EST NEWS 13

THE EUROPEAN SOLAR TELESCOPE NEWSLETTER

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COORDINATOR'S CORNER

This last semester has led to an important step forward for the EST project: the EST Canarian Foundation (EST-CF) was created on July 25 by nine research institutions from seven European countries. One of them (the University of Sheffield) signed as representative of the six universities forming the UK Universities Consortium. Other institutions are expected to join in the near future, increasing the strength of the project in more and more countries. After the signature took place, a set of administrative steps were started. The inclusion of the EST-CF in the Registry of Foundations was the first mandatory step, the members of the different executive bodies were ratified or appointed, the bank account administrators were nominated... Not all steps are finalised yet, but the Foundation will go ahead in all legal aspects by early 2024. A phase with new possibilities will then begin. Some information regarding the first steps of the Foundation were already advanced in our social media and are now summarised in this newsletter.

We complement this issue with technical progress that continuously takes place within the project. Information is presented about an important subsystem of the EST optical system (the so-called Pier Optical Path, or POP), about some of the instruments, about seeing calculations in the EST surroundings, and about an alternative adaptive secondary mirror. These advances have been possible thanks to the dedication of the project office staff (whose creation is also described in a dedicated article of this issue) and the collaboration of the EST partners and subcontracted companies.

As usual, this issue includes a report of communication and outreach activities and a presentation of the new EST team members. In particular, the importance of the Sun in our society was highlighted in a SOLARNET meeting attended by almost 100 participants that took place in Mestre/Venice.

The whole EST project hopes you enjoy this newsletter and wishes you all the best for the coming year 2024.

M. Collados, EST-CF President

EST CANARIAN FOUNDATION DEED SIGNED

On July 25, representatives of 9 research institutions from 7 European countries signed the deed that formalised the establishment of the EST Canarian Foundation (EST-CF).

Visit to EST headquarters after signature of the the EST-CF deed on July 25, 2023. Credit: Inés Bonet/IAC.

The founding members of the EST Canarian Foundation (EST-CF) are Astronomický Ústav AV ČR, V. V. I. (Czech Republic), Astronomický ústav Slovenskej Akadémie vied (Slovakia), Agencia Estatal Consejo Superior de Investigaciones Científicas–Instituto de Astrofísica de Andalucía (Spain), Instituto de Astrofísica de Canarias (Spain), Leibniz-Institut für Sonnenphysik KIS (Germany), Max-Planck Institute for Solar System Research (Germany), Stockholms Universitet (Sweden), Università della Svizzera italiana–Istituto Ricerche Solari Aldo e Cele Daccò (Switzerland) and University of Sheffield (UK), representing the United Kingdom Universities Consortium. In the future, other institutions may join the Foundation.

The signing of the deed, which took place in Santa Cruz de Tenerife, was personally attended by the following representatives from the participating European institutions: Manuel Nogales (CSIC), Alejandra Martín (IAC), Jorrit Leenaarts (Stockholm University), Manuel Collados (IAC), Rafael Rebolo (IAC), José Javier Soto (Notary), Svetlana Berdyugina (KIS and USI-IRSOL), Anselmo Sosa (IAC), Sergio González (KIS), Peter Gömöry (AISAS), and Philippe Bourdin (Graz University).

The remaining foundation members granted power of attorney to authorise the representatives to sign on their behalf.

The EST-CF is the legal entity chosen to facilitate the transition between the recently completed preparatory phase and the construction phase of EST. This entity also provides legal personality to the project consortium and lays the groundwork for its development.

The Foundation gives the involved institutions decision-making power over all scientific and technological aspects of the project. Its objectives are, among others:

- Ensure that the design of EST meets technical and scientific requirements through participation and organisation of scientific and engineering research activities.
- Create a European Research Infrastructure Consortium (ERIC) that brings together the national ministries of partner countries to execute and oversee all aspects of the construction and operation of the European Solar Telescope.
- Contribute to the EST project for the benefit of society at large by generating technological knowledge and organising R+D+i activities to

improve the competitiveness of the industry.

- Support the training of personnel in all fields of knowledge related to science and engineering linked to EST.

The establishment of the EST Canarian Foundation marks a pivotal moment in the project, enabling legal advancements toward achieving these objectives.

It also paves the way for subsequent stages that will transform EST into a reality, positioning Europe at the forefront of solar physics research.

Alongside the Foundation, its three governing bodies were established: the Board of Trustees, the Executive Committee, and the Director. The latter is yet to be determined.

The members of the BoT, representing all the institutions involved, are the following:

Rafael Rebolo (Instituto de Astrofísica de Canarias, ES); Manuel Collados (Instituto de Astrofísica de Canarias, ES); Casiana Muñoz (Instituto de Astrofísica de Canarias, ES); Francisco Javier Moreno (Consejo Superior de Investigaciones Científicas, ES); Luis Bellot (CSIC-Instituto de Astrofísica de Andalucía, ES); Jorrit Leenaarts (Stockholm University, SE); Sami Solanki (Max-Plank Institute for Solar System Research, DE); Joseph Bruls (Leibniz Institute for Solar Physics, DE); Svetlana Berdyugina (Università de la Svizzera italiana, CH); Jan Jurcak. (Astronomical Institute of the Czech Academy of Sciences, CZ); Peter Gömöry (Astronomical Institute of the Slovak Academy of Sciences, SK); and Robertus Erdelyi (University of Sheffield , UK).

The Board of Trustees is the governing body tasked with representing the EST Canarian Foundation and wielding all the necessary authority to accomplish the EST-CF objectives.

FIRST MEETING OF THE EST CANARIAN FOUNDATION BOARD OF TRUSTEES

The first meeting of the Board of Trustees of the European Solar Telescope Canarian Foundation took place online on September 19, 2023.

The main governing body of the European Solar Telescope Fundación Canaria is its Board of Trustees. This body shall represent the Foundation and shall exercise all the powers necessary to achieve the Foundation's aims. The Board of Trustees shall administer with due diligence the patrimony of the Foundation, maintaining their productivity according to the economic and financial criteria of a good manager.

During its first meeting on September 19, 2023, the Board of Trustees went through the usual steps required by this type of organisations. In this meeting, all the Trustees confirmed their acceptance of their positions and the representatives of the main executive bodies were chosen. In this way, Manuel Collados was elected as President of the Board of Trustees and Peter Gömöry as Vice-President. The President and the Vice-President, together with trustees Jorrit Leenarts, Svetlana Berdyugina and Robertus von Fay-Siebenburgen were elected to conform the Executive Committee of the Foundation.

The President shall, among other duties, represent the Foundation's Board of Trustees in all areas of its activities, coordinate and promote the activity of the Foundation, developing its internal regulations. The Vice-President shall be responsible for substituting the President in the event of illness, absence or inability to act on the part of the President and those functions that the Foundation statutes or the President may entrust to him.

The Executive Committee is in charge of the examination of all documentation to verify compliance with the budget and the accompanying explanatory report, as well as the adoption of appropriate measures to correct any deviations that may occur. It shall also carry out all activities delegated or entrusted to it by the Board of Trustees.

In addition, in this first meeting the Board of Trustees decided upon key aspects necessary to start with the running of the newly created entity, such as the formalisation of the steps for the legal registration of the Foundation and the approval of the processes to appoint the Director and Administrator.

THE PROJECT 'EST PREPARATORY PHASE PROJECT OFFICE' COMES TO AN END

Funded by the Canary Islands Government, it has allowed to set up the EST Project Office.

The European Solar Telescope was included in the Research and Innovation Strategies for Smart Specialisation (RIS-3) of the Canary Islands for the period 2014-2020, approved by the Canary Islands Governing Council on December 26, 2013 and ratified by the Canary Islands Parliament on March 10, 2014. A priority objective of the Canary Islands Government was to generate scientific and technical knowledge of excellence in the areas declared prioritary for the Canary Islands.

The Government Council of the Canary Islands approved in April 2017 a multi-annual budget as a contribution to the EST preparatory phase Project Office with a total budget of 4.5 million euros. On September 2023, this project has come to the end, with a successful development, achieving its main goal of creating the EST Project Office (EST PO).

