# THE SCIENCE OF EST

Scientific challenges to be addressed by the **European Solar Telescope**

EST NEWS
THE EUROPEAN SOLAR TELESOPE NEWSLETTER

JUNE 2020

## INSIDE THIS ISSUE



## COORDINATOR'S CORNER

During the last months, and despite the COVID-19 pandemic, all the groups of EST and EST-related projects have continued working hard towards the final definition and consolidation of EST. This issue of the EST Newsletter highlights some of the most important milestones achieved in this period.

A major step has been the formation of the EST Board of Directors composed by representatives of the EST partner institutions and community. Its first (virtual) meeting took place on June 23rd, right before the release of this newsletter. The General Assemblies of EAST and of the EST-related H2020 projects PRE-EST and SOLARNET were held in Prague in January. There, Portugal joined EAST represented by Coimbra University. A number of events have been organised since then to introduce EST to the scientific and industrial communities of this country. Welcome Portugal!

The most relevant activities of the Science Advisory Group and the EST Project Office are also updated in this issue. The system specifications have been reviewed to take into account the new science requirements released in December 2019, the first calls for tenders (design of the telescope structure, primary mirror, adaptive secondary mirror, pier and enclosure) have been announced, the light distribution definition is taking shape to accommodate the full suite of instruments in the most efficient way, detailed CFD simulations of the proposed site on La Palma are on the way, the components for the MCAO demonstrator are starting to arrive, and an internal Review Panel has been created to follow up the various tasks. All in all, these activities demonstrate the deep involvement of the whole EST community to achieve the final construction proposal within the next couple of years.

Outreach and education activities are also a fundamental part of EST. The "Science of EST" book has been released and is available both in paper and online on the project's website. The presence of EST in social media is continuously improved. The youngest generation is targeted with our EST Virtual Solar Kit and a videogame that will soon be released.

*M. Collados, EST project coordinator*

# FIRST MEETING OF THE EUROPEAN SOLAR TELESCOPE BOARD OF DIRECTORS

*The EST Board of Directors will boost the involvement of national funding authorities. It represents a big step towards the realisation of the main goals of the EST Preparatory Phase.*

The main goal of the current preparatory phase of EST is to provide a detailed plan for the implementation of EST, delivering the information needed to make decisions and addressing both technical and organisational issues, as well as costs and risks analysis. The preparatory phase will take the detailed design of EST key elements to the required level of definition for their final implementation.

The progress made so far has been satisfactorily assessed by the European Commission, who declared that the EST Consortium is demonstrating its relevant role as an essential step towards the realisation of the European Solar Telescope.

However, the lack of a direct involvement of the potential funding bodies in the governance scheme, at least in an advisory capacity, is hindering further progress and a larger, permanent involvement of potential funders is deemed important at this juncture, without waiting for the conclusion of the preparatory phase.


*Virtual meeting of the EST Board of Directors on June 23rd, 2020*

The formation of a Board of Directors for the European Solar Telescope is a key step towards the realisation of the main goals of the European Solar Telescope preparatory phase, and for boosting the involvement of national funding authorities. The board members will make the decisions required to reach the European Solar Telescope project goals and achieve a final construction plan.

The EST Board of Directors is formed by representatives of the EST partner institutions, national funding agencies and other entities providing significant resources to the project. The first (virtual) meeting of the EST Board of Directors took place on June 23rd, when the members approved the Terms of Reference. The next meeting is scheduled for September. The Chair of the Board will be elected in that meeting.

## MEMBERS OF THE EST BOARD OF DIRECTORS

- Prof. Dr. Arnold Hanslmeier (University of Graz, Austria)
- Prof. Dr. Stefaan Poedts (Katholieke Universiteit Leuven, Belgium)
- Mr. Staša Skenžić (Ministry of Science and Education, Croatia)
- Mr. Marek Vyšinka (Ministry of Education, Youth and Sports, Czech Republic)
- Prof. Dr. Svetlana Berdyugina (Leibniz-Institut für Sonnenphysik, Germany)
- Prof. Dr. Sami Solanki (Max Planck Institute for Solar System Research, Germany)
- Dr. Filippo Zerbi (Istituto Nazionale di Astrofisica, Italy)
- Prof. Per Lilje (Institute of Theoretical Astrophysics, Oslo University, Norway)
- Dr. Ing. Chiara Manfletti (Portugal Space, Portugal)
- Prof. Elena Domínguez (Consejo Superior de Investigaciones Científicas, Spain)
- Prof. Rafael Rebolo (Instituto de Astrofísica de Canarias, Spain)
- Prof. Jorrit Leenaarts (Stockholm University, Sweden)
- Dr. Benedetto Lepori (Università della Svizzera italiana, Switzerland)
- Dr. Gerry Doyle (Armagh Observatory and Planetarium, United Kingdom)

# PORTUGAL STRENGTHENS ITS TIES WITH THE EUROPEAN SOLAR TELESCOPE

*Portuguese researchers and industrial stakeholders are showing an increasing interest in the project*

Portugal joined EAST in 2019 represented by Coimbra University and, from then on, its involvement and interest in the European Solar Telescope have steadily increased. Although not yet a member of the EST consortium, the country has nevertheless joined the Board of Directors of the European Solar Telescope, where it is represented by Portugal Space, a government agency whose job is to implement the national strategy 'Portugal Space 2030', facilitating the growth of its national space sector.

"Being engaged in a project that will be a cornerstone of the European ground-based astronomy is fundamental to the development of not only the European but also the Portuguese expertise in this science field", said Chiara Manfletti, president of Portugal Space, in a press release.

Joining the Board of Directors is the last step in a year in which the country has strengthened its ties with EST thanks to researchers João Fernandes, EST principal investigator in the country, and Teresa Barata, both from Coimbra University. Scientists Nuno Peixinho and Ricardo Gafeira, from the same


*Image of the online webinar held on May 22nd, 2020*

University, complete the core team.

"We are looking for the possibilities of Portugal to be part of EST, taking into account that this is a very good opportunity for both national science and space industry", says Fernandes.

The Portuguese researchers did also organised a virtual info-day for the 25th of June, in which the European Solar Telescope was presented in detail to industries, universities, and policymakers. Bilateral meetings were organised with companies interested in knowing more about current and future procurement opportunities.

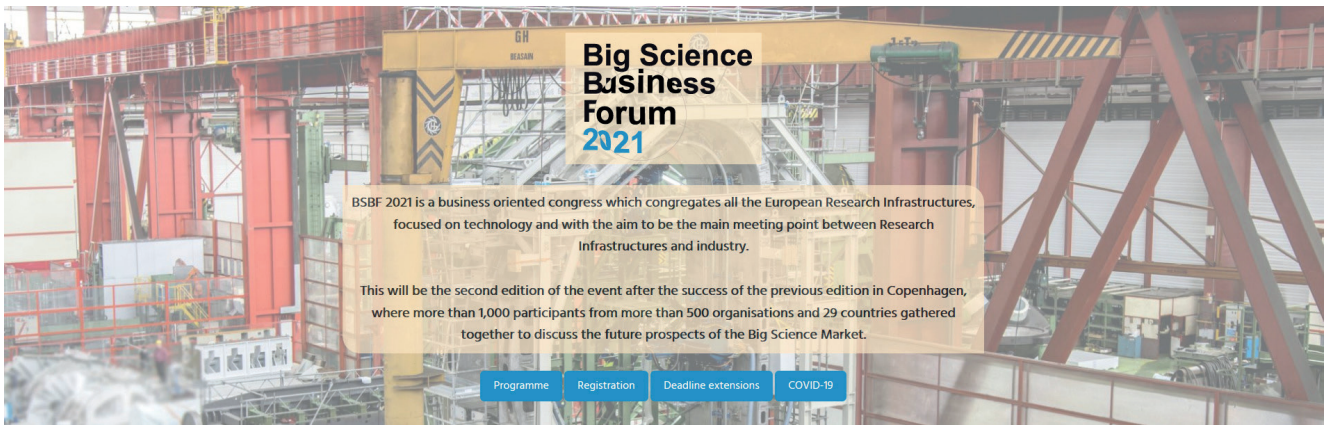
This info-day was yet another step in the increasing involvement of Portugal in the European Solar Telescope. It was preceded by an online webinar, held on May 22nd, and organised by the Instituto de Astrofísica e Ciências do Espaço, Coimbra University, the Observatório Geofísico e Astronómico, and the Centre for Earth and Space Research. The webinar was attended by 52 people, mostly scientists, technology transfer officers, and policymakers.

On the 28th of February 2020, the project was presented to Chiara Manchetti, president of Portugal Space. Previously, it had been introduced to a selection of Portuguese researchers and industries in a series of meetings organised by UC Business (the Technology Transfer Office of Coimbra University) together with AED, a Portuguese cluster of companies working in the aeronautics, space and defence sectors. The EST Lead Thermal Control Engineer also met with Active Space Tech, a Portuguese company with expertise in space instrumentation and structural and thermal control systems for space applications.

*EST participants in the meeting organised by UC Business and AED*

# EST WILL PARTICIPATE IN THE BIG SCIENCE BUSINESS FORUM 2021, TO BE HELD IN SPAIN

*The European Solar Telescope will be an Affiliated Big Science Organisation at this important meeting point between European science organisations and European industries.*




*Home of the BSBF website. The address is [www.bsbf2020.org](http://www.bsbf2020.org)*

The European Solar Telescope will be one of four Affiliated Big Science Organisations of the Big Science Business Forum (BSBF) 2021, a business-oriented congress which constitutes the main meeting point between European research infrastructures and industry. The event —originally intended to be held in Granada (Spain) in October this year— has been postponed until September 2021 due to Covid-19.

