

European Solar Telescope for the French heliophysics community

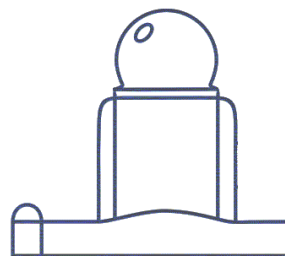


Colloque scientifique de l'ATST, Biarritz, FR, 1-5 juin 2026



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Major ground-based solar telescopes & projects



Facility	Aperture	1st light	Country
DST	0.8 m	1969	USA
VTT	0.7 m	1989	Germany
THEMIS	0.9 m	1996	France (form. Italy)
SST	1.0 m	2002	Sweden (& Norway)
GST	1.6 m	2008	USA
NVST	1.0 m	2010	China
GREGOR	1.5 m	2012	Germany
DKIST	4.0 m	2022	USA
CLST	1.8 m	?	China

- **European ground-based solar telescope landscape presently dominated by aging national facilities**

Facility	Aperture	Status	Country
WeHoST	2.5 m	Construction	China
EST	4.2 m	Project	EU
NST	2.0 m	Project	India
GCST	8.0 m	Project	China

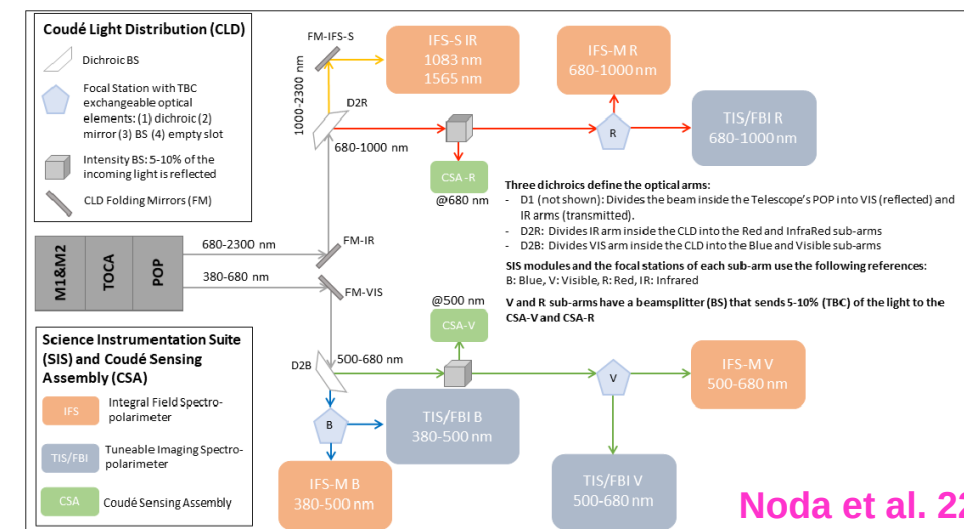
- Strategic risks :
 - Missed major scientific opportunities
 - **Lost of expertise** in historic leadership in visible-IR in high-resolution solar physics
→ impact on space instrumentation developments in spectropolarimetry, driven by ground-based instrumentation
 - **Reliance on non-EU datasets** for high resolution observation and high quality magnetic field measurements

The European Solar Telescope (EST)

- **EST is the unique European project of the next-generation telescope for solar physics in the 21st century**
- Site: RQM observatory @ La Palma, Canarias, ES
- 4.2-m aperture
- State-of-the-art multi-conjugated adaptive optics
- Perform world-best multi-layer spectropolarimetry
 - On-axis design & simultaneous observations in IR, blue-, & red-white-light spectral ranges
- Seven innovative 1st-light instruments
 - State of the art Fabry-Perot spectro-imagers
 - Next-generation integral field units:
 - micro-lenses & optical fiber



Courtesy Socas-Navarro & EST foundation



Noda et al. 22

Unique scientific opportunities offered by EST



- EST paper: **Noda et al. 22**
- Science Requirement Document (v3): **Schliechenmaier et al. 25**
- Highest-resolution solar physics
 - Resolving structure at $0.02''$;
~ 20km on the sun
- **Highest-quality B field estimation**
 - World best spectropolarimetric measurements
- Simultaneous multi-layer observations in low-solar atmosphere
 - Suited to study energy transfers through the most complex layers of the solar atmosphere.
- **Sustain space weather research (this talk)**

arXiv:1912.08650v2 [astro-ph.SR] 18 Dec 2025



Science Requirement Document (SRD)
for the
European Solar Telescope (EST)

