EST NEWS 15

THE EUROPEAN SOLAR TELESCOPE NEWSLETTER

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DIRECTOR'S CORNER

The European Solar Telescope Foundation is now fully operational, a milestone marked by the recent appointment of its new director, administrator, scientific and technical advisor, and the upcoming recruitment of a dedicated team of engineers for the Project Office coordination. This edition of EST News celebrates the vibrancy of our expanding team as we chart a course towards the construction of the European Solar Telescope, an ambitious project that will push the frontiers of solar physics and technology. We stand ready to meet the challenges ahead as a team, working together with a full commitment to excellence.

In this issue, we spotlight the transformative milestones achieved this year. Foremost among them is the successful independent review of the optical design (PDR), a crucial achievement that enables us to progress confidently toward a fully consolidated design of the entire project. Equally noteworthy is the ongoing process to welcome Italy as a new member of the EST Foundation, a development that reinforces the pan-European essence of our mission. Meanwhile, our German partners have spearheaded an impressive effort, with the help of the entire EST team, to draft a comprehensive proposal for Germany's contribution to EST construction, exemplifying the collaborative spirit that lies at the heart of this ambitious project.

This newsletter also touches on the very important subject of communicating EST to a wider audience, including participation in high-impact events such as the Big Science Business Forum. As we press forward, the EST Foundation is resolute in its mission to foster international collaboration and technical innovation. Together, we are shaping a future where the mysteries of the Sun are revealed through unprecedented sharp and precise observations.

H. Socas-Navarro, EST Foundation director

ITALY TO JOIN THE EST FOUNDATION

A consortium of three Italian Universities requested joining the EST Foundation in November 2024. The Foundation will now comprise 11 European institutions from 9 different countries.

Presentation of the EST Foundation director at the University of Rome Tor Vergata in November 2024. Credit: F. Berrilli (UTOV).

On November 22, 2024, the president of the Board of Trustees of the EST Foundation received a formal letter from an Italian Joint Research Unit (JRU) requesting admission as member of the Foundation. This unit, known as EST-IT JRU, is a formal association comprising the Universities of Calabria, Catania, and Rome Tor Vergata. Its primary objective is to coordinate Italian efforts to contribute to the EST project through active participation in the Foundation.

During a general assembly held on October 8th, the EST-IT JRU approved the decision to apply for member status within the EST Foundation, appointing Dr. Luca Giovanelli as their representative on the Foundation Board of Trustees. The Italian application is scheduled to be discussed and voted upon at the upcoming meeting of the EST Foundation Board of Trustees on December 19th, 2024.

To advance this initiative, the EST Foundation director, Héctor Socas-Navarro, traveled to Rome from November 18th to 20th to meet with representatives of the EST-IT JRU. The discussions focused on the application and the positive contributions that Italian participation would bring to the Foundation and the broader EST project.

During his visit, Socas-Navarro also met with the rector of the University of Rome Tor Vergata, Prof. Nathan Levialdi, who expressed strong and enthusiastic support for the project. Additionally, he held talks with Dr. Roberto Ragazzoni, the newly appointed president of the Italian Istituto Nazionale di Astrofisica (INAF), to explore long-term plans for Italian involvement in the project.

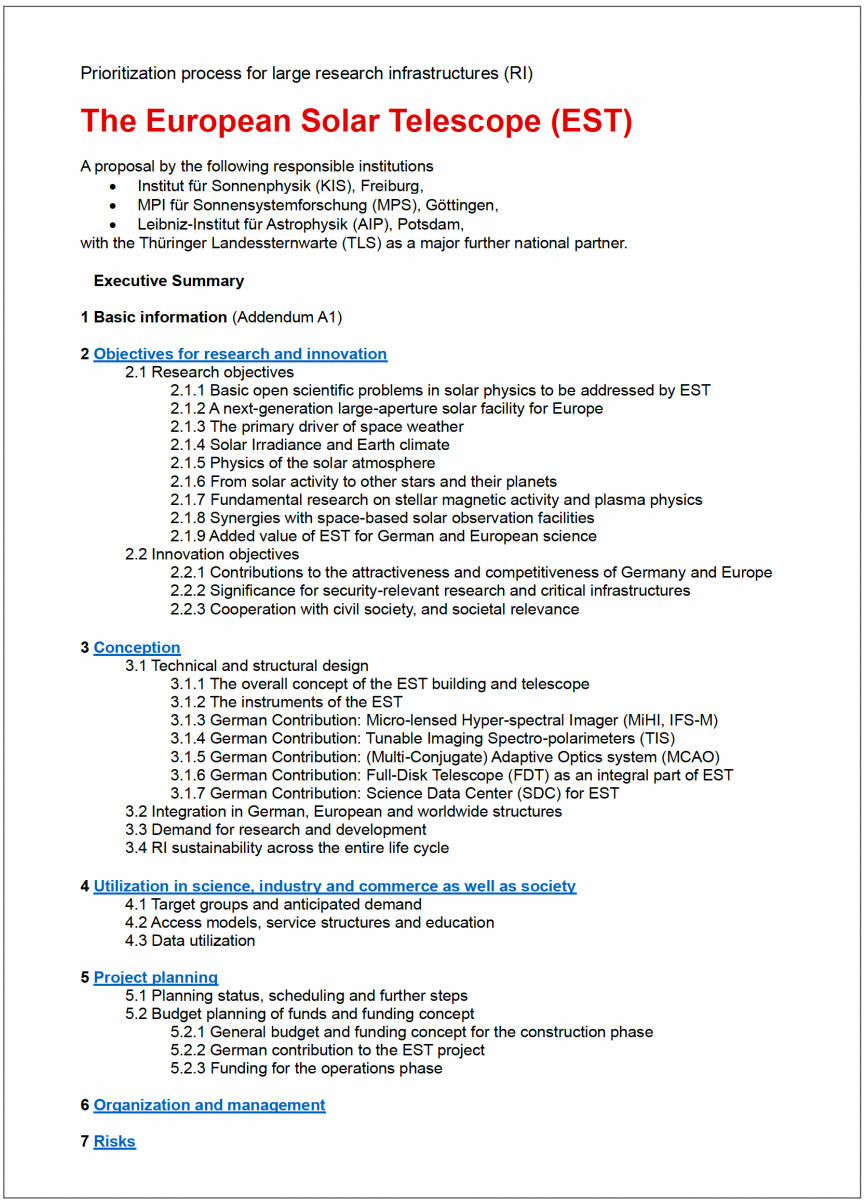
In a large-scale international project like EST, which spans multiple decades, it is crucial to foster engagement with younger generations. Reflecting this vision, the EST Foundation director delivered a public lecture at the University of Rome Tor Vergata during his visit. This talk, aimed at students of physical sciences, provided an introduction to solar physics and the EST project, in hopes of inspiring some of the next generation of scientists to contribute to this groundbreaking initiative.

PROPOSAL FOR A GERMAN CONTRIBUTION TO EST

Four German research institutes, KIS, MPS, TLS, and AIP, submitted an EST proposal to the German Federal Ministry for Education and Research.

In summer 2024, the German Federal Ministry for Education and Research started a national prioritisation process for large research infrastructures and invited proposals for projects that require a German contribution of at least 50 million euros for the installation phase, with a deadline of October 25th, 2024.

The German solar community responded to this call and the Institut für Sonnenphysik (KIS) in Freiburg submitted the proposal together with the Max Plank Institut für Sonnen-systemforschung (MPS/Göttingen), the Leibniz-Institut für Astrophysik (AIP/Potsdam) and the Thüringer Landessternwarte (TLS/Tautenburg/Jena). In the context of this proposal, a full cost life-cycle budget of EST including realistic numbers for the installation phase, 30 years of operation, and dismantling was set up in close collaboration with the EST Project Office. The proposed German contribution will be about 60 million euro, i.e., about 25% of the total EST costs for the installation phase.



Prioritization process for large research infrastructures (RI)

The European Solar Telescope (EST)

A proposal by the following responsible institutions
- Institut für Sonnenphysik (KIS), Freiburg,
- MPI für Sonnensystemforschung (MPS), Göttingen,
- Leibniz-Institut für Astrophysik (AIP), Potsdam,

with the Thüringer Landessternwarte (TLS) as a major further national partner.

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Cover page of the proposal for a German contribution to EST submitted to the Bundesministerium für Bildung und Forschung.