## THE FORUM, INTENDED TO BE HELD ON OCTOBER 2020, HAS BEEN POSTPONED UNTIL THE END OF SEPTEMBER 2021

Being an Affiliated Big Science Organisation will offer EST the opportunity to participate in specially designed sessions with European industries. In addition, the project will also have its own dedicated booth at the exhibition area.

"Building EST will give European industry a unique opportunity to make returns on its expertise in the field of astrophysics. EST will contribute to maintain Europe at the frontier of solar physics research and at the same time will mobilise European industry to fully participate in the technological challenges to be faced up in the next decade", remarks Manuel Collados, coordinator of the European Solar Telescope.

EST is now in the middle of its preparatory phase, whose ultimate goal is to complete a detailed design and construction plan within the next two years. To accomplish this, the telescope's consortium is working to maximise the participation of industry to make use of their good practices and expertise.

The EST preparatory phase will end by 2022, and the work is expected to be carried out both through contracts and through in-kind contributions of the EST partners. Once the preparatory phase is accomplished, the detailed design and construction of the telescope will be carried out for the following 6 years. EST first light is planned for 2028, with an estimated operation period of at least 30 years.

The 2021 Forum will be the second edition of this single one-stop-shop where European companies and other stakeholders can learn about Europe's big science organisations' future investments and procurements. The previous edition, held in Copenhagen in 2018, gathered together more than 1000 participants from over 500 organizations and 29 countries.

## BEING AN AFFILIATED BIG SCIENCE ORGANISATION, EST WILL PARTICIPATE IN SPECIALLY DESIGNED SESSIONS

The hosts organisers for BSBF2021 are the Spanish Ministry of Science and Innovation, CDTI (Centro para el Desarrollo Tecnológico e Industrial) and CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas). The event is co-organised with other European big science organizations (CERN, EMBL, ESA, ESO, ESRF, ESS, European XFEL, FAIR, F4E, ILL and SKA). It also counts with the support of Instituto de Astrofísica de Andalucía-CSIC (one of the EST consortium members), and the programme includes a visit to Calar Alto Observatory (Almería, Spain).

More information about the Forum can be found on the website [https://www.bsbf2020.org](https://www.bsbf2020.org)

# PRE-EST BOARD MEETING HELD IN PRAGUE

*The EAST General Assembly also took place in the city. The events brought together a significant representation of the European solar physics community*

*Members of the PRE-EST Board gathered in Prague*

The consortium of the European Solar Telescope (EST) met on January 23rd in Prague to discuss the roadmap towards the future implementation of the telescope, and assess the progress of EST-related projects. The meeting, held over three days at the Czech Academy of Sciences, brought together a significant representation of the European solar physics community in the field of high spatial resolution.

## PROJECT MEMBERS SHARED THE LATEST STRATEGIC DEVELOPMENTS IN THE EUROPEAN SOLAR TELESCOPE

Members of PRE-EST —the project funded by the EU H2020 program to develop a detailed plan for the implementation of EST— shared the latest strategic developments in relation to the European Solar Telescope, including the advances made in defining the project governance and legal structure, the financial scheme, and transnational convergence.

There were also presentations about the scientific and technical developments, including the site evaluation process and the consolidation of the preliminary design, which now includes an 800-mm adaptive secondary mirror to ensure that the telescope is equipped with the most advanced technology available.

### EAST General Assembly

The European Association for Solar Telescopes (EAST) also held its annual meeting during the same dates. Dr. Salvo Guglielmino (Università di Catania, Italy) was elected as the new EAST Executive Director in substitution of Dr. Marco Stangalini.

Founded in 2006, the association is now formed by 26 institutions from 18 countries (Austria, Belgium, Croatia, Czech Republic, France, Germany, Greece, Hungary, Italy, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, The Netherlands and the United Kingdom). Its mission is to ensure that European solar astronomers have access to world-class ground-based high-resolution observing facilities. EAST is also the promoter of the European Solar Telescope.

The meetings were supported by the Czech Republic Ministry of Youth, Education and Sport under the large research infrastructure project LM2018095. The commitment of the Czech Republic with EST was recently reaffirmed in the last update of the Czech National Infrastructure Roadmap, which prioritised and consolidated the Czech participation in the construction and operation of the European Solar Telescope.

## EAST, PROMOTER OF EST, IS NOW FORMED BY 26 INSTITUTIONS FROM 18 COUNTRIES

SOLARNET H2020 also held its first annual meeting in Prague. The EU-funded project, which continues the work started by its predecessor under the same name, aspires to integrate the major European infrastructures in the field of high-resolution solar physics. During this first meeting, a comprehensive review of the annual activities was made.

# SOLARNET H2020 HIGHLIGHTS

*Despite the COVID-19 pandemic, the project continues to run smoothly*


*Members of the SOLARNET project during the first General Assembly, held in Prague on the 23rd of January 2020.*

The SOLARNET H2020 project had a very successful first year of achievements. Thanks to the efforts of its 35 consortium members, it fulfilled all the deliverables and milestones within the envisaged timeline.

SOLARNET's first General Assembly commenced in Prague on January 23, 2020 at the Czech Academy of Sciences. Attended by 56 associates from all the partner institutions, the key aspects for the implementation of the SOLARNET objectives were discussed.

With the outbreak of the COVID 19 pandemic, some SOLARNET programmes have been severely affected. Besides, adapting to new working environments has been quite challenging. The Executive Board of SOLARNET met on April 29th to discuss the status and impact of the pandemic situation.

**Triggering Force Majeure.** The Project Office triggered Article 51, Force Majeure, informing the European Commission that SOLARNET might not be able to fulfill some of the obligations specified in the grant agreement, at least within the initially proposed time scale. Nevertheless, the partners believe that it will be possible to fulfill all of SOLARNET's objectives during the whole project lifetime.

**Impact on Schools and Workshops.** An important objective of SOLARNET is to train the next generation of solar observers via workshops, schools and conferences. However, with travel restrictions imposed, several of the planned activities had to be postponed.

The school 'A holistic view of the solar atmosphere' is now due to take place in January 2021 at MSSL-UCL, UK. The 'Public Engagement Training Workshop' at Northumbria University, UK, has also been called off. The summer school on 'High-resolution solar observations', (Graz, Austria), and the 1st Science Meeting (Venice, Italy) have also been postponed to 2021.

These decisions were taken by SOLARNET's Executive Board, as it is still unclear when international travel might resume. The hands-on training sessions 'Week above the Clouds, August 2020' had to be cancelled for this year as it will not be possible to re-arrange the observing schedules at GREGOR and VTT.

**Mobility Program.** SOLARNET's Mobility Program has also been affected by the travel restrictions. The second call had awarded 3 early career and 3 senior researchers with travel grants. When the pandemic escalated early March, some of the research stays had to be cut short or delayed.

**Joint research activities.** However, as the saying goes, every dark cloud has a silver lining. The SOLARNET team has managed to establish enhanced scientific communication using digital platforms. One noteworthy achievement was the successful delivery of the Field Splitter Design and Microlens Array Specifications within the scheduled time frame by MPS, Germany. The collaborative efforts between the scientists and engineers of IAC, NAOJ, Canon Inc, and Winlight System have resulted in achieving an important milestone on the ability to design and manufacture thin metallic image slicers.

**Transnational Access Programme**. Two SOLARNET PI-led observing campaigns were scheduled to be held in April 2020 at the Swedish 1-m Solar Telescope. However, with lockdown restrictions imposed, the PIs were unable to fly on-site. Thanks to the forts of the SST support astronomer, Pit Sütterlin, the SST woke up from its winter hibernation. He took all the observations by himself, with the help of Stockholm's service observer, Gregal Vissers. The 18 days PI-visitor-based campaigns transformed into two 9-days service-based campaigns. Data were obtained in both campaigns and are now being reduced.

# THE SCIENCE ADVISORY GROUP FORMS A REVIEW PANEL FOR TECHNICAL ITERATIONS

*The Science Requirement Document was published in December 2019. Iterations with the EST Project Office have taken place during the first half of 2020*

In December 2019, the second edition of the EST Science Requirement Document (SRD) was published by the Science Advisory Group (SAG). A copy can be found at https://arxiv.org/abs/1912.08650.

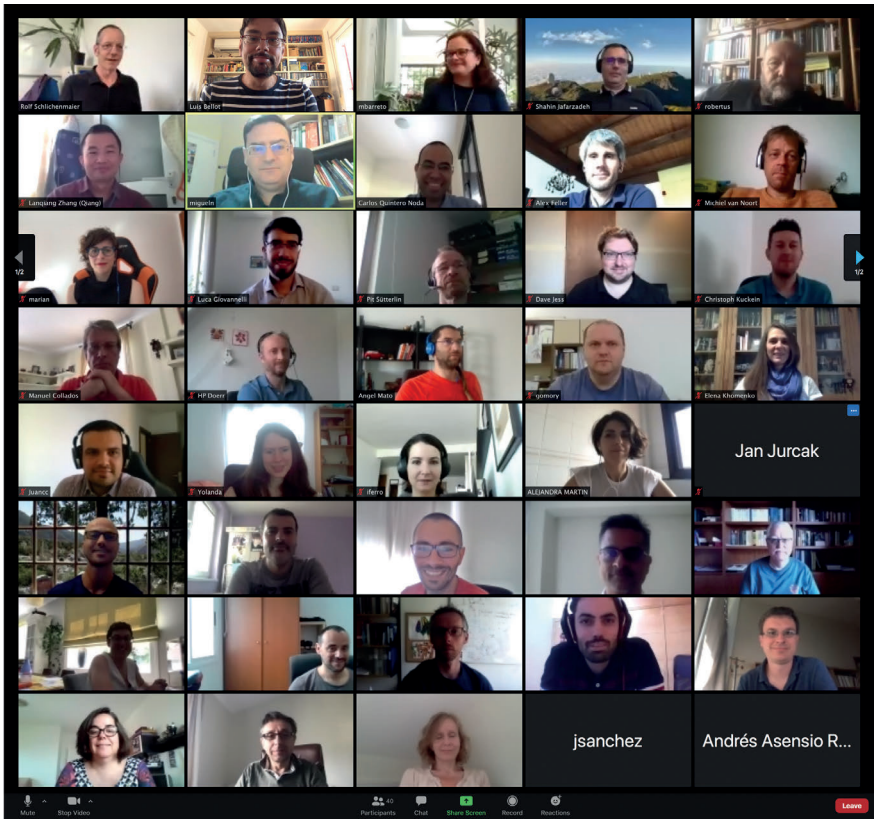
The SRD addresses the top-level science goals for the European Solar Telescope, and contains 93 observing programmes that are devised to reach those goals. Through these observing programmes, the SAG characterised the data sets that are needed. In particular, they specify the spatial and spectroscopic resolution, the spectral lines and wavelength ranges, the signal-to-noise ratio, the time cadence, the field of view of each observation, and which types of instruments are needed simultaneously.

