106° Congresso Nazionale

Il Telescopio Solare Europeo EST: Un telescopio di prossima generazione per studiare il Sole

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The 6 W's

Why, **W**hat, ho**W**, **W**here, **W**ho, **W**hen

Why ?

SCIENCE WITH EUROPEAN SOLAR TELESCOPE

Study astrophysical processes

What can the Sun teach us about fundamental astrophysical processes, both in stars and other celestial objects? Observations of the Sun reveal intricate patterns of magnetic fields and the complex dynamics of a stellar atmosphere at their intrinsic spatial scales.

Solar variability

What drives solar variability on all scales? The Sun varies on a wide range of spatial and temporal scales, producing very energetic phenomena. We still do not fully understand these changes and cannot accurately predict basic aspects of solar variability.

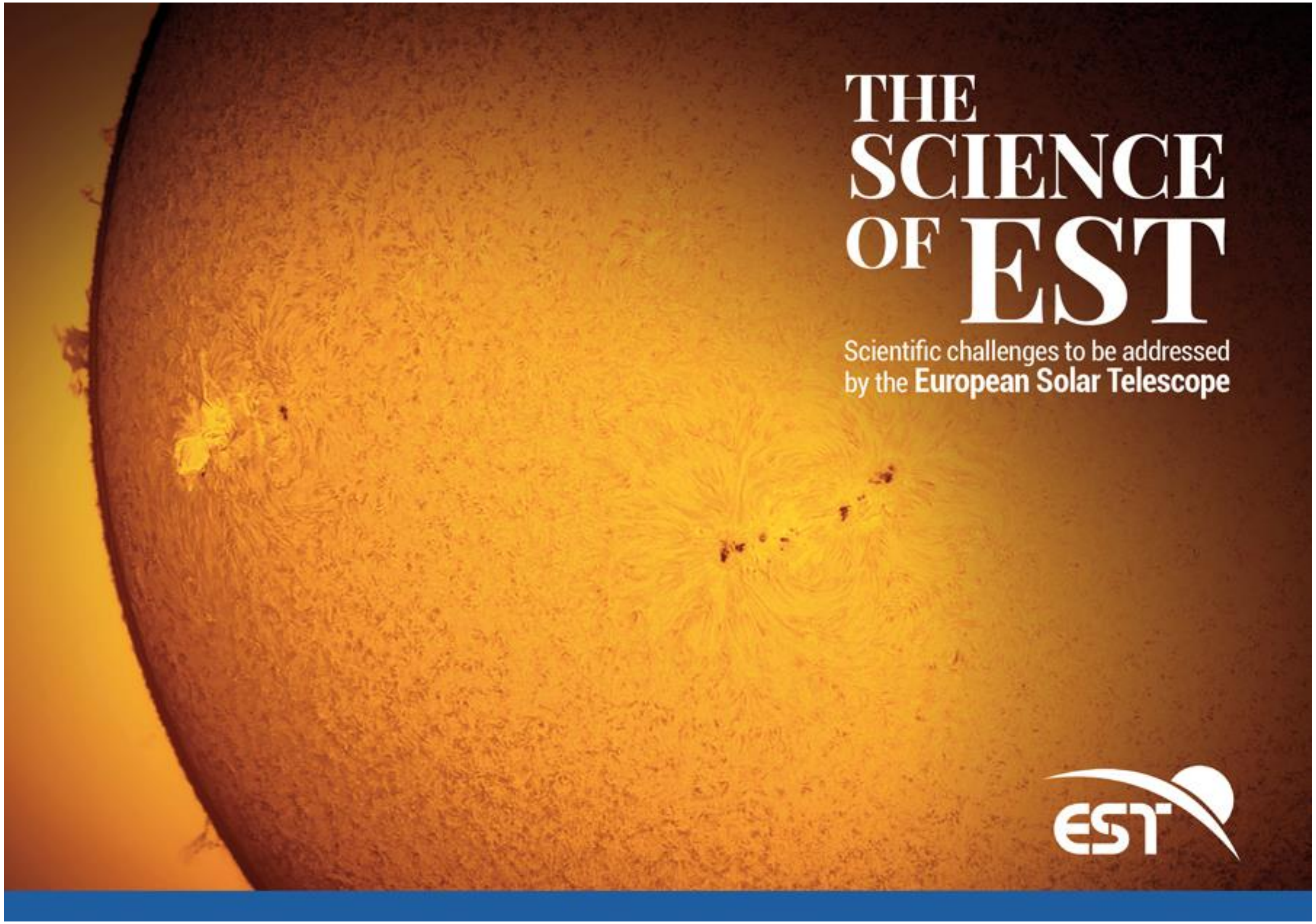
Solar activity impact

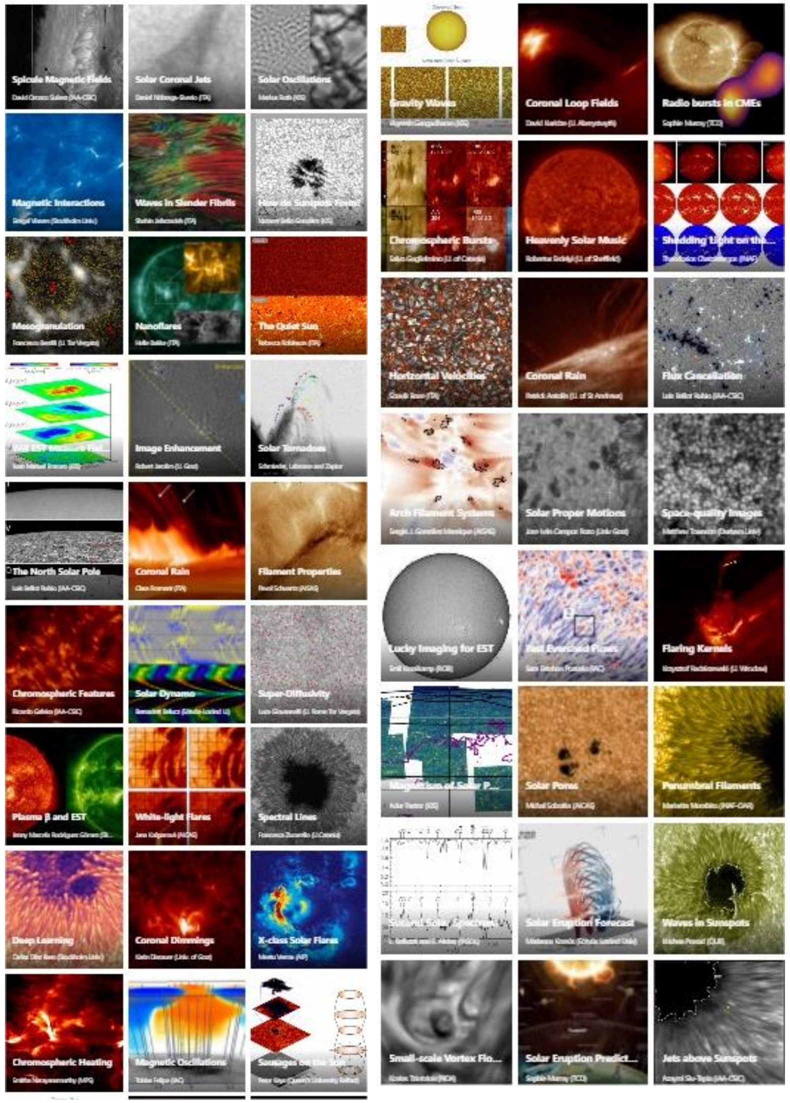
What is the impact of solar activity on Earth? Solar magnetic activity can affect millions of people on short and long time scales. We need to predict disturbances of the space environment induced by the Sun and to understand the links between the solar output and the Earth's climate.

http://www.est-east.eu/

JUNE 30, 2020 - **NEW BOOK: THE SCIENCE OF EST**

The articles of this educational series, published on the EST social media between May 2018 and May 2020, are now compiled in a book that can be download freely at: *http://www.est-east.eu/the-science-of-est*





Why a 4-m telescope?

When we observe a star at the **fundamental scales** of physical processes occurring on the surface, the domain of **astrophysics expands**.

We enter the domain of Physics of complex systems, of turbulent convection, of magneto hydro-dynamics, of fast and strongly non-linear processes in plasma.

Mean free paths and scale heights

Photons emerging from an optically thick atmosphere arise mostly from regions centered around optical depth $\tau = 1$ (last scattering surface).