The EST PO was started in 2018 and consolidated over the following years. During the funding period, the EST PO worked on the preliminary design of telescope subystems and reviewed externally subcontracted designs.

The revision and consolidation of the conceptual design allowed closing the technical specifications for the calls for tenders for the preliminary design of the main telescope subsystems: primary mirror, adaptive secondary mirror (ASM), structure, pier, enclosure (which have been concluded) and heat rejecter (in progress).

All the preliminary design contracts have been divided in 3 phases: consolidation of the baseline designs, development of the preliminary design and fabrication of prototypes to verify the more challenging requirements. All the closed preliminary designs have passed the corresponding sub-system preliminary design reviews.

Since the ASM represents a challenge, two alternative calls for tenders have been announced to develop designs based on different technologies, thus minimising risks and ensuring that the best solution for EST is approached. The second call for tenders was awarded in 2023.

In parallel to the execution of the external contracts, which have been monitored and reviewed by the EST PO staff, work has continued on the rest of the telescope systems with the objective of closing their conceptual and/or preliminary designs.

The EST PO has specialised in transient and seeing analysis, with the support of external consultants (covered by the Canarian Government funding), to minimise the local seeing by optimising the telescope design.

Verifications have continued also on the multiconjugated adaptive optics (AO) demonstrator test bench, progressing from classic AO to ground layer AO and hopefully soon to multiconjugated AO.

The approval on May 21, 2021 of the EST site at Roque de los Muchachos Observatory has allowed adapting the building design to the final location. The technical documentation for the next call for tenders for the basic civil works project has been completed.

At the moment of closing this funding line from the Canary Islands Government, the ESP PO is established and continues working on the documentation for the Preliminary Design Review in the third quarter of 2024.

The funding of the EST PO was approved as an action of strategic interest for the archipelago to contribute to the leadership of the Canary Islands in the astronomy sector. Both the EST PO and the EST team acknowledge the support during this phase from the Agencia Canaria de Investigación, Innovación y Sociedad de la Información del Gobierno de Canarias (ACIISI) and the European Regional Development Fund (ERDF) under grant with reference SD 17/01 EST GOBCAN.

Members of the EST project office at the EST headquarters in La Laguna.

SOLARNET CONFERENCE 'SUN IN SCIENCE AND SOCIETY' SUCCESSFULLY ACCOMPLISHED

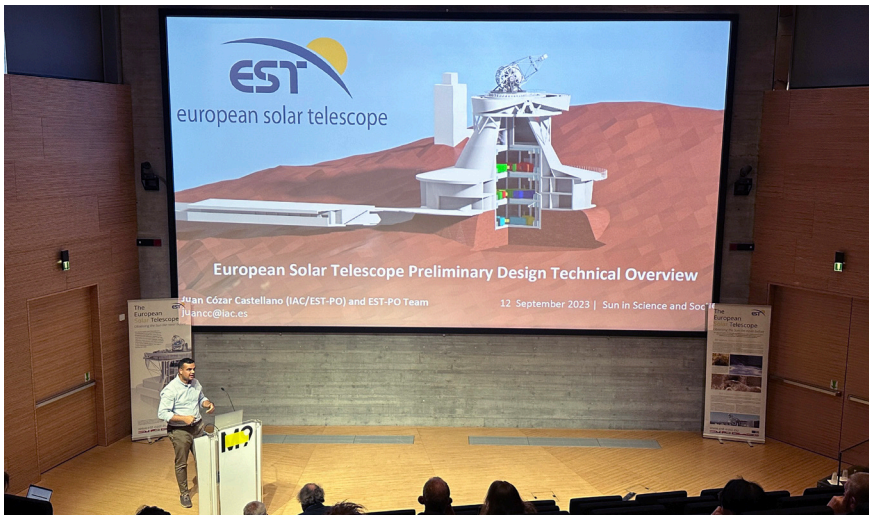
Different communities discussed how the Sun is a model for physics and astrophysics.

The conference "Sun in Science and Society", organised as part of the H2020 SOLARNET Project by the University of Rome Tor Vergata and the University of Catania, took place at the Museo del '900 M9 in Venice/Mestre (Italy) from September 11 to 15, 2023. The event aimed to explore the Sun's role as a variable magnetic star and its impact on space climate, space weather, the terrestrial environment, and global technological infrastructure, which collectively influence the global economy.

The conference provided a platform for heliophysics scientists to present the latest advancements in solar theory, the Sun-Earth connection, and forecasting capabilities. It also facilitated discussions between stakeholders and economists who assessed user needs and requirements.

Five days were devoted to delve into various topics related to the world of solar research, ranging from solar activity and its drivers to the impact of solar physics on the economy and society, data for civil society, education, and awareness. Of particular international socio-economic importance were the more technical insights, where high-resolution ground-based telescopes and technology for solar physics were discussed.

Moreover, this international conference highlighted the Sun as a paradigm in astrophysics, fostering discussions on how recent solar research findings could be applied to other astrophysical contexts. It aimed to identify problems in various fields that could benefit from cross-disciplinary collaboration, encouraging researchers working in solar studies to engage with those from other scientific domains.



EST preliminary design presented at the conference. Credit: L. Bellot / IAA-CSIC

The scientific programme featured six sessions:

1. Solar Activity and Its Drivers
2. Sun, Space, and Society
3. High-Resolution Ground-Based Telescopes and Technology for Solar Physics
4. Sun, Space, and Society (exploring the solar physics impact on the economy and society, data for civil society, education, and outreach).
5. The Sun as a Rosetta Stone for Astrophysics.
6. The Sun as a Rosetta Stone for Physics.

The conference was a resounding success, drawing 90 participants from both European and non-European countries. Organisers thoughtfully considered geographical representation, gender balance, and the relevance of proposed contributions to the conference's central objectives when defining the scientific programme.

The presence of experts from different communities made it possible to describe the contribution that the study of the Sun can give in different fields, including Earth's climate, space weather and space climate, extrasolar planets, as well as how the Sun constitutes a Rosetta stone in the understanding of a large number of physical processes.

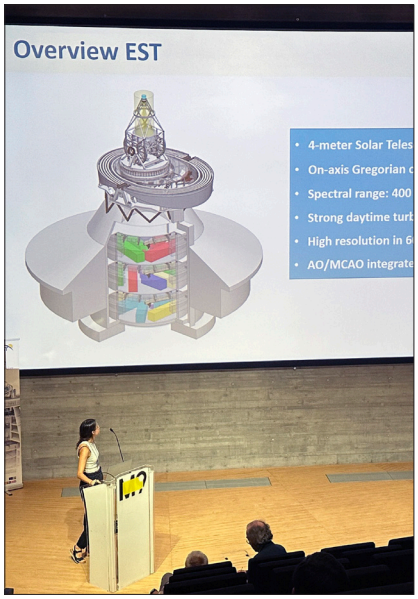
The conference saw an important participation of the EST project. The preliminary design of different EST sytems and subsystems was presented in various talks by members of the EST Project Office. The educational activities of the consortium were also presented by members of the EST Communication Office, as an example of how the Sun can be used to teach different science topics and promote STEM vocations in schools. The "Sun in Science and Society" conference attracted a lot of media attention and triggered an

Participants in the international SOLARNET conference "Sun in Science and Society" in Mestre (Italy).

interview to Prof. Francesco Berilli of University of Rome Tor Vergata on the how to understand the cosmos by studying the Sun.

"The Sun is the closest star to us. It is the only astrophysical object that allows us to observe in great detail those physical processes that are present in all the other stars, albeit in different ways. We know that there are much hotter and much colder stars, but let's say that some key processes, especially the magnetic ones, are present in other stars but are not observable", explains Berrilli.

"In the case of the Sun, we are able to study the physics that helps us understand how these processes occur. Major space missions, such as the James Webb Telescope, or future large telescopes like ELT, will attempt to observe the atmospheres of other planets, seeking to understand the possibility of life in other planetary systems. Therefore, the Sun and the planets in the Solar System in some way represent a system that we can observe in great detail. If we wish to study closely how a star communicates with nearby planets and their interactions, not only in terms of light but also in terms of relationships related to the magnetic field, for instance, which is expelled along with coronal material, or particles, and how these interact with different planets, we can understand it by observing the Sun,



EST presentation at the conference.

observing how it interacts with Earth, Mars, Jupiter... So, in our Solar System, we have a wealth of details that allow us to understand how this interaction also works on distant objects."