The SRD puts these requirements into context with the concept for the telescope design and infers telescope specifications in terms of field of view size, pointing accuracy, optical quality, optical throughput, polarimetric properties, and wavelength range to be observed.

### From science requirements to technical specifications

As soon as the SRD was published, the EST Project Office (PO) started its work on iterating the technical specification and the optical concept that can fulfil the science requirements. This process of transferring scientific requirements into technical specification needs interaction and iterations between the SAG and the PO.

To make this process more efficient, the SAG formed a Review Panel (RP) which consists of SAG members with instrumental background and of external instrument experts from the community. In total the RP has 11 members.




*Online meeting between the Science Advisory Group, the Review Panel and the Project Office held on June 3rd, 2020. More than 40 people attended.*

**FIRST PRELIMINARY CONCEPTS ON LIGHT DISTRIBUTION AND INSTRUMENT SUITE WERE APPROVED BY THE SAG, PO AND THE REVIEW PANEL**

During the first half of 2020, numerous (tele-) meetings took place to discuss various aspects of scientific versus technical aspects. Prominent topics of discussion were to find a definition of optical quality that is common to engineers and scientists, to understand the technical constraints on the size of the central obscuration, to decide how the beam will be delivered to the instruments, and whether certain requirements can be relaxed to ease technical feasibility. The interaction between the PO and the RP, and the RP and the SAG is crucial to optimise the optical design of EST.

In parallel to working on the telescope optical design, the Project Office and the Review Panel started to develop a concept for the light distribution and the suite of instrument. First preliminary concepts on light distribution and instrument suite, which are compatible with the SRD, were discussed and approved at the meeting between the Science Advisory Group, the Review Panel, and the Project Office on June 3, 2020, which had more than 40 participants.

# LIGHT DISTRIBUTION SYSTEM AND INSTRUMENT SUITE PROPOSED FOR EST

*In the last months, the EST PO has worked on the definition of the EST light distribution system and instrument suite, using the guidelines laid down by the Science Requirement Document*

The Science Advisory Group (SAG) delivered the Science Requirement Document (SRD) to the EST Project Office (PO) in December 2019 and also made it publicly available on arXiv.

The SRD provides information on the science to be done with EST. A total of 61 science cases are presented in the SRD. More importantly, there is a section that groups the main observational requirements through 93 Observing Programs (OP). There, the SAG specified the required measurements in detail, e.g. which wavelength regions need to be observed, what types of instrument should be used, their spatial resolution, their cadences, etc.

The information provided by the SRD is essential to define the light distribution system and the instrument suite of EST. This can be done using the OPs as a baseline and trying to satisfy as much as possible the observational requirements. In this article, we present results from a statistical analysis of the OPs and a proposal for the light distribution and the instrument suite of the telescope. The EST PO presented these preliminary designs to the SAG on June 3rd, 2020 to receive feedback. After that, the EST PO will proceed to the next phase where the specifics of the instruments and the optical elements in the light path will be defined.

**OP statistics.** We started the statistics of the OPs analysing the different spectral regions requested in the SRD. We show the results in Figure 1, where we can see that there are certain regions that are much more demanded than others. In particular, the Ca II spectral line at 854 nm is requested in 80% of the observing programs. There are additional lines that follow in popularity, like He I 1083 nm, the Fe I pair at 630 nm, and the Ca II H and K transitions in the blue at 390 nm. In addition, there are various OPs that request to observe those spectral lines at the same time. In particular, the most common scenarios are Ca II 854 nm (in general with He I 1083 nm), together with a photospheric line at 630 nm (sometimes at 1565 nm instead) and context images in Ca II H at 390 nm. These results are the baseline for the light distribution system proposed by the EST PO.

**Light distribution.** Figure 2 shows the light distribution design based on the previous results. The solar light comes from the left and enters the telescope. It is divided by an optical element, i.e. a dichroic beamsplitter, that sends part of the spectrum to a first arm and the rest to a second arm. In this case, we are not reducing the intensity of the spectrum, just dividing the spectral range. This process is repeated again to create red and near-infrared arms (top dichroic) and visible and blue arms (bottom dichroic). The reason for dividing the light in four is based on the results presented in Figure 1. This design allows multi-wavelength observations to be performed. In particular, observers can have access to the Ca II 854 nm and He I 1083 nm lines simultaneously. It also makes it possible to have the most demanded photospheric lines –the Fe I pair at 630 nm– and the requested context chromospheric observations at 390 nm in separate instruments. Therefore, those transitions could be observed strictly simultaneously for the first time ever in any solar telescope.

**Instrument suite.** After designing how the light is distributed in wavelength, the next step is to define the instruments we will have in each spectral arm. To that end, we checked the OP tables in the SRD again, focusing this time on different aspects. For instance, we checked how the community wants to observe the Ca II 854 nm and He I 1083 nm lines. In both cases, more than 75% of the OPs want to use an Integral Field Unit (IFU) instrument, while the rest of cases requested to observe the spectral lines with Tunable Band Imager (TBI) instruments. Moreover, a similar ratio

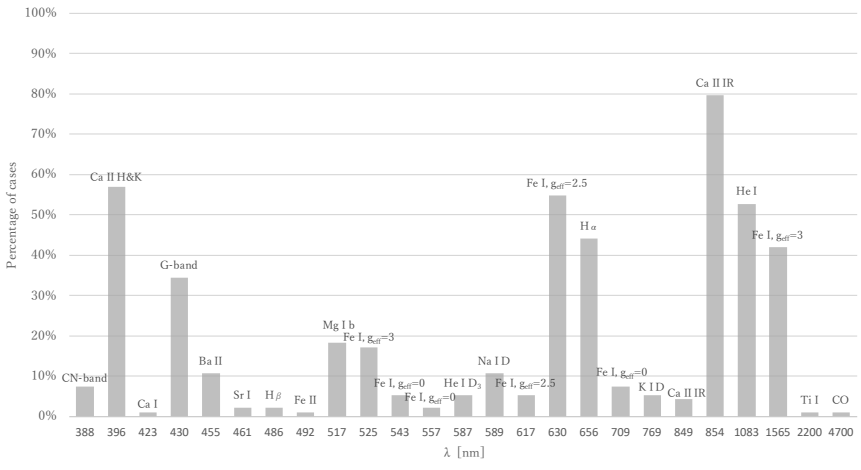



*Figure 1. Spectral lines required by the observing programs in the SRD*

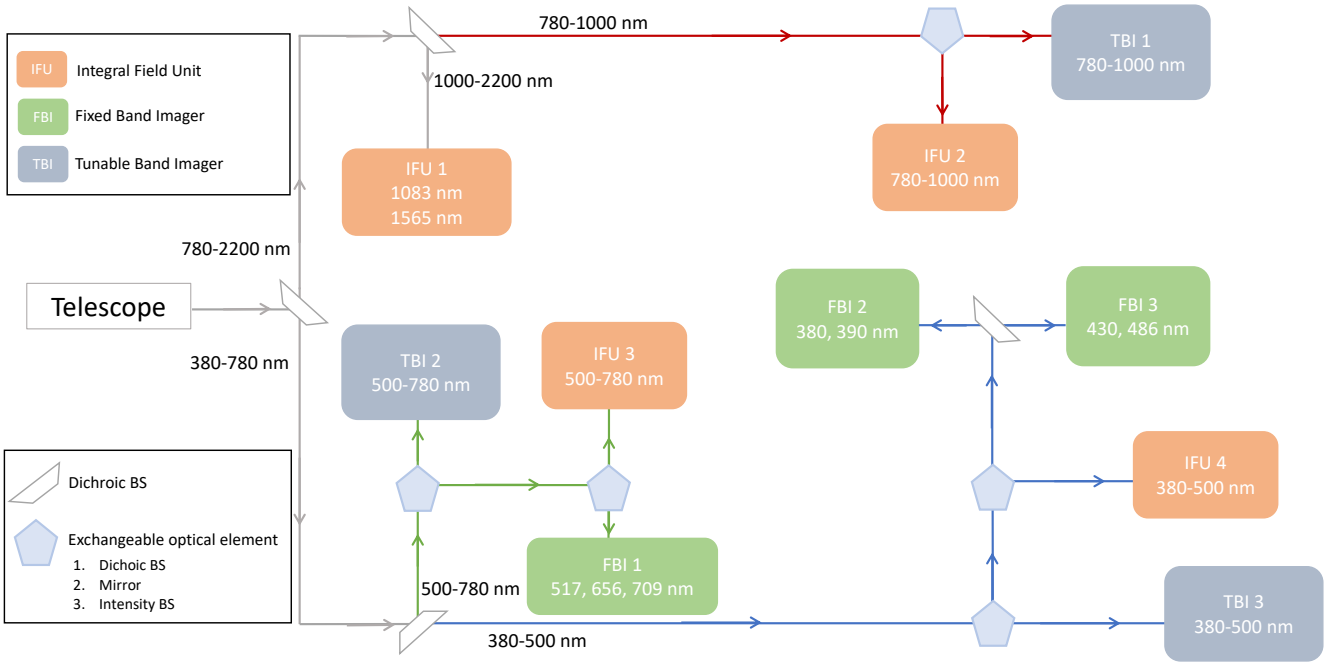



*Figure 2. Proposed light distribution system and instrument suite*

of instruments was found for the visible photospheric lines at 630 nm. Thus, we decided that we should have one IFU system per arm in the visible, red, and the infrared. On top of that, we thought that we should include a fourth IFU in the blue to perform seamless multi-wavelength observations with state-of-the-art IFU systems (orange boxes in Figure 2). In fact, EST is going to be the first telescope equipped with one IFU system per spectral region. Currently, microlens arrays and image slicers are the two IFU systems baselined for EST.

