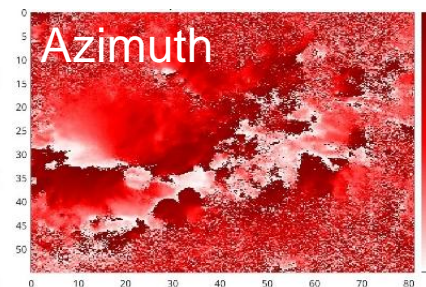
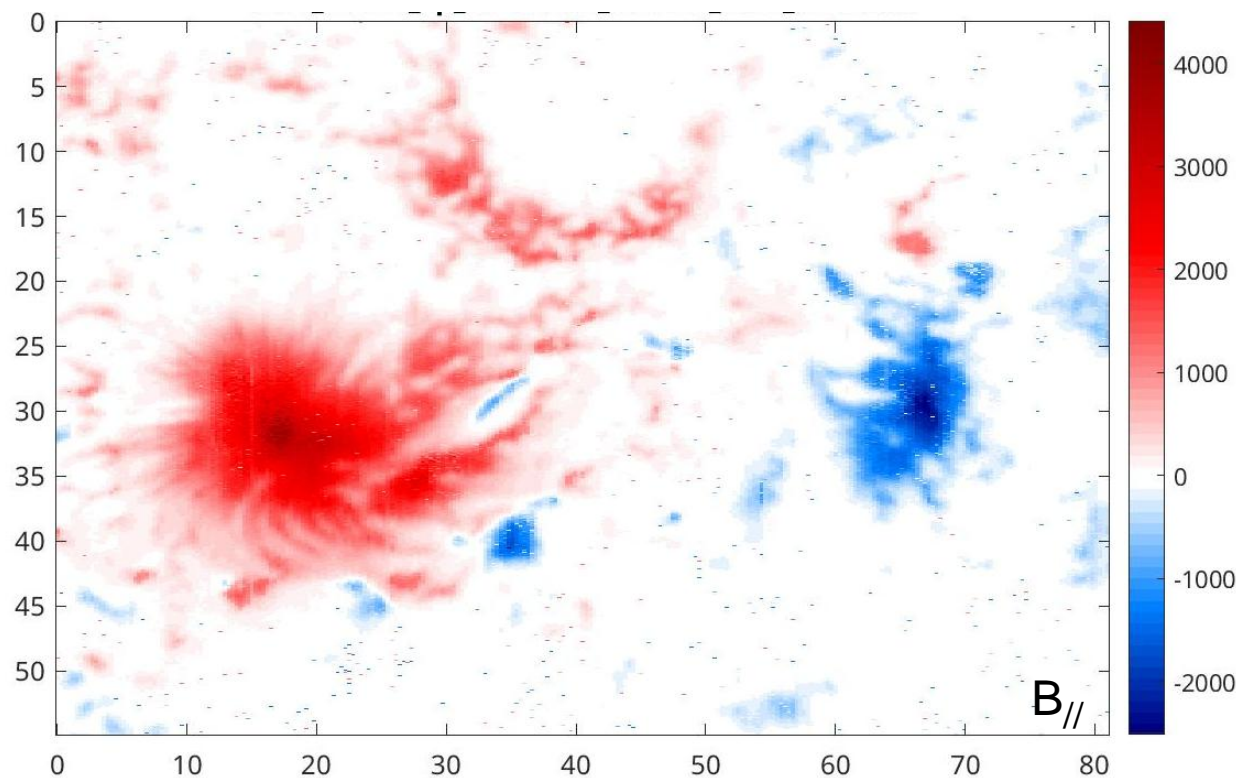
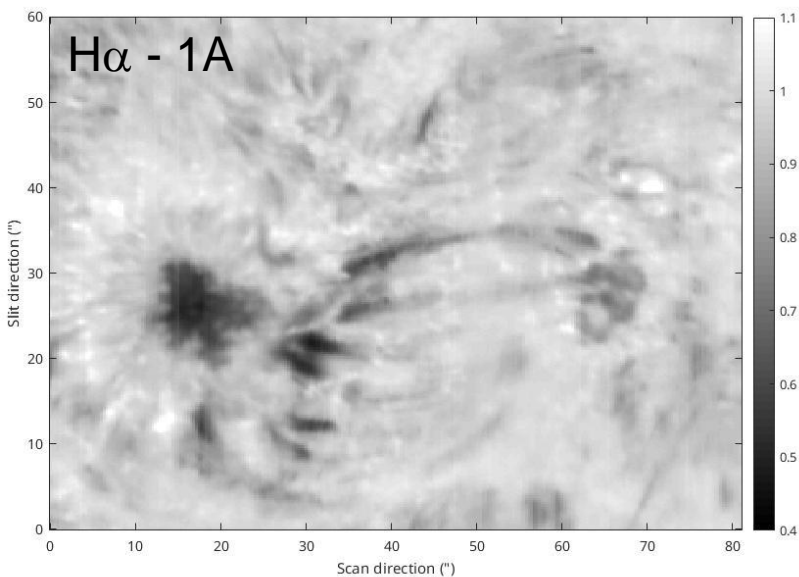
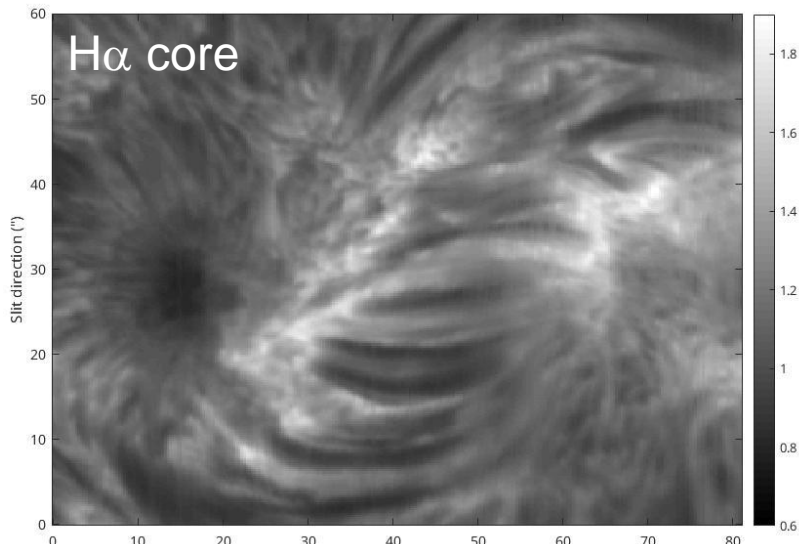
$$M_{THEMIS} = \begin{pmatrix} 1.000 & -0.009 & -0.003 & 0.001 \\ -0.008 & 0.885 & 0.016 & -0.033 \\ 0.014 & -0.436 & 0.872 & 0.033 \\ -0.019 & 0.415 & 0.008 & 0.873 \end{pmatrix}$$