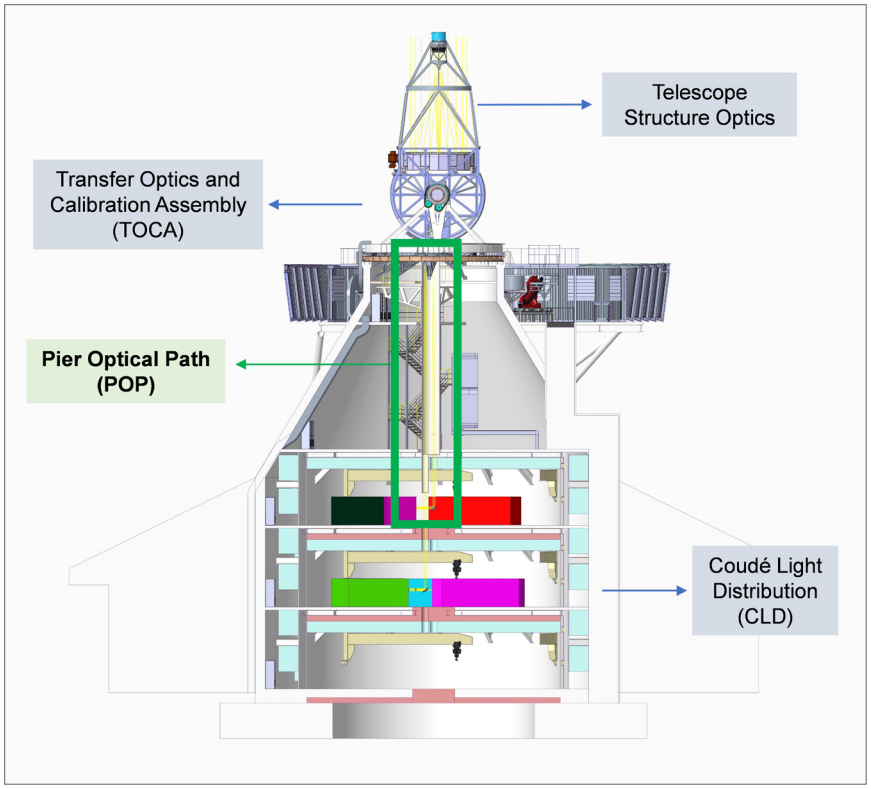
"If we want to give an example in the field of physics," Berrilli continues, "we know that we currently cannot produce low-cost, clean energy through nuclear fusion because we cannot stabilise plasmas inside tokamaks. Studying how the star's magnetic field interacts with the atmospheric plasma in the chromosphere and the corona will also allow us to study this instability. So, here, it is a way in which we study astrophysical and physical processes with a natural laboratory, the Sun."

From space to Earth, the Sun influences many human activities, which it is essential to understand its role. The Sun "is important because our planet lives with living with this star. The Sun has a continuous impact on the economy. We have worked with some companies interested in photovoltaics which wanted to know, for example, the effects of a solar eclipse and the effects of solar variability. The Sun is not a calm star; it is magnetically variable and variable in terms of brightness. If it changes, how much does it change? Does it change in the same way in the visible and the ultraviolet? If I build a solar panel, I need to know where to make it more sensitive. The Sun has nothing to do with global warming, but it does impact the climate. It helps us to make nuclear fusion power plants work," explains Berrilli. "The Sun's impact on our society is enormous. Just think about space weather, which refers to all the effects that solar activity can have on technological infrastructures, satellites, GPS, from ATMs to the systems we use on phones to check for traffic or more —these are all high-tech systems impacted by solar activity," adds the physicist. Moreover "thousands of years ago, there were superflares, nothing comparable to the solar activity of recent decades. The last major solar events occurred at the end of the 19th century. If events of that intensity were to occur today, they would be capable of disrupting almost all satellites. We would go back to the 1950s."

THE EST PIER OPTICAL PATH

A description of the preliminary design of the EST Pier Optical Path is given.

The Pier Optical Path (POP) is the dioptric system in charge of transferring the light from the aplanatic secondary focal plane to the science focus, in order to feed the scientific instruments that will be located in the Coudé rooms. The accompanying figure shows the position of the POP.



Position of the POP sub-assembly in the telescope optical path.

This subassembly will be housed in a vacuum vessel to avoid local seeing degradation along the optical path, from the telescope structure to the Coudé rooms (20 metres length). The vacuum tube will use the first and last lenses of the POP as entrance and exit windows, respectively.

Several trade-offs between a two-magnification stage system and a three magnification stage system have been studied with the aim of obtaining the best solution that ensures compliance with all the requirements established.

In terms of image quality, the optical designs that have been explored are nominally diffraction-limited for the full field of view of the telescope (90x90 arcsec) covering a wavelength range from 380 to 2300 nm.

Chromatic behaviour was one of the key aspects studied during the POP design, given that the system shall generate a maximum chromatic focus shift of 30 mm in each subarm of the Coudé room (blue, visible, red and infrared). Besides, it shall also be achromatic for several spectral lines of interest (517.3 nm, 617.3 nm and 632.2 nm in the visible arm and 1083 and 1565 nm in the infrared arm). For that reason, a beam splitter dividing the beam into the visible and infrared arms is placed in the optical path. The infrared arm will be transmitted and the visible will be reflected. Thus, in order to redirect the visible beam to the scientific instruments, a folding mirror is placed in its intermediate pupil plane.

Other guidelines for the design are that the F-number delivered to the instruments shall be 50, that the system shall create an intermediate pupil plane, that the exit beams shall be telecentric with a maximum departure from telecentrism of 0.3°, and that the optical path length shall comply with the pier mechanical envelope and with the optical path required to reach the instruments.

These design considerations also play an important role in the choice of the beam that is delivered to each Coudé room, as well as in the design of the Coudé Light Distribution system. On the one hand, the division of the beam by the dichroic beam-splitter allows having a dedicated room for visible instruments and another for infrared instruments. On the other hand, the optical path needed to distribute the light to the instruments and their envelopes make it more appropriate to house the infrared instruments in the upper room and the visible ones in the middle room.

Conversations with blank lens suppliers have started to ensure the manufacturability of all the components of the POP subassembly. Currently, a refinement of the design is being performed to adapt the alternatives using the feedback received from the companies.

SEEING ESTIMATION FOR EST

The methodology and results of local seeing estimations for EST are presented.

The European Solar Telescope aims to deliver observations of the highest optical quality under several environmental conditions. One of the main effects degrading the image quality of any ground-based telescope is seeing. This is a consequence of the turbulent Earth atmosphere, which produces random changes in the refractive index of the air. Observatories and telescopes use seeing to characterise their site in terms of optical performance. The image degradation that seeing can introduce on a telescope may be decomposed in two main sources: atmospheric and local seeing. Here the term 'local seeing' refers to the contribution of EST itself to the seeing. The geometrical distribution of the different parts of the building and telescope and their thermal behaviour have a clear influence on the seeing. This contribution cannot be measured experimentally until the telescope is built. However, computational methods may be used to estimate these numbers and asses design decisions before construction.

The EST-PO has implemented a multi-physics approach combining thermal, computational fluid dynamics (CFD), and optical analyses to evaluate the local seeing. Every step of this workflow has a specific contribution: the thermal model calculates surface temperatures, which feed the CFD analysis to calculate the air temperature and the refractive index inside the telescope. The optical analysis uses the air refractive index within the telescope's optical path to compute the contributions to image degradation with respect to a perfect telescope.

The transient thermal analysis runs for a full day of observation considering the predominant wind directions at the site and the median wind speed. This model considers the nearby William Herschel Telescope and the Swedish Solar Telescope and the observatory topography in a radius of 300 metres. Figure 1 shows the surface temperatures resulting from this analysis.