Landi Degl'Innocenti (2013) demonstrated the curious property that, in stratified layers when the opacity is proportional to pressure, the **photons emerge from a region with an intrinsic thickness of ≈ 1 pressure scale height (H)**.

The photosphere and low chromosphere comprise a partially ionized stratified layer with $T \approx 6000$ K, and a pressure scale height (H)

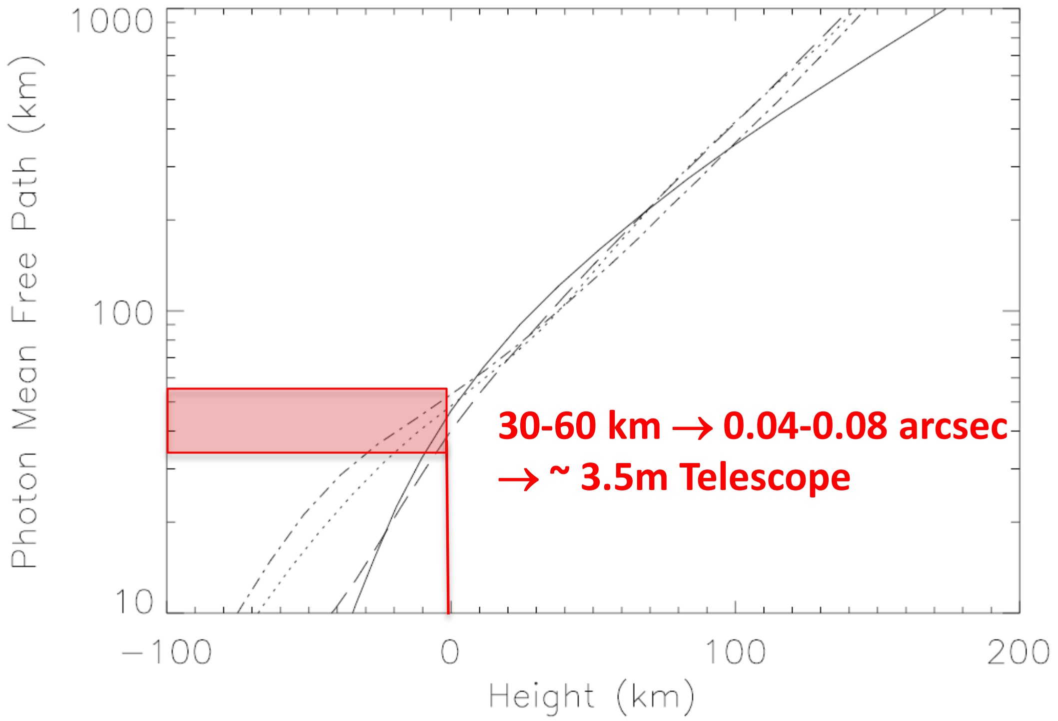
$$H = -\left(\frac{d\ln p}{dz}\right)^{-1} = \frac{kT}{\mu m_H g} \approx 130 \quad \text{km}$$

Now, the MFP of a photon where $\tau = 1$ must be $\approx \Delta$ (thickness of the region emitting most observed photons).

$$\text{MFP} \approx \Delta = 2H / (m+1)$$

The photon MFP is of the same order as the pressure and density scale height in the photosphere ($m = 1$) and lower chromosphere ($m = 0$).

Adapted from Judge et al., Sol Phys, 2015



Photon MFP at 500nm versus geometrical height for different model atmospheres: quiet sun (solid line), plage (dots) or large spot (dashes).

Adapted from Sobotka, 2001

Imaging spectropolarimetry and plasma dynamics

The measurement of the solar magnetic field (possibly B vector) is a key aspect for the study of MHD dynamics of solar plasma.

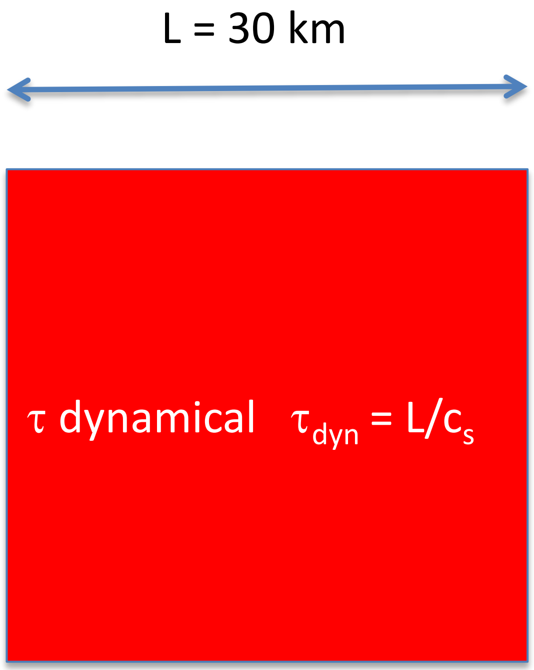
Spectropolarimetry is a powerful tool for measuring these fields.

Question: **Does building a bigger telescope provide you with more photons?** Answer: **Yes and No**

YES - A larger telescope collects more photons, and these are presented to the focal plane of the telescope.

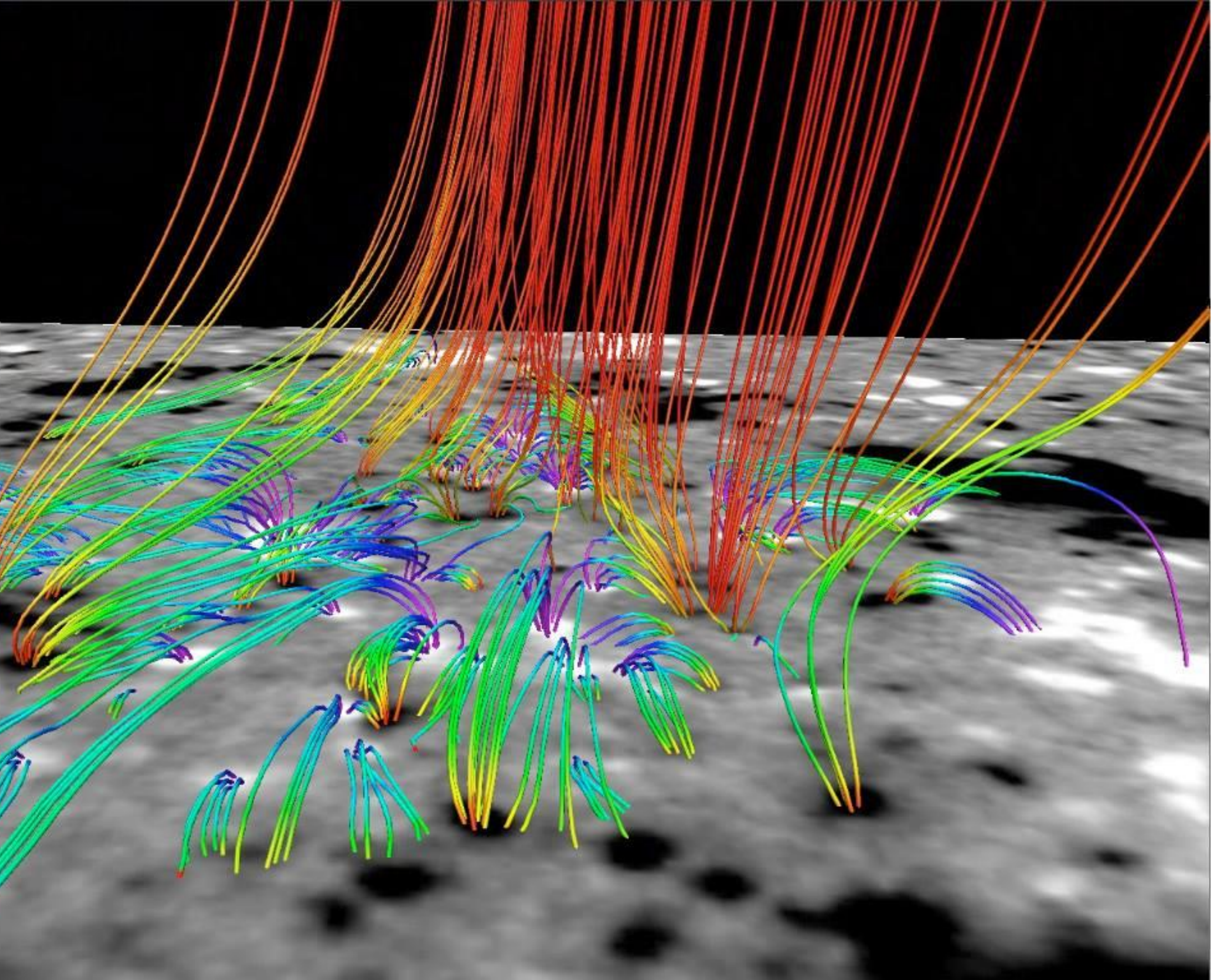
NO - The Sun is an extended source of light: it fills the image plane of a telescope. The photon flux from the Sun per diffraction resolution limit θ is independent of aperture diameter D.