After that study, we examined the statistics related to the context instruments, the so-called Fixed Band Imagers (FBIs). We found that most of the OPs request to use FBIs in the blue and visible arms (see Figure 3). Thus, we considered that we should have instruments in those regions only. At the same time, we also found that most of the OPs require simultaneous observations of the photosphere at 430 nm and the chromosphere at 390 nm. Therefore, we propose to have two instruments in the blue, allowing for the possibility of strict simultaneity between these two spectral regions (see the green boxes in Figure 2).

The next step was to define the TBI instruments. They are less requested than IFU systems (45% vs 65% of the OPs) but these are the only instruments that can provide a large field of view (FOV), e.g. 40x40 arcsec$^2$, with high spatial resolution, complementing the limited FOV of IFU systems. Aiming to fulfil the seamless multi-wavelength coverage philosophy of EST, we decided to go for one TBI per arm. However, we did not see a strong demand in the infrared arm, neither at 1083 nor at 1565 nm, so we did not include a TBI in that arm, defining a system with 3 TBIs instead (blue boxes in Figure 2). Finally, there is a low demand for traditional long-slit spectrographs and we opted to propose a design without them.

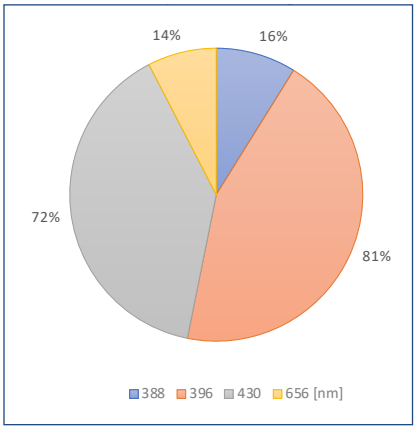



*Figure 3. Required FBI wavelengths*

Regarding how the light is distributed within each of the arms, we included a pentagon symbol to represent up to three different optical elements depending on the observer's needs. The pentagon could be a dichroic beamsplitter (like the white trapezoids) that sends part of the spectrum to one instrument and the rest to the other. It could also be a mirror (or nothing at all), sending all the light to one single instrument. Finally, it could be an intensity beamsplitter that sends the same wavelength range (with a different amount of intensity) to two different instruments. In this way, following the EST philosophy we provide the users with the largest number of combinations possible so we do not limit the type of observations they can perform with EST. These optical elements will be exchangeable then and we foresee that they will be set up at the beginning of every campaign.

# EST SYSTEM SPECIFICATIONS WORKED OUT BY EST PROJECT OFFICE

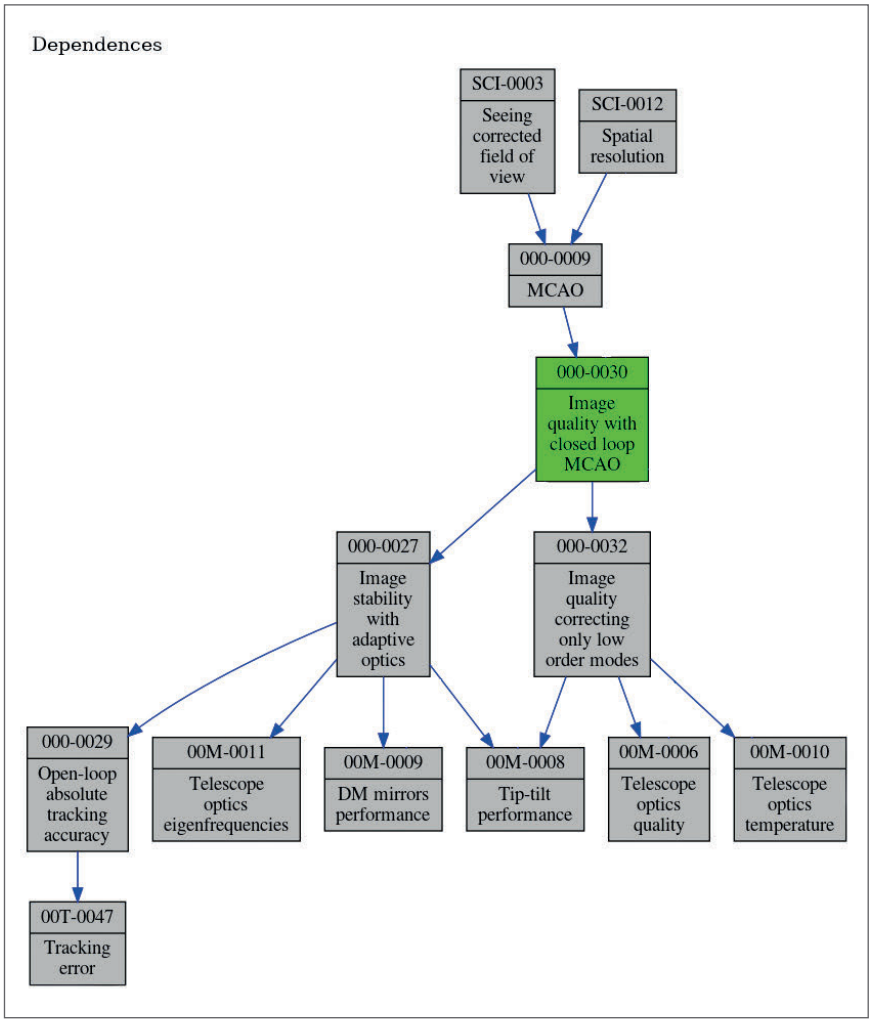
*The EST Project Office has defined the EST system specifications from the Science Requirement Document prepared by the Science Advisory Group.*

The EST Project Office (PO) has to accomplish the preliminary design of the telescope systems and subsystems, down to the level that detailed design and construction can be started once the preparatory phase of the European Solar Telescope is finished. Over the last months, the PO has defined the EST system specifications, using as input the second edition of the Science Requirement Document prepared by the EST Science Advisory Group.

The system specification is the set of requirements that connects the top-level science requirements with the low level engineering requirements. Each requirement is a clear statement defining what the functionality or performance of the system must be. In the case of EST, "the system" includes the telescope, the instruments and the support facilities.

For instance, there is a science requirement defining the telescope optical quality corrected with adaptive optics from disturbances produced by the atmosphere or the wind shake. That science requirement is translated into a system level requirement and then broken down to lower level engineering requirements such as optics temperature, telescope structure vibration frequencies and dynamic performance of the deformable mirrors.

The EST Project Office has already written more than 400 requirements and they are managed with a software tool called cosmoSys-Req. This tool produces diagrams of dependencies like the one shown in the figure. The knowledge of these dependences allows us to answer questions such as what is the impact of modifying one science requirement now or within a couple of years?, what is the potential influence in the top level performance if an engineering low level requirement can be improved beyond expectations? or maybe the other way around, what if the requirement cannot be fulfilled as expected?




*Dependency diagram produced by cosmoSys-Req for the requirement on image quality (in green)*

The good inter-connection between the science requirements and the system specifications has been discussed between the review panel and the Project Office. The review panel is formed by members of the EST Science Advisory Group and external solar instrumenttion experts from the EST partner institutions. As a result of these efforts, a new version of the system specification will be produced in June, including the proposed improvements and recommendations.

This document is the starting point for the preliminary design of the various telescope subsystems.

# FLUID DYNAMIC SIMULATIONS TO EVALUATE THE IMPACT OF EST AT ORM

*The EST PO is currently studying the impact of the proposed location of EST on nearby facilities at Observatorio del Roque de los Muchachos, in particular the William Herschel Telescope*

As part of the European Solar Telescope design consolidation process, the selected site shall be deeply studied under different perspectives, since it could strongly influence aspects such as the design of the pier, the orientation and shape of the annex building, the height of the telescope or the complexity of the civil works needed to erect EST. In addition, the location of the telescope could affect the quality of the observations of other telescopes in the surrounding areas, and EST observations could be affected by the neighbouring infrastructures depending on their specific location.

An important tool to evaluate these influences consists in calculating the wavefront distortions induced by different configurations. These errors are caused by variations in the refractive index of air, which deviate the light from a straight line path as it travels from the light source to an instrument through the telescope. The wavefront degradation leads to a reduction of the Fried parameter ($r_0$), an increase of the Greenwood Frequency (fg) and a larger width of the thinnest features of the image, which are the most common parameters used to quantify the wavefront distortions at observatories. In partnership with CIMNE, the EST project developed a method to compute these parameters in turbulent flows (Codina et al., 2010, Computers & Fluids, 39, 87), as part of the thermal analysis process which aims to minimise the local seeing degradation produced by immediate surroundings of the telescope.