# Vector ( $B_x$ , $B_y$ , $B_z$ ) magnetic field maps production

- **New pipeline to produce vector B maps**

- **Spatial resolution  $< 0.5''$**  ~400 km res. on the Sun (along scan dir.)
  - ~Hinode/SOT; ~x4 better than HMI/SDO
- UNNOFIT magnetic inversion (Bommier et al. 07)
- **From observation to vector maps in ~1hr**



Unnofit inverted  
vector B map

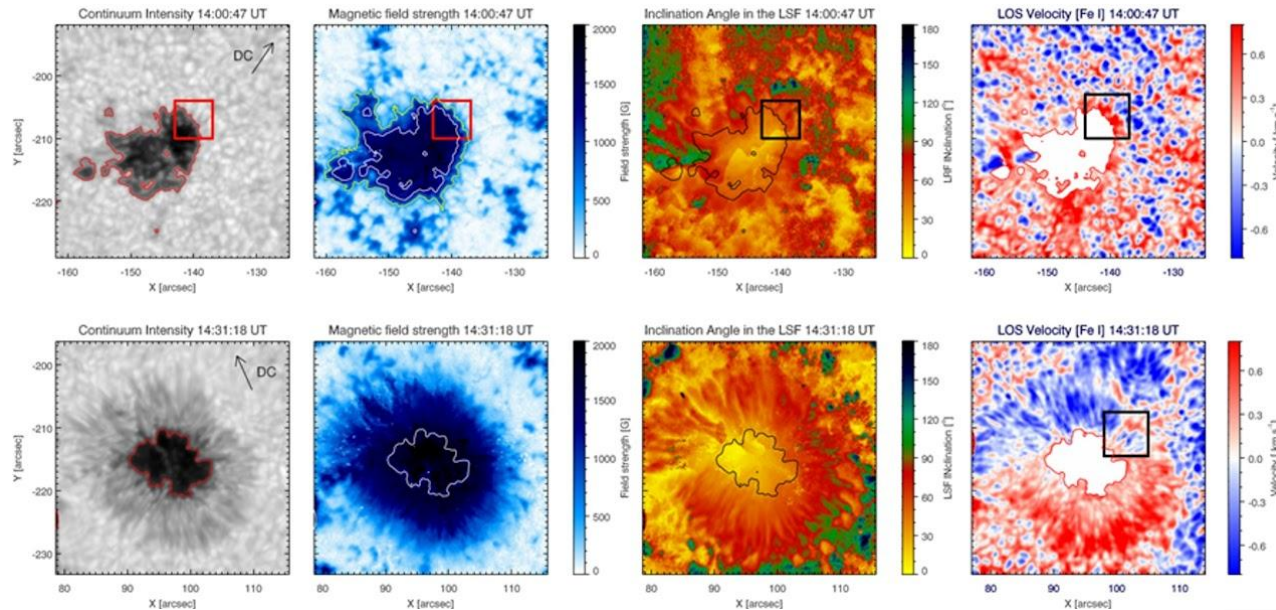
NOAA 14443 ;  
22/05/2026  
9:42-10:10 UT

# Upcoming : IBIS 2.0 @ THEMIS



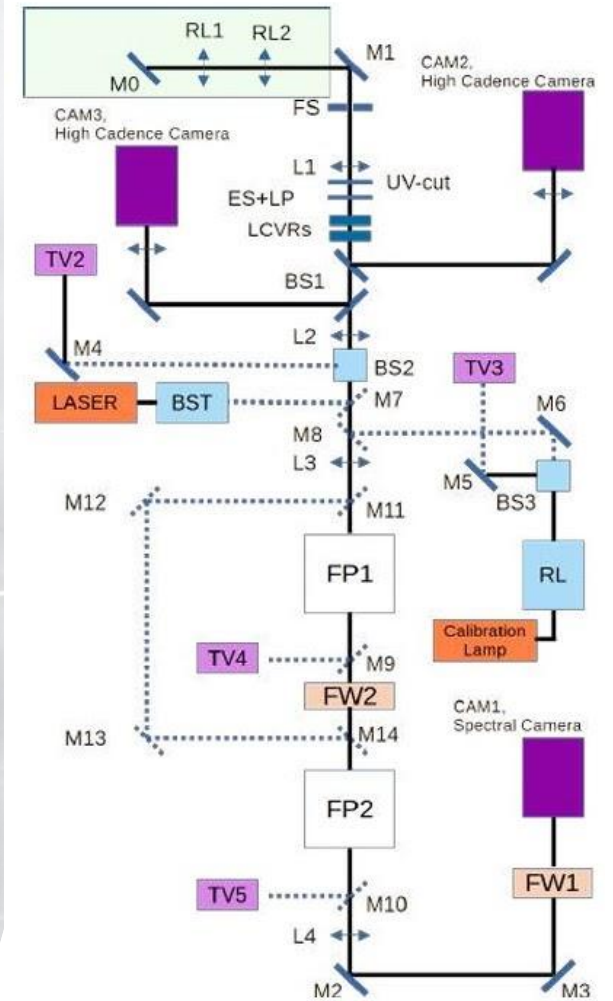
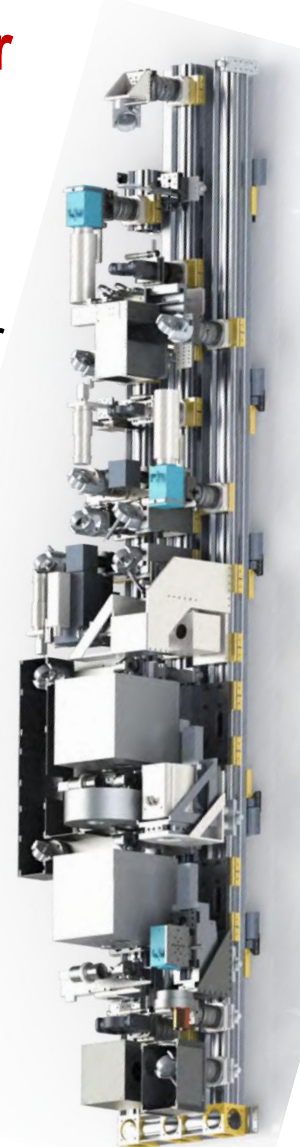
## IBIS : Interferometric Bldimensional Spectrometer