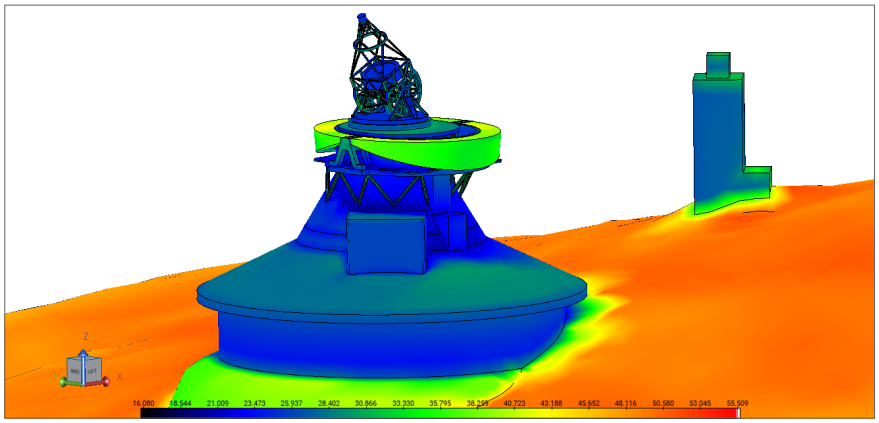


Fig. 1. Temperature (C) at EST and the surroundings for an observing day in summer.

CFD analyses are transient but on a different time scale, as local seeing effects are evaluated on instantaneous time steps. However, a sufficient virtual time of simulation is used to gather data and obtain statistical data that represent the overall behaviour. These analyses use a fixed configuration of temperature and telescope orientation according to thermal analysis. The CFD model uses a larger computational domain of 1 km, as the aerodynamics at the telescopes depend on the topography. Figure 2 shows a snapshot of the vorticity –an indicator of mechanical turbulence– in a vertical plane aligned with the telescope.

An optical volume of 15 metres from the primary mirror vertex is used to per-

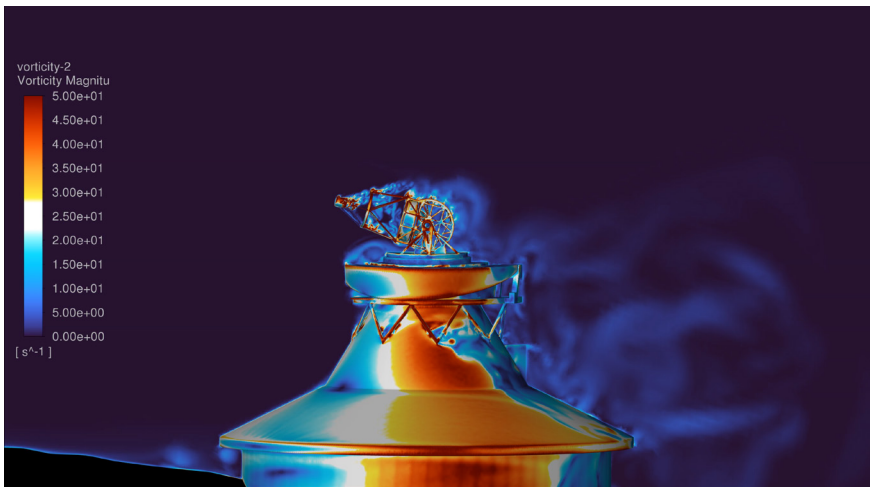


Fig. 2. Vorticity in a vertical plane containing the telescope optical axis.

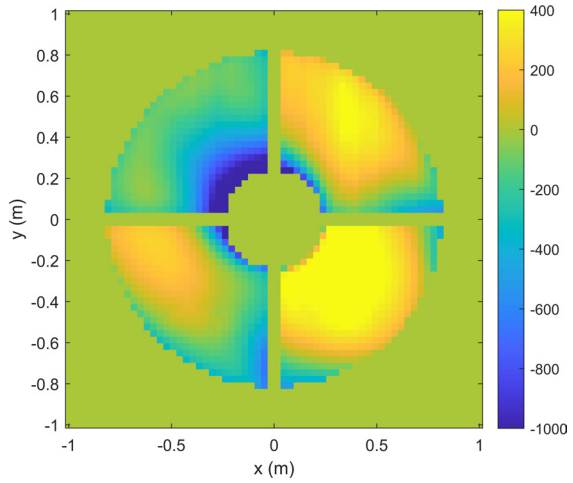


Fig. 3. Average OPD (nm) integrated along the optical path.

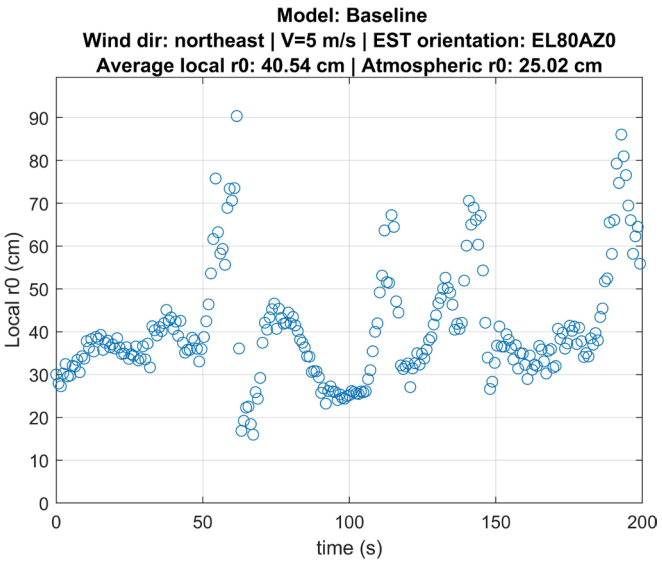


Fig. 4. Local Fried parameter during a 200 s observation.

form the optical analysis. Following the CFD analysis, the temperature of every air cell is used on a post-processing script to calculate several optical variables. These include the Optical Path Length (OPL), the Optical Path Difference (OPD), and ultimately the seeing integrated along the EST optical path. The local seeing variables obtained are the standard ones: Full Width Half Maximum (FWHM) of the seeing disc and the Fried parameter (r0). Figure 3 shows the average OPD in nm and Figure 4 the instantaneous and average Fried parameters for one simulation.

This methodology is being currently used to perform several trade-off studies of design parameters. They will provide solid knowledge of the main parameters influencing local seeing to optimise the EST design in terms of optical quality before the Preliminary Design Review. The conclusions of those analyses will be used during the Detailed Design Phase as input for every subassembly.

USE OF COMPOSITE MATERIALS IN THE ELEVATION STRUCTURE OF EST

A feasibility study has been conducted to evaluate the performance of composite materials for EST.

The structure of the EST telescope has already been defined at the preliminary design level. The structure is made of steel and complies with requirements.

To improve the design and perform a materials trade-off, we have studied the feasibility of implementing a carbon fibre reinforced polymer (CFRP) design for the upper part of the Elevation Structure, to reduce the mass and to keep the stiffness, thus increasing the system's eigenfrequencies to have a higher bandwidth for the control of the main axes of the telescope.

This study has been carried out by the company ESTEYCO in collaboration with the FIDAMC foundation, developing a manufacturing strategy for the Elevation Structure that minimises the composite manufacturing costs.

In order to develop this study, the number and disposition of laminates for each part has been optimised and a direct comparison with the stiffness of the baseline steel design has been performed. Therefore, independent finite element models have been developed for the Elevation Structure to analyse eigenfrequencies and the image motion of this alternative design. Finally, a cost budget has been estimated.

The conclusions of this study could be summarised as an improvement of the CFRP Telescope Structure performance mainly in eigenfrequencies and image motion. However, this slight improvement does not justify the composite manufacturing cost.