The EST Project Office, at the SUCOSIP request, is using thermal analyses and seeing evaluation to estimate the impact of EST on the William Herschel Telescope (WHT), due to its proximity to the proposed EST location at the Observatorio del Roque de Los Muchachos (ORM). Thirty-six cases have been analysed, varying the wind speed, the wind direction, and the orientation of the line of sight. The optical parameters mentioned above have been evaluated for each line of sight.

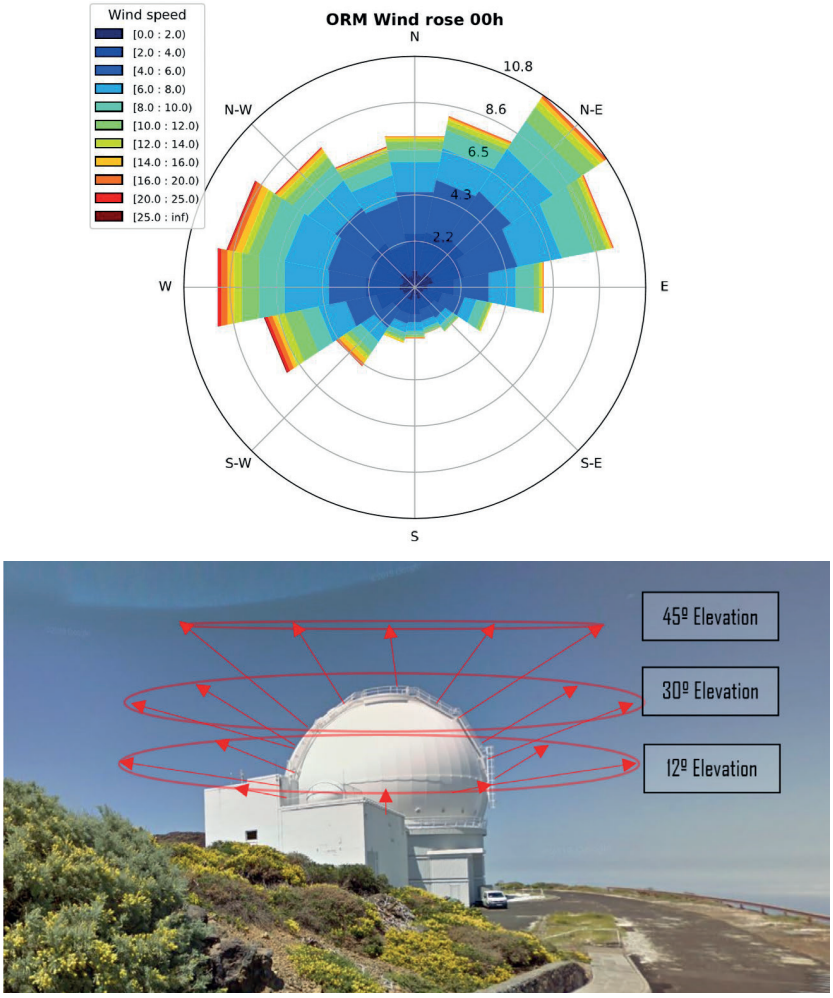



*Figure 1. Top: Wind rose for ORM at 0 hours, showing the direction where the wind blows from. The numbers represent the percentage of days for a particular wind velocity (colours) and direction. Bottom: Lines of sight evaluated at WHT.*

**Model weather parameters.** Reanalysis climate databases are ideal for an homogeneous study of the climate parameters affecting a site. Reanalyses are created by combining numerical models with an unchanging data assimilation scheme (e.g., orography, vegetation cover or landmarks are invariant). The most valuable feature of reanalysis databases is the availability of global datasets with consistent spatial and temporal resolutions over decades. The datasets contain dozens of climatology parameters in a stable data assimilation system that are accessible and can be used freely. We have chosen the *Uncertainties in*

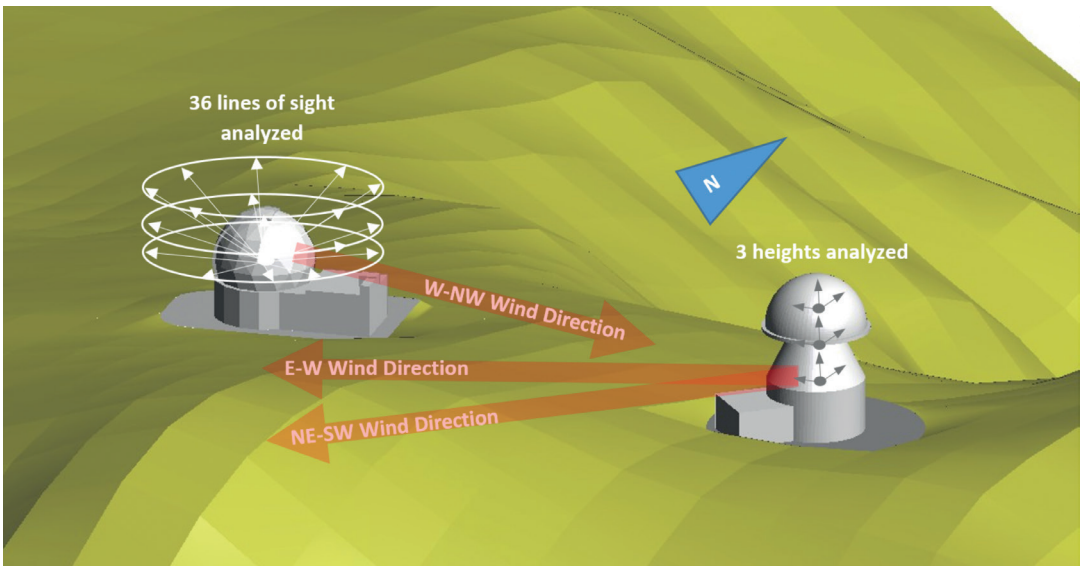



*Figure 2. CFD model with both telescopes placed at the ORM topography. Red arrows indicate wind directions and the white arrows around WHT show the lines where seeing parameters are evaluated.*

*Ensembles of Regional Reanalyses* (UERRA) database. UERRA is a dataset from the European Center for Medium-Range Weather Forecasts. It contains analyses of surface and near-surface essential climate variables from the UERRA-HARMONIE (a 3-dimensional variational data assimilation) and the MESCAN-SURFEX (a complementary surface analysis) systems. The UERRA dataset provides air temperature, relative humidity, wind speed and wind direction with a 11 km x 11 km horizontal resolution for 24 levels of upper-air pressure. Data are available from January 1961 to July 2019 every six hours. For the present study, data from January 2003 until May 2019 (the last month that was available at the time of writing) were selected (Hidalgo et al. 2020).

Using the UERRA dataset, we obtained the wind distribution at ORM (Figure 1). The values in the wind rose show the percentage of days with wind blowing from a specific direction. The coloured polygons show the wind velocity in m/s. The size of the polygons is proportional to the frequency of days within such velocity range. The wind distribution reveals two main wind directions: one in the range W-NW and another in the NE direction. For the simulations, a total of 36 cases were analysed, with three wind directions (NE, W-NW, and E —the WHT telescope location with respect to EST) and three wind velocities (2, 5, and 10 m/s). These wind and velocity selections were combined with different initial conditions for EST and the WHT telescope.

The daily temperature profile has been extracted from the WHT temperature database. The dataset covers the period 1994-2008 with 10-minute sampling.

**Thermal analysis and seeing evaluation.** The first step of the analysis is a transient simulation of the telescope, once the model, the geometry parameters and the weather conditions have been set. Several days of simulations are necessary to stabilise the model due to the thermal inertia of the elements. The results, in terms of the temperature of each surface of the geometry, are extracted from the fourth day at a specific moment of the day. To study the influence of the European Solar Telescope on WHT, the results are taken at 22:00 in summer, when EST has received the entire daily cycle irradiation and WHT starts operating. In a second step, CFD-seeing analyses are carried out to evaluate the performance of each case in terms of optical parameters. The CFD domain includes the topography of the observatory and the geometries of the two telescopes in a volume that varies in different steps of the analysis (see Figure 2). Initially the model uses a gross mesh in a large volume (a semi-sphere of 28 km of diameter), then the initial conditions for a reduced domain are calculated (a cube of 2 km side), and finally the mesh is refined around critical areas, such as the telescopes, and analysed as the final model where the optical parameters are evaluated.

The results, expected by the end of August, will answer several questions:

- Does EST affect WHT observations? If yes, how much? In which wind directions? In addition, which WHT angles of observation are affected?
- How much does the observation quality change with height above ground at the proposed EST location? The answer to this question will come from the evaluation of the optical parameters at the EST location and at different heights, as a preliminary study to evaluate the variation of the seeing conditions with respect to telescope height for the selected site.

Further analyses will study in detail the optimal configuration of the European Solar Telescope (building orientation and shape, pier shape, etc).

# UPDATE ON THE MULTI-CONJUGATED ADAPTIVE OPTICS TESTBED FOR EST

*The EST project is simultaneoulsy developing the adaptive optics system and an MCAO testbed*

EST specialises in high spatial and temporal resolution, and shall correct the image blur due to turbulence in the Earth's atmosphere. To do so, it will include an innovative adaptive optics (AO) system.

