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# EST: the European future of solar ground-based observations

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**Abstract.** EST (European Solar Telescope) is a pan-European project involving 29 partners from 9 different countries (14 scientific institutions and 15 industries). It aims at the realization of a 4-m class solar telescope, with spectropolarimetric and imaging instruments characterized by high spatial and temporal resolution and observing in the wavelength range UV-NIR. EST is aimed at answering to a number of questions made by the international scientific community: determine the mechanisms responsible for the interaction between magnetic fields and plasma, single out the physical processes at the basis of energy transport in the solar atmospheric layers, acquire the capability of predicting phenomena that might directly or indirectly affect the Earth, etc. At present the project is in the Design Phase Study, financed by the European Union in the framework of FP7 - Research Infrastructures.

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

## 1. Introduction

The need to realize a next generation large aperture solar telescope to fully understand the fundamental processes of plasma physics that are at work in the outer layers of the Sun is unanimously shared by solar physicists.

In this regard, we remind that in the draft report *A Science Vision for European Astronomy* a principal facility is recommended: A large-aperture (3-5 m) solar telescope with adaptive optics and integral-field spectropolarimeters to observe astrophysical processes at their intrinsic scales, and thereby observe the interaction of magnetic fields and plasma motions in the solar atmosphere.

In the last years, several European institutes have reached a high degree of competence in projecting, building, and managing instruments which allow state-of-the art ground-based solar observations. The combined European expertise makes now the design and construction of a large aperture solar telescope and related instrumentation feasible, minimizing risks and exploiting the strengths of each country.

In this framework, the consortium EAST (European Association for Solar Telescopes) was formed in 2006 with the aim, among others, of undertaking the development of the European Solar Telescope (EST), to keep Europe in the frontier of international Solar Physics.

Several partners of the EAST consortium, together with a number of industrial partners, in order to proceed with the realization of EST, submitted a funding request to the European Union (EU) in the framework of the Seventh Framework Program - Capacities Specific Programme - Research Infrastructures.

The funding request, characterized by a total budget of 6.7 M Euro, was accepted, with a contribution from the EU of 3.2 M Euro. The starting date of the contract was February 1, 2008 and a Kick-Off Meeting was held in Madrid on 21-22 February 2008.

The main objectives of the EST project are summarized in the following paragraph, reporting a part of the FP7 proposal (Annex I - Description of Work).

The optical design and instrumentation of EST should be optimized for studies of magnetic coupling between the deep photosphere and upper chromosphere. This will require diagnostics of the thermal, dynamic and magnetic properties of the plasma over many scale heights, by using multiple wavelength imaging, spectroscopy and spectropolarimetry. The EST design will therefore strongly emphasize the use of a large number of instruments simultaneously, thereby improving photon efficiency and diagnostic capabilities relative to other existing or proposed ground-based or space-borne solar telescopes. To implement the EST science goals, also high spatial and temporal resolution will be needed.

## 2. Scientific Objectives

The Science Core Team (SCT) of the EST project has the role of defining the science requirements that allow starting Design Study activities in all Work Packages (see Section 3).

The following main science goals have been identified:

- Emergence and cancellation of magnetic flux (surface manifestations of magneto-convection; evolution of small-scale magnetic structures; turbulent dynamo)
- Photospheric/chromospheric magnetic coupling (magnetic topology of the photosphere and chromosphere; conversion of mechanical to magnetic energy in the photosphere; magnetic twist and torsion)
- Chromospheric heating (wave propagation from photosphere to chromosphere; energy dissipation in the chromosphere; chromospheric nanoflares; large-scale chromospheric release of magnetic energy; observational determination of electric currents)
- Magnetized plasma processes (dynamics of large-scale magnetic structures; wave mode conversion; non-ideal MHD and electric fields)
- The solar corona (boundary conditions for coronal studies; dynamics of the higher atmospheric layers)