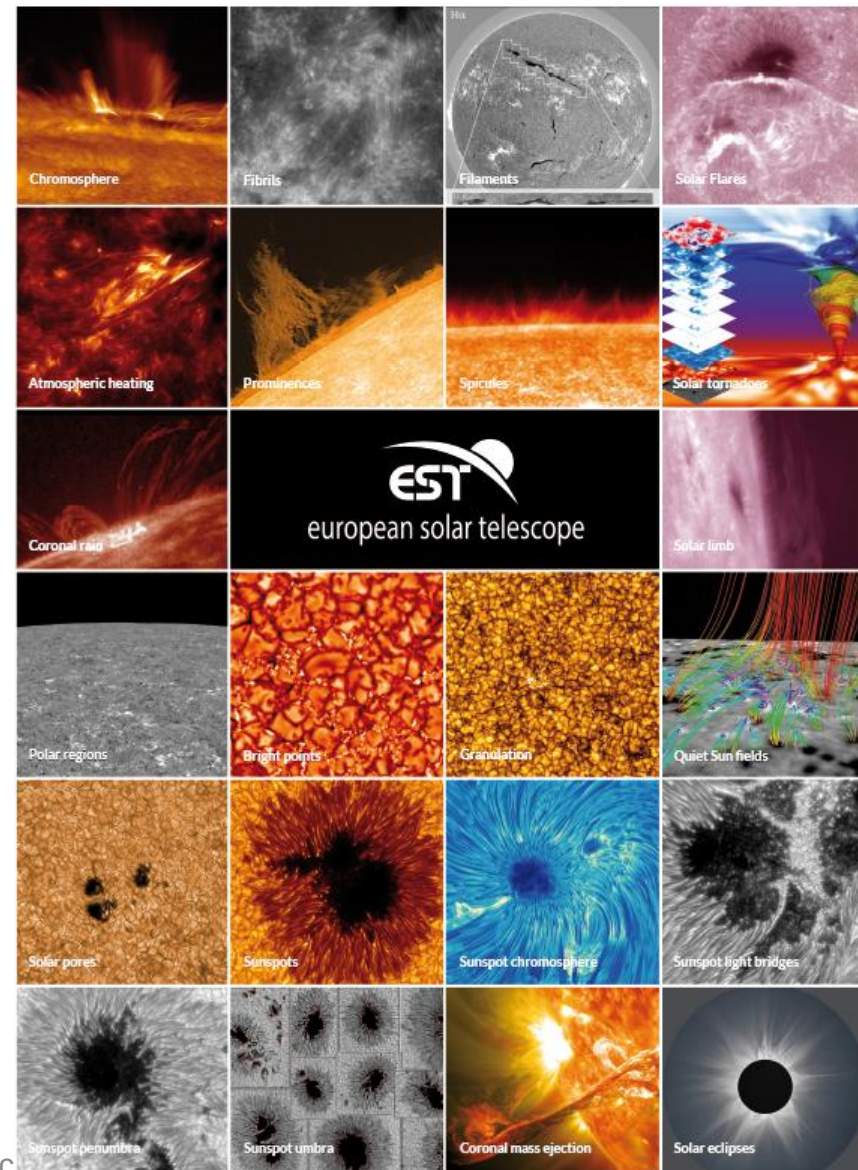
3rd edition, December 2025

Schliechenmaier, R.¹; Bellot Rubio, L.R.²; Collados, M.^{3,4}; Erdelyi, R.^{5,6,7}; Feller, A.⁷; Fletcher, L.^{8,13}; Jurčák, J.⁹; Khomenko, E.²; Leenaarts, J.¹⁰; Matthews, S.¹¹; Belluzzi, L.^{12,1}; Carlsson, M.^{13,14}; Danilovic, S.¹⁰; Górný, P.¹⁶; Kuckein, C.³; Manso Sainz, R.¹⁷; Martínez González, M.³; Mathioudakis, M.¹⁸; Ortiz, A.^{24,25}; Riethmüller, T.L.⁷; Rouppe van der Voort, L.^{13,14}; Simoes, P.J.A.¹⁹; Trujillo Bueno, J.^{2,20}; Utz, D.²¹; Zuccarello, F.²²; de la Cruz Rodríguez, J.¹⁰; Giovanelli, L.²³; Jafarzadeh, S.¹⁸; Jess, D.B.¹⁸; Milic, I.¹; Nelson, C.²⁶; van Noort, M.⁷; Ruiz de Galarreta, C.³; Zeuner, F.¹²

(Author affiliations given on page 2.)



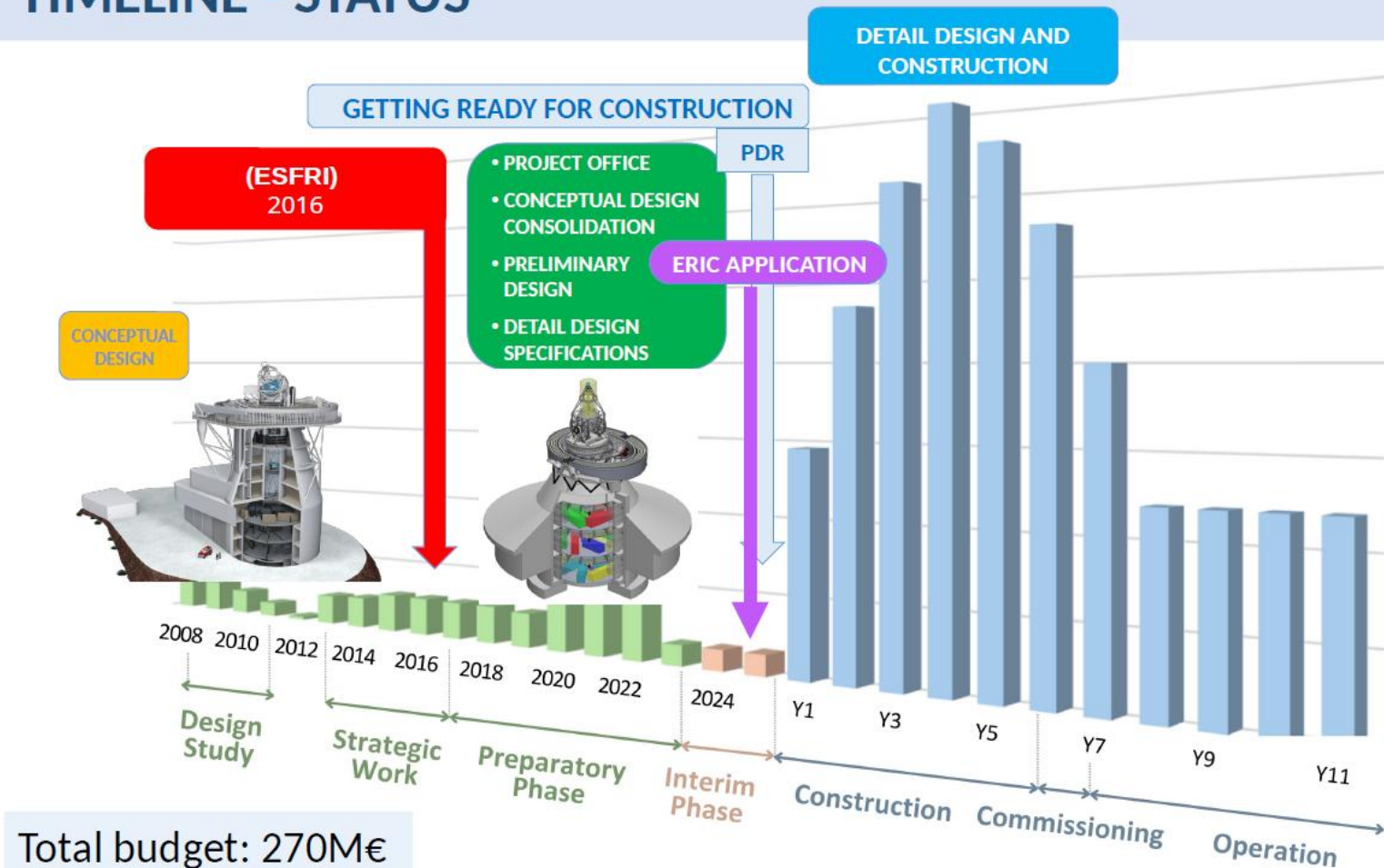
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739 500"