The German participation will be through a direct contribution to the costs of the building and the telescope and in-kind contributions for instrumentation and data centre. The latter contributions will include: (1) further developments of classic and multi-conjugate adaptive optics that will be an integral part of EST, (2) contributions to the EST Tunable Imaging Spectropolarimeter and Fixed Band Imager (TIS/FBI) instruments, expanding experience gathered from building the Visible Tunable Filtergraph for the Daniel K. Inouye Solar Telescope, (3) Micro-lensed hyper-spectral imagers as Integral Field Spectropolarimeters for EST, (4) a full-disc telescope that provides the context information for EST, and (5) contributions to the data centre concepts and the installation of a EST science data centre in Germany.

Now an evaluation based on scientific, technical and cost aspects is being conducted and the results of the evaluation and a shortlist of infrastructures are expected to be published in summer/autumn of 2025. Before funding, a full proposal would then have to be submitted and granted.

VISIT OF EST FOUNDATION AND SPANISH MINISTRY REPRESENTATIVES TO SLOVAKIA

Both countries are currently engaged in high-level conversations to define their collaboration in EST.

Peter Gömory (AISAS), Héctor Socas Navarro (EST Foundation) and Manuel Collados (IAC) at the European Researchers Night.

In September 2024, a delegation from the EST Foundation alongside representatives from the Spanish Ministry of Science, Innovation, and Universities visited Slovakia to strengthen the collaborations between the two countries on this project. The EST delegation consisted of Héctor Socas-Navarro and Manuel Collados, director of the EST Foundation and president of the Foundation's Board of Trustees, respectively. Joining them from Spain's Ministry of Science, Innovation and Universities was Ana Aricha, deputy director of Consortia, Organisations, and International Scientific Infrastructures.

The group traveled to Bratislava, where they engaged in a series of high-level meetings. The visit commenced with a reception hosted by Spain's ambassador to Slovakia, Ms. Lorea Arribalzaga, at her official residence. This event was also attended by two prominent Slovak scientists: Pavol Šajgalík, president of the Slovak Academy of Sciences, and Peter Gömöry, Slovakia's representative to the EST Board.

The discussions focused on enhancing scientific collaborations between Spain and Slovakia. Ambassador Arribalzaga reaffirmed her strong commitment to fostering these ties and was instrumental in facilitating contacts at the ministerial level. The collaborative agreement between the Slovak Academy of Sciences and the Spanish National Research Council (CSIC) which was recently signed is an example of framework that can be used to boost the collaboration of the two countries in EST-related matters. The EST Foundation expresses its deep gratitude to the ambassador for her unwavering support in promoting these scientific contacts and partnerships.

Following the meeting at the ambassador's residence, the delegation held discussions with representatives of Slovakia's Ministry of Education, Research, and Development. These talks centred on Slovakia's active participation in the EST project. Slovakia has expressed a firm desire to become a key partner in the EST initiative, both within the Foundation and during its future ERIC and construction phases.

The visit concluded with a public event organised by the Slovak Academy of Sciences to celebrate the European Researchers' Night. The event was highly successful and attracted a large audience to many stands with science demonstrations. The event concluded with a public debate on the EST project featuring Peter Gömöry, Héctor Socas-Navarro and Manuel Collados, who highlighted the scientific and technical achievements of the project and its importance to the European solar physics community.

EST, AN ASSOCIATED BIG SCIENCE ORGANISATION AT THE BSBF 2024

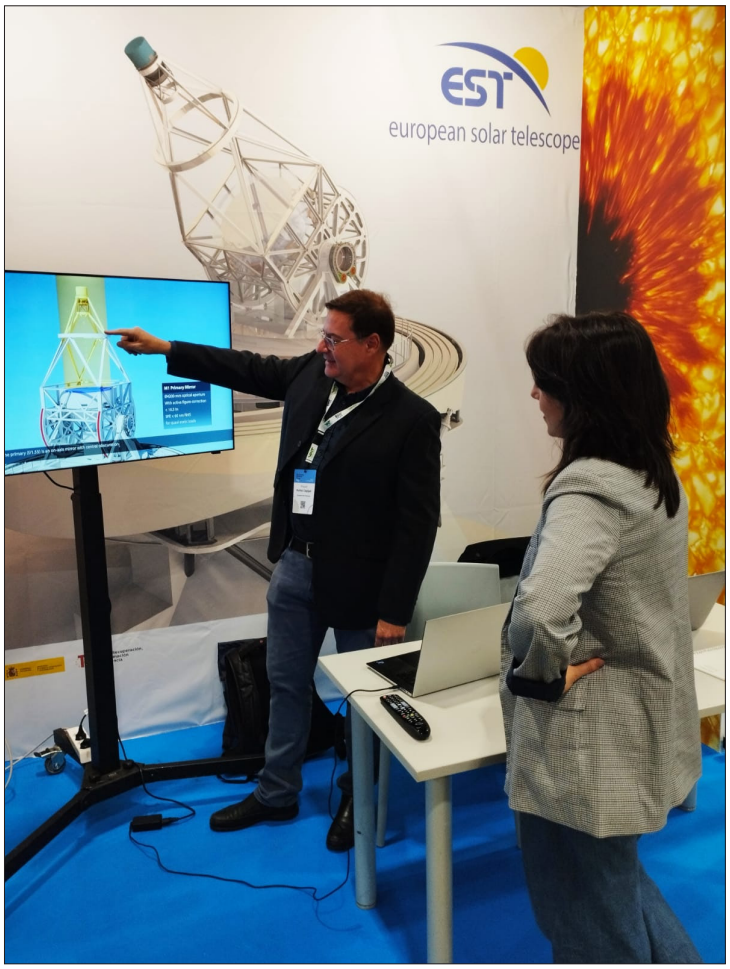
After participating in the Big Science Business Forum 2022, EST returned to the third edition of this meeting in 2024 as an Associated Big Science Organisation.

The Big Science Business Forum (BSBF) is a significant industrial event at a European level, aimed at companies involved in high technology and innovation. BSBF serves as a meeting point between research organisations and technology companies, with the goal of identifying business opportunities in the construction of large-scale scientific infrastructures, while also offering services to the academic world.

The third edition of the BSBF took place in Trieste (Italy) from 1-4 October 2024. Following a selection process through an open call, EST attended the congress as an Affiliated Big Science Organisation (ABSO).

EST had its own stand to promote the project and connect with companies interested in receiving information on future development and investment, as well as contracting opportunities. EST systems engineer Miguel Núñez and mechanical engineering head Juan Cózar were in charge of the EST stand, welcoming visitors and engaging in discussions with them. Additionally, on October 2, 2024, Núñez gave a talk titled 'European Solar Telescope Status and Future Opportunities', where he outlined the plans for the development of EST and business opportunities for the coming years.

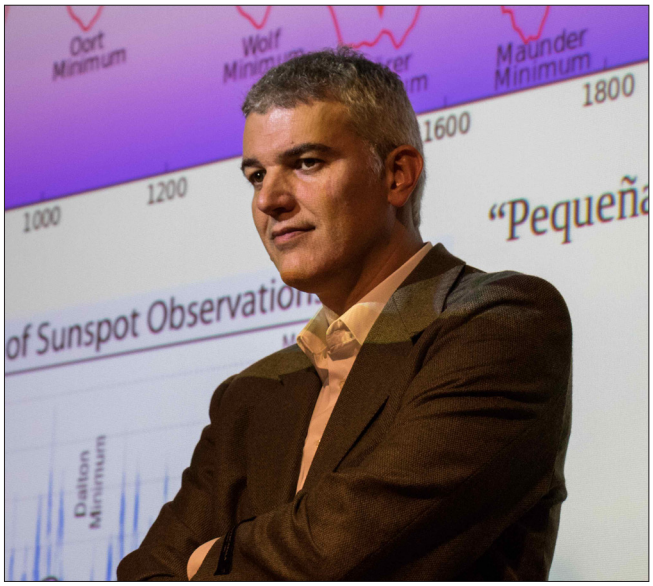
An outcome of BSBF 2024 will be a procurement book with information about the needs of international research organisations in the near future. EST will be present in that book, as a way to disseminate information about the EST development and construction plan and secure the participation of technology companies in the process.



EST stand and staff at the Big Science Business Forum 2024, held in Trieste (Italy).

DIRECTOR AND ADMINISTRATOR OF THE EST FOUNDATION SELECTED

The selection process for the positions of director and administrator of the EST Foundation ended with a unanimous decision by the Board of Trustees regarding the selected candidates.



Left: Héctor Socas-Navarro, director of the EST Foundation. Right: Alejandra Martín, administrator of the EST Foundation.

At the beginning of 2024, the selection process for the positions of director and administrator of the EST Foundation was opened. After careful evaluation of the received applications, the Foundation's Board of Trustees unanimously decided to make an offer to two suitable candidates.