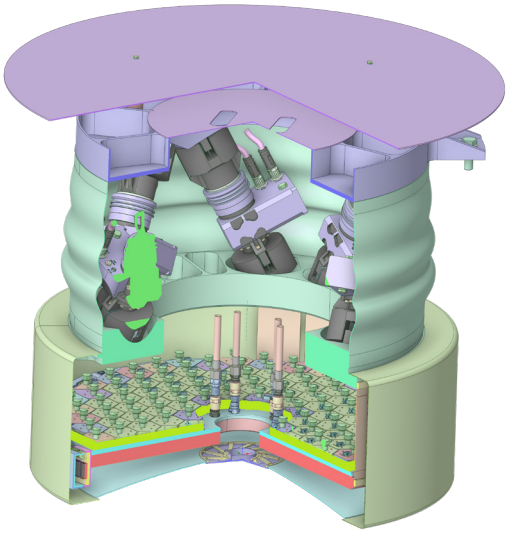
AN ADVANCED PROTOTYPE FOR THE EST ASM BASED ON COIL ACTUATORS TECHNOLOGY

The industrial contract for the design and supply of a prototype of a deformable secondary mirror with coil actuators for EST is well underway.

One of the distinguishing features of EST is that it includes a deformable secondary mirror (Adaptive Secondary Mirror or ASM) to correct the distortions caused by the atmosphere in an optimised way. In addition, this ASM allows to reduce the number of optical surfaces of the telescope, decreasing the loss of light in the optical path. The result is that more sensitive measurements can be taken, which makes EST one of the most advanced tools to observe the Sun from the ground.

Although there are nighttime telescopes with an ASM, currently no solar telescope has one. There are many differences in the technical requirements for an ASM for night or daytime observing and state-of-the-art development is needed to build the EST ASM. To ensure that the results of this development are aligned with the scientific needs of EST, the two technologies available for constructing ASMs are being evaluated: internal reluctance actuators or non-contact moving coil actuators in combination with reference capacitive sensors. A thorough analysis of the pros and cons of each technology, together with a small-scale test bench built in the IAC laboratories, allows us to demonstrate the concepts that will then be scaled appropriately to the EST dimensions. By approaching this issue in a thorough and methodical manner, we aim to mitigate the risks of such a novel system.

The contract for the design and construction of a prototype based on coil actuators was awarded to AdOptica. AdOptica is a consortium of two companies, A.D.S. International and Microgate, and is the only company that manufactures ASMs based on this technology. It currently has



Coil-actuator ASM baseline design. Credit: AdOptica.

ASMs operating on night telescopes with excellent results (e.g. the MMT telescope in Arizona, the Large Binocular Telescope in Arizona and the Very Large Telescope in Paranal).

The project held its kick-off meeting in May 2023, starting the Phase 1 where a number of trade-offs were conducted. This resulted in a baseline design presented at the End-of-Phase 1 Review Meeting in November 2023 (see figure).

The coil actuator technology allows no contact between the reflecting surface of the mirror and the actuator itself. Each actuator is accompanied by a capacitive sensor that allows the position of the mirror's reflective surface to be known with respect to the main body at the nanometre scale. Theoretically, this allows the mirror deformation to be controlled very precisely and at all times to correct any type of disturbance, induced not only by the atmosphere but also by gravity and wind. In addition, non-contact technology makes the mirror intrinsically fail-safe with respect to the failure of individual actuators.

The ASM prototype will have around 100 actuators, which represents 5% of the actuators needed by the EST ASM. These are separated by a distance of 16.2 mm, the same distance they will have in the EST ASM. In Phase 1, tradeoffs have been made as to the best strategy for cooling this system and the manner in which the prototype will be tested to verify its performance has been established.

We are now in Phase 2 and about to hold the Phase 2 review meeting. The fundamental task of this phase is to design the prototype and define the test plan. In particular, the prototype shall allow verifying the requirements related to distance between actuators, thermal control for electronics, tip-tilt dynamics, and mirror deformation dynamics. Phase 2 will end in June 2024 with a design of a prototype to be built and tested during Phase 3. The contract will conclude in January 2025.

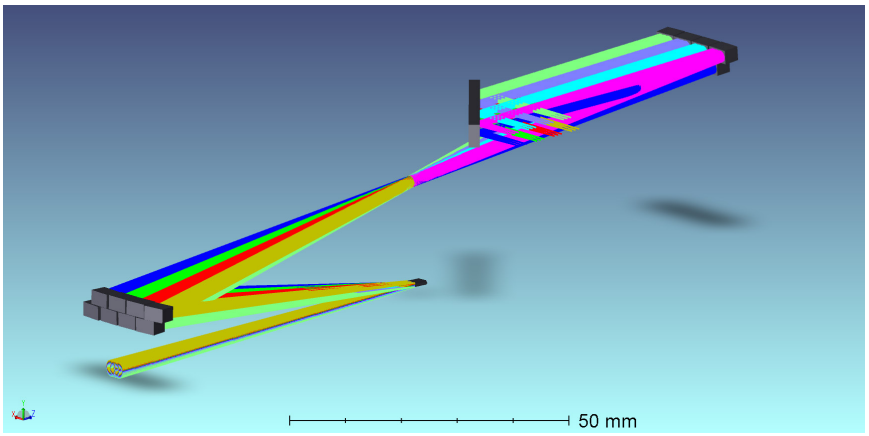
EST NEAR-INFRARED INTEGRAL FIELD SPECTROGRAPH BASED ON MIRROR SLICERS

Some ideas and the team behind the near-infrared IFS-S are presented.

Imagine a deck of cards. Now, you are told to organise them over a table. You just have a way too big deck, with way too many cards, so you need to cover a quite larger fraction of area as compared to a single card. Not too much of a trouble. Except when building such a large table is a technological challenge, with the only available ones too small for your purpose. With a small table, you would need to keep just some of the cards, or to keep them all while cutting them so they are smaller. This is the main problem we face with the near-infrared Integral Field Spectrograph based on mirror Slicers (IFS-S): current near-infrared detectors are too small to cover large areas on the Sun at the diffraction limit of EST and with a good spectral coverage.

The present scientific requirements from the EST Science Requirements Document demand the observation of a 10” x 10” area of the Sun sampled at the diffraction limit of the telescope, and to cover a spectral range of 1 nm with a spectral resolution of 200000. Moreover, the instrument has to reach a polarimetric sensitivity of 1 polarised photon in 10000 photons with short (5 s) integration times. These requirements cannot be fulfilled all together.

First, the infrared sensor required to record the three-dimensional cube containing the spatial and spectral information does not exist at present. The largest sensor available on the market (4k x 4k) forces us to either relax the spectral resolution and spectral range, or the spatial resolution and area coverage, or both. Moreover, we need to collect as many photons as possible to reach the desired polarimetric sensitivity. This can be achieved with such a large photon collector as EST, but with a spatial resolution larger than the diffraction limit.



Top: Ray tracing of the GRIS IFU. Bottom: Examining the GRIS image slicer prototype constructed within the framework of the SOLARNET project.

Within our group, we are studying a conceptual design of the IFS-S to image a large area on the Sun (close to 10” x 10”), to record a wide spectral range (about 3 nm, to perform multiline analyses), and to prioritise the polarimetric sensitivity (1/10 000) over the spatial sampling of the images. The exact numbers are to be decided in consensus with the Science Advisory Group at the beginning of 2024.

As of today, the group of the IFS-S is composed by Project Scientist Carlos Quintero Noda, Optical Engineer Silvia Regalado Olivares, and Principal Investigator María Jesús Martínez González. We are also involved in the development and upgrade of the IFS-S for the GRIS instrument at the GREGOR telescope (see accompanying figure). These technological developments at GRIS are crucial studies for the design of the IFS-S for EST.

EST TIS/FBI DESIGN UPDATE

The conceptual optical design of the three Tunable Imaging Spectropolarimeter/Fixed-Band Imager instruments foreseen for EST has been completed in 2023.

The Tunable Imaging Spectropolarimeters and Fixed-Band Imagers (TIS/FBIs) are one of the key instruments foreseen for the European Solar Telescope (EST). The development of the TIS/FBIs is carried out by a consortium formed by the Spanish Space Solar Physics Consortium (S3PC) —led by Instituto de Astrofísica de Andalucía (IAA-CSIC)—, University of Rome Tor Vergata (UNITOV), the National Institute of Astrophysics of Italy (INAF), University of Catania (UNICAT), Stockholm University (SU), Queen's University Belfast (QUB), Mullard Space Science Laboratory (UCL-MSSL), Istituto di Ricerche Solari (IRSOL), and Leibniz-Institut für Sonnenphysik (KIS).