- spectro-imager  $(x, y, \lambda)$  : dual Fabry-Perot & interference filters
  - 200 000 spectral resolution
  - short exposure times / polarimetric mode
- Between 2003 & 2019 IBIS was running at the Dunn solar tower
- ~100 papers based on IBIS over 15 years



Intensity, magnetic field strength, field inclination angle & l-o-s velocities on 2012 May 28 (14:00-14:30 UT): before (top) and after (bottom) penumbra formation. (Murabito et al. 16)

<https://www.ibis20.inaf.it>



Ermolli et al. 2024

# Upcoming : IBIS 2.0 @ THEMIS



IBIS upgrade, IBIS 2.0 has been looking for a suitable host telescope since 2019.

## IBIS 2.0 as guest instrument at THEMIS

- **IBIS2.0 is an outstanding synergic complement of THEMIS long slit spectrograph**
  - TAO performance attractive for IBIS
  - THEMIS has no equivalent instrumental mode
  - Foster and renew French-Italian scientific collaboration in high-resolution solar physics, beneficial at large for EU solar physics (e.g. EST)

### Installation schedule

- ➔ Memorandum of Understanding signed between INAF and CNRS in winter 2024-2025
- Nov. 25: preparatory installation of optical bench
- June-July 2026 : IBIS 2.0 installation & commissioning.