The new director of the EST Foundation is Héctor Socas-Navarro, a staff scientist at the Instituto de Astrofísica de Canarias. After obtaining his PhD in Physics from the University of La Laguna in 1999, he spent nine years at the High Altitude Observatory, part of the US National Center for Atmospheric Research. There, he conducted research in solar physics and contributed to the development of advanced solar instrumentation. He led the construction of the spectro-polarimeter SPINOR and participated in major initiatives such as the DKIST solar telescope and the Solar Dynamics Observatory and Hinode space missions, led by NASA and JAXA, respectively. In 2008, he returned to the Instituto de Astrofísica de Canarias and served as the EST project scientist, chairing its Science Working Group until 2018. From 2019 to 2023, he was the director of the Museum of Science and the Cosmos of Tenerife.

Dr. Socas-Navarro has a record of over 100 peer-reviewed scientific publications and has been involved in multiple projects funded by the Spanish Science and Innovation Ministry. Moreover, his contributions to research have been recognised with several awards. An active science communicator, he is the creator and host of the popular weekly podcast 'Coffee Break: Señal y Ruido,' which discusses current science news.

The position of administrator of the EST Foundation has also been filled. The selected candidate is Alejandra Martín, a Research and Technological Development (RTD) manager with extensive knowledge of the management of research infrastructures and European Union's RTD funding schemes. Martín has more than 15 years of working experience at the Instituto de Astrofísica de Canarias and its observatories, as well as at the Spanish Office for Science and Technology in Brussels. She is currently the Secretary of the Board of Trustees and the Executive Committee of the EST Foundation.

The EST Foundation, formed by 11 research institutions from 9 different countries, was created in 2023 and sets an appropriate framework for the development of EST and the legal entity that will be responsible for the construction and operation of the telescope.

SCIENTIFIC AND TECHNICAL ADVISOR TO EST FOUNDATION'S DIRECTOR APPOINTED

The Board of the EST Foundation has announced the appointment of Göran Scharmer as the new Scientific and Technical Advisor to the EST director.

Effective October 2024, Göran Scharmer, professor at Stockholm University, has been appointed as the Scientific and Technical Advisor to the Director of the EST Foundation (STAD). Among the responsibilities he will fulfil in this role, the most notable is the regular interaction with the director of the Foundation on the scientific and technical progress of the EST project. To achieve that, Scharmer will maintain direct contact with the EST Science Advisory Group and the EST Project Office staff, enabling him to obtain up-to-date and accurate information on the project's status. Likewise, he is expected to provide the scientific and technical teams with valuable suggestions.

Göran Scharmer, Scientific and Technical Advisor to the EST Foundation's director

The role of Scharmer will be particularly important in identifying potential factors that could jeopardise the development and success of the EST project. In such cases, he will need to design and recommend corrective measures to Héctor Socas-Navarro, current director of the EST Foundation.

The Board's decision to offer the STAD position to Göran Scharmer is based on his unique experience in the development of telescopes, instrumentation, adaptive optics, and image reconstruction techniques. Throughout his professional career, Scharmer has made significant contributions to the field of solar physics, playing a key role in the development of advanced instrumentation for high-resolution solar observations. He developed three adaptive optics systems using a novel approach based on cross-correlation algorithms, as well as two of the most powerful and scientifically productive solar Fabry-Pérot spectrometers in the world (CRISP and CHROMIS). Additionally, he pioneered the use of phase-diversity image restoration techniques with solar data and developed real-time frame selection techniques to create the first-ever high-resolution solar movies from a ground-based solar telescope.

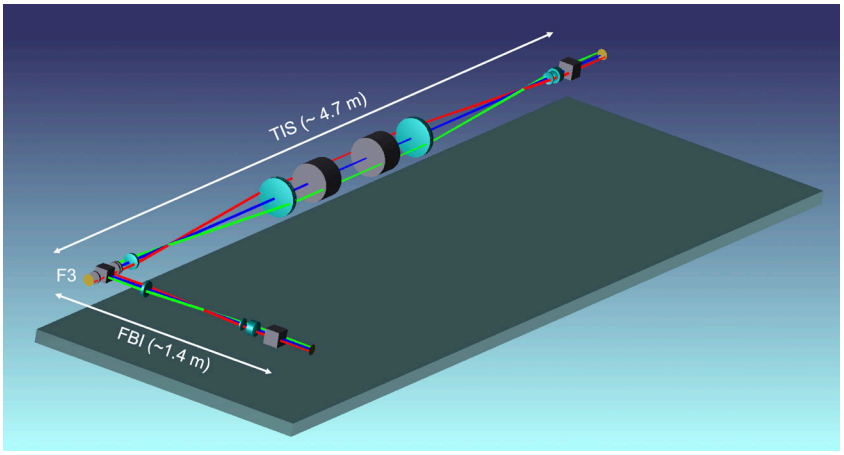
Göran Scharmer has served as the director of the Institute for Solar Physics (ISP), first associated with the Royal Swedish Academy of Sciences and later with Stockholm University. During the decades he led the institute, he oversaw the development and operation of the Swedish Vacuum Solar Telescope (SVST) and the Swedish 1-m Solar Telescope, two solar telescopes located at the Roque de los Muchachos Observatory on La Palma (Spain). Both telescopes were developed with a very short lead time, at low cost, and delivered the expected performance from the very beginning.

Scharmer expresses his pleasure in seeing how the EST project is "developing its full potential both through the choice of a proven excellent site on La Palma, and in terms of an optical design that seeks to minimise the number of optical surfaces in order to maximise throughput and image quality". He further states that he fully supports both the decisions made and the concepts adopted so far, which is why he is pleased to accept this new position. "This is a project that obviously is of fundamental importance to the future of European solar physics, and it needs the full support of the entire solar community", he adds.

SCIENCE ADVISORY GROUP ACTIVITIES

An update on the SAG activities in 2024 is presented in this article.

The EST Science Advisory Group (SAG) consists of twenty two European scientists. The SAG is defining the scientific requirements of EST and is monitoring their consequences for the technical specifications of the EST design. Observing programmes have been devised to address the science objectives of the Science Requirement Document that was last updated in 2019 and is available under reference arXiv:1912.08650 at the University of Cornell's arXiv system that the astronomical community uses to share publications. The suite of post-focus instruments and their distribution in the Coudé lab of EST was approved in 2022 and is described in the science article "The European Solar Telescope" published in the journal Astronomy & Astrophysics in October 2022 (Volume 666, A21).