EST Timeline

- EST is in the list of the ESFRI (European Strategy Forum on Research Infrastructures) since 2016
 - **ESFRI review in 2026!**
- EST listed as a high priority for ground-based observations by ASTRONET.
- **Creation of EST ERIC (European Research Infrastructure Consortium) presently being discussed**
 - 3 committed nations: Spain, Slovakia and Czech Republic.
 - ~40% of 274 M€ budget
 - Phase I : 186 M€
 - Phase II : 88 M€

TIMELINE - STATUS



Courtesy Socas-Navarro & EST foundation

- **French researchers from diverse laboratories** (IRAP, LIRA, LPP, THEMIS, UNIDIA) **have continuously been associated with the development of the EST project**
 - FR in the European Association for Solar Telescopes (EAST) since creation
 - MSDP concept proposed as 1st light instrument (**Malherbe et al. 2023**)
 - Involved in EST Conceptual Design & co-authors EST main paper & EST SRD
- 2 EST-France workshops: 2010 & 2025
- **Strong interest of several French high-tech industry** (in optics): key expertise for EST construction → guarantee return to investment for France
- **White paper, highlighting how EST will uniquely advance French research in solar physics & space weather.**
 - **Thanks for strong support from the whole ATST community**
 - Personnels from 15 French laboratories co-signing



Atelier EST France 2025

11-12 Jun 2025 Paris (France)

FR EH

Connexion

NAVIGATION

Accueil

Annnonce

Inscription

Nouveau dépôt

Programme

Plan d'accès

Liste des participants

SUPPORT

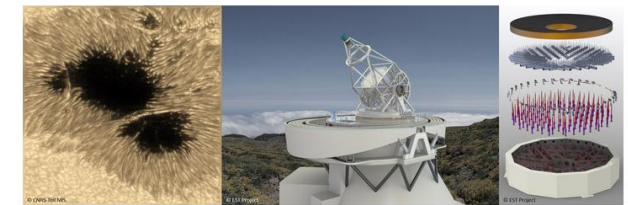
@ Contact

OBJECTIFS

L'European Solar Telescope (EST ; <https://est-east.eu/>) est un télescope solaire de nouvelle génération à grande ouverture. Avec un miroir primaire de 4,2 mètres, il sera optimisé pour l'étude du couplage magnétique de l'atmosphère solaire. Cela nécessitera des diagnostics des propriétés thermiques, dynamiques et magnétiques du plasma sur plusieurs échelles de hauteur, en utilisant l'imagerie multi-longueur d'onde, la spectroscopie et la spectropolarimétrie. L'EST se spécialisera dans l'observation à haute résolution spatiale et temporelle, en utilisant plusieurs instruments simultanément pour produire efficacement des informations spectrales en 2D. L'EST sera situé aux Îles Canaries, un site de premier ordre pour les observations astronomiques. Ce projet, inscrit dans la feuille de route de l'European Strategic Forum for Research Infrastructure (ESFRI), est actuellement dans une phase cruciale de consolidation.

L'atelier EST France 2025, organisé avec le soutien de l'action thématique Soleil-Terre (ATST ; <https://atst.osuniv-paris-saclay.fr/>) de l'INSU/CNRS, vise à réunir les cadres européens d'EST avec les communautés françaises, scientifique et industrielle, intéressées par la mise en place du projet. L'atelier permettra la présentation du projet, son intérêt et son utilisation par la communauté française et des discussions sur la stratégie d'implication de la France dans le consortium scientifique d'EST.

Plusieurs présentations données lors de l'atelier sont publiquement disponibles (Creative Commons CC BY-NC 4.0 license) sur le site de dépôts de fichier déposé (cliquez sur le lien).



White paper on the relevance of the European Solar Telescope (EST) for the French heliophysics community.