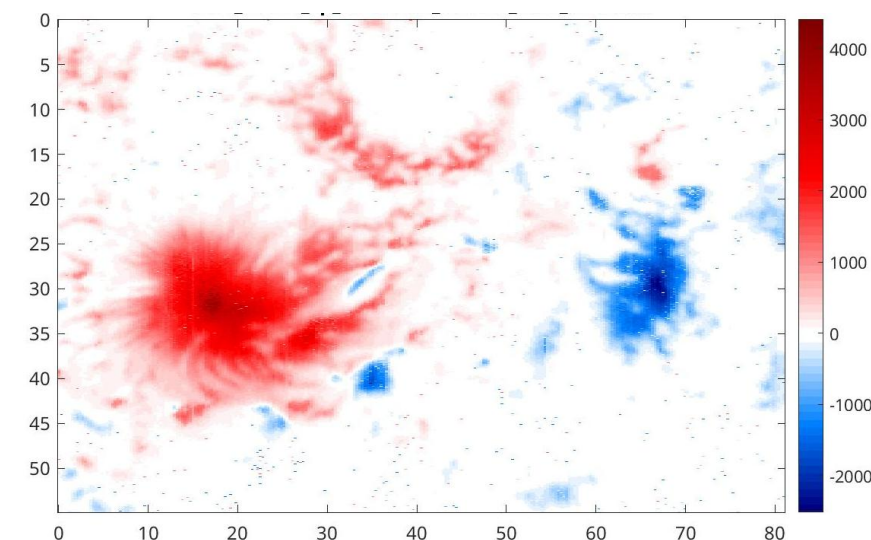
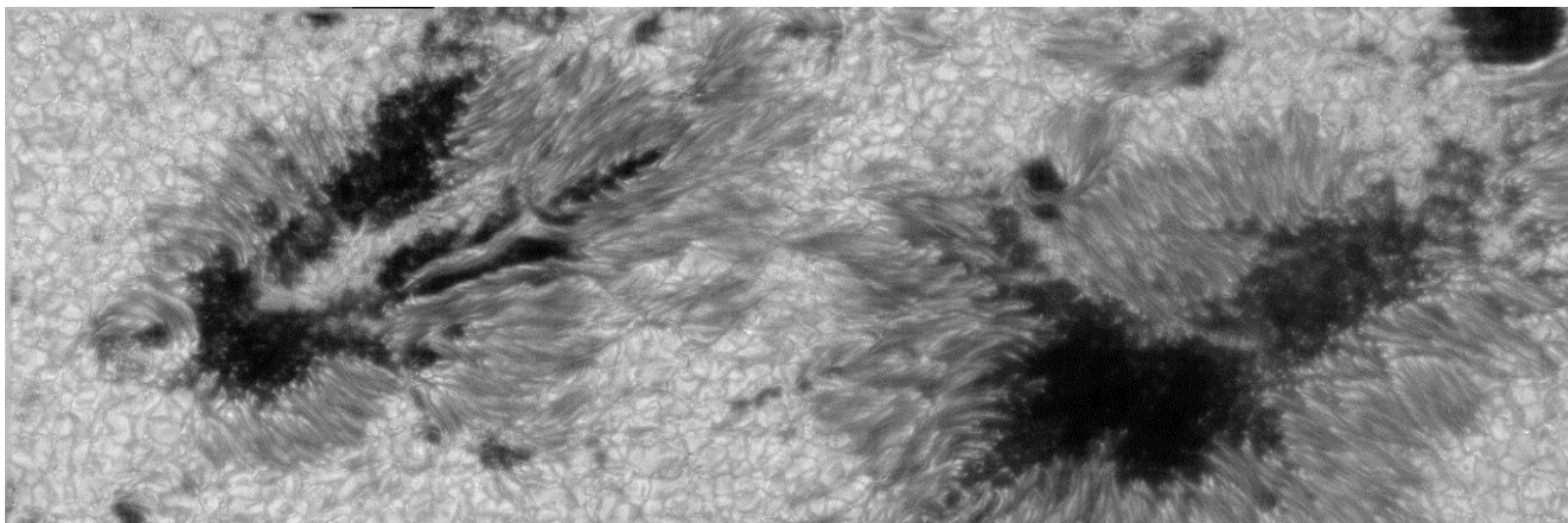
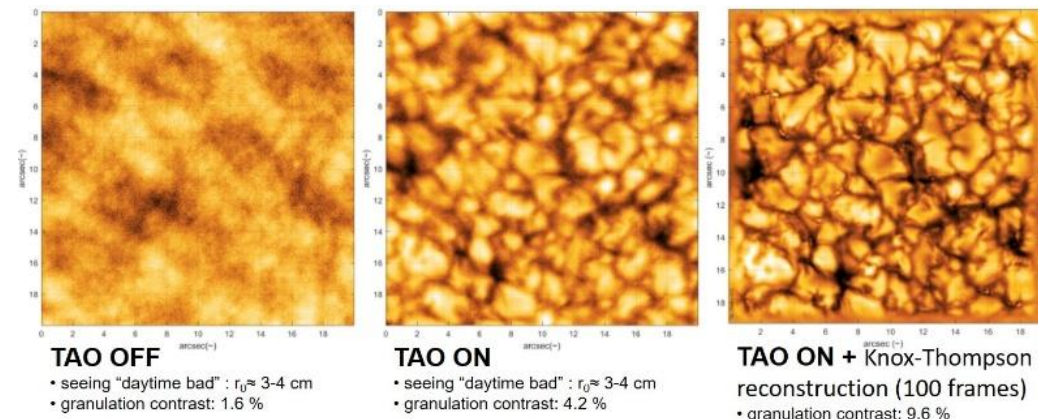
Nov. 2025

# THEMIS in the next few years

## • THEMIS is presently a competitive telescope with unprecedented capacities

- THEMIS is a real challenger in the 1m class of solar tel..
- Installation of the IBIS 2.0 will trigger a larger EU interest.
- Growth of staff (PhD, Postdoc) thanks to key project: JET2SB (projet ANR-25-CE31-741)