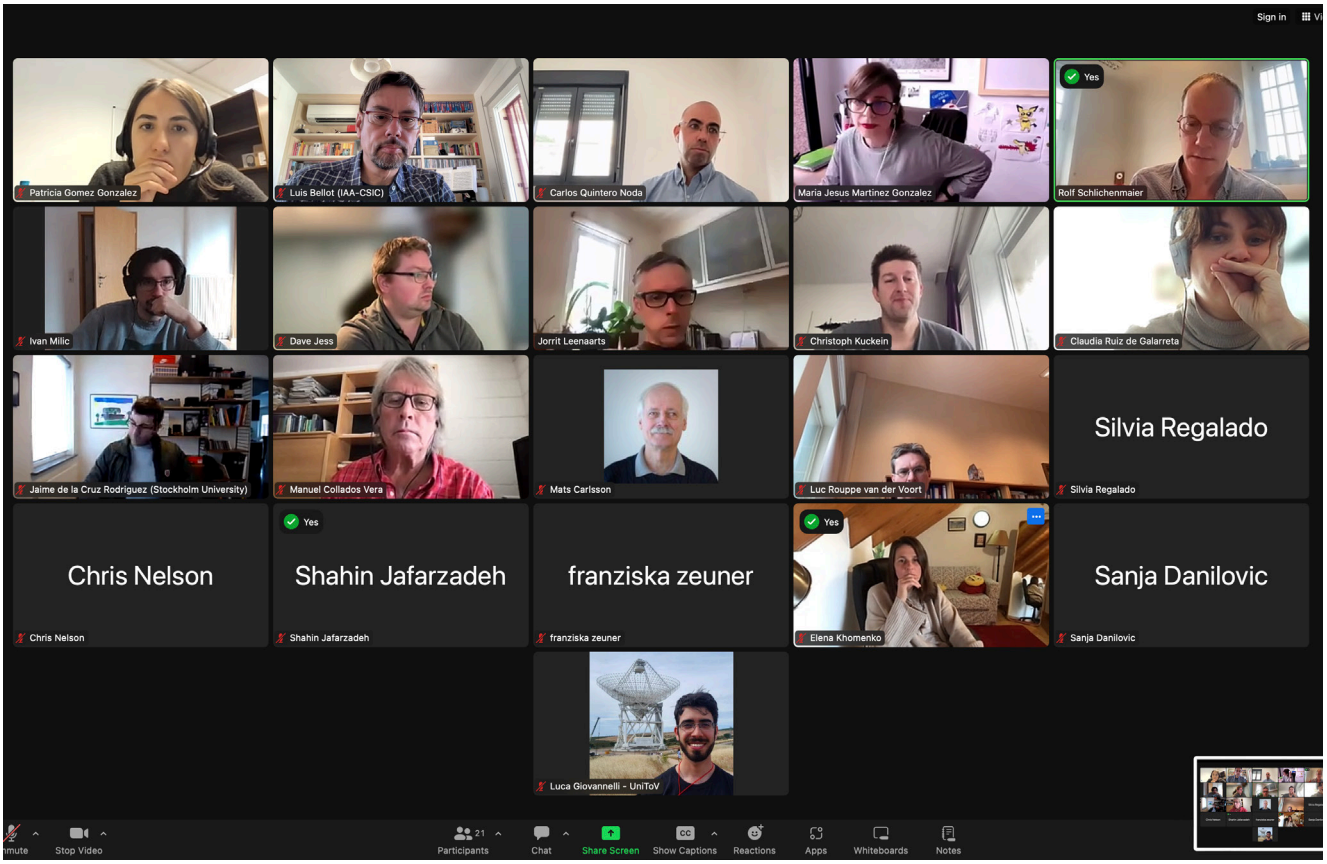


3D render of the TIS/FBI optics assembly. Credit: TIS/FBI consortium

The instrument suite of EST comprises two types of spectropolarimeters. The first type consists of two-dimensional narrow-band Fabry-Pérot spectrometers that scan across individual spectral lines. These instruments have a large field of view, but need a finite time for the scanning. They are called Tunable Imaging Spectropolarimeters/Fixed-Band Imagers (TIS/FBIs), as they also have the capability to do simultaneous broad-band imaging. A total of three TIS/FBIs are foreseen for EST. They will observe simultaneously in three spectral regions: the blue (390-500 nm), the visible (500-680 nm), and the red (680-1000 nm). The second type are spectrograph-based integral field units that measure the spatial two-dimensional domain and wavelength strictly simultaneously, at the cost of a limited field of view. This instrument type is called Integral Field Spectropolarimeter (IFS), and for EST, four such instruments in the blue, visible, red, and near-infrared (1000-2300 nm) are planned. While all IFSes are based on a grating spectrograph, the spatial mapping is done with different techniques: for the near-infrared arm, an image slicer (IFS-S) is used, while for the shorter wavelengths, micro-lens hyperspectral imagers (IFS-M) will be employed.

As all instruments advance in their design, it is necessary to revise the technical specifications of the instruments. In particular, compromises between photon flux, spectral range, spectral resolving power, polarimetric accuracy, spatial pixel size and field of view need to be found. Performance limitations are primarily due to two reasons: on the one hand, the number of solar photons is limited while the solar atmosphere is dynamic on very short time scales, and on the other hand, even though detector made enormous developments in recent decades, their sizes and pixel numbers are still limited. The SAG is responsible for discussing the consequences of those parameters and needs to find the best possible compromise between them to ensure the best scientific performance of the instruments.

Two meetings in the first half of 2024 were dedicated to discuss the requirements and specifications of the IFS-S and TIS/FBI instruments. The IFS-S design is led by the IAC based on their experience with the GRIS image slicer at the German GREGOR telescope. The instrument is called EMBER (EST spectropolariMeter Based on slicEr-mirrors for the near infraRed). For technical feasibility reasons the number of detector pixels is limited and in addition the solar photon flux decreases from the visible towards the infrared, i.e., compromises are necessary for the spatial pixel size and the field of view. The EMBER group analysed the scientific impact of these technical parameters on the scientific objectives of relevant observing programmes and presented their conclusions at the SAG meetings on February 19 and March 20, 2024. The instrument will be optimised for



Online SAG meeting on February 19, 2024. Credit: L. Bellot (IAA-CSIC)

					Integration time per wavelength point (s)		
Instrument	**λ [nm]**	**Δλ [pm]**	**R=λ/Δλ**	**Pixel size (arcsec)**	**SNR=1754**	**SNR=1000**	**SNR=500**
TIS/FBI-B	396	7,8	50769	0,010	13,14	4,27	1,07
TIS/FBI-B	460	10,6	43396	0,010	2,96	0,96	0,24
TIS/FBI-V	517	4,2	123095	0,013	2,40	0,78	0,20
TIS/FBI-V	630	6,2	101613	0,013	1,66	0,54	0,13
TIS/FBI-R	854	10,4	82115	0,017	1,00	0,32	0,08

Table 1. Integration times needed by the TIS/FBI instruments to reach the specified signal-to-noise ratios with the resolving power R.

the He I 1083.0 nm spectral region. It will provide a field of view of 10" x 10" (plus mosaicking) with a spatial resolution of 0.1", a spectral resolving power of 120 000, a wavelength range of 1.5 nm, and a polarimetric sensitivity of 5 x 10^{-4} in the He I 1083.0 nm line core. EMBER will have a diffraction-limited context imager. The overall concept and the proposed numbers were approved by the SAG on March 20, 2024.

The second major task accomplished in 2024 was to define the spectral resolving power of each of the three TIS/FBI instruments. The TIS/FBI consortium, led by IAA-CSIC, studied the wavelength-dependent throughput of the telescope, the Coudé Light Distribution system and the instrument to derive the integration times needed to collect enough photons to fulfil the required signal-to-noise ratios. The results of this analysis were presented and discussed by the SAG in February and March 2024 (see Table 1). Driven by the requirements of the observing programmes in the three optical arms, the following spectral resolving powers are considered to be the best compromise: 50 000 at 396 nm for TIS/FBI-B, 100 000 at 630 nm for TIS/FBI-V, and 80 000 at 854 nm for TIS/FBI-R.

As the design of the instruments progresses, their scientific requirements and technical specifications will need to be studied and monitored by the SAG continuously. The discussion on what spectral resolution is needed for the IFS instruments in the blue, visible, and red is ongoing.

EST OPTICS AND ADAPTIVE OPTICS PRELIMINARY DESIGN REVIEW COMPLETED

EST successfully passed the Optics and Adaptive Optics Preliminary Design Review in October 2024 and is now ready to progress to the System Level Preliminary Design Review.

Participants in the EST Optics and Adaptive Optics Preliminary Design Review held in La Laguna. Credit: I. Bonet (IAC)

The EST Optics and Adaptive Optics Preliminary Design Review (OPRD) took place on October 10 and 11, 2024. The EST Project Office (EST-PO) team met with an external review panel composed of international experts in the development of large telescopes and solar instrumentation. The seven reviewers were Predrag Sekuliç (chair; Technology Innovation Institute, United Arab Emirates), Kjetil Dohlen (Laboratoire d'Astrophysique de Marseille, France), Fernando Gago (European Southern Observatory, Germany), David Harrington (National Solar Observatory, USA), Luke Johnson (National Solar Observatory, USA) François Rigaut (Australian National University, Australia), and Thomas Rimmele (National Solar Observatory, USA).

The meeting was also attended by other members of the EST project and representatives of the EST Scientific Instrument Suite, including Luis Bellot (TIS/FBI PI; IAA-CSIC), Thomas Berkefeld (KIS), Valentín Martínez Pillet (IAC), Jorge Sánchez-Capuchino (IAC), Göran Scharmer (EST STAD; SU), Rolf Schlichenmaier (EST SAG chair; KIS), and Michiel van Noort (IFS-M PI; MPS).

As an integral part of the adaptive optics design, the Adaptive Optics Real Time Controller (AORTC) contributed by the University of Durham (UK) and led by Tim Morris was also reviewed. The University of Durham team participated as EST designers and their work was reviewed by the external reviewers.

At the end of the meeting, the review panel declared the revision passed and provided a list of recommendations to improve the EST optics and AO design.

The preliminary design is the continuation of the conceptual design. It was started with a revision of the EST science requirements by the EST Science Advisory Group in 2020. Following a top-down flow, the science requirements were translated into engineering requirements that were used to advance the preliminary design of key telescope systems (M1, M2, structure, dome, pier and heat rejecter) via industrial contracts awarded to external companies through public calls for tender. In parallel, the EST engineers continued the design of the remaining telescope systems: global optical design, polarimetry, adaptive optics, control software, Transfer Optics and Calibration Assembly (TOCA), Pier Optical Path (POP), Coudé Light Distribution, Coudé sensing assemblies (CSA), civil works, facilities, and interfaces between telescope, instruments and data centre.

As the external companies concluded their work, the corresponding designs were reviewed intensively by the EST-PO and then the subsystems were put together and reviewed globally in the Optics and Adaptive Optics Preliminary Design Review. This time, the EST-PO team was not the reviewer but was reviewed by external experts that have never contributed to the EST design, to ensure a fully independent revision.