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EST science for French astrophysics community

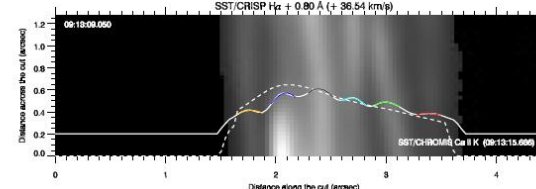
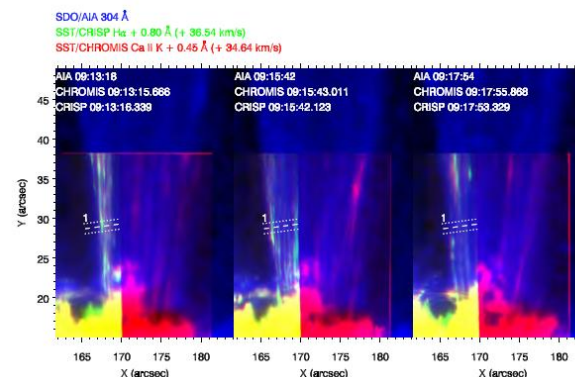
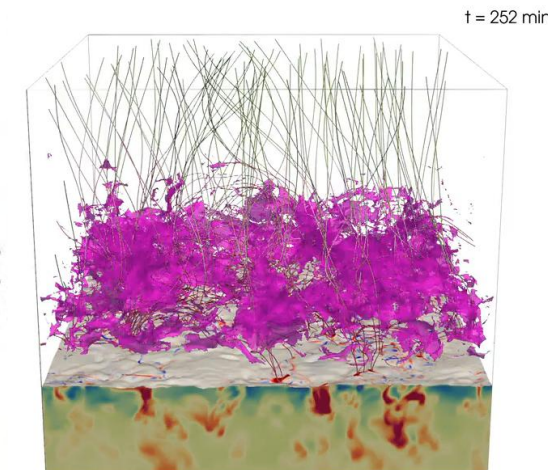
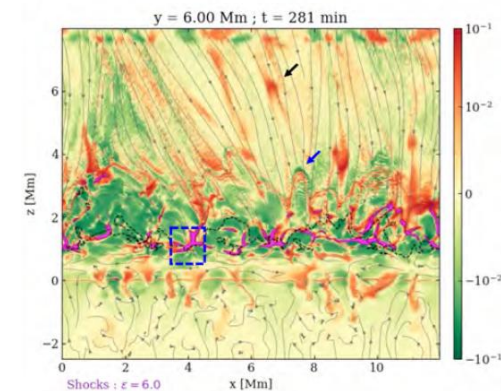
• Solar Physics

- Observation & modelling of the granulation scales (cf. Talk Doebele)
- Dynamics of low atmosphere plasma (cf. Talk Faurobert)
- Magnetism of the Quiet-Sun & ARs (cf. Talks Brun ; Degott)
- High-fidelity measurements of electric currents
- Small-scale dynamics & heating of the solar atmosphere (cf. Talks Parenti ; Dolliou)
- The photosphere-corona-wind connection (cf. Talk Poirier)
- Coronal rain and its relationship with coronal heating (cf. Talk Le Nestour)
- Low atmospheric signature of coronal eruptive phenomena (cf. Talks Aulanier; Nóbrega ; Touresse ; D'herbomez)
- Modulation of the element abundance in the solar atmosphere and wind (cf. Talk Mzerguat ; Sukarmadji)

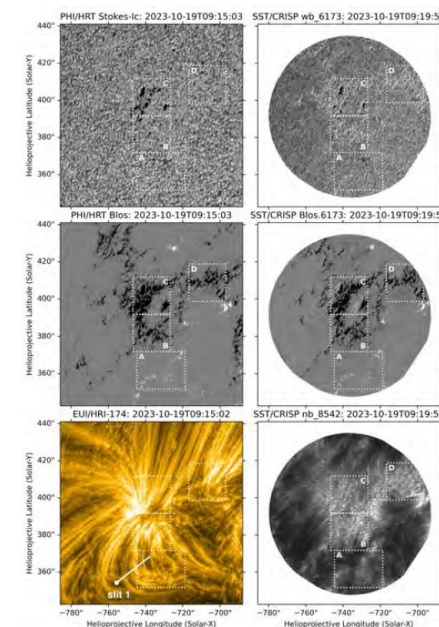
• Adaptive optics (**instrumental opportunities**)