The project is simultaneously developing a final AO system and a laboratory MCAO testbed. The testbed will have reduced capabilities than the telescope AO, but it shall be commissioned in advance, so the lessons learned will improve the final design of the telescope MCAO system. The main components of the MCAO testbed are:

- Illumination system. It provides different sources required in the testbed, both for calibration and for performing the MCAO tests. It is composed by a LED source illuminating the integrated sphere and an object mask.

- Turbulence simulator. This system provides turbulence at the entrance of the testbed, simulating the turbulence expected in EST but adapted to the constrains imposed by the optomechanical design of the testbed. The simulator can emulate a vertical profile with 5 tuneable altitudes.

- Wavefront sensor. Two different wavefront sensing strategies will be implemented: correlation Shark-Hartmann wavefront sensing and Artificial Neural Networks. The wavefront sensor optics and camera design shall be similar for both strategies, only the microlens array and the image processing will change.

- Deformable mirrors. Three ALPAO deformable mirrors are under construction, one with 820 actuators and two with 468 actuators.

Each module has been characterised independently and the whole testbed will be operative during the next months.

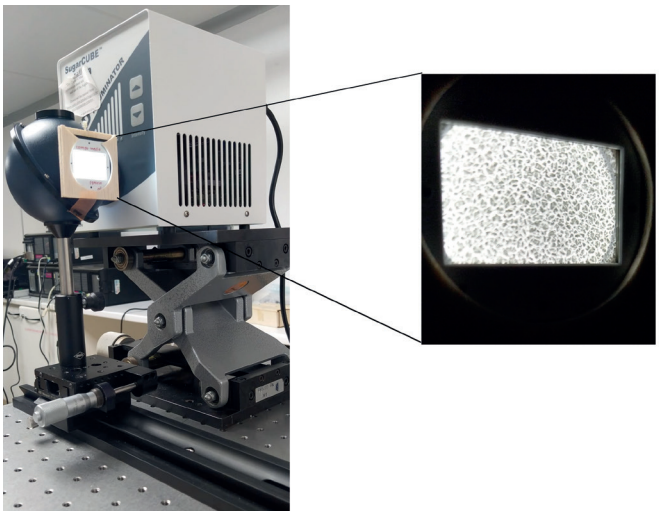


*Figure 1. Illumination system*

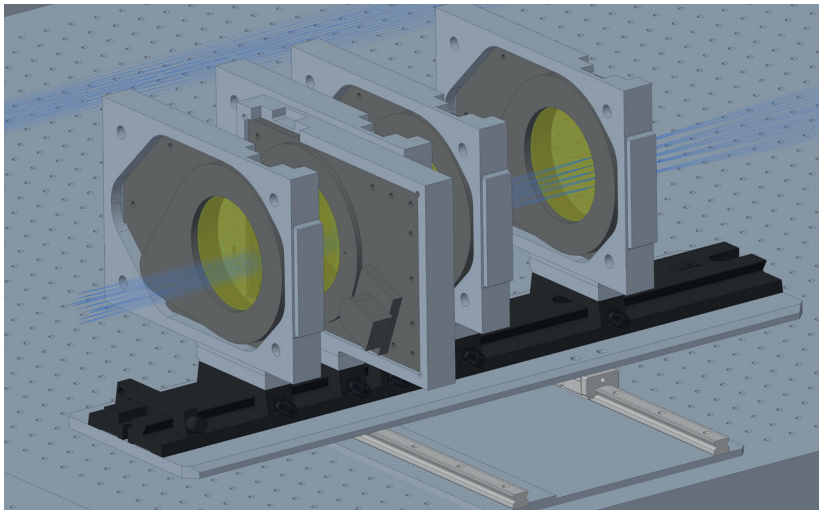


*Figure 2. Turbulence Simulator*

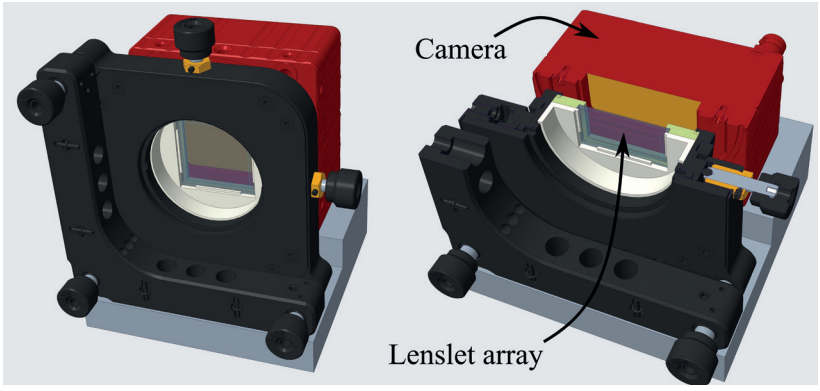



*Figure 3. Wavefront sensor*

# CALL FOR TENDERS FOR THE PRELIMINARY DESIGN OF THREE MAIN SYSTEMS ISSUED

*In March 2020, a call for tenders was released and then suspended due to the coronavirus crisis. The process is now reopened and the deadline is August 7, 2020.*

On the 9th of March 2020, the PRE-EST coordinating institution, the Instituto de Astrofísica de Canarias, released the publication of the Call for Tenders for the Preliminary Design of the European Solar Telescope's three main systems: the primary mirror assembly (Figure 1); the telescope structure, pier and enclosure (Figure 2); and the adaptive secondary mirror (Figure 1). The reference number is LIC-20-006.

Following the European Union guidelines, this call is open to companies all around the world to guarantee competition and the best quality/cost ratio.

**FOLLOWING THE EU GUIDELINES, THE CALL IS OPENED TO COMPANIES ALL AROUND THE WORLD. DEADLINE IS AUGUST 7, 2020**

On March 14th, the Spanish Government declared the state of emergency all over Spain to deal with the health crisis caused by the coronavirus disease (COVID-19). The state of emergency included suspension of conditions and interruption of deadlines for all administrative proceedings under way.

The process was reopened on June 22nd, with a new deadline of August 7th at 23:59 local time for receipt of tenders. The link to the publication in the Tenders Electronic Daily (TED) can be found at http://tiny.cc/ESTatTED.

All the procurement documents are available at http://tiny.cc/licitaciones for unrestricted and full direct access, free of charge.

Any information regarding this call must be requested at contratacion@iac.es.

*Figure 1. Telescope structure. The primary and secondary mirrors are in blue and yellow*

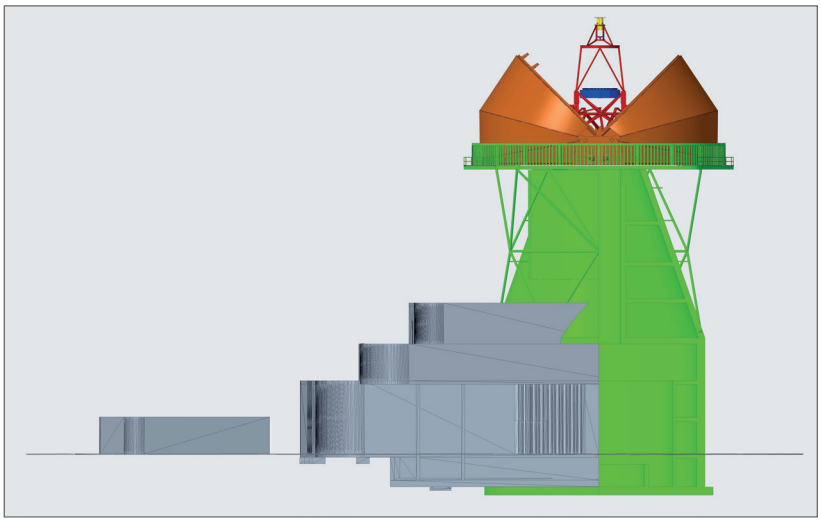
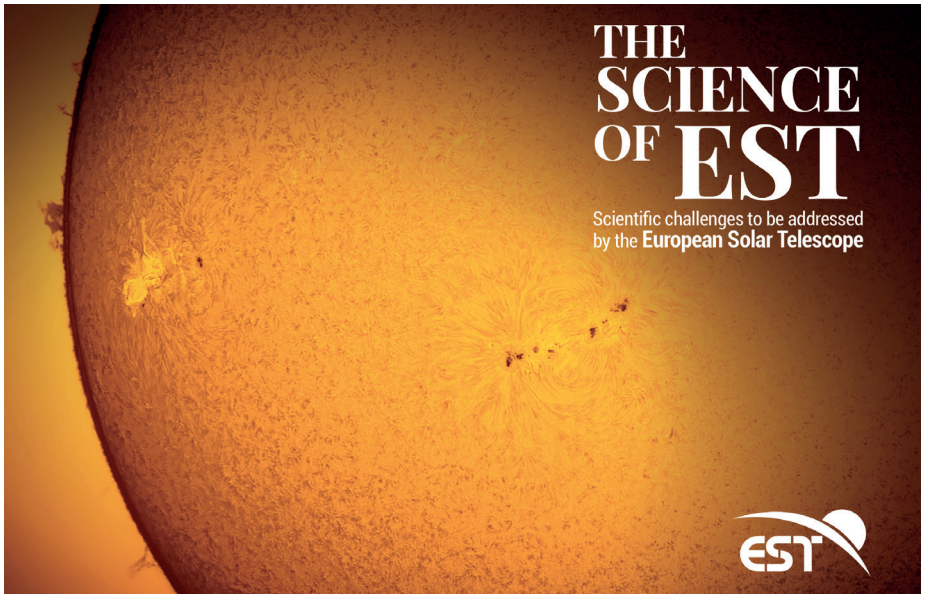


*Figure 2. Telescope structure (red), pier (green) and enclosure (orange) of EST*

# NEW BOOK: THE SCIENCE OF EST

*The articles of this educational series, published on the EST social media between May 2018 and May 2020, are now compiled in a new book.*

The EST Communication Office has just released the book "The Sience Of EST", which collects 77 short articles on hot topics of solar physics research that will benefit from the future European Solar Telescope. The articles are written in plain language by professional solar astronomers from 30 institutions across Europe, reflecting the pan-European collaboration behind the EST consortium.