• → Cf. Posters: S. Diaz Castillo ; J. Romero Castañeda



- Past

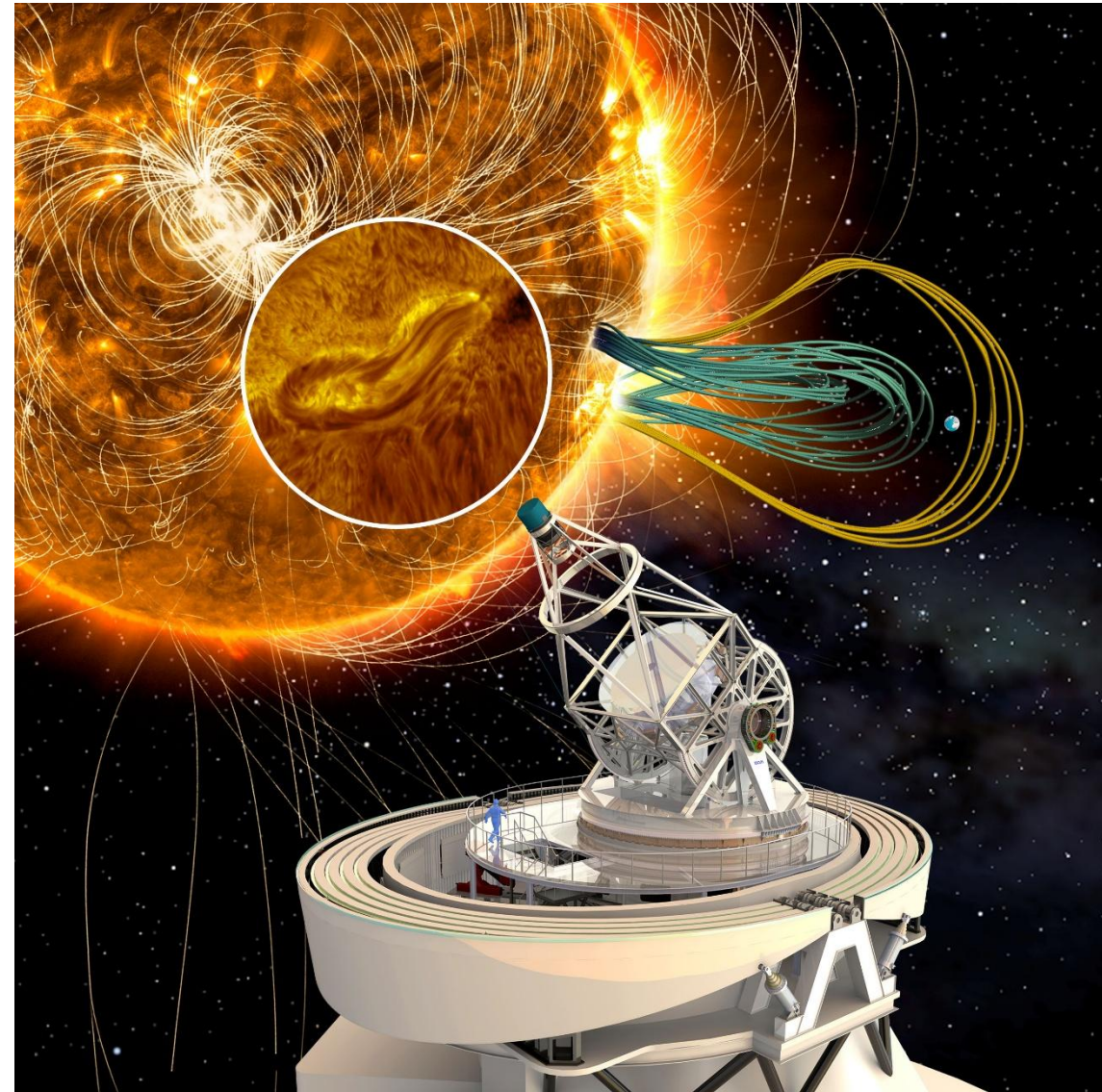
- Present

- Future

THEMIS **IS not**  
the future of research-oriented  
ground-based solar physics



the European Solar Telescope **IS !**  
Cf. talk about EST this Thursday



# Where will THEMIS be in 10 years ?



- THEMIS will eventually be outdated by >4m-class telescope such as DKIST (USA), the European Solar Telescope (in project), the Chinese Giant Solar Telescope (in project).
  - **THEMIS relevance as an observation-campaign oriented telescope will faint**
- **The exploitation of THEMIS in service mode, oriented toward space-weather, appears as the most relevant use for THEMIS beyond the 10 years horizon.**
  - THEMIS can provide unique type of datasets of interest for SW applications
  - Research for SW is a strength of the French heliophysics community:
- Since its commissioning, THEMIS has been running in obs. campaign mode
  - Variability of scientific objectives and targets (granulation, quiet sun, coronal holes, filament, AR, ...)
  - Telescope set-up can strongly changes from campaign to campaign : advantage of THEMIS high versatility
- **The THEMIS team is initiating such reflection toward the production of unique datasets of interest for SW : high-resolution vector magnetograms of eruptive regions (active regions, filaments, ...)**

