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The Italian contribution to the design study of the European Solar Telescope EST: current status and future steps

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Abstract. The EST (European Solar Telescope) is a 4-m class telescope, four times larger than any existing high resolution solar telescope. It is designated with the highest priority among the ground-based, medium term (2016-2020) new projects in the ASTRONET Roadmap (Panel C). The EST will be equipped with a suite of instruments to perform spectropolarimetric and imaging observations at high spatial and temporal resolution in the range UV-NIR. The conceptual design study, which has been funded from EU in the framework of FP7, started on February 2008. We summarize the Italian participation to the EST project, which includes detailed design of various subsystems affecting the opto-mechanical structure, the suite of post-focus instruments, the data handling, and the control system.

Key words. Sun: high resolution observations – Sun: atmosphere – Sun: magnetic fields

1. Introduction

The main objective of the Design Study is to demonstrate the scientific, technical, and financial feasibility of EST to observe the solar photosphere and chromosphere by means of high resolution spectro-polarimetry in the visible and near-infrared.

The study started on February 2008. It is organized in three phases, with an approximate duration of one year each, corresponding to the following objectives: a) Phase I: Definition of technical requirements and alternatives, b) Phase II: Trade-off analysis of technical alternatives, c) Phase III: Preliminary design and analysis.

During Phase I, the Science Core Team established the science requirements, which then were translated by the Systems Engineering group to technical requirements for the main system and for all its components. Moreover, the technical alternatives for each sub-system were identified. The current Phase II works out the trade-off among the technical alternatives identified during Phase I, in order to derive the conceptual design for each sub-system.

Currently there are Italian researchers from the ten institutes (INAF: OAA, OACt, OAR, OATs, IFSI, UToV, UCal, UCt, UFi, UAq) and one medium-sized Company (SRS) involved in the EST study. They are working on the definition of Science requirements, optomechanic components (heat stop and rejector, MCAO system, M2), post-focus instru-

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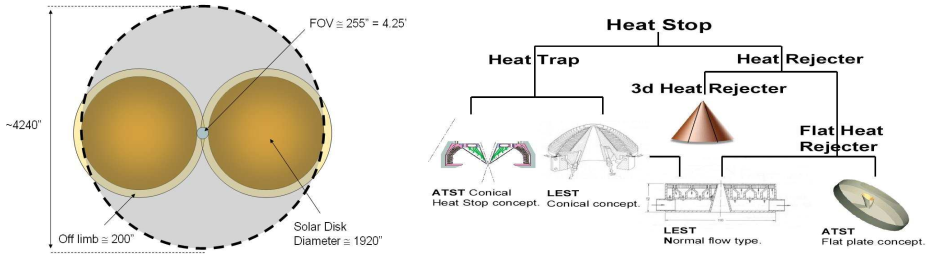

(a) (b)

Fig. 1. a) Solar images (yellow) on Heat Stop (gray). Assuming focal ranges from 8000 mm to 6000 mm, we obtain Heat Stop minimum sizes from 166 mm to 124 mm; b) Various heat stop design solutions.

ments (broad-band imager, tunable spectro-polarimeter), data handling, and observatory control. Some information about the activities carried out to date are summarized in the following.

More information about the EST project and the Italian participation can be found at http://www.iac.es/proyecto/EST/ and http://webusers.oact.inaf.it/estwiki, respectively.

2. Optomechanics

2.1. Heat Stop / Rejector

The Heat Stop (HS) presents to the optomechanical designer a collection of challenges that are at the heart of technical feasibility of the project. The HS acts like a diaphragm and removes (dumps and/or rejects) a large percentage of the light concentrated by the primary mirror (M1) on the first focal plane. This percentage will be assumed equal to 100 % because the diaphragm hole (diameter ∼ 8 mm) has an area which is negligible (∼ 1.7 %) respect to the entire Sun area (Fig. 1 a). Hence, the incoming heat power (from M1) ranges from about 12.8 to 14.4 kW (it depends on the primary mirror reflectivity). The large incident flux expected over a 4-m telescope HS is leading researchers and engineers to investigate innovative architectural alternatives for effective, reliable and secure systems. Several HS architectures, which employ pseudo-conical or flat structural designs, are proposed and analyzed (Fig. 1 b). Multiple parameters, such as heat dumping efficiency, mechanical accommodation, optical performance, safety, cost, and restoration strategy have to be considered for the architectural comparison.

If the Heat Trap configuration is chosen the HS must dissipate the entire incoming heat power. But this is not the only problem because, whatever be the HS diameter, the heating power is always concentrated on the same area that is on a ”hot spot” corresponding to the solar image on the focal plane. The heat flux density on the hot spot ranges 3.3 to 3.7 MW/m^2, that is 330 to 370 W/cm^2. If a Heat Rejecter configuration is chosen, a large amount (from 85% to 95%) of incoming heat flux is reflected away, but the residual 5% to 15% must be dissipated in any case. This means that the heat power to be dissipated ranges 0.7 to 2.9 kW, and that the heat flux density is about 19-50 W/cm^2.

3. MCAO

Using LOST (Layer Oriented Simulation Tool) code (Arcidiacono et al. 2004) and a Solar Package plug-in, we have simulated EST MCAO performances. We study different AO configurations to determine their performance in correcting the wavefront.