- Next generation wide-field low-contrast AO
- Multi-conjugated AO

Noraz et al. 26



Froment et al. 20



Poirier et al. 25

EST for space weather research

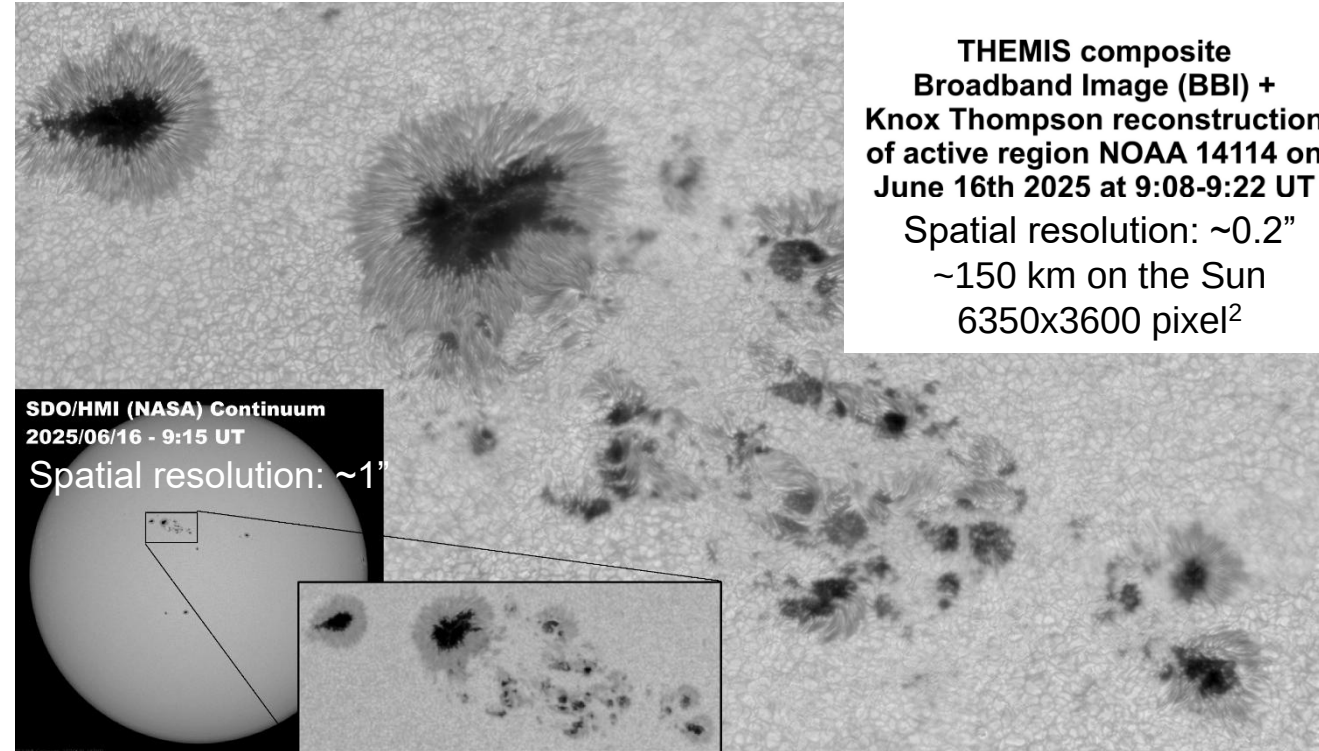
- Ground-based telescope for space weathers applications

Main limitations:

- Observation limited to daylight and quality affected by seeing
- FOV very limited: 1'-2' $\Leftrightarrow$ ~45-90 Mm on Sun

Main advantages:

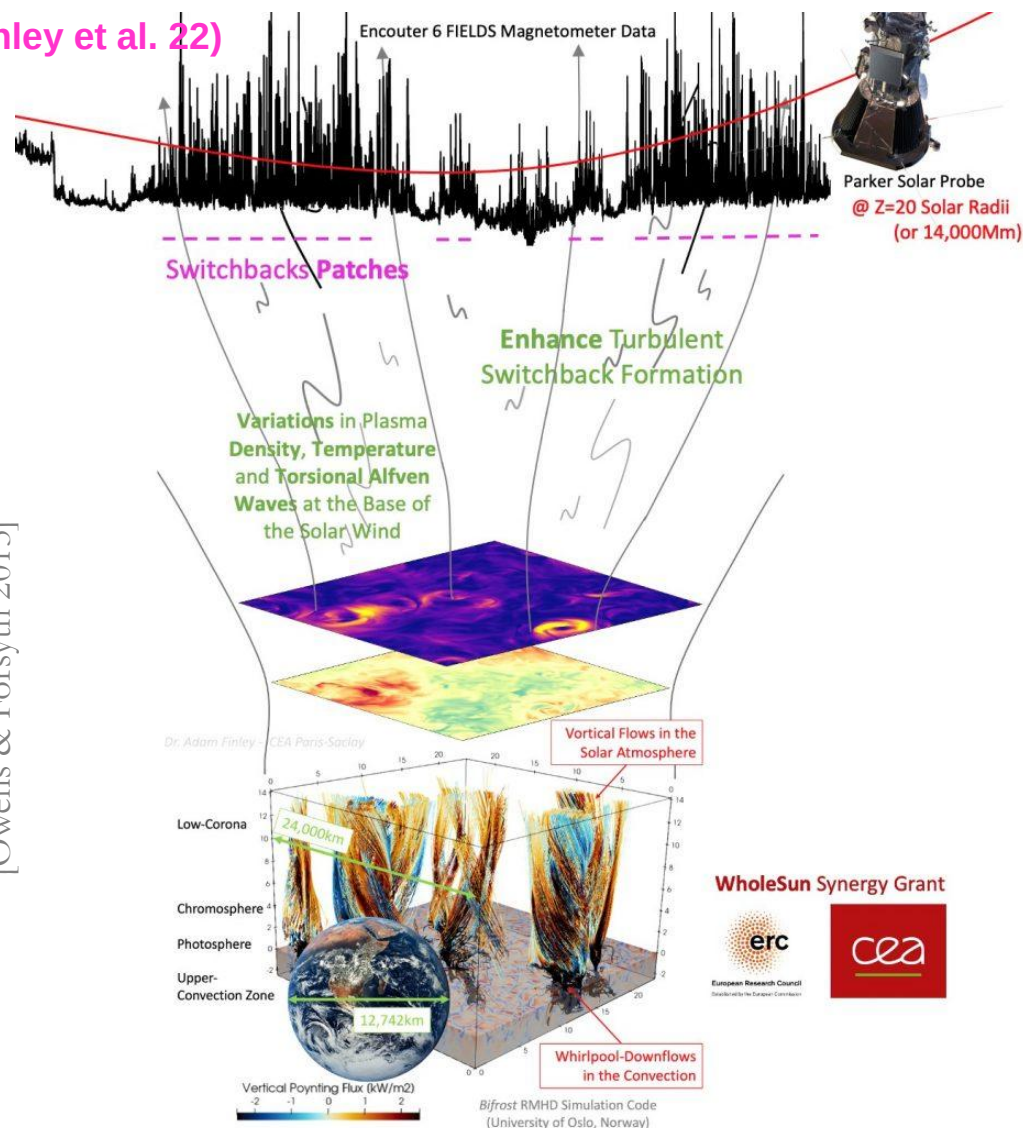
- **Ground-based instruments can reach unrivaled resolution, in particular in region prone to solar eruptions**
 - With EST: 0.02" $\Leftrightarrow$ ~20 km on Sun
 - $\times 10^3$ in area resolution % SDO
- High-spectral, high-temporal resolution at high-polarimetric sensitivity $\rightarrow$ **high quality measurements of low atmosphere vector B**
- **Multiple space weather research topics uniquely addressed by EST**