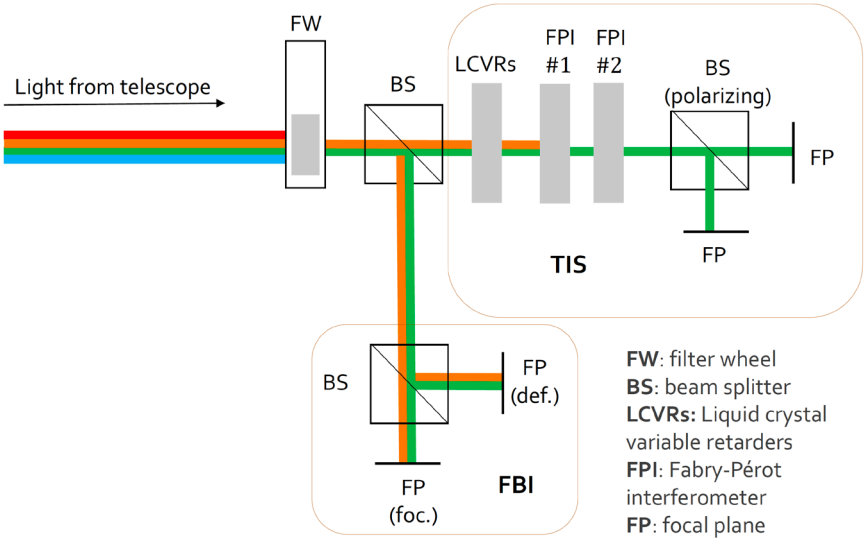


Figure 1. Conceptual layout of the TIS/FBI instrument.

The TIS/FBIs will be responsible for providing maps of the thermal, dynamic and magnetic properties of the solar photosphere and chromosphere over a circular field of view of 60 arcsec at very high cadence and diffraction-limited spatial resolution. To achieve this goal, they will measure the four Stokes profiles of selected spectral lines by means of a Fabry-Pérot etalon system.

Three TIS/FBIs will be built to cover the following spectral ranges: 390-500 nm, 500-780 nm, and 780-850 nm. Each instrument will be able to observe different spectral lines, typically four to five. This capability grants them exceptional versatility, enabling the simultaneous observation of multiple combinations of three lines. Moreover, the instruments will combine two different operation modes. In one mode, they will work as tunable narrowband spectropolarimeters (TIS mode). In the other mode, they will work as context fixed-band imagers (FBI mode).

TIS/FBI concept

The conceptual layout of the instruments is depicted in Figure 1. Light coming from the telescope will first illuminate a filter wheel hosting a set of pre-filters centred about the wavelengths of interest. These filters will let pass a very narrow part of the spectrum (about 0.1 nm) into the instrument. Then, the transmitted light will be divided between the TIS (90-95%) and the FBI (5-10%).

The TIS will modulate the incoming light polarimetrically with two liquid crystal variable retarders (LCVRs) and will scan the spectral line selected by the pre-filter with a system of two Fabry-Pérot interferometers that will achieve a spectral resolution of 5-10 pm, depending on the wavelength.

Finally, a polarising beam splitter will divide the modulated beam into two orthogonal polarisations that will be recorded by two cameras in order to reduce seeing-induced crosstalk. The FBI is much simpler, as spectral and polarimetric analyses are omitted. In this case a focused channel will be used for image reconstruction through the Multi-Object Multi-Frame Blind Deconvolution (MOMFBD) technique and for alignment of the TIS. A defocused (auxiliary) channel will observe the same scene with a difference of phase (phase diversity) in order to increase the capabilities of the MOMFBD technique.

The TIS arm

The three TIS instruments foreseen for the European Solar Telescope will record the spectrum of the four Stokes parameters of the incident light with a resolving power larger than 50.000, excellent (diffraction-limited) optical quality, and a polarimetric sensitivity as high as 10^{-3} thanks to the use of dual-beam polarimetry.

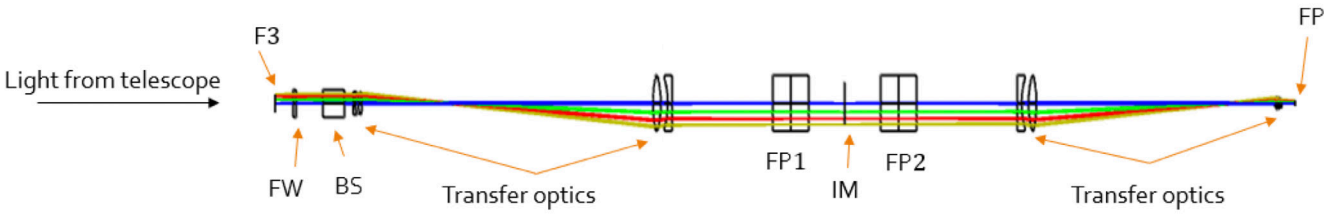


Figure 2. Optical design of the TIS/FBI instrument. F3 is the telescope focal plane. FW stands for filter weel, BS for beam splitter, FP1 and FP2 are the two etalons, IM is an intermediate image, and FP represents the final focal plane.

The TIS optical design is depicted in Figure 2. Right after the filter and the beam splitter that divides light between the TIS and the FBI (Figure 1), two group of lenses will produce a slow (f/150) telecentric image of the solar scene. The dual Fabry-Pérot system will be placed close to this intermediate image. Illuminating the etalons with such a large f-number will prevent the harming pupil apodisation effects that appear in this (telecentric) configuration from being too large. Finally, another two groups of lenses will produce a telecentric image with the required plate scale and size on the detector.

One of the major advantages of this design is that no folding mirrors are needed. As a consequence, light absorption in the entire optical system is minimised, which increases the photon flux on the focal plane and, hence, reduces the time needed to achieve the required signal-to-noise ratios. In fact, thanks to the high throughput of both the telescope and the TIS instrument, scanning of a spectral line at 10 wavelength positions will take less than 20 seconds in most cases, according to the photon budget calculations that have been performed by the TIS team.

The main downside of this design is probably that the slow telecentric beam of f/150 requires the etalons (and also the optics) to have diametres of the order of 18 cm, several times larger than those used by similar ground-based instruments. No doubt, manufacturing such large etalons with high optical quality will be one of the biggest challenges of the project.

The FBI arm

FBIs will be employed to make broadband (0.1-0.5 nm) photometric observations of the solar surface with larger signal-to-noise ratio —and potentially faster cadence— than the TISes. These observations will then complement the measurements taken by the TISes, thereby increasing the flexibility and the overall capabilities of the instrument.

One noteworthy potential of the FBIs is their capacity to infer the wavefront degradation introduced by the instrument and the telescope in real time, as well as the residual atmospheric aberrations produced by seeing which are not corrected by the telescope adaptive optics system. The combined effect of these two sources of wavefront degradation is expected to reduce the final image quality. The ability to infer the wavefront error allows for subsequent compensation during image restoration with the MOMFBD technique.

To accurately sense the aberrations introduced by the instrument, the FBI and TIS optical paths must be as similar as possible. Ideally, the FBIs should be an exact replica of the TISes. However, the two largest doublets seen in Figure 2 have a very limited impact on the aberrations, as their focal length is much larger than that of the other lens groups. Aberrations produced by optical elements placed close to an image plane (etalons, filter wheel, LCVRs and beam splitter) will also be negligible, as the footprint of the incident beam on them is very small. Thus, only the first and last groups of TIS lenses must be replicated in the FBI, effectively reducing the size of the FBI arm by a factor of 4.

The current TIS/FBI design results in three 6 m × 1.5 m instruments (Figure 3). These dimensions are compatible with the envelope required to accommodate them into the Coudé room alongside other instruments. In view of the large size of the telescope, these dimensions are actually quite moderate.