New large telescopes will often operate well away from their diffraction limits in order to gather enough photons for high-precision polarimetry.



Assuming a typical sound speed (c_s) = 7 km s^{-1} and a scale of 30 km in the photosphere it takes about 4 seconds for the information to travel into the observed plasma element by **setting a limit on the spectral sampling rate and integration time**s.

Adapted from B. W. Lites - Solar Polarization Measurements: Instruments and Techniques
https://www2.hao.ucar.edu/sites/default/files/csac/files/instrumentation_spectropolHAO2018_2.pdf

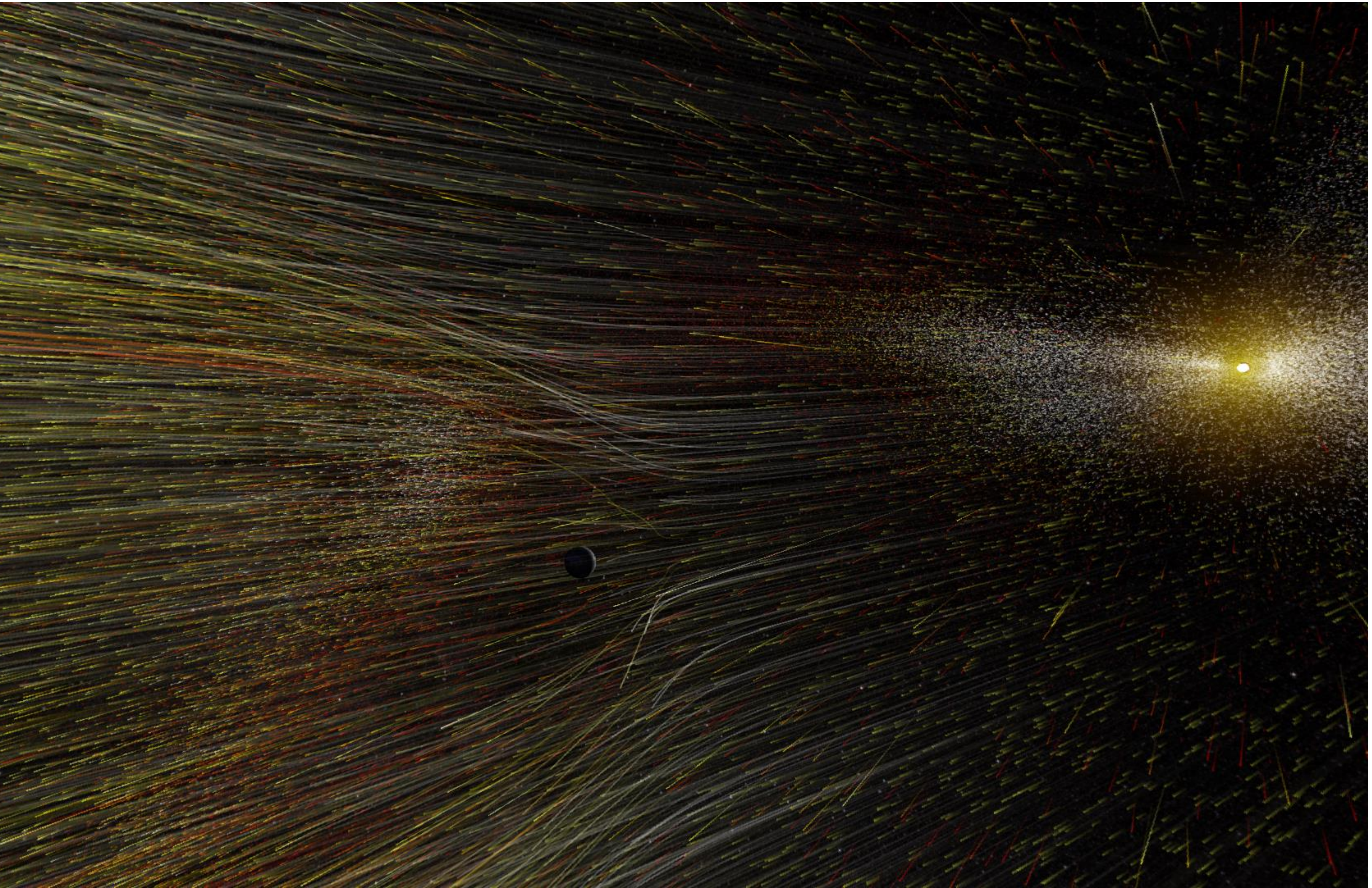


The quiet Sun is the area of the solar surface outside of active regions. Dominated by granular convection, it appears to be dull and uninteresting. However, observations with high sensitivity have demonstrated that the quiet Sun harbors ubiquitous magnetic fields.

These fields are extremely weak, but may contain most of the magnetic energy of the solar surface, outweighing sunspots and active regions by far. Unfortunately, we do not know much about their properties and evolution due to the lack of sensitive measurements at high spatial resolution.

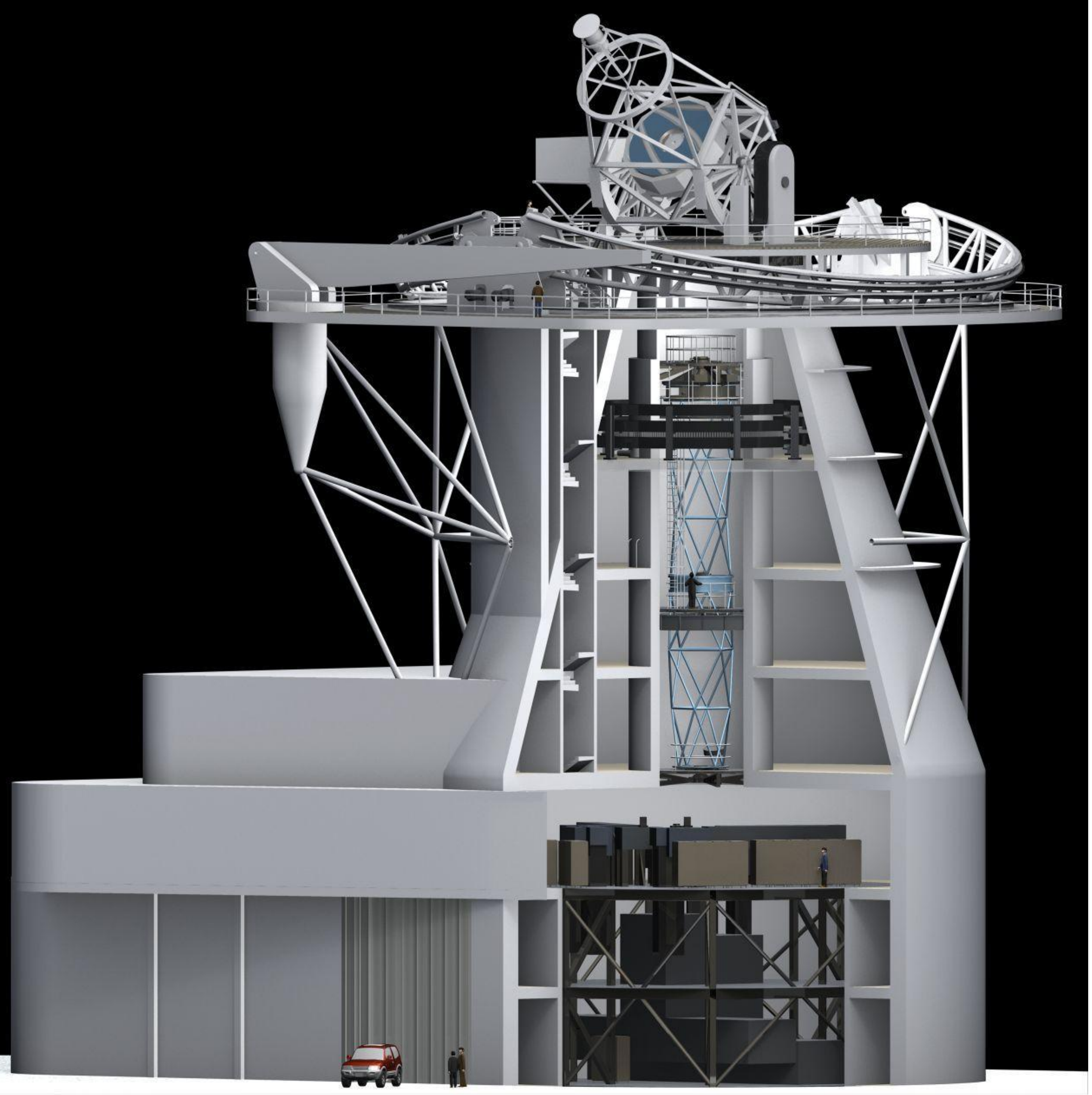
Credit: M. Gosic, M. Cheung, L. Bellot Rubio