- Constraints for solar wind modeling
- Monitoring of active nests
- High-resolution characterization of CME progenitors
- Improving active region **B** reconstructions
- Anticipation of solar eruptions

EST & solar wind modelling

(Finley et al. 22)



[Owens & Forsyth 2013]

Need to understand solar wind structure and heating in order to predict correctly the trajectory of transients

Magnetic transfers between the various solar layers affect the **structure of the large-scale interplanetary magnetic field + heating** that leads to the final speed

→ Need to **couple small to large spatial scales** in the solar atmosphere (with codes such as **Wind Predict** and **Wind Predict-AW**)

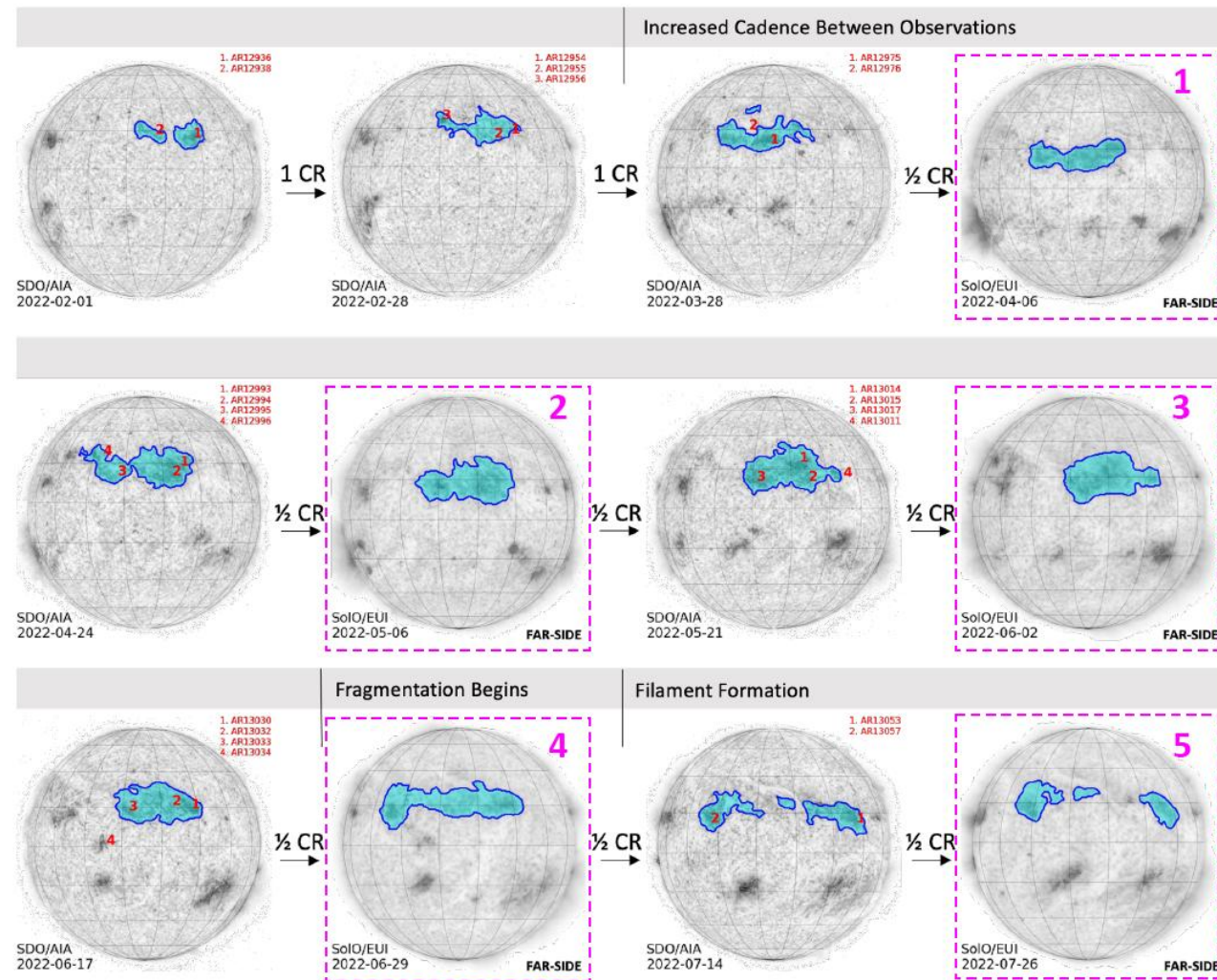
(Réville et al. 2015, 2020, Perri et al. 18)

By providing high-resolution measurements of the **photospheric magnetic field**, especially at the borders of active structures, **EST will help the French community to improve their previsions of solar connectivity.**