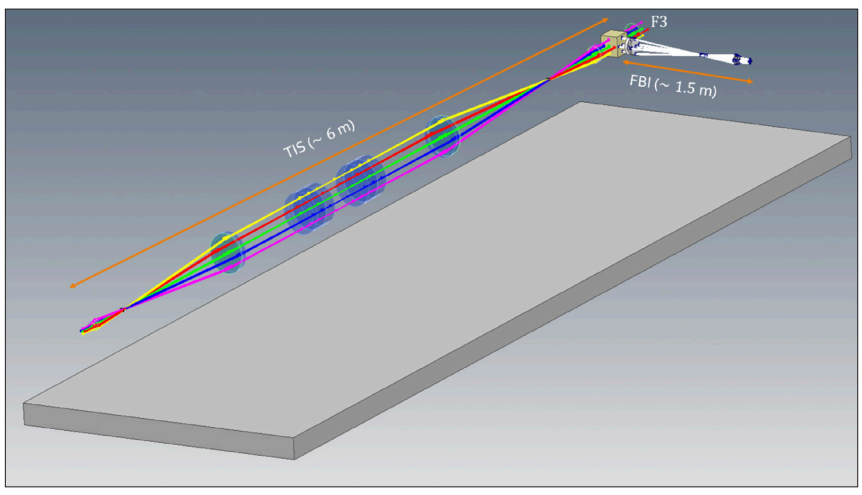
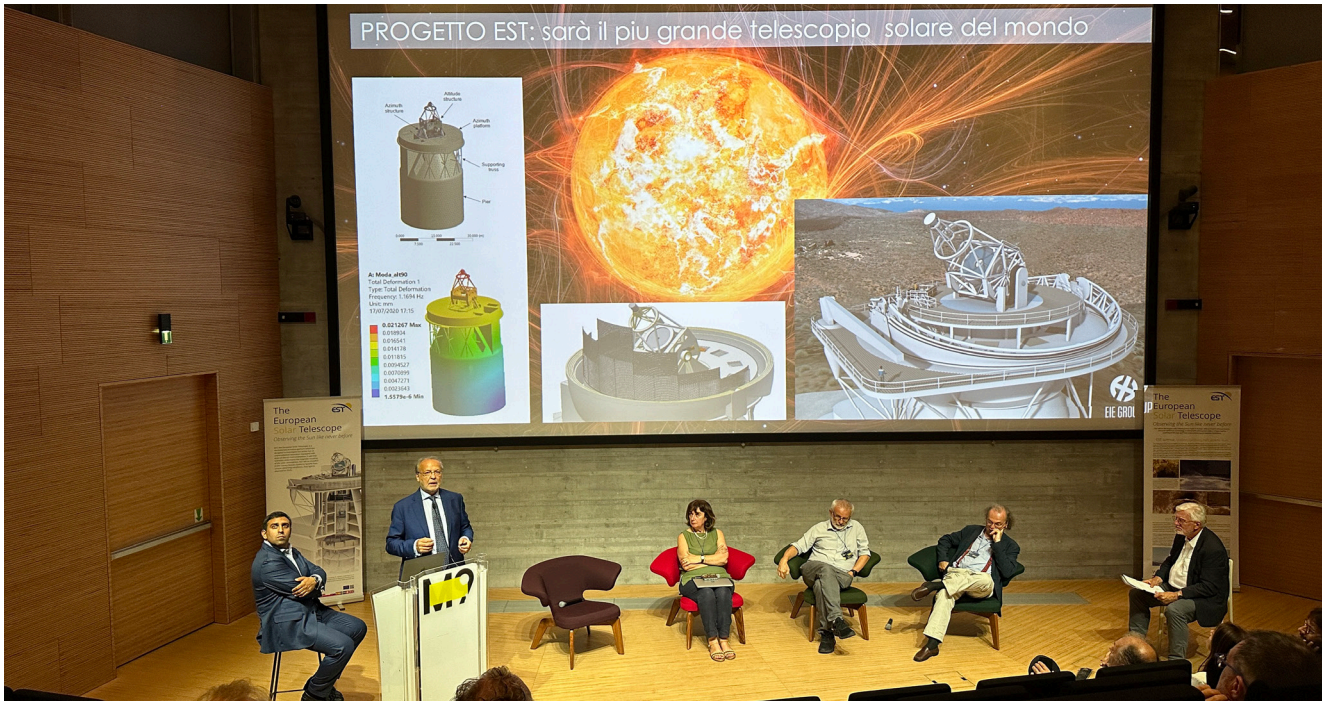


Figure 3. Three-dimensional view of the TIS/FBI instrument.

COMMUNICATION AND OUTREACH ACTIVITIES

The EST consortium members have participated in several outreach activities during the last months, reflecting efforts to raise awareness of the EST project at local and regional level.



Public event 'Un sole, Nessun Sole, Centomila Soli' in Venice (Italy). Credit: Luis Bellot/ IAA-CSIC.

The Association of Spanish Researchers in Norway organised the event 'Tapas of Science' on May 8, where Ada Ortiz (Expert Analytics AS), delivered an informal talk about the Sun and EST, titled "A tour of the Sun, so close, so mysterious." Ada was also interviewed on the radio program "Gente despierta" by the Spanish public radio broadcasting company RNE. During the interview, she explained various details about the EST project and solar research to the audience.

On June 23 and 24, the Slovak Academy of Sciences celebrated its 70th anniversary with a weekend full of outreach activities designed for science enthusiasts. At the stand reserved for the Astronomical Institute of the Slovak Academy of Sciences in the square in front of Eurovea (Bratislava), EST material was showcased, including a model produced with a 3D printer.

During the public event "Un sole, nessun Sole, centomila Soli" held on September 12 at the '900 Museum in Mestre, Italy, the EST documentary "Reaching for the Sun" was screened in English with Italian subtitles as part of the international conference "Sun in Science and Society". This event was organised by the EIE Group and the SOLARNET project.

In addition to the documentary screening, the audience engaged in discussions focused on the science and technology of EST.

EST also had a presence at the opening of the interactive exhibition 'Sole' which took place on September 16. It is the result of the collaboration between the Istituto ricerche solari Aldo and Cele

Interactive exhibition 'Sole' in Lugano, Switzerland. Credit: Renzo Ramelli / IRSOL.

IX Spanish Congress on Social Communication of Science (Granada, Spain). Credit: Ana Tamayo.

Daccò (IRSOL) and scientific mediators from L'ideatorio of the Università della Svizzera italiana (USI).

The EST project was a partner of the exhibition and contributed to the proposal submitted to the Swiss National Science Foundation. Promotional material from EST was displayed at the entrance. In the same way, during the European Researchers' Night 2023 held on 29 September, brochures and posters featuring information about the EST project were distributed to visitors and interested people at the stand of the Instituto de Astrofísica de Andalucía (IAA-CSIC) set up in Granada.

The most recent event took place in Granada, Spain, from October 25 to 27 It was the IX Spanish Congress on Social Communication of Science, where over 400 communicators from different parts of Spain and South America gathered to discuss current challenges in social science and share best practices. During the event, Luis Bellot (IAA-CSIC), presented the organisation and execution of the school competition "The Sun at a Glance", which was conducted in the framework of the PRE-EST project.

EST in the media

With the establishment of the EST Canarian Foundation on July 25, a common pan-European communication strategy was devised. Each of the partner institutions translated the EST press release into their respective languages and sent it to local, regional and national media.

This news raised significant interest among the media, resulting in over 70 articles published in online newspapers and specialised magazines. It received 7 mentions on radio and television. Approximately 10 online newspapers from other countries such as India, Portugal and Australia also covered the news. Links to the press releases published by each institution in their respective languages can be found on the news section of the EST website.

The announcement also garnered considerable attention and visibility on social media. Posts related to the establishment of the foundation reached over 10000 people and surpassed 700 interactions on the official EST social media accounts. In addition, the partners and the press published a total of 35 and 20 posts respectively on X, Facebook, Instagram and LinkedIn, covering the establishment of the EST foundation.

On September 16, during the press conference held on the occasion of the 80th anniversary of the first observation made at the Skalnaté Pleso Observatory, the State Secretary of the Ministry of Education of Slovakia provided strong support to EST, stating that "The European Solar Telescope is therefore one of the very important steps to preserve independence in the security of Europe and Slovakia, especially in connection with the current geopolitical situation."