The analysis of the efficiency of wavefront reconstruction has been addressed by using a modal base (Zernike and Karhunen-Loeve) approach. We estimate the minimum number of Zernike polynomials necessary to correct for the turbulent layers. We study new basis or-

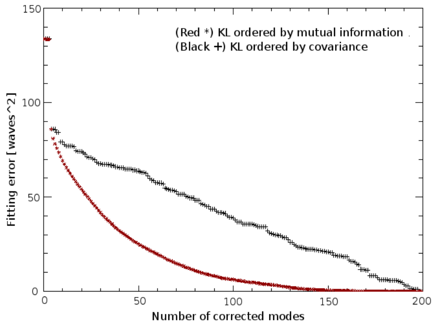

Fig. 2. Fitting error using modal base ordering by covariance (black) or mutual information (red).

Table 1. BBI Detector Requirements

Parameter	Range
Format	4k × 4k → 6k × 6k (FOV: 2' × 2') 8k × 8k → 12k × 12k (FOV: 3' × 3')
Pixel Size	10 - 20 μm
Well Depth	60000 e^-
Frame rate	20 - 100 frame/s
Bit-pix	16
Read noise	< 10 e^-
Dark Current	Few e^-/s
Quantum Efficiency	$> 60\%@\lambda < 400$ nm $> 80\%@\lambda > 400$ nm

dering to optimize the WF reconstruction with fewer modes.

For example in Fig.2 we present the different performance obtained by reordering the K-L polynomials by covariance or mutual information: the same WF reconstruction error can be obtained with fewer polynomials if they are ordered by mutual information (MI). The MI is a measure of how much information can be carried by each KL polynomial. We have found that MI is a powerful tool to choose the best ordering for a modal basis and this produces the steepest fitting error functions, allowing us to reduce basis dimension with a faster descending fitting error.

Table 2. Tunable Spectro-polarimeter characteristics

Parameter	Range
Wavelength range	850 - 1090 nm
Spectral resolving power	167400 - 200000
Parasitic light	0.73 % - 1 %
Ghosts	0.8 %
Field Of View	72 arcsec
Exposure time (S/N ≥ 100)	4 - 5 ms
Spatial sampling	2 - 2.6 pixel/res. el.

4. Instruments

4.1. Broad Band Imager

The Broad Band Imager (BBI) is aimed at obtaining high spatial resolution images over the full EST telescope field of view at multiple wavelengths and at high frame rate. Field of view will be 2'x 2' (goal 3' x 3'), angular resolution will be better than 0.04" at 500 nm, spectral range will span from 390 nm (goal 350 nm) to 900 nm.

The BBI will consist of re-imaging optics, beam splitters and dichroics to accommodate from 3 to 5 different channels working simultaneously. It will have a minimum of 9 filters with band-passes between 0.05 nm to 0.5 nm. To achieve the maximum spatial resolution, the instrument shall implement one of the image reconstruction techniques. Speckle, Multi-Object Multi-Frame Blind Deconvolution (MOMFBD) and Phase Diversity methods are under consideration. The number of detectors as well as some of their characteristics will depend on the adopted reconstruction technique (see Table 1).

4.2. Tunable spectro-polarimeter

The main characteristics of the tunable spectro-polarimeter are reported in Table 2.

5. Data handling and control

The development of the general strategy for controlling the observatory during the operational phase of the EST and for handling the data generated by the telescope is in charge of INAF researchers. The analysis of technical requirements derived from science cases showed that the system to be controlled is composed of a) the telescope (pointing-tracking, mechanical devices, AO/MCAO sub system), b) the auxiliary full-disk telescope, c) the instruments and detectors, d) the dome and surrounding environment. The identification of functional requirements pointed out that, as to the telescope control, the EST shall have performance requirements similar to those of current medium size night-time telescopes. The survey of existing and future projects for solar, night-time, and radio telescopes showed an increasing tendency of observatories in adopting common solutions, industry standards, and common software. Distributed control has become a standard. In terms of programming languages, Java is used for high-level software; C/C++ are adopted for low-level and real-time software. Python seems widely adopted as a scripting tool; Java and Python/Tk are mostly used for the presentation layer; XML for data representation. All adopted databases support SQL interfaces.

The survey of existing and future projects also showed that current night-time telescopes and newer solar projects consider the development of data handling system as an integral part of the telescope development. The main functional requirements identified from science cases include the handling of scientific data generated by the EST, the monitoring of data and metadata quality, the preliminary processing at the telescope of the data generated for quick-look purposes and data volume reduction, and the delivery of calibrated data, science-ready and OV-compliant, to final users. However, the data rate (10-200 GB/s) and data volume (several 100's TB/day) envisioned for the EST are about ten times larger than those of the most data demanding night-time projects. This points to the need to consider very efficient means to transmit data and metadata from the instruments and telescope to a real-time repository, as well as to identify very efficient means to process the data and to deliver them to off-site institutes and users.

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References

Arcidiacono, C., Diolaiti, E., Tordi, M., Ragazzoni, R., Farinato, J., Vernet, E., Marchetti, E. 2004, Applied Optics IP, 43, 4288

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