The active sun as the source of the Space Weather



A constant outflow of solar material streams out from the Sun, depicted here in an artist's rendering. On June 20, 2019, NASA selected two new missions – the Polarimeter to Unify the Corona and Heliosphere (PUNCH) mission and Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS) – to study the origins of this solar wind and how it affects Earth. Together, the missions support NASA’s mandate to protect astronauts and technology in space from such radiation.
Credits: NASA

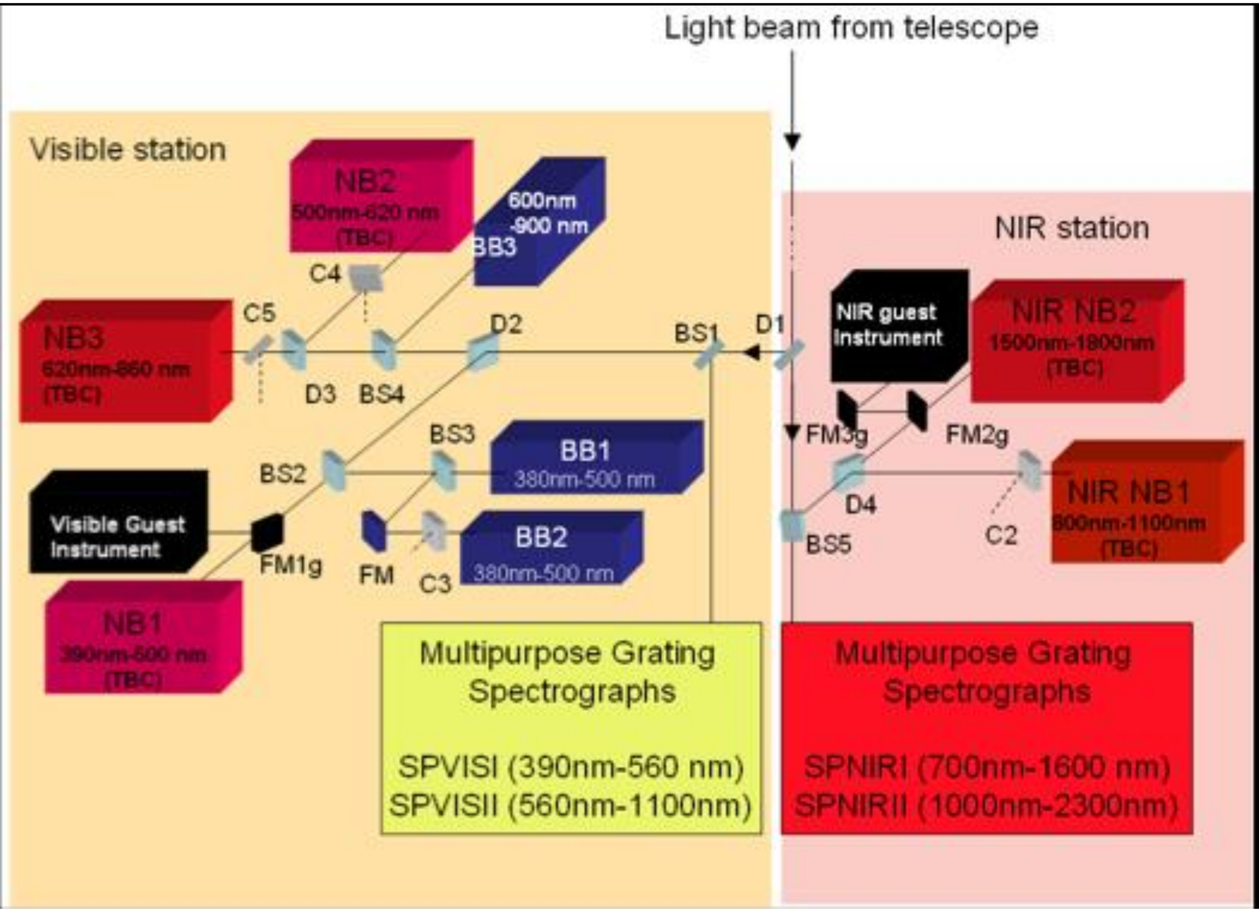
What ?



The European Solar Telescope (EST) is a next generation large-aperture on-axis solar telescope with a 4.2-m primary mirror and a suite of instruments for multi-wavelength (multi-layer) imaging, spectroscopy and spectropolarimetry.

EST will specialise in high spatial and temporal resolution, using several instruments simultaneously to efficiently produce 2D spectral information (3D in the solar atmosphere).

EST Focal Plane Instruments



Broad Band Imagers

- 3x in the VIS

Narrow Band Tunable Interferometers

- 3x in the VIS
- 2x in the NIR

Spectro-Polarimetric Tunable Imagers

- 2x in the VIS
- 2x in the NIR

hoW ?

Contribution of the Italian Community: Technology

- M1 thermal control (EST)
- Heat rejecter (EST, GREST)
- AO and MCAO & DM2 (EST, SOLARNET, GREST, SOLARNET2)
- Broad Band Imager (EST)
- Narrow Band Tunable Imager (EST, SOLARNET2)
- Large Etalons and digital control (EST, GREST)
- Detectors (EST)
- Telescope Control and Data Handling (EST, SOLARNET)
- VSO (SOLARNET)
- Polarization induced by DM (GREST)

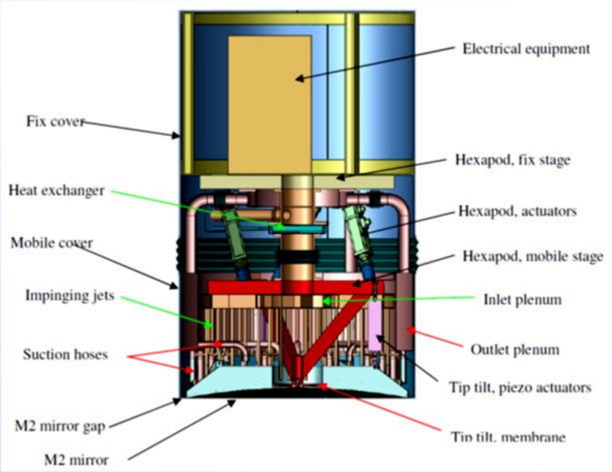
35 Italian researchers from

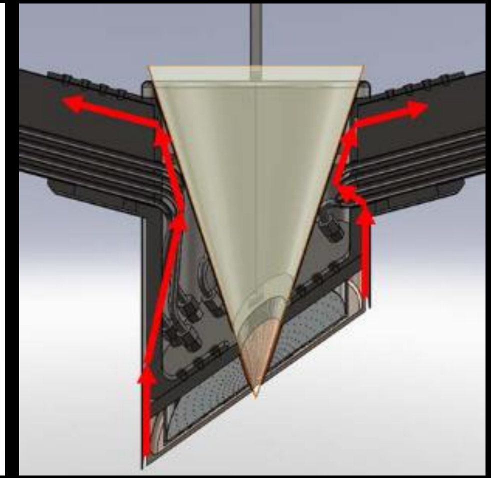
- 8 **INAF Institutes**: Observatory of Arcetri, Catania, Naples, Palermo, Rome, Trieste, IAPS, TNG-FGG
- 6 **Universities**: Calabria, Catania, Florence, L'Aquila, Palermo, Rome Tor Vergata
- CNR-INO