Meeting room with tables for the EST-PO team (left), the review panel (right) and observers (behind). Credit: L. Bellot (IAA-CSIC).

This OPDR has been the first partial EST PDR. During 2025 there will be revisions of all other aspects of the project, concluding in a System Level PDR.

The OPDR was started in the first week of September delivering a set of 12 reports to the reviewers and observers, along with the EST optical model, some polarisation scripts and an image stability model. After analysing the documentation and models, the reviewers wrote 281 questions, comments and discrepancies that were answered by EST-PO team members. Of those, 150 were considered clarified and hence definitively closed. Another 80 were closed but required actions to be carried out by the EST-PO, and 51 remained open and needed to be discussed during the meeting in La Laguna. They included topics such as flowing down science requirements to engineering requirements, vibrations in the telescope, adaptive optics, AORTC, active optics, atmosphere statistics, optical performance, optics integration concepts, telescope polarisation, project risks or thermal aspects.

The meeting started with a reception where reviewers, observers and EST-PO members visited the EST Multi-Conjugated Adaptive Optics demonstrator in the IAC laboratories.

Participants visiting the EST MCAO demonstrator, led by Luzma Montoro (IAC).

During the two days of the meeting, questions that required further clarification were discussed, adding more data, plots, CADs or prototypes as needed. Finally, all the questions were closed (147) or closed with actions (134).

There was sufficient time to organise independent splinter meetings about science requirements, polarisation, vibrations, active optics, adaptive optics and recommendations on how to manage the EST construction.

At the end of the splinter meetings, the reviewers held a discussion and finally presented their conclusions about the evaluation. They declared that the PDR was passed and recommended a list of actions to improve the EST design, emphasising the competence of the team and the need to enlage the engineering group to cope with the challenges ahead. They highlighted that the optical design is solid and the adaptive optics is sufficiently mature. As usual in these reviews, critical aspects were identified and recommendations to mitigate the problems were issued, including aspects of thermal control and polarisation analysis.

The EST project wants to thank all the participants for their contribution and especially the reviewers for their very valuable and generous contributions.

EST ADAPTIVE OPTICS FOR FIRST LIGHT

The adaptive optics strategy adopted for EST at first light is described below, together with simulation results aimed at validating it.

The European Solar Telescope (EST) will include an advanced adaptive optics (AO) system, a cutting-edge technology designed to counteract image distortions caused mainly by the Earth's atmosphere. In the initial first-light configuration, EST will implement a near classic AO setup, with a corrected field of view limited by the atmosphere. EST will integrate two deformable mirrors, one per spectral arm of the Pier Optical Path (POP). Once tested and calibrated, EST will be in conditions to progress into a more sophisticated multi-conjugated adaptive optics (MCAO) arrangement capable of compensating atmospheric disturbances across a broader 60-arcsecond field of view. This article is about the first-light configuration.

The initial configuration includes an adaptive secondary mirror (ASM), managed by a wavefront sensor (WFS) in the infrared Coudé room. A second deformable mirror (M7), placed in the visible spectral arm of the POP, will be controlled by a wavefront sensor in the visible Coudé room. Both sensors are correlating Shack-Hartmann sensors. The second control loop will receive an image already corrected at 680 nm and its purpose is to optimise the correction at 500 nm. To enhance performance, the system will feature a fast tip-tilt camera and a wide-field camera for telescope calibration and image quality assessment.

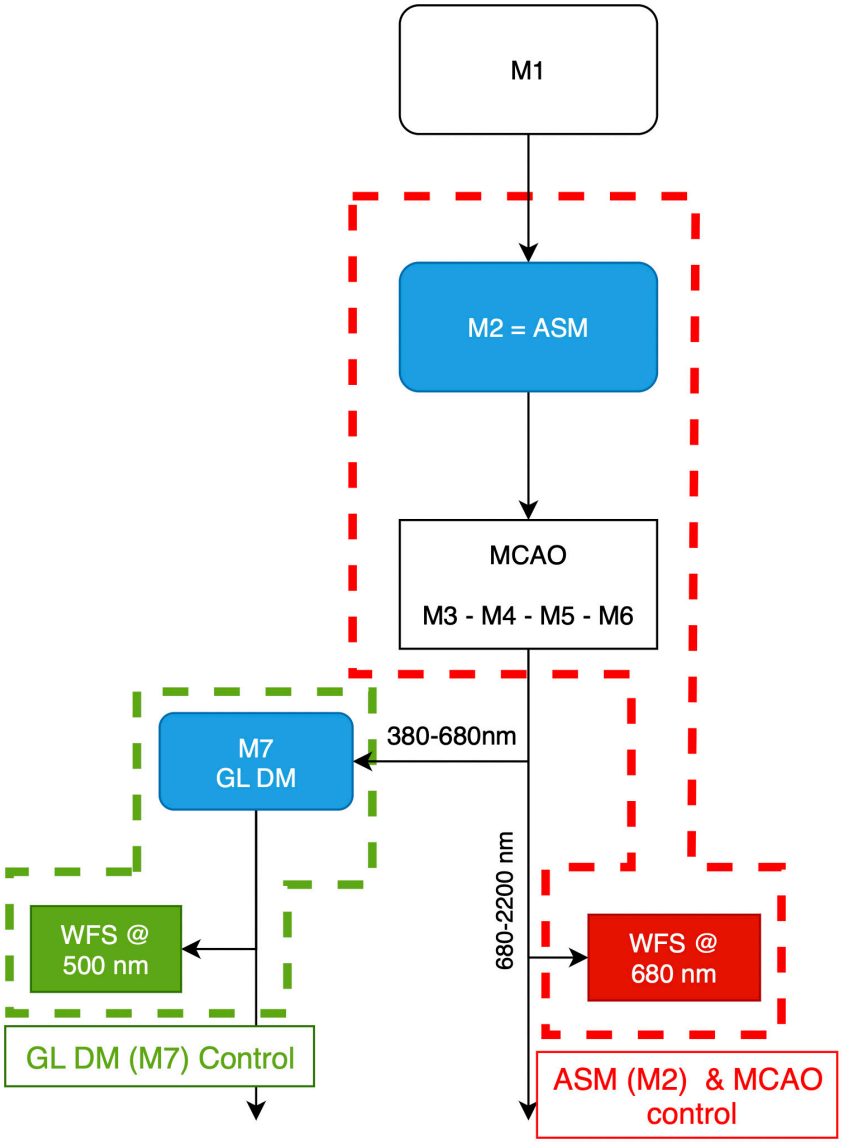


Figure 1. EST AO configuration. The ASM plus red WFS constitutes a first control loop (red line). M7 plus the visible WFS provide the second control loop (green line).

Having a deformable mirror in each spectral arm has three main advantages for EST compared to having only one. Firstly, the different atmospheric wavefront errors at different wavelengths caused by chromatic anisoplanatism when the telescope is pointing below 25° elevation will be compensated separately. Secondly, each deformable mirror compensates local seeing and vibrations specific for each Coudé instrument room. Finally, the deformable M7 will be faster that the adaptive secondary mirror, as needed for the visible arm.

The adaptive secondary mirror allows reducing the number of optical surfaces but it was identified as a risky development. For that reason a preliminary design has been requested to two different companies, TNO and Adoptica. TNO started earlier and has already ended the design, while

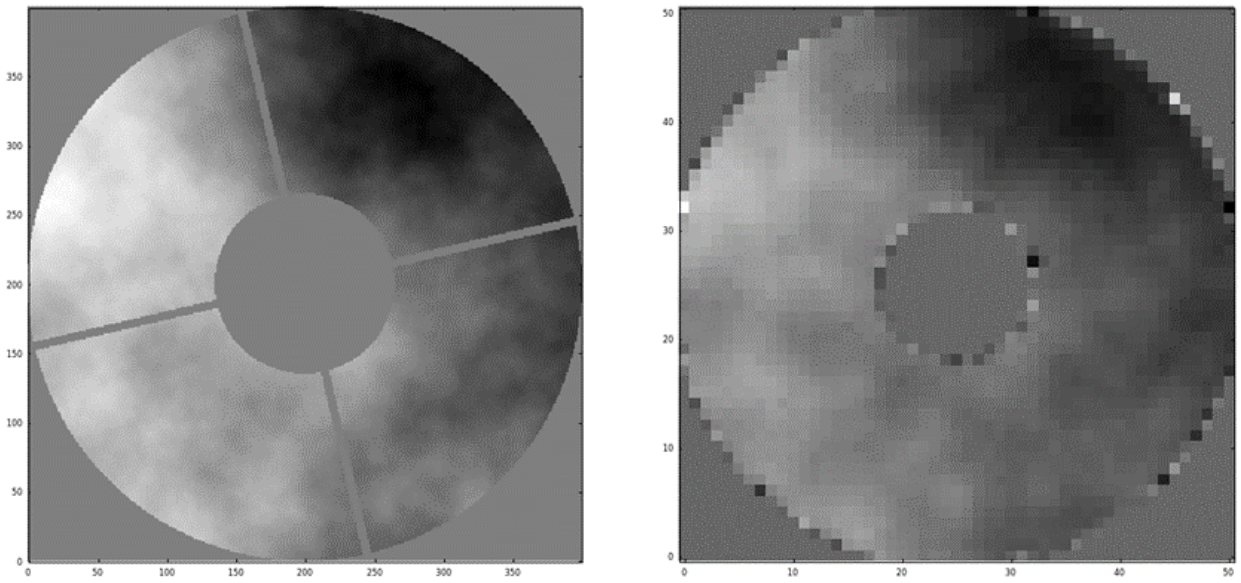


Figure 3. Simulation results for an atmospheric seeing of r_0= 7 cm. Left: Turbulence projected in the pupil plane showing the central obscuration and the spider rotated 13º. Right: The corresponding phase reconstructed by the EST AO closing the loop.