Slide courtesy of B. Perri

Track & monitor early emergence in active nests

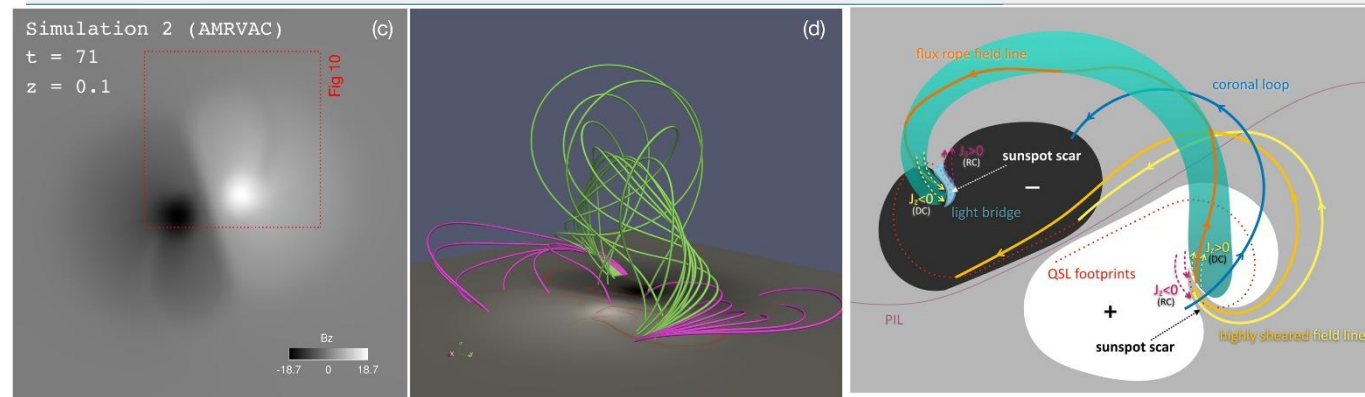
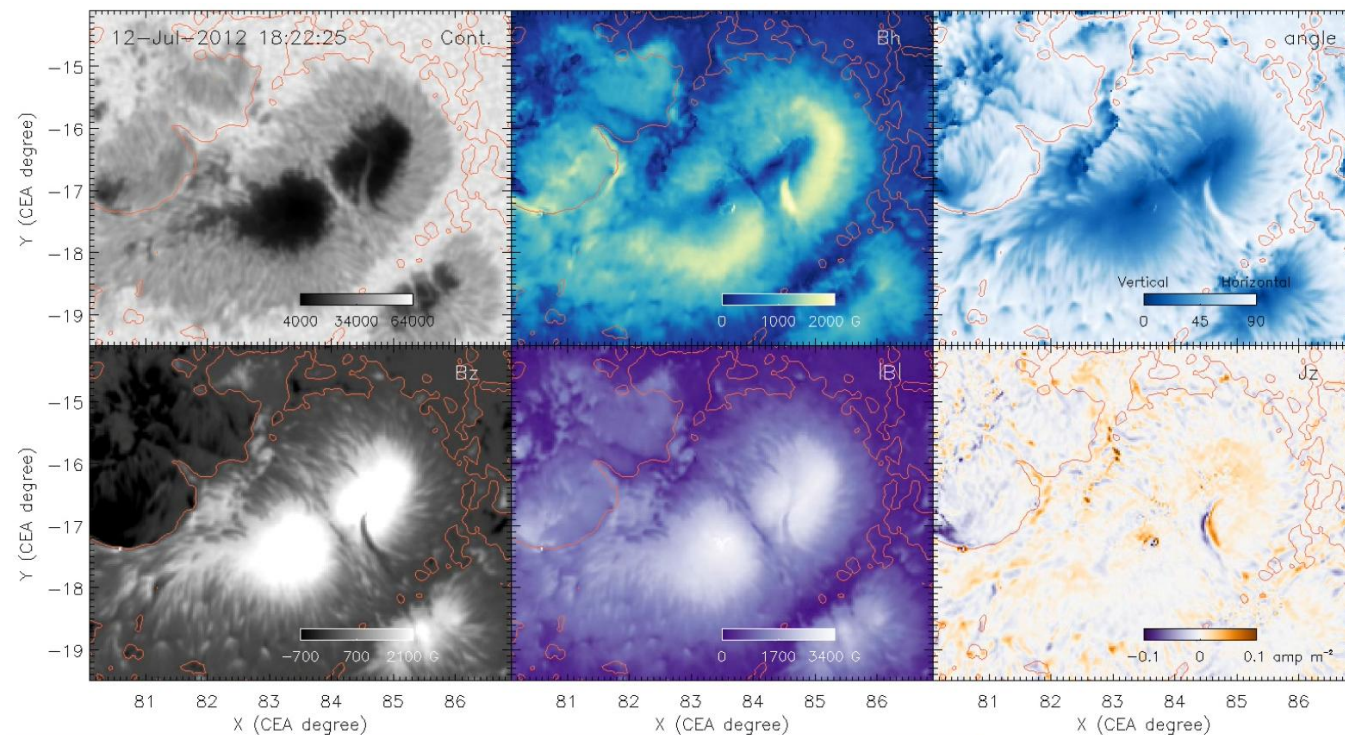
- AR emergence is structure by the underlying solar dynamo
- Almost 50% of ARs appear close to another AR (Schrijver & Zwaan 2008), in magnetically active zones, called **active nests, that can survive several solar rotations.**
- **Finley et al. 25: 6 months tracking of an active nest that contributed up to 70% of the total solar flaring activity.**
- Magnetic flux emergence starts at small scale and is difficult to capture with low-spatial resolution instrument
 - ➔ **needs of long term monitoring of active region, at high resolution, in synergy with space observations**
 - **EST can fill such observation needs**