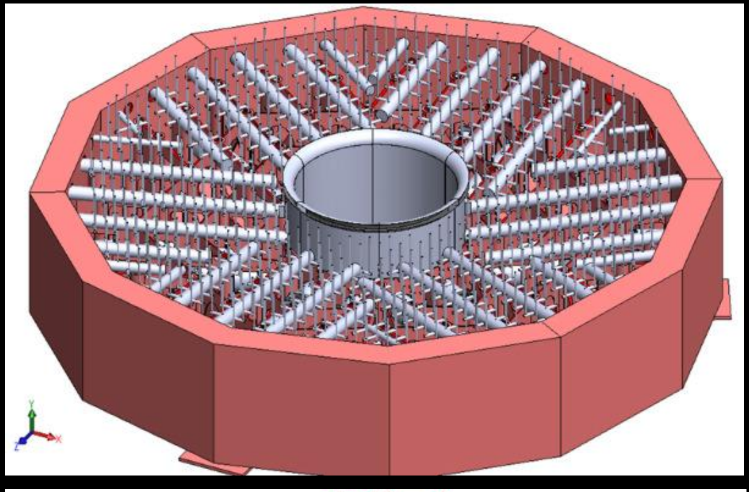
- 3 medium-sized Companies: S.R.S. Engineering Design, A.D.S. International, B.D.P. Engineering -Opto Service

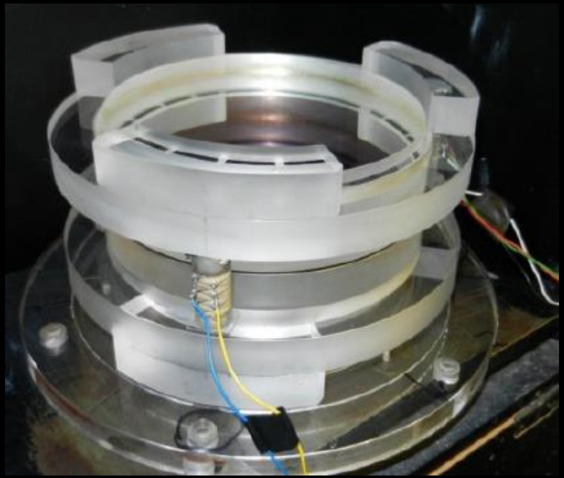
Yellow shows the projects financed under FP7 and H2020

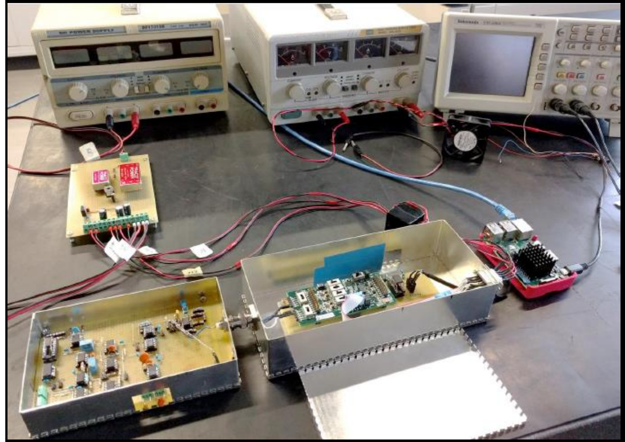
Contribution of the Italian Community: Technology

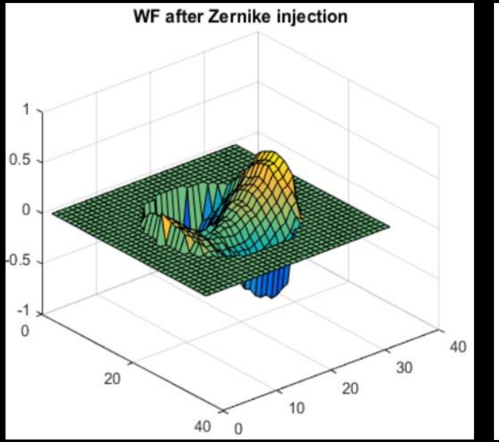


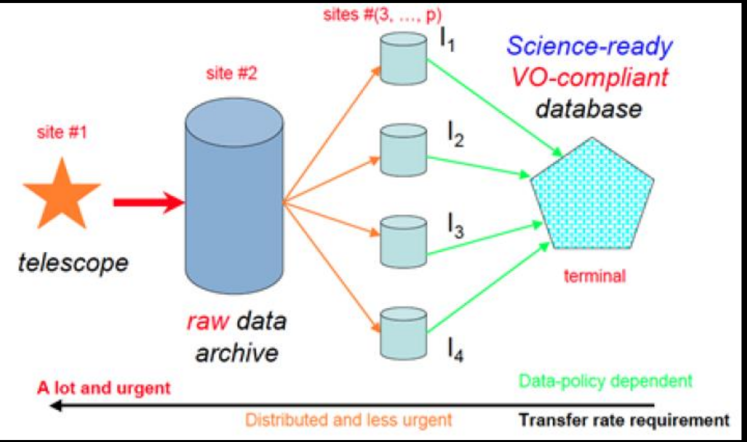


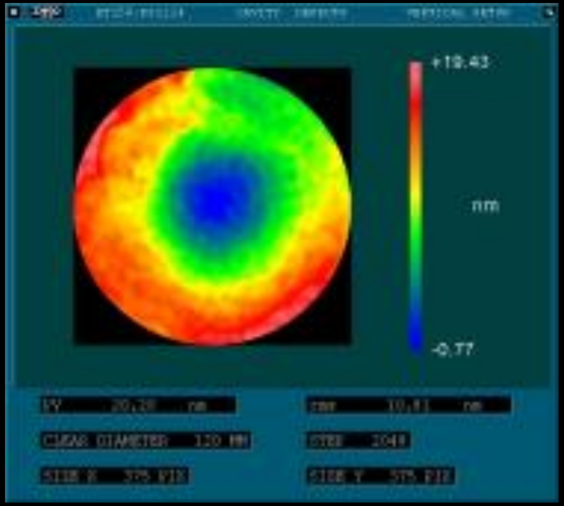












The **Heat Rejecter** (HR) is a vital system of EST and a challenge for the engineers.

From an optical point of view it is the **Field Stop** of the telescope. But from a thermal point of view it must perform two tasks: reflect the heat in F1 (to **reduce the thermal load** in the optical path), have a **temperature close to the environment** one in order not to produce convective plumes that would affect the optical quality.

The energy concentrated in the focal plane can reach up to 5 MW m^{-2}, a density similar to the one in the core of a nuclear reactor.