Adoptica started at a later time and will conclude the work in 2025. Both designs include a representative prototype that the EST engineering team will compare in the laboratory under the same conditions. Finally, a technical recommendation to go for one company or the other will be issued.

In the visible arm, a deformable mirror appropriately sized for the working wavelength of 500 nm is needed. This mirror, known as M7, will have an slightly elliptical optical aperture and will include about 2000 actuators (Figure 2). It will be able to work under vacuum conditions and its electronics will be able to receive and process 2000 commands per second.

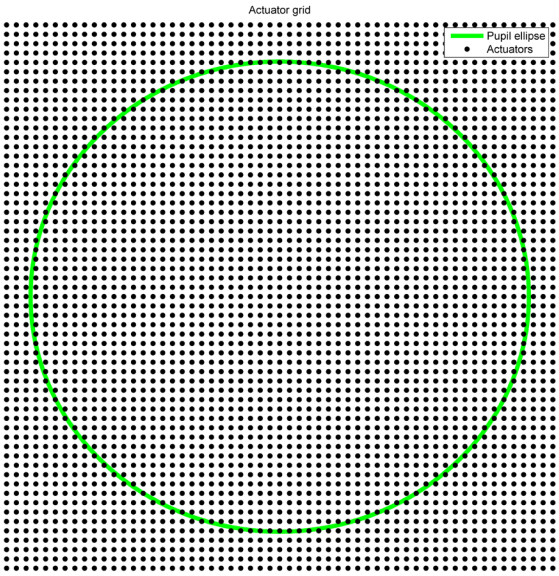


Figure 2. M7 deformable mirror actuator pattern.

In order to achieve diffraction limited observations, it is of utmost importance to have good image stability. Image stability is disturbed mainly by the atmosphere, by wind buffeting over the telescope structure and by mechanical vibrations produced by the telescope itself. Among them, vibrations are expected to be the more challenging disturbance to compensate, particularly those at frequencies higher that 40 Hz. For that reason, an integral plan for vibrations is being prepared that combines two different aspects. Firstly, the telescope design minimises the amount of vibrations that are produced. Secondly, a fast tip-tilt camera that can run at up to 4000 frames per second is foreseen, to reduce the time delay in the control loop and extend the adaptive optics to higher frequencies.

To verify its feaibility, the proposed adaptive optics configuration has been tested using the DASP simulator from the University of Durham (UK). The simulations include the central obscuration of the entrance pupil due to the M2 projection over M1 and also the shadowing of the 4 arms of the M2 support over the entrance pupil. The results of the simulations show that, despite these effects, the EST adaptive optics will be capable of reconstructing the phase, and hence to compensate the atmosphere (see Figure 3). The simulations also verified that the two control loops represented in Figure 1 can be used simultaneously in stable operation.

EST COUDÉ LIGHT DISTRIBUTION SYSTEM

The light collected by EST will be distributed to the various scientific instruments through a complex Coudé Light Distribution System (CLD) which is described below.

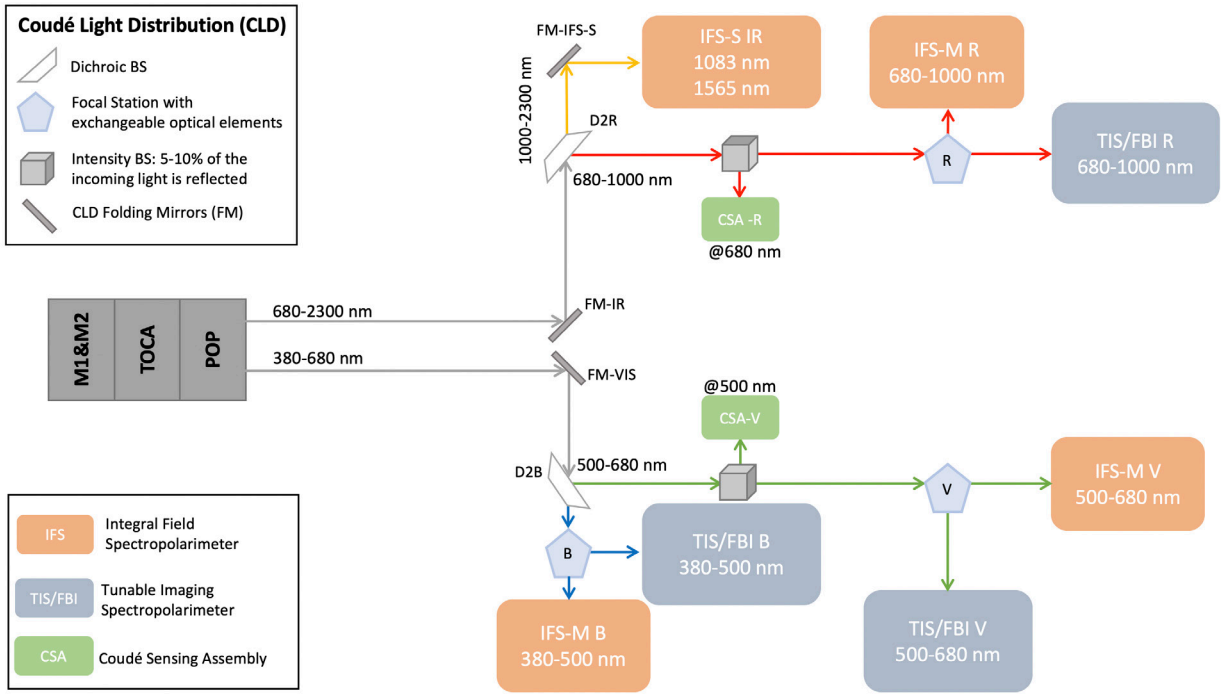


Figure 1. Coudé Light Distribution and Science Instrument Suite diagram..

One of the main goals of EST is to clarify the origin of the magnetic processes taking place in the solar atmosphere. This goal is a top-level requirement to perform simultaneous spectro-polarimetric measurements in multiple spectral lines. For this purpose, EST will be equipped with a set of instruments working simultaneously in different spectral ranges:

- Tunable Imaging Spectropolarimeters based on Fabry-Pérot interferometers, coupled to Fixed-Band Imagers (TIS/FBIs).

- Integral Field Spectropolarimeters based on different technologies: micro-lens arrays (IFS-M) and image slicers (IFS-S).

In addition to the science instruments, the Coudé Sensing Assembly (CSA), which is part of the telescope's Adaptive Optics system, will also be installed in the Coudé rooms.

Once the light from the telescope has passed through the various subsystems, it is split at the Pier Optical Path (POP) level into the visible (380-680 nm) and infrared (680-2300 nm) arms, hereafter referred to as VIS and IR arms, respectively. Also, the POP lenses provide a telecentric science focus that reaches the Coudé rooms where the instruments are installed: the upper floor is reserved for IR instruments, the middle floor for VIS instruments and the ground floor for future guest instruments. The optical elements that form the Coudé Light Distribution (CLD) system are strategically distributed across the Coudé rooms, providing each instrument with a tailored Coudé focus that matches its specific spectral requirements.

The CLD comprises both fixed and interchangeable optical components, allowing the flexibility to generate the required operating modes for the science instrument suite (see diagram in Figure 1).

Two fixed dichroic beam splitters in the VIS and IR arms divide the light into four spectral sub-arms:

- D2B splits the light of the VIS arm into Blue (B) and Visible (V) sub-arms ranging from 380 to 500 nm and 500 to 680 nm, respectively.