# THANKS FOR YOUR ATTENTION

- New THEMIS website:
  - Feedbacks welcomed
- New Instagram account
  - Follow us @themis\_solar
- Downloadable posters on THEMIS highlights

## THEMIS Solar Telescope

The "Télescope Héliographique pour l'Étude du Magnétisme et des Instabilités Solaires" (THEMIS) of CNRS-INSU is a 1-meter-class optical solar telescope, primarily dedicated to studying solar magnetism and the dynamical processes within the Sun's atmosphere (such as sunspots and solar flares). THEMIS can also perform observation of near-Sun objects such as Mercury and comets.

THEMIS is located at the Teide Observatory of IAC, with a base office in La Laguna, in Tenerife, Canary Islands, Spain.

**!!! Call for the 2026 observing campaign is open !!!**  
 Deadline for "French" and "International" time: February 13th, 2026.  
 Deadline for "Spanish" time: January 21st, 2026.

January: Presentation of THEMIS and IBIS at the "Methods and techniques for high-resolution spectro-polarimetry" conference in Freiburg (GER).

November: **First screw of the Italian IBIS 2.0 Spectro-imager @ THEMIS.**

Downloadable posters highlighting recent high-resolution observations of solar active regions by THEMIS

Click for information on: [How to reach THEMIS locations](#) ; [How to contact the THEMIS team](#)