*"The Science of EST" book cover*

The book has been edited by Instituto de Astrofísica de Andalucía-CSIC for the EST project. It is authored by Luis Bellot Rubio (IAA-CSIC, Spain), Christoph Kuckein (AIP, Germany), Sergio J. González Manrique (AISAS, Slovakia), Ada Ortiz (Expert Analytics, Norway) and Adelina Pastor (IAA-CSIC, Spain). The articles cover the whole range of current solar physics research, from quiet Sun magnetic fields to waves throughout the solar atmosphere, chromospheric dynamics and magnetism, and flares.

Available in paperback and online at www.est-east.eu/the-science-of-est, the book is the result of the series "The Science Of EST", published weekly on the EST social media and the EST website from May 2018 to May 2020. With the present book, the EST project wants to offer the solar physics community an useful resource to promote solar physics among a wide range of audiences, including students, teachers, fellow scientists, policymakers, and the general public.

# NEW EDUCATIONAL SERIES: TECHNOLOGY OF EST

*A new educational series of articles on the engineering and management efforts required for the construction of the European Solar Telescope is about to start.*

How is a telescope designed? How do you make scientists' vision come true? What are the challenges of developing a technology intended to obtain new and better results than those previously achieved?

The EST Communication Office is launching a new educational series of publications on the technological, engineering and managerial efforts required to develop a large, state-of-the-art telescope such as the European Solar Telescope. Among other topics, it will cover the primary and secondary mirror design, solutions used to compensate for turbulence, internal seeing, and polarisation (EST will be the first telescope free from instrumental polarisation), adaptive optics, data mining, and instrumentation.

The articles are written by the EST Communication Office based on interviews with the engineers and scientists involved in the project.

This series is the logical follow-up to *The Science Of EST*: whereas the former explained the science questions to be adressed by the European Solar Telescope, this one will be devoted to the efforts of engineers and non-technical personnel (such as project managers) to develop and implement the cutting-edge technological solutions that will enable the telescope to meet its scientific goals.

The articles will published every second Thursday on the EST web site and social media begining July 16, 2020.

# THE EST YOUTUBE CHANNEL GETS UPDATED WITH NEW CONTENT AND STRUCTURE

*In addition to Facebook, Twitter, Instagram, and LinkedIn, the European Solar Telescope is also present on YouTube. All audovisual materials of the project are available there.*

The EST YouTube channel is a useful repository of videos and animations about the Sun and the European Solar Telescope. Moreover, it is an open window to show the project to the world.

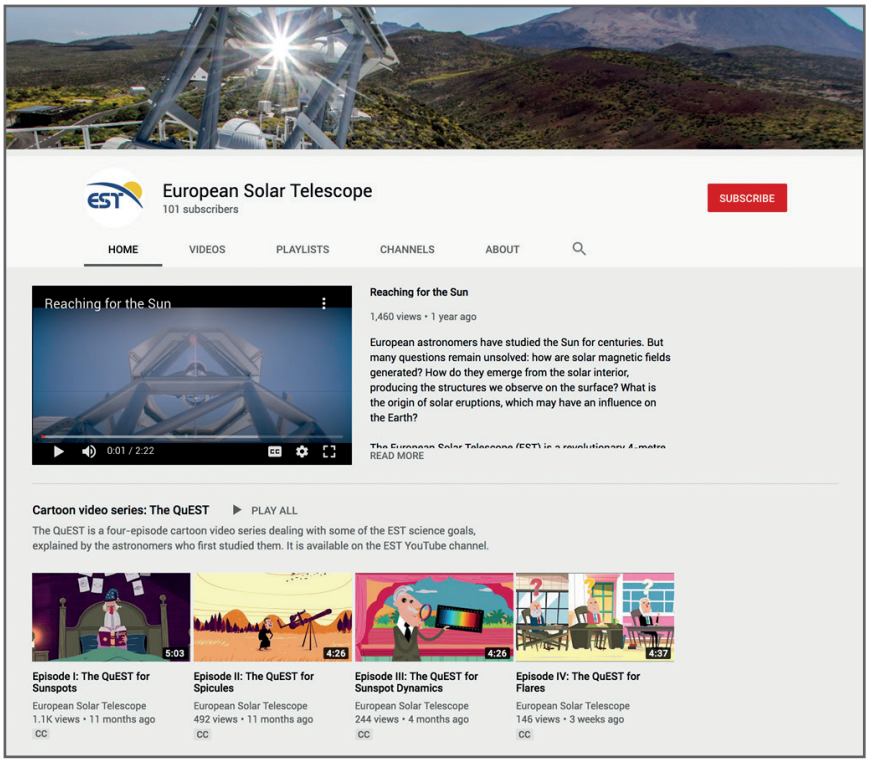
The channel was created in 2014 and the EST Communication Office has updated it recently, uploading new content and reorganising the structure to make navigation easier and more intuitive. Currently, our channel offers approximately 80 videos grouped in 12 different playlists.

Visitors to the EST YouTube channel are now welcomed by the trailer of "Reaching for the Sun". This is an emotional video that raises curiosity about solar research and invites people to stay on the page and discover more about the European Solar Telescope.

A major wake-up call for this channel has been the cartoon video series "The QuEST". YouTube was the platform used to show and share the animated stories about some of the main astronomers in the history of solar research and the challenges EST will face. The last episode, "The QuEST for Flares", was released in May 2020, concluding the series in English. All episodes are subtitled in eleven European languages plus Chinese. This has been possible thanks to the collaboration of several EST members and colleagues from different institutions.

The EST YouTube channel also hosts the "The QuEST" episodes narrated in Italian, Slovak, and Spanish. This whole series has reached more than 3000 views over the last year.

Another novelty on the EST YouTube channel is the incorporation of the audiovisual resources used to illustrate the articles of "The Science of EST" series. All those videos are available in the playlist "Solar resources". They help explain some of the scientific problems that will be addressed by the European Solar Telescope. Besides, another playlist with videos about the research activities carried out in some partner institutions and telescopes like IAA-CSIC, IAC, and GREGOR have been included. We encourage other members of the EST community to submit their institutional videos to showcase them in this section too.




*The EST YouTube channel*

In addition, visitors can learn more about the EST project through videos and presentations that show what we do and where we want to go, together with interviews and summaries of meetings that reflect some of the activities carried out during these years.

Furthermore, people interested in the construction and inner workings of the European Solar Telescope can watch several 3D animations of EST. They range from panoramic views of the building to details of the dome, the telescope, the optical path, and the mirrors. This information is complemented with other videos about the construction of the EST model.

The EST YouTube channel has received 9.000 views so far and is followed by more than a hundred subscribers. From the EST Communication Office, we encourage all partners and people interested in the project to visit it, subscribe, and use and share its videos. The address is https://www.youtube.com/user/ESTtvCHANNEL.

# "SOLAR MISSION EST": THE VIDEOGAME

*The astronomers and engineers that will use EST in the future are now kids. This videogame addresses kids between 8 and 12 and anyone interested in science.*


*Characters of "Solar Mission EST". From left to right: Spot, Flare, Eclipse, UV, Ms. Prominece and Spectro.*

The astronomers and engineers that will use EST in the future are now kids. The videogame "Solar Mission EST" is focused on bringing solar physics research closer to them, in a funny and entertaining way. A team of solar astronomers with superpowers will help us achieve that goal. They will have to figure out what is happening on the Sun… and save the world!

This activity sets off with the previous experience of the video game "Let's go to Mars", part of the H2020 UPWARDS project devoted to the exploration of Mars. That experience was very successful and showed a new way to communicate science and technology using the latest methodologies. The EST videogame is designed for Android and iOS mobile platforms. The target audience is kids between 8 and 12 years, together with people of any age interested in science and games.

The adventure begins with people waking up one day, only to discover that their toasters shoot bread slices and their ovens try to kill them. Because of an unknown reason, the magnetic field of the Sun has gone crazy and this affects all the machines on Earth, spreading chaos. To solve this situation, it is necessary to complete the construction of the European Solar Telescope, a big science infrastructure and our only hope to study the Sun in detail.

To accomplish this task, a group of solar astronomers will have the mission of collecting pieces to make EST work. As in real scientific research, the astronomers in different observatories will have to help their colleagues, providing them with some data or information needed to complete a task. The aim is to show that EST is the result of collaborative work between European partners. Moreover, the players will be introduced to some of the most relevant topics of solar research, such as sunspots, magnetic fields, granulation, etc. They will also work with the instruments and technology needed to study the Sun, including adaptive optics systems, spectrographs, filtergraphs…

"Solar Mission EST" is being developed by the EST Communication Office at IAA-CSIC with the help of Gambusino Labs. Many members of the EST consortium have contributed ideas to define the concept, targets, characters, and challenges that will be part of the game. The character design phase is over now. We will have six solar astronomers, one for each scenario plus EST. Their names have been chosen to be reminiscent of solar structures and processes: Spot, Flare, Eclipse, UV, Ms. Prominence, and Spectro. The scenarios are inspired in real European observatories and are currently being programmed.

The videogame "Solar Mission EST" will be released in a few months time.