- D2R splits the light of the IR arm into Red (R) and Infrared (IR) sub-arms ranging from 680 to 1000 nm and 1000 to 2300 nm, respectively.

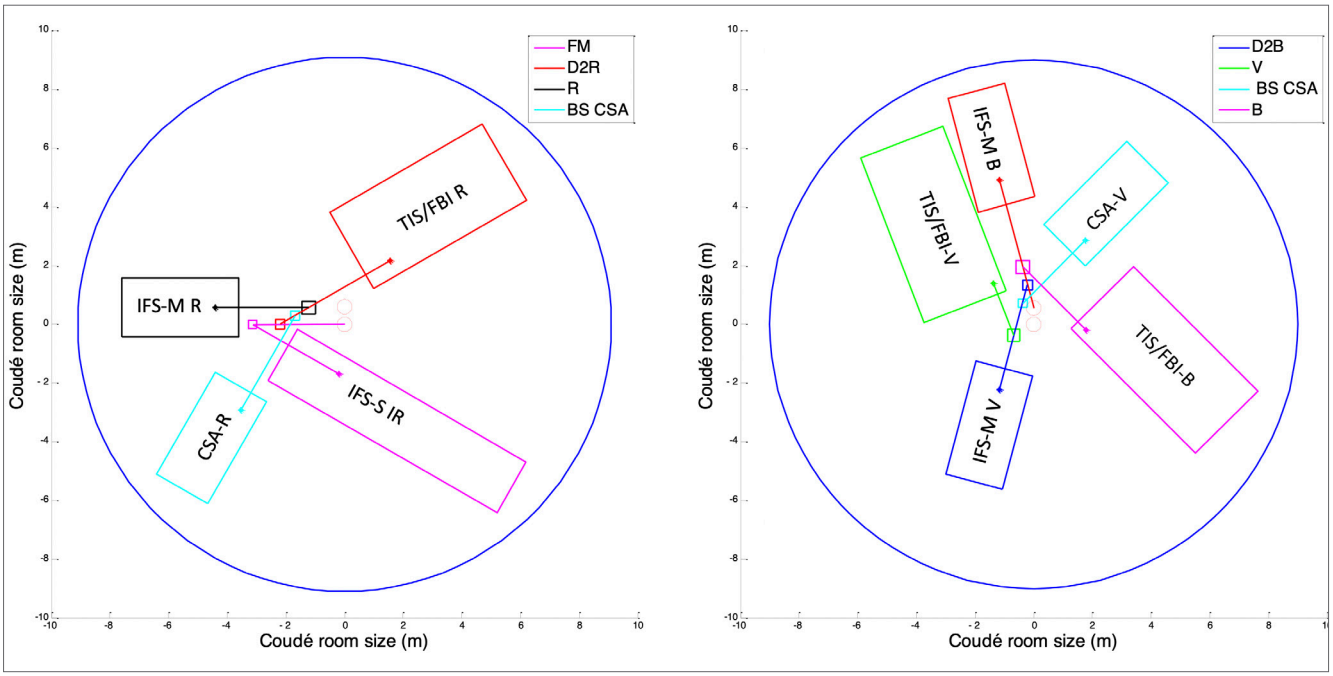


Figure 2. Instrument layout and elements of the Coudé Light Distribution in the IR and VIS Coudé rooms (left and right panels).

The Blue (B), Visible (V), and Red (R) sub-arms each accommodate a focal station equipped with interchangeable optical elements, including mirrors, beam splitters, dichroic filters, plates, and empty slots. This setup enables two different observing modes.

In single operation mode, all the light across the full wavelength range of a sub-arm will be directed to a single type of instrument using a mirror, a plate, or an empty slot.

In dual operation mode, however, the light across the full wavelength range of a sub-arm can be split in two different ways: (a) all the light within a specific wavelength range is directed to one instrument, and the light ouside of that range goes to another instrument using a dichroic filter; or (b) all the light within the sub-arm is directed to the different instruments with different intensities, using an amplitude beam splitter.

The observation programs proposed by the scientific community through the EST Science Requirements Document can be accomplished with 5 filters in the B focal station, 7 in the V focal station, and 4 in the R focal station.

The IR sub-arm hosts only an IFS-S instrument called EMBER that will permanently use the full intensity and spectral range provided by this optical branch (1000-2300 nm) during all scientific operations.

Finally, the V and R sub-arms host the CSA that is part of the AO system required at EST system level. The R and V CSAs will work around 500 nm and 680 nm, respectively, picking 4-6% of the incoming light by means of an intensity beam splitter or a plate by Fresnel reflection.

The CLD is designed to maximise throughput while preserving the optical quality. To achieve this, the number of optical surfaces has been minimised. Furthermore, the angle of incidence on the optical elements is carefully controlled to minimise astigmatism and polarisation effects.

The optical filters are placed in a converging beam resulting in a footprint size ranging from 190 mm to 220 mm. In the preliminary CLD design, all substrates are fused silica plates incorporating a wedge to avoid parasitic reflections and interference fringes. The optical quality specifications are stringent to minimise non-common path wavefront errors that cannot be compensated by the AO system. The coatings of each filter, which are intended to ensure high efficiency at the specific observing wavelengths, are under study with manufacturers. Some filters will require an efficiency spectral profile with a very narrow slope to meet these specifications, necessitating extremely precise design and manufacturing.

The mirrors are specified to be made of Zerodur, coated with protective silver in the IR arm and with UV-enhanced silver in the VIS arm.

The position of each optical element within the Coudé rooms ensures sufficient clearance to accommodate the optomechanical mounts and avoid beam vignetting. Furthermore, the CLD is being adjusted to accommodate the envelopes and input beam positions required by the instruments, as shown in Figure 2.

COMMUNICATION AND OUTREACH ACTIVITIES

The EST consortium is continuing to promote the project through various outreach and communication activities, summarised here.

IAA-CSIC stand at the European Researchers' Night 2024, featuring the EST rollups and other promotional material.

In the second half of the year, the EST project reached several significant milestones which have been duly covered by the EST Communication Office. These include the appointment of the director, administrator, and scientific and technical advisor of the EST Foundation, the acceptance of the Portugese Space Agency and the University of Oslo as observers in the Foundation Board, and the EST optics preliminary design review. All these announcements are accessible on the News section of the EST website.

Interview with Peter Gömöry on the Slovak TV programme Specktrum 24.

EST in the media

The dissemination and promotion of the project has also been active across various formats and media outlets. In July, Héctor Socas-Navarro gave an interview to the Spanish newspaper El Español, where he discussed EST and the new phase of the project following his appointment as director of the EST Foundation. A month later, he appeared on the Spanish science podcast Universo de Misterios. In a two-part interview, Socas-Navarro addressed the future of the European Solar Telescope.

Furthermore, Peter Gömöry, vice-president of the Foundation Board, was interviewed in the Slovak TV programme Spektrum 24. Gömöry had the opportunity to present the EST project on this science and technology-focused show, which provides a weekly overview of the latest global discoveries and scientific advances.

Outreach activities

On September 27, the EST project participated actively in the European

EST presentation at the Information Day on Large Scientific Infrastructures held at CSIC headquarters in Madrid on November 7.

Researchers' Night organised in various cities, including Bratislava (Slovakia), Budapest (Hungary), and Granada (Spain). In these events, promotional materials were distributed and the EST roll-ups were displayed, bringing the European Solar Telescope closer to the public. In Bratislava, as it is customary, an event full of experiences was held, allowing attendees to discover the complexities of quantum science. Representing the EST Foundation were Manuel Collados, Peter Gömöry, Héctor Socas-Navarro, and Ana Aricha (deputy director for Consortia, Organisations and International Scientific Infrastructures at the Spanish Ministry of Science, Innovation, and Universities), along with the Secretary of State of the Ministry of Science of Slovakia. During the event, Manuel Collados and Peter Gömöry presented the European Solar Telescope, detailing its current development and future prospects.

The Hungarian Solar Physics Foundation (HSPF) continues to strengthen its commitment to scientific outreach and the promotion of astronomy in Hungary by organising impactful events. Among these, the fifth edition of the 'Gyula Astronomy Days 2024', held on October 26–27 at the Almásy Castle in Gyula, stands out. Furthermore, the HSPF played a prominent role in the national initiative 'A Week Under the Stars 2024', Hungary's largest public astronomy event. During that week dedicated to raising astronomical awareness, HSPF opened the doors of the Bay Zoltán Solar Physics Observatory in Gyula.

Solar observations at the Gulya Astronomy Days 2024, held at Almásy Castle.