Edit

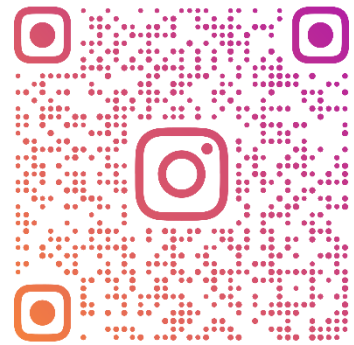
### Overview of telescope status



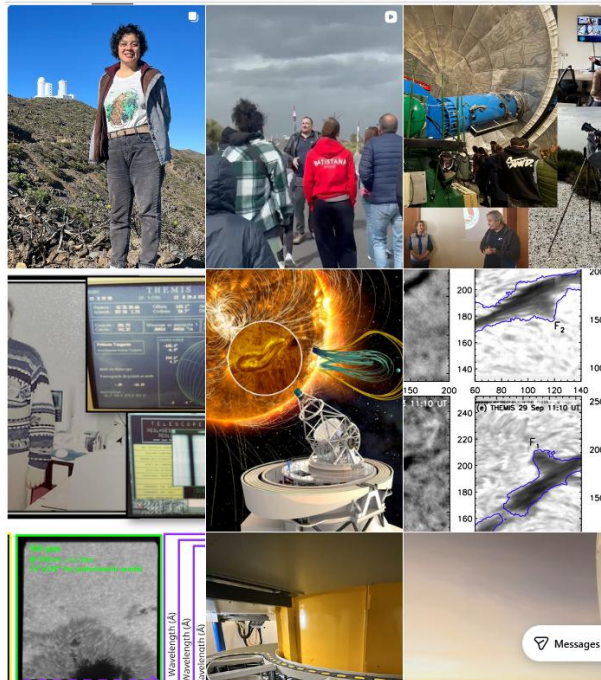
Last image from THEMIS full Sun guider



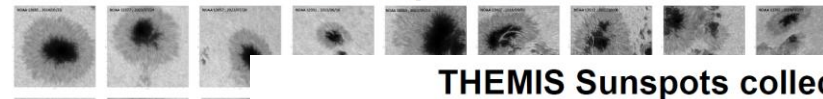
<https://www.themis.iac.es>



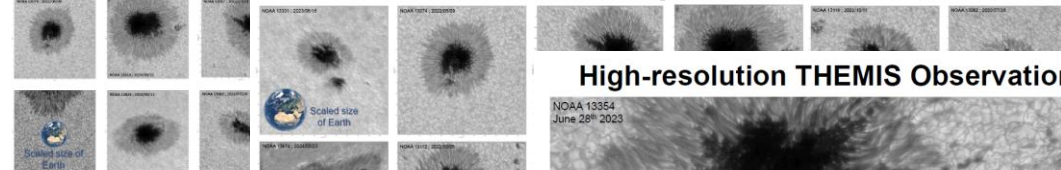
THEMIS\_SOLAR



## THEMIS Sunspots collection



## THEMIS Sunspots collection



Each image corresponds to a field-of-view of  $\sim 5'$  ( $\sim 10$  nm passband centered around 656 nm).

Active regions are transient features of the Sun's atmosphere. They are characterized by a strong and complex magnetic field. Sunspots are the signature of the presence of such intense magnetic fields. They thus appear cooler & emit less light. They thus appear darker than the quiet solar surface.

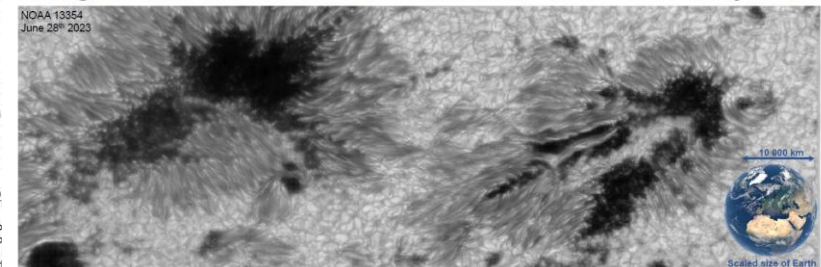


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## High-resolution THEMIS Observation of Solar Sunspots



The "Télescope Héliographique pour l'Étude du Magnétisme et des Instabilités Solaires" (THEMIS) of CNRS-INSU is a 1m-class Ritchey-Chretien optical solar telescope, primarily dedicated to studying solar magnetism and the dynamical processes within the Sun's atmosphere, such as sunspots and solar eruptions.

The image correspond to a field-of-view of  $\sim 5'$  ( $\sim 10$  nm passband centered at 656 nm). The image has been produced from three series of snapshots side by side. In each sub-image, a Knox-Thompson image reconstruction method has been used from 100 acquired snapshots. The images have been captured in the white-light red continuum ( $\sim 10$  nm passband centered at 656 nm). The image resolution ( $\sim 0.17''$ , close to THEMIS diffraction limits ( $\sim 0.15''$ ), is enabled thanks to the use of THEMIS adaptive optics.

Active regions are transient features of the Sun's atmosphere. They are characterized by a strong and complex magnetic field. Sunspots are a signature of the presence of intense magnetic fields. As the most intense magnetic field concentrations inhibit the transport of energy, such regions are cooler, emit less light. They thus appear darker than the quiet solar surface. Unlike sunspot, the quiet sun regions are dominated by the granulation pattern. Granules are the convection cells in the Sun's photosphere. They are caused by currents of plasma in the Sun's convective zone, directly below the photosphere.

THEMIS main characteristics are the following:  
 Observational spectral coverage: 400-1100 nm.  
 Imaging field-of-view:  $\sim 2' \times 2'$ , square shaped.  
 Overall focal ratio: f/62.  
 Effective aperture: 92 cm.  
 Effective focal length:  $\sim 57$ m.