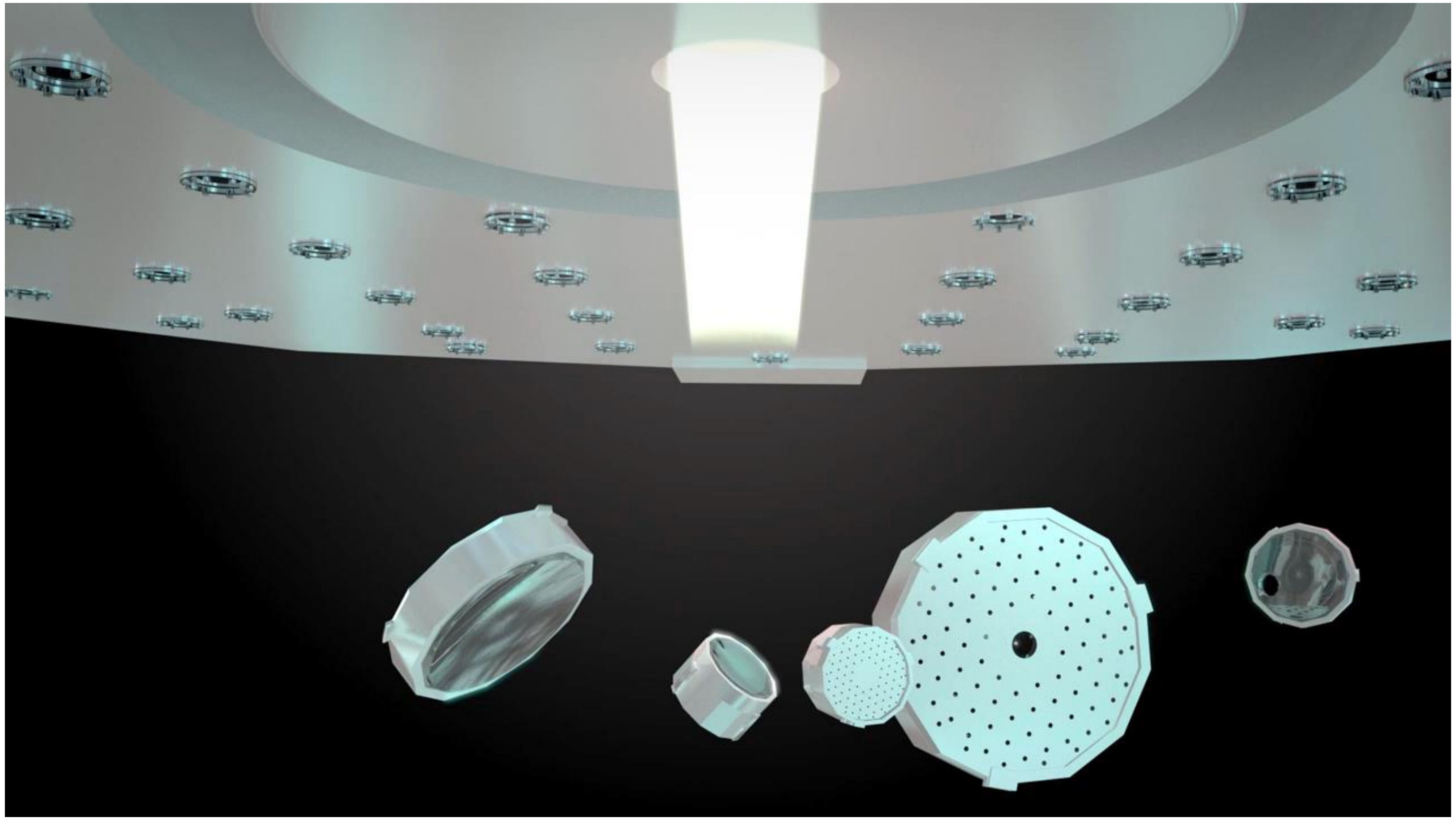
An Italian team designed a HR based on **Multiple Jet Impingement** (heat tr. Coeff. 25-40 kW/m^2 ^oC) technology, similar to the one used in cooling system adopted in nuclear fusion reactor divertors.

The **transfer optics subsystem** is a fundamental system of EST because it must maintain the image quality, contain the MCAO mirrors and cancel out spurious polarization effects.

Transfer optics (M9 to M14) transfer the light from the main axes subsystem to the Science Coudé Focus.

In addition, this assembly integrates the MCAO mirrors inside its light path and also works as the field de-rotator of the telescope.

This subsystem houses two off-axis magnification stages (M9 and M13) to get an adequate f-ratio at the MCAO post-focus DMs and the Science Coudé Focus.



Where ?

Solar high-resolution national facilities in Europe

Observatorio del Teide Tenerife - OT

Observatorio del Roque de Los Muchachos – La Palma -ORM

VTT 70 cm
(Germany, 1989) -- OT

SST 100 cm
(Sweden, 2002) -- ORM

THEMIS 90 cm
(France, 1996) -- OT

DOT 45 cm
(Netherlands, 1997) -- ORM

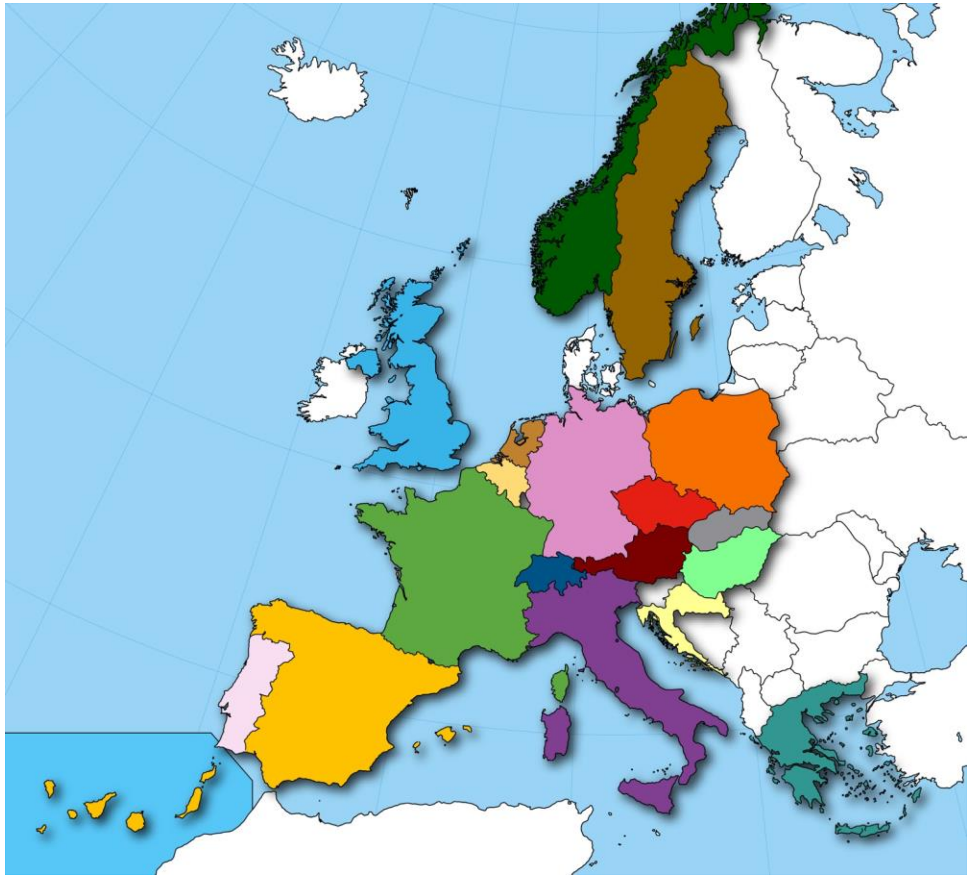
GREGOR 150 cm
(Germany, 2012) -- OT

Proposed EST site at Observatorio del Roque de los Muchachos, near the Swedish Solar Telescope (lowermost facility) and the William Herschel Telescope (at the top left). / Photo: Gabriel Pérez (IAC).

The EST project presented a proposal to the International Scientific Committee of the Observatorios de Canarias (CCI) to consider a location near the Swedish Solar Telescope (SST) at the Observatorio del Roque de Los Muchachos (ORM, La Palma) as a preferential site for the telescope, following the decision adopted by the EST project Board

Who ?

EST Scientific partners



EAST

European Association for Solar Telescopes

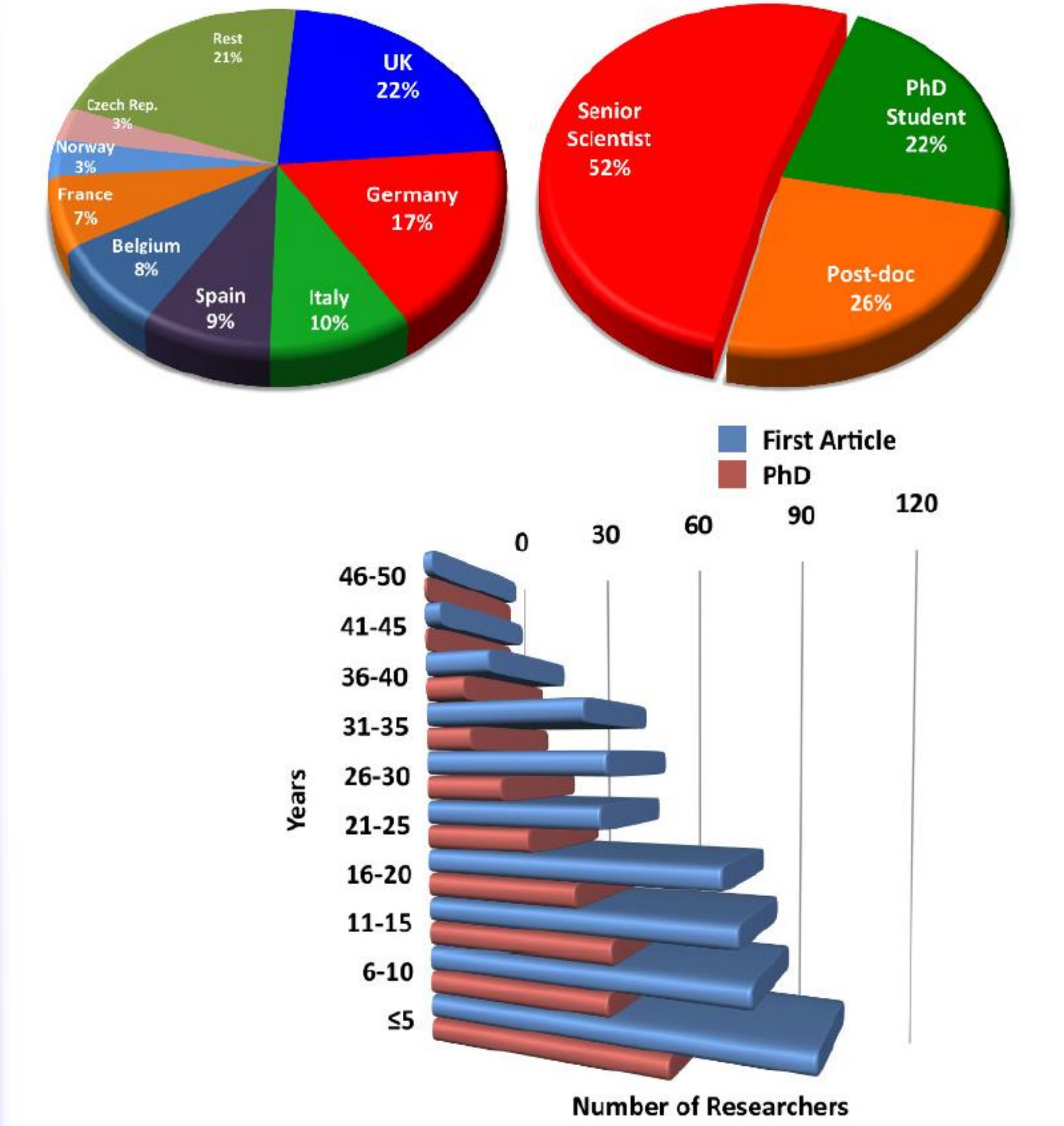
Bringing together research groups from 18 European countries