# EST VIRTUAL SOLAR KIT: HANDS-ON ACTIVITIES FOR SECONDARY SCHOOL STUDENTS

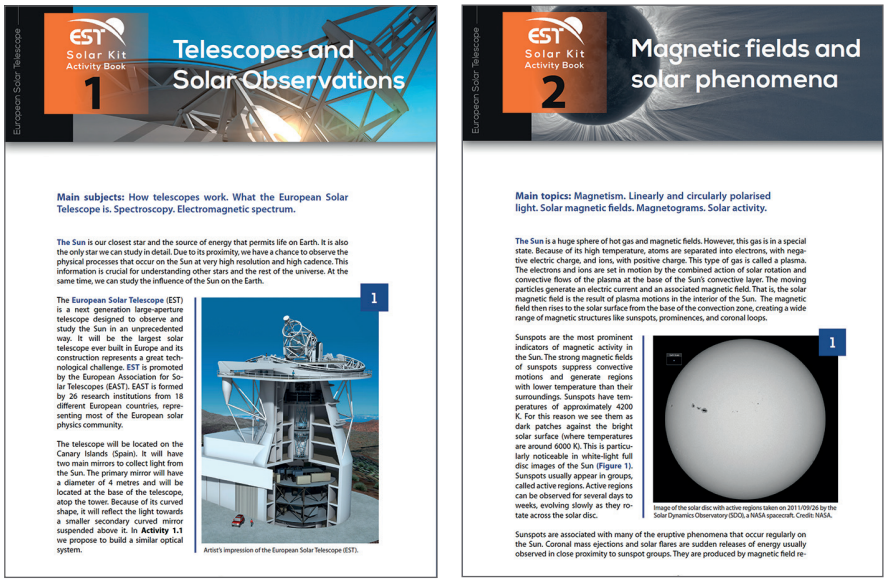
*The activities deal with telescopes, magnetic fields and solar phenomena. They are targeted to students between 10 and 16*

The EST Communication Office has recently released two hands-on activity books for secondary school students, as part of its commitment to the educational community. They form the EST Virtual Solar Kit, one of the deliverables of the PRE-EST project.

The two activity books deal with "Telescopes and solar observations" and "Magnetic fields and solar phenomena". These topics are cornerstones of the EST project, so they were chosen for the EST Virtual Solar Kit from the outset. Each book contains three activities for students between 10 and 16, which can be carried out in the classroom in sessions of one hour or less. They also have a short introduction to put the various activities in context, with practical guidelines for the teacher.

Most of the activities have been developed by the EST Communication Office from scratch. Some are truly unique because they address topics never considered before or because they use innovative approaches. For example, in activity 1.1, students learn how solar telescopes —in particular EST— work. They are asked to build a very basic telescope using two concave mirrors of the type employed for make-up. In this way, we want them to understand the concept of light reflection and how a telescope forms an image of an object. Furthermore, the students learn basic optical concepts such as the focal length.

This is just one example out of a range of activities devised to show the students how we observe the Sun, the instruments we build, the tools we use, the solar features we study, and the physical concepts we apply, including optics, spectroscopy, polarisation, and magnetism. We hope these activities are useful resources to teach science and engineering topics in the classroom, particularly those related with astronomy and solar physics. We also hope they will engage the educational community, both teachers and students.




*Covers of the two activity books*

The Virtual Solar Kit can be donwloaded from the EST website. It is currently offered in English, but translations to other languages are already underway.

The EST project is commited to promoting STEM topics in school. This is achieved through a range of actions, such as developing detailed hands-on activities for students, producing innovative audiovisual materials like The QuEST cartoon video series, and creating repositories of high-quality images and videos of solar features, solar telescopes, and the history of solar physics. We also actively participate in educational events, such as the Spanish Meeting of Astronomy Teaching held in Úbeda in June 2019. The EST project is in contact with the educational community with a view to support their activities and develop synergies. After all, the kids and teenagers of today are the future users of the European Solar Telescope!

To learn more about the educational resources developed by the EST project, check out www.est-east.eu/education.

**FULL SET OF ACTIVITIES**

**Book 1. Telescopes and solar observations**
- How a solar telescope works
- Build a spectroscope
- Measuring the rotation of the Sun

**Book 2. Magnetic fields and solar phenomena**
- Simulating solar magnetic structures
- Experimenting with circularly polarised light
- Measuring solar magnetic fields

# EST NEWCOMERS

## MANUEL CABRERA MORALES

### SOLARNET SOFTWARE ENGINEER

Manuel has a degree in Computer Engineering from the University of Granada. He has more than 10 years of experience in the private sector, having worked for areas as diverse as online tourism and German automotive. During those years, he has always been involved in projects that required the automation of large amounts of data. Currently, he works on the optimisation and parallelisation of Milde-Eddington inversion codes for execution in HPC and GPU environments. He joined the IAA-CSIC team in June 2019.

## HARESH MANGHARAM CHULANI

### AO CONTROL ENGINEER. MCAO TEAM

Haresh obtained his Bachelor and Master degrees in Telecommunication Engineering at University of the Basque Country and his PhD in Physics and Engineering at University of La Laguna. His PhD research consisted of a novel centroiding algorithm for a Shack-Hartmann wavefront sensor. He has more than 25 years of experience in astrophysical and scientific instrumentation, both ground and space based, working at the IAC's Electronics Department. His specialisation areas include digital and statistical signal processing, information theory and servocontrol design.

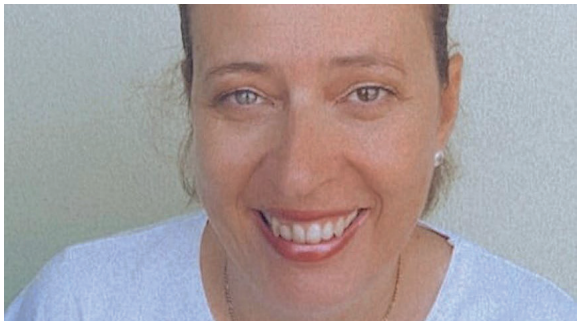
## CARLOS QUINTERO NODA

### SUPPORT SCIENTIST. EST PROJECT OFFICE

Carlos obtained his PhD in Solar Physics at the IAC and University of La Laguna in 2014. He then moved to Japan and worked at the Japan Aerospace eXploration Agency for four years. There, Carlos helped to design new instrumentation for the third flight of the Sunrise balloon and used 3D numerical simulations to study the best configuration to achieve the instruments' scientific requirements. After that, he spent one year at ITA-University of Oslo, where he improved his skills in working with numerical simulations. He also used that opportunity to start collaborating in the EST project.

## MARILUZ SÁNCHEZ RODRÍGUEZ

### EST PROJECT OFFICE



Mariluz is a technician in Business and Tourist Activities, and also has a superior cycle in Administration and Finance. She has worked as administrative staff in several public institutions. Since 2008 she works in the Administration Area of the Instituto de Astrofísica de Canarias. She joined the EST Project Office in 2018.

# EVENTS

## EST INVITED TALKS

Due to the COVID-19 crisis, most meetings that were scheduled for the second half of 2020 have been postponed to 2021. Until the normal activity resumes, a list of EST invited talks in past international meetings will be given here. An updated list is available on the EST website at http://www.est-east.eu/est-invited-talks

**EUROPEAN SOLAR TELESCOPE: RECENT PROGRESS**
Andreas Lagg in the *5th Asian-Pacific Solar Physics Meeting*, Pune (India), 3-7 February 2020

**FUTURE ADAPTIVE OPTICS INSTRUMENTATION AT THE CANARY ISLANDS**
Íciar Montilla in *Future instruments for the telescopes at the Observatorios de Canarias*, La Laguna (Spain), 11-13 November 2019

**SST AS A TRAILBLAZER FOR THE EUROPEAN SOLAR TELESCOPE**
Dan Kiselman in *Future instruments for the telescopes at the Observatorios de Canarias*, La Laguna (Spain), 11-13 November 2019

**EUROPEAN SOLAR TELESCOPE STATUS**
Mary Barreto in *Future instruments for the telescopes at the Observatorios de Canarias*, La Laguna (Spain), 11-13 November 2019

## OTHER EVENTS

**NASA HELIOPHYSICS SUMMER SCHOOL: EXPLOSIVE SPACE WEATHER EVENTS AND THEIR IMPACTS**
ONLINE, July 14-21, 2020

**3RD NCSP DKIST DATA TRAINING WORKSHOP: MILNE-EDDINGTON SPECTROPOLARIMETRIC INVERSIONS**
ONLINE, July 20-24, 2020

**SPIE ASTRONOMICAL TELESCOPES + INSTRUMENTATION**
San Diego (USA), August 3-7, 2020

**AGU FALL MEETING**
San Francisco (USA), December 7-11, 2020

**IAUS 367, EDUCATION AND HERITAGE IN THE ERA OF BIG DATA IN ASTRONOMY**
San Carlos de Bariloche (Argentina), December 9-14, 2020

**DYNAMIC SUN III: A NEW ERA OF MULTI-WAVELENGTH SOLAR AND STELLAR OBSERVATION**
San Pedro de Atacama (Chile), December 16-20, 2020

**43RD COSPAR SCIENTIFIC ASSEMBLY**
Sidney (Australia), January 28- February 4, 2021

**HINODE-14/IRIS-11 JOINT SCIENCE MEETING**
Washington DC (USA), May 24-27, 2021

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**ADDITIONAL CONTRIBUTORS**: Mary Barreto (IAC), Alberto Escobar (IAC), Sebastián Hidalgo Rodríguez (IAC), Víctor Aníbal López (IAA-CSIC), Miguel Núñez (IAC), Luzma Montoya (IAC), Carlos Quintero Noda (IAC), Rolf Schlichenmaier (KIS), Tirtha Som (KIS), Nauzet Vega (IAC)

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