(Finley et al. 25)

Active region « scars » as flux rope indicators

- Flux rope in active region are key pre-eruptive magnetic structure
 - Determining their presence has been very elusive so far
- **Xing, Aulanier, et al. 24** : « Sunspot scar », arc-shaped structure wedges into a sunspot, marks the edge of the pre-eruptive flux rope footpoint
 - Usually difficult to observe
- **EST will possess the quality and precision to detect this strong pre-eruption indicators**
- **➔ EST will improve early prevision of solar eruptions**



Improve coronal magnetic field reconstructions

- **EST will provide B maps of the highest quality**

- Excellent polarimetric sensitivity
- High-spatial resolution
- Extensive sampling of spectral lines

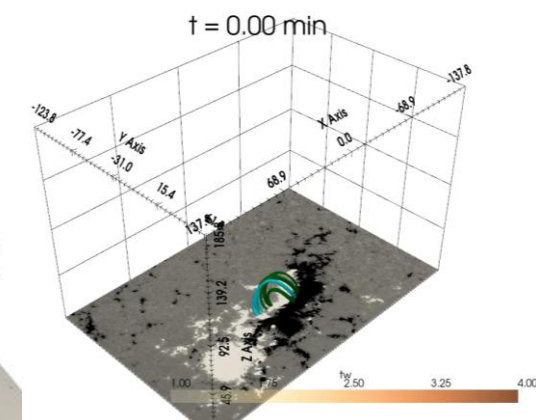
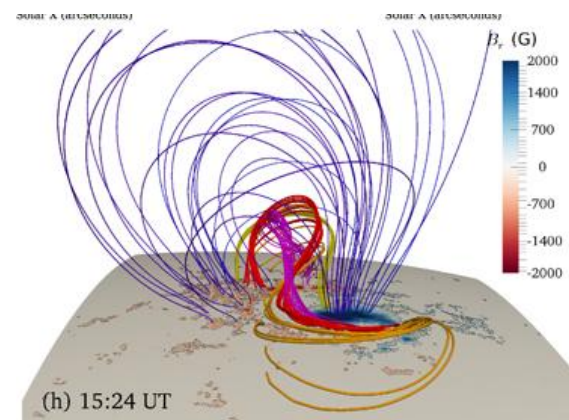
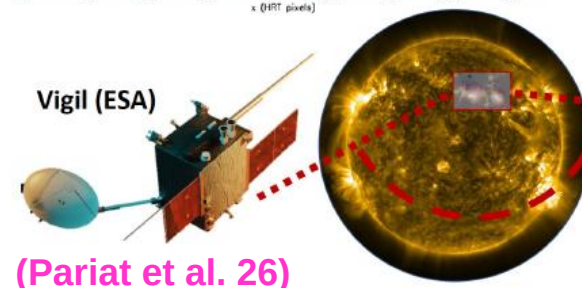
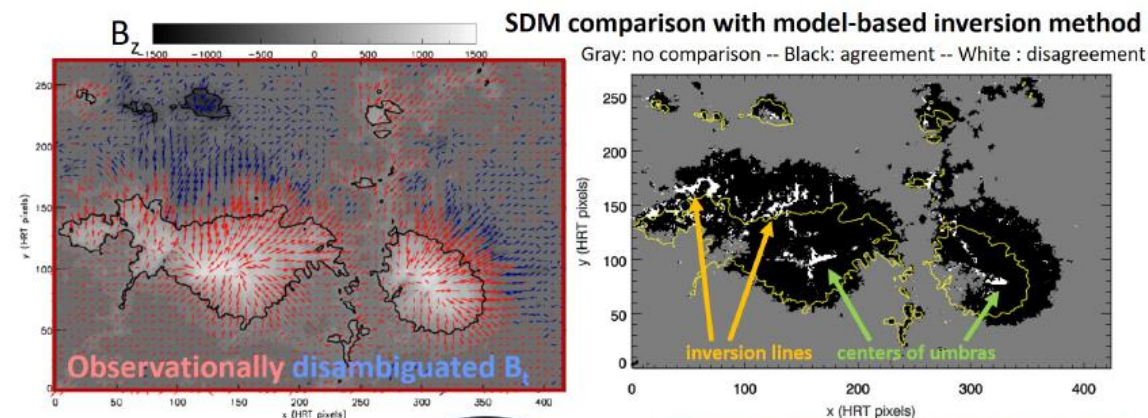
- Synergic stereoscopic observation of EST & VIGIL will provide disambiguated B_{trans}

- SDM method (Valori et al. 22, 23)

- New generation of fast and efficient magnetic field inversion methods, relying on AI (e.g. Asensio Ramos et al. 25, Diaz Baso et al. 25)

- **EST will enable:**

- ➔ ground breaking improvements in 3D reconstruction of the coronal B field from 2D photo. & chromo. magnetograms.
- ➔ High-fidelity representation of the magnetic structure & energy content of active centers
- ➔ Improved modelling of solar eruptions



Conclusions: Relevance of EST for Space Weather

Anticipation

- High-resolution monitoring of active region nests & AR emergence
- Early prediction of solar eruptions
- Next generation reconstruction of coronal B field of eruption sources

Geo-effectiveness

- Improved estimation of orientation of ICMEs (Bz)
- Improved magnetic connectivity modeling

Impact

- High-fidelity energy budget of eruption source regions & energy transfer between layers
- Improved characterization of ICMEs properties