Italy: INAF, UNICAL, UNICT, UNITOV

EST became an ESFRI Strategic European Infrastructure in March 2016

Size of the community

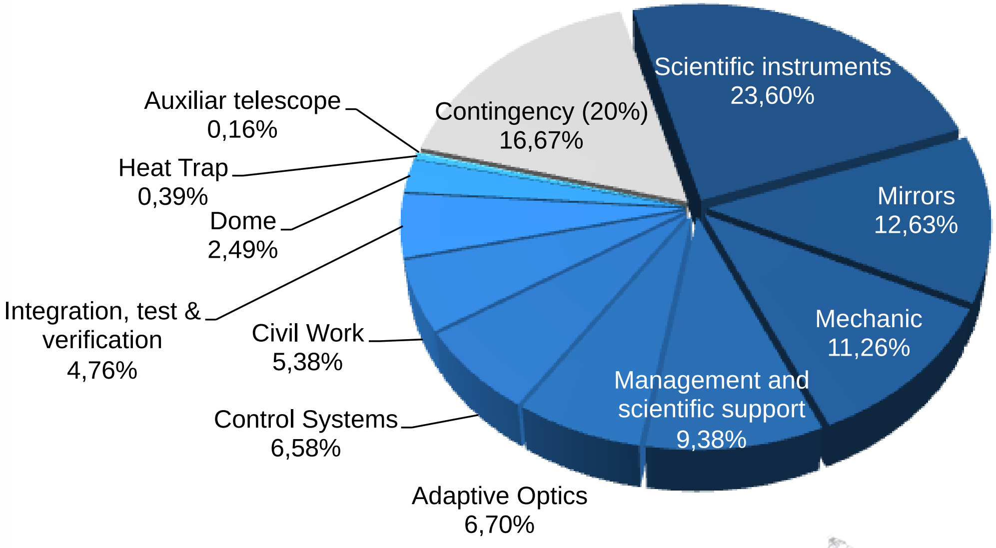
- A total of 615 researchers have been identified in 22 European countries.
- UK, Germany and Italy represent close to 50% of the total solar community.
- The first 9 countries concentrate more than 80% of the community.



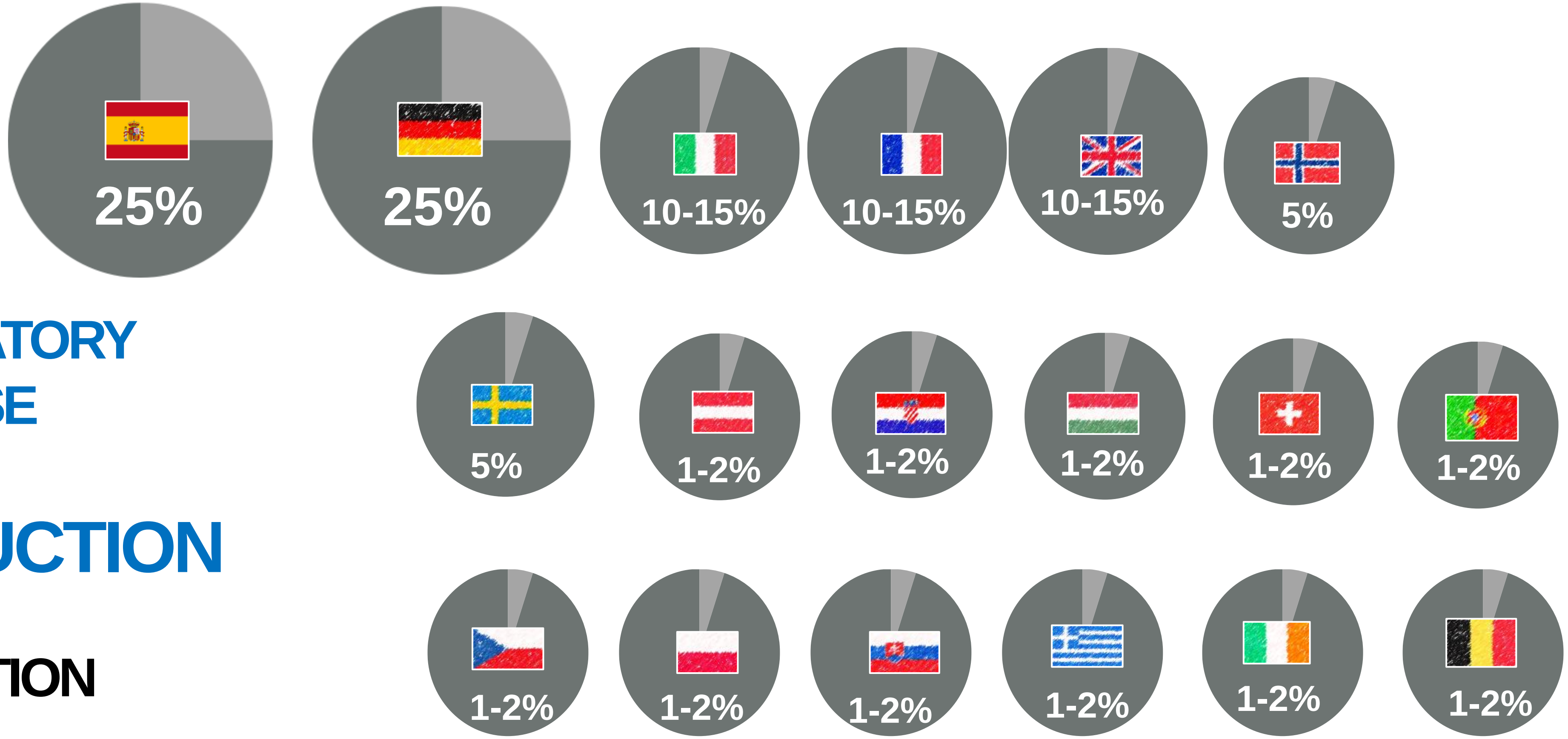
When ?