On November 7, EST took a prominent role in the "Information Day on Large Research Infrastructures", organised by the Spanish National Research Council CSIC in Madrid. The project was presented as one of the major international scientific infrastructures in which Spain plays a strategic role. During the event, the relevance of EST for solar astronomy was highlighted,

as well as its inclusion on the ESFRI Roadmap and its contribution to Spain's scientific and technological leadership in international projects.

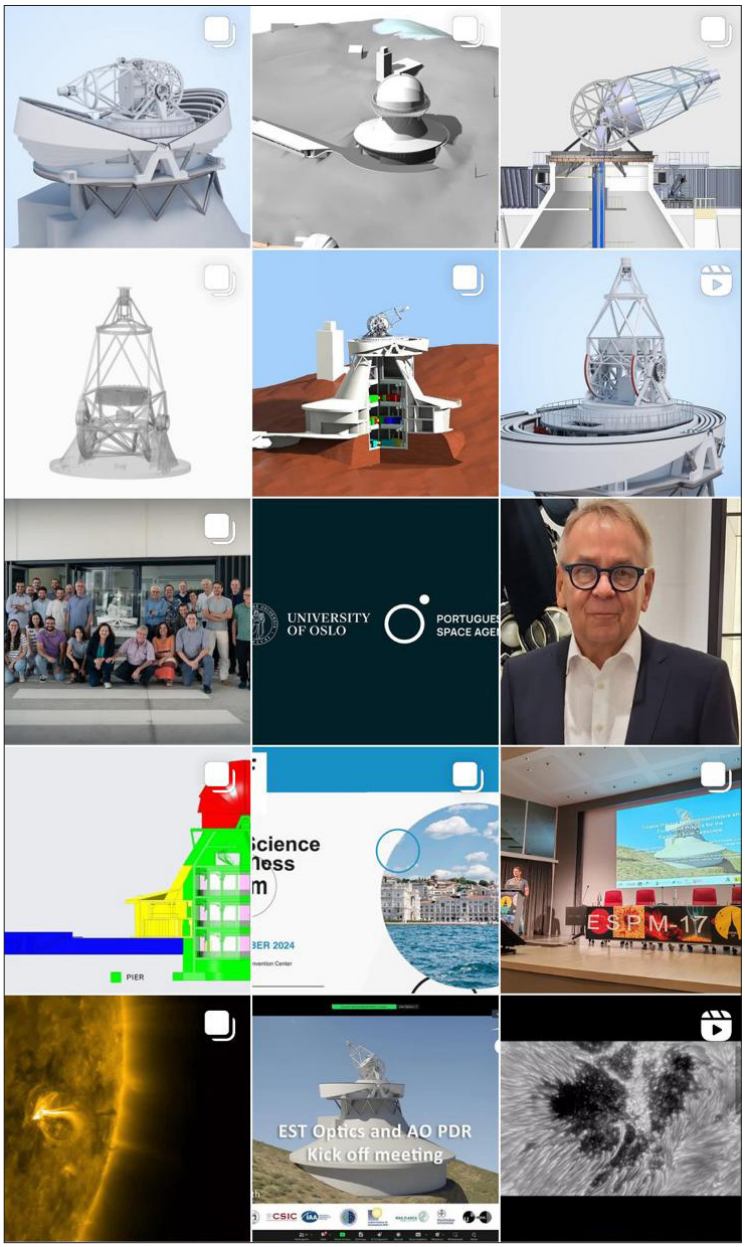
EST also participated in the first CESAR Teacher Training Course devoted to the sun and solar eclipses, which was held in a hybrid format on November 18-21. Luis Bellot Rubio (IAA-CSIC), Sergio Javier González Manrique (ULL) and Christoph Kuckein (IAC) lectured in this course, describing past, present and future solar telescopes. They paid special attention to EST, including its scientific and technical objectives and various design phases. The telescope structure, optics, and adaptive optics were also explained.

Social media

In terms of social media, the project has demonstrated significant activity over the past year. The growth of followers on the EST social platforms has been notable, with an increase of 16% from 2023 to 2024. We now have a total of 7300 followers across Facebook, Instagram, X, LinkedIn, and YouTube as of December 2024.

Throughout the year, we have had a considerable impact, generating more than 2.8 million impressions in around 315 publications in our social networks, covering a wide range of topics related to the EST project. Particularly sucessful was the series "Sunlit Mondays: a journey through the EST Solar Gallery", where we visually explained over 24 solar phenomena, such as sunspots, prominences, filaments and flares.

Recently, we launched a new post series titled "The EST Image Gallery: an inside look", where we share images and renders of the telescope, its structure, optics, and site, offering fascinating details about each aspect. Taking advantage of recent updates to the technical sections of the EST website regarding the various telescope's systems, we have begun publishing two posts per month to introduce these updates, bringing our audience closer to the latest advancements in the project.



EST Instagram feed showing some of the post series that are currently active.

Additionally, we have shared EST's participation in various outreach activities, scientific meetings, congresses, and technological and scientific conferences, highlighting key moments and important news about the project.

EST website

The technical description of the telescope is not the only information that has been updated on the EST website. The EST roll-ups were also redesigned with updated information and images. Both roll-ups —one general, titled "Observing the Sun like never before", and another with detailed information about EST's science and technology— are now available for download in English, Spanish, and Czech.

Additionally, the EST Press Kit has been created. This is a visually appealing document providing key information about the project to facilitate media coverage and dissemination. This material will be completed and published soon on the EST website.

EST NEWCOMERS

MABEL RUIZ LÓPEZ

OPTICAL ENGINEER

Mabel Ruiz López holds a degree in Optics from the University of Granada and an MSc in Photonics from the University of Barcelona. During her PhD at the University of Bern, she specialised in optical technologies, EUV radiation, and laser systems. Her research focused on developing a Schwarzschild objective for EUV lithography, addressing complex alignment challenges. During her tenure at DESY's Beamlines and Optics Department in Germany, she advanced wavefront sensor technologies and refined optical propagation codes.

She joined the IAA-CSIC in September 2024, to work as an optical engineer for the Tunable Imaging Spectrometers/Fixed Band Imagers (TIS/FBI) of EST.

JOSUÉ BARRERA MARTÍN

SOFTWARE ENGINEER

Josué holds a Master's degree in Industrial Engineering from the University of Las Palmas de Gran Canaria since 2010 and a Master in Internet of Things from the International University of La Rioja. His professional career has been focused on industrial automation, mainly working as Certified LabVIEW Architect for several years on projects related with the automotive, railway and aerospace sectors. He joined the IAC in 2020 as software engineer for the New Robotic Telescope, working in the development of the control system using DevOps principles.

Since September 2024 he has been working with the EST team.

PEDRO JOSÉ GARCÍA MARTÍN

FACILITIES ENGINEER

Pedro José holds a bachelor's degree in Industrial Engineering from Las Palmas de Gran Canaria University and a Master in Renewable Energy and Energy Management from Escuela Europea de Dirección y Empresa. He has gained experience as a freelance engineer since 2013, working with enterpreuners to start up their business writting the technical projects and managing licenses with public administrations. Interested in making a more sustainable planet, he will put all his efforts in demissing the CO_2 footprint of the EST facilities.

Pedro José joined the EST team to do facility support for all systems of the telescope.

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

EUROPEAN SOLAR TELESCOPE: STATUS AND FUTURE OPPORTUNITIES
Miguel Núñez, in Big Science Business Forum 2024, Trieste (Italy), 3 October 2024

EST PRELIMINARY DESIGN, STATUS AND FUTURE STEPS
Miguel Núñez, in EAS 2024 Symposium 15, Padova (Italy), 5 July 2024

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

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

UPCOMING EVENTS

SUN, SPACE WEATHER AND SOLAR-STELLAR CONNECTIONS
Bangalore (India), 20-24 January 2025

SDO 2025 SCIENCE WORKSHOP: A GATHERING OF THE HELIO-HIVE
Boulder (USA), 17-21 February 2025

HINODE-18/IRIS-16 CONFERENCE
London (UK), 23-27 June 2025

IAUS 400: SOLAR AND STELLAR MULTI-SCALE ACTIVITY
Medellín (Colombia), 23-27 July 2025

AOGS2025: ADVANCES IN PLASMA FLOWS AND WAVES IN THE SOLAR ATMOSPHERE
Marina Bay Sands (Singapore), 27 Jul-1 Aug 2025

2025 IAGA-IASPEI SCIENTIFIC ASSEMBLY
Lisbon (Portugal), 31 Aug - 5 Sep 2025

PARTIALLY IONISED PLASMAS IN ASTROPHYSICS (PIPA2025)
Bergen (Norway), 1-5 September 2025

SOLAR POLARIZATION WORKSHOP 11
Prague (Czech Republic), 8-12 September 2025

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