A week later, Peter Gömöry, vicepresident of the EST-CF Board of Trustees, presented the Astronomical Institute of the Slovak Academy of Sciences on the Slovak public TV broadcasting corporation RTVS and took the opportunity to discuss EST.

Interview with Peter Gömöry on the Slovak public broadcasting channel RTVS.

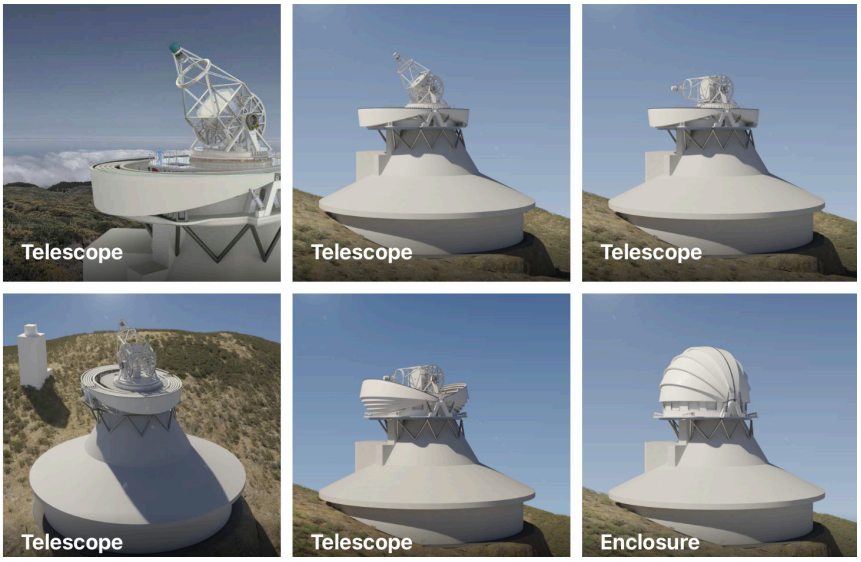
EST website update

In the last six months, work has been carried out to update the EST website.

Firstly, a new section on the EST Canarian Foundation has been set up. It contains information on the goals of the foundation and its governing structure, with brief resumees of the Board of Trustees members. News related to the EST foundation are compiled in that section as well.

On the technical side, the descriptions of some EST systems and subsystems have been updated to reflect the current preliminary design status. This includes the EST image gallery, where new 3D renders, high-resolution images, and animations have been integrated and old images from the 2011 conceptual design have been archived. For instance, both the long and short versions of the video developed by IDOM, showing the structure, pier and enclosure of the future telescope, are now available.

Furthermore, a new website section has been created specifically for the mini-series 'Here Comes the Sun', the audiovisual project developed by the University of Rome Tor Vergata. Among the resources available on the website are behind-the-scenes photographs taken during the filming process, the series trailer, and its five episodes, each accompanied by downloadable English and Italian subtitles.



Pictures from the updated EST image gallery website.

Finally, additional materials and resources have been added to the EST documentary section on the website. These include 3D infographics produced for the documentary as well as footage captured by drones at various European observatories.

All resources available on the website are accessible and can be downloaded and utilised under a Creative Commons international license.

EST NEWCOMERS

JAVIER LEÓN GIL

AUTOMATION AND CONTROL ENGINEER

Javier holds a bachelor's degree in Industrial Electronics and Automatic Control Engineering from Universidad de La Laguna, and a Master's degree in Industrial Computing and Automation from Universitat Politécnica de Valencia. He has years of experience in the private industry, working on R&D projects for redox flow batteries as an automation and control engineer. He joined the IAC in 2021 as a software engineer for the New Robotic Telescope (NRT), developing its low level control system, and joined the EST team in October 2023 as an automation and control engineer, in charge of the telescope control.

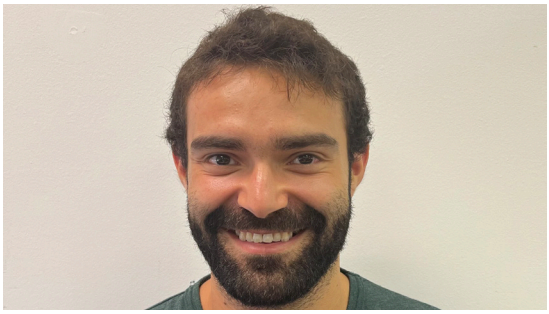
AMANDA LÓPEZ MORENO

COMMUNICATION OFFICER

Amanda holds a degree in Audiovisual Communication from the University of Granada, a Master's degree in Graphic Design from the University of La Rioja, and a Master's degree in Social Communication of Scientific Research from the International University of Valencia. She has experience in the field of scientific communications, having worked in the Scientific Culture and Innovation Units of the University of Granada and the University of Cantabria, as well as in the communication department of the Parque de las Ciencias in Granada. Amanda joined the EST project in July 2023 as the new EST Communication Officer.

NICOLÁS RODRÍGUEZ LINARES

ELECTRONICS ENGINEER



Nicolás has a degree in Industrial Electronics Engineering and Automation from University of La Laguna, a Master's degree in Industrial Engineering and a Master's degree in Automatic Control and Robotics from Technical University of Catalonia. He has experience working for the Institut de Robòtica i Informàtica Industrial, a joint Research Center of CSIC and UPC, as research support Eegineer for the European project LOGISMILE and for the national project ROCOTRANSP. Nicolás is now part of the EST team, working as control engineer for the Multi-Conjugate Adaptive Optics testbench.

ESTHER SORIA HERNÁNDEZ

OPTICAL ENGINEER

Esther holds a degree in Optics from the University of Zaragoza, complemented by a Master's degree in Optical and Imaging Technologies from the Complutense University of Madrid. Esther embarked on her professional journey with a two-year stint as a dedicated researcher at the CSIC. Driven by a passion for advancing scientific knowledge, Esther then pursued her PhD at the IAC. Her doctoral research focused on the development of new wavefront sensing techniques, specifically tailored to applications in the realm of astronomy. Esther recently joined the EST team as an optical engineer.

EVENTS

EST INVITED TALKS

A list of EST invited talks and presentations in national and international meetings is available on the EST website at http://est-east.eu/est-invited-talks

THE EUROPEAN SOLAR TELESCOPE
Rolf Schlichenmaier, Manuel Collados, Luis Bellot Rubio, in "Heliophysics in Europe", Noordwijk (The Netherlands), 31 October 2023

EUROPEAN SOLAR TELESCOPE: MORE STEPS FORWARD
M. Collados, in VIII Spanish Meeting of Solar and Heliospheric Physics, Granada (Spain), 13 July 2023

STATUS AND PERSPECTIVES OF THE EUROPEAN SOLAR TELESCOPE
Manuel Collados, in SOLARNET Sun in Science and Society, Mestre (Italy), 13 September 2023

THE EUROPEAN SOLAR TELESCOPE: SCIENCE AND INSTRUMENTS
Rolf Schlichenmaier, in The Many Scales of the Magnetic Sun, Potsdam (Germany), 9 May 2023

UPCOMING EVENTS

JOINT SOLAR ORBITER/PARKER SOLAR PROBE/DKIST WORKSHOP
San Antonio (USA), 8-12 April 2024

IAU SYMPOSIUM 388: SOLAR AND STELLAR CORONAL MASS EJECTIONS
Krakow (Poland), 5-10 May 2024

CORONAL COOLING CONFERENCE
Leuven (Belgium), 21-24 May 2024

21ST AOGS ANNUAL MEETING
Pyeongchang (South Korea), 23-28 June 2024

11TH CORONAL LOOP WORKSHOP
La Laguna (Spain), 25-28 June 2024

COSPAR 2024 45TH SCIENTIFIC ASSEMBLY
Busan (South Korea), 13-21 July 2023

HINODE-17/IRIS-15/SPHERE MEETING
Bozeman (USA), 23-27 July 2024

IAU SYMPOSIUM 390: A MULTI-POINT VIEW OF THE SUN
Cape Town (South Africa), 6-8 August 2024

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Luis Bellot Rubio (IAA-CSIC)

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