Current EST Construction budget

CHAPTER		Cost (k€)
CONSTRUCTION PHASE		
Civil engineering		10.159,14
Cooling system		1.319,81
HAVC system (heating, ventilation, air conditioning)		2.632,25
Auxiliary services (electrical system, water supply, etc.)		616,36
High precision mechanics and mechatronics		3.518,28
Design/manufacturing of support structures		3.061,81
Design/manufacturing of large mobile structures		27.582,51
Actuators systems		1.230,28
Optical instrumentation		33.097,81
Design/manufacturing of large mirrors		20.316,69
Optics manufacturing (lens, mirrors, coating, polishing, etc)		1.644,10
Adaptive optics & DM mirrors		7.040,62
Detectors and data acquisition		9.561,37
Software and control system		12.261,70
	Subtotal	**134.042,74**
PROJECT OFFICE MANPOWER		19.542,80
CONTINGENCY COSTS (20%)		26.808,55
	Subtotal	**180.384,09**
FIRTS LIGHT ARRANGEMENTS		**5.000,00**
	TOTAL	**185.384,09**



EST (aimed) budget distribution



PREPARATORY PHASE

+

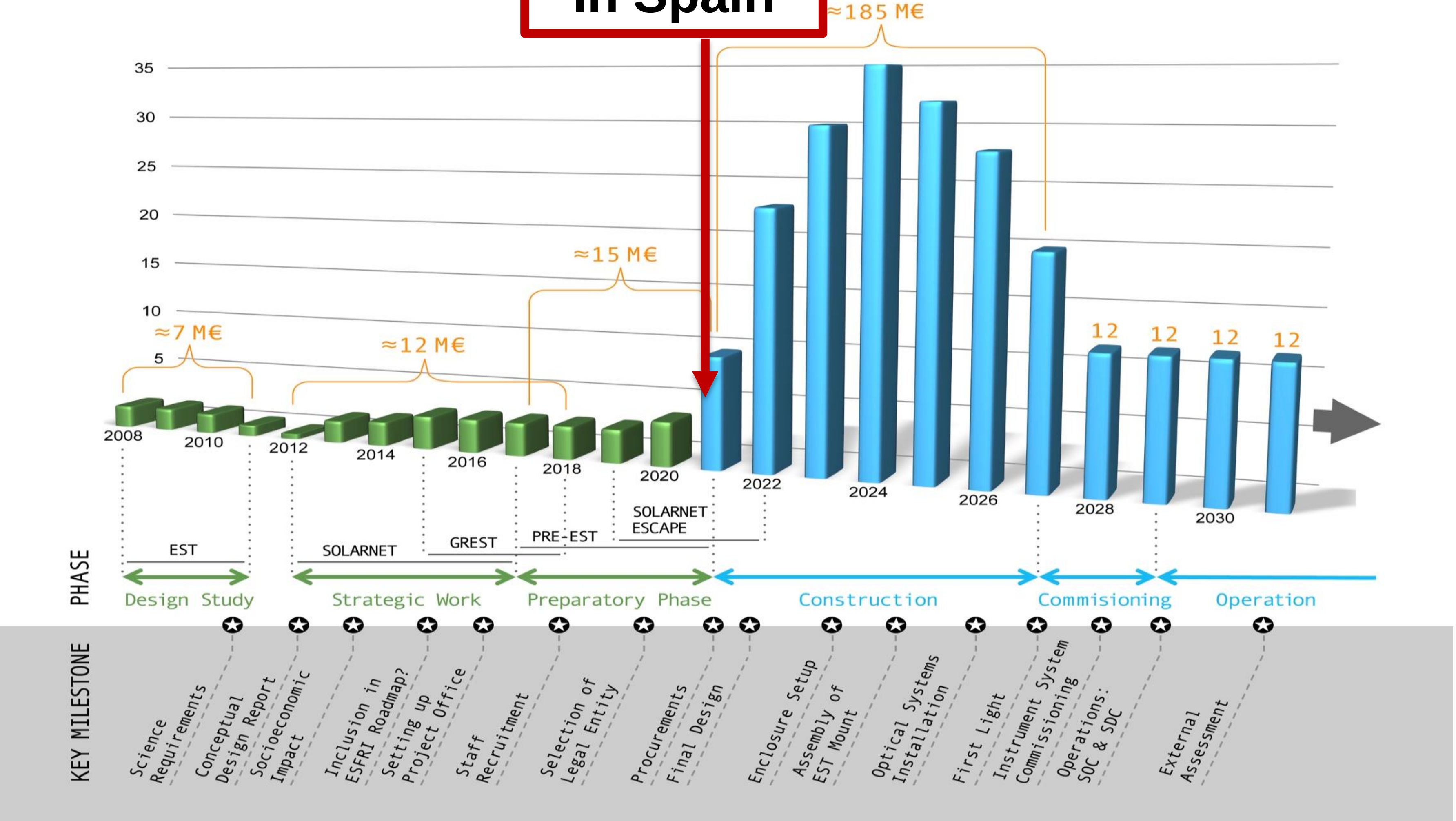
CONSTRUCTION

OPERATION

DISMANTLING

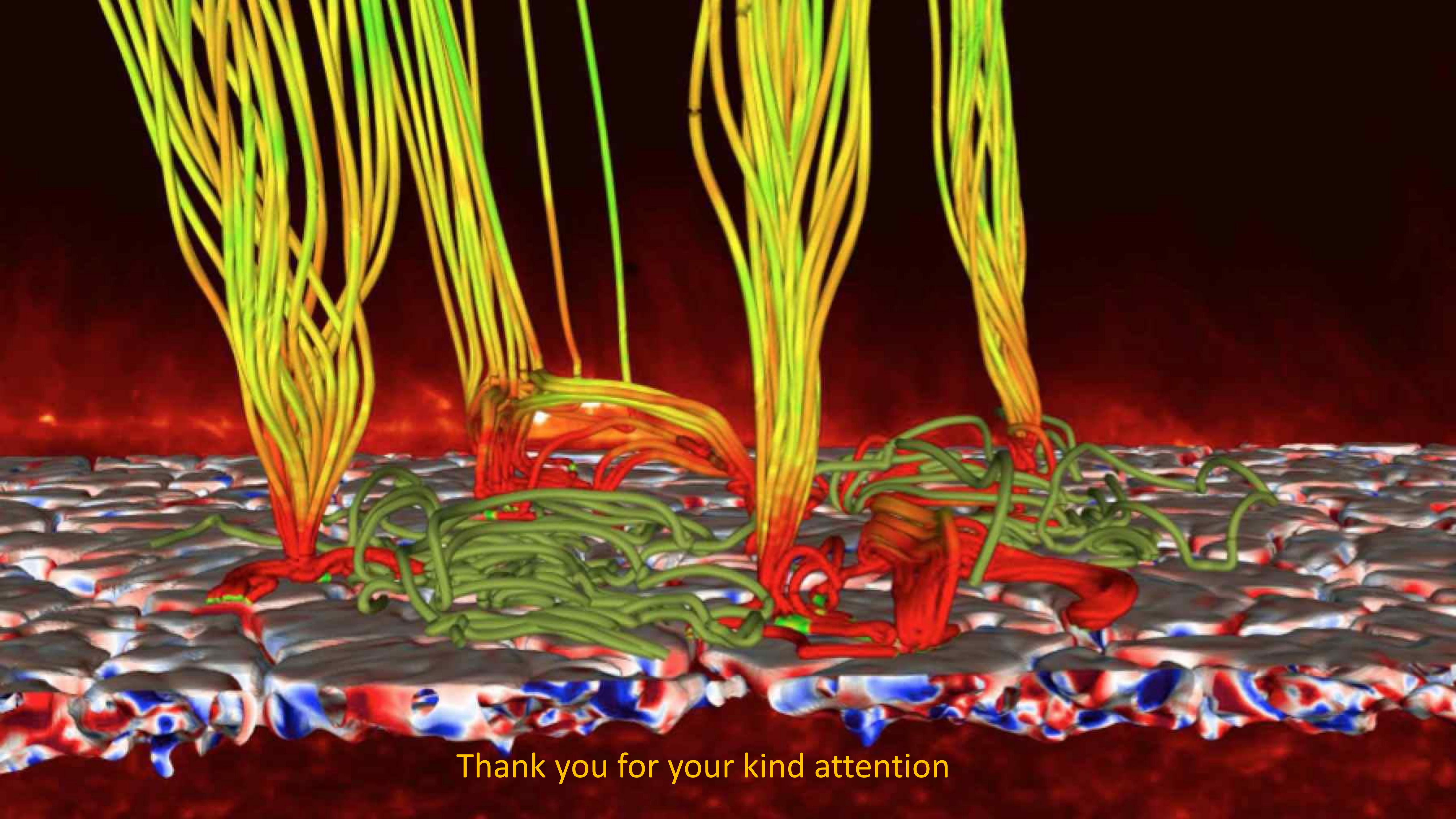
EST Timeline

ERIC
In Spain



PREPARATORY PHASE
+
CONSTRUCTION

200 M€


Thank you for your kind attention