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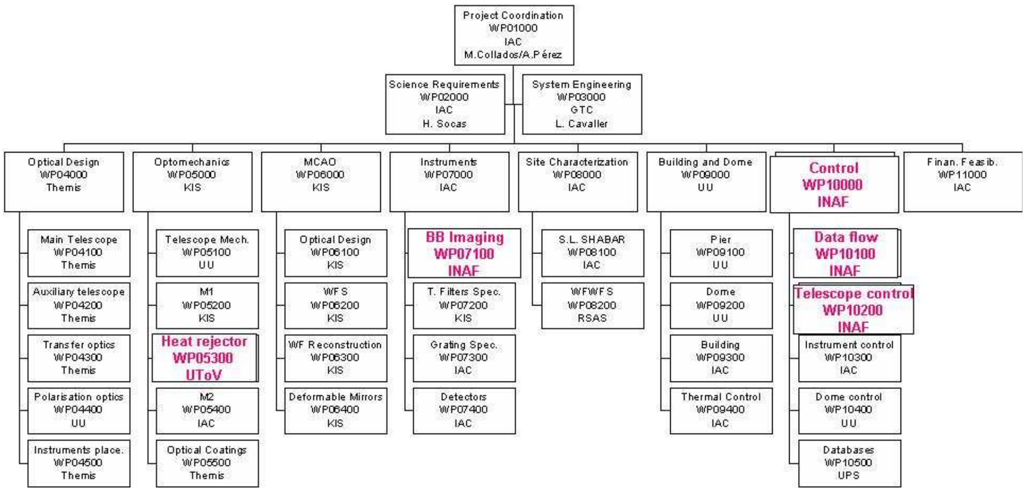



**Fig. 1.** Work Packages in the EST Project. The boxes with red text indicate the Work Packages leaded by Italian partners.

- The explosive Sun (solar flares; magnetic complexity and flare prediction; the fine structure of white-light flares)
- Atomic physics (atomic polarization; testing quantum theory predictions)
- Non-solar astrophysics (stellar magnetism; planetary physics; accretion disks and protoplanetary systems; detection of exoplanets)

The careful examination of the science requirements led the SCT to provide the following indications:

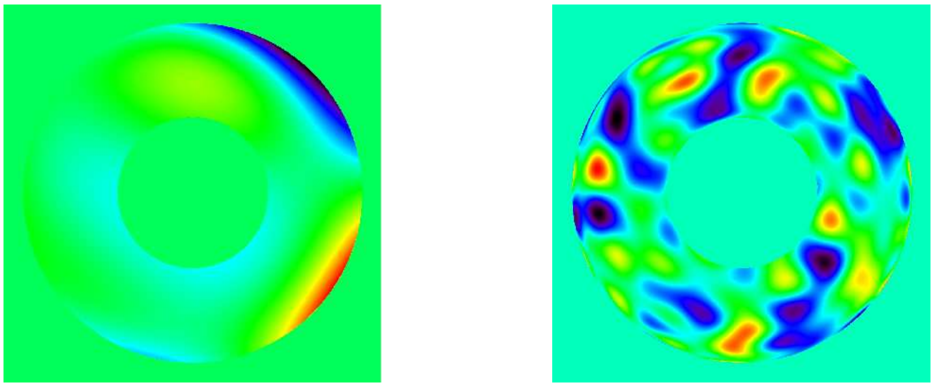
- Broad Band Imager: Continuum at 350 nm (Balmer), 417 nm (Paschen),840 nm (Brackett), 1600 nm; Spatial resolution: $\leq 0.05''$ with optimal resolution over $30'' \times 30''$; Field of view $2' \times 2'$
- Tunable filter: Photosphere: Fe I 525, 557, 630, 1565 nm; Chromosphere: Ca II H line, $H_\alpha$, Ca II IR, He I 1083 nm; Spatial resolution: $\leq 0.1''$; Field of view $30''\times30''$, $1'\times1'$, $2' \times 2'$, mosaics of $30'' \times 30''$
- Spectrograph: Spatial resolution: $\leq\ 0.1''$; Field of view $2'$ with optimal resolution over $30''$.

Moreover, other requirements concern the total telescope transmission, that must be better or of the order of 10 % and the polarimetric sensitivity, whose required value is $10^{-4}$ in S/I, where S is any Stokes parameter.

## 3. Work Package distribution in the project

The Design Study aims at demonstrating the scientific, technical and financial feasibility of EST. To this aim, the project is divided in 11 Work Packages:

- WP01000 - Project Coordination and Management
- WP02000 - Science Requirements
- WP03000 - System Engineering
- WP04000 - Produce the telescope optical design
- WP05000 - Optomechanical structure
- WP06000 - Multi-Conjugate Adaptive Optic (MCAO) system, capable of giving diffraction-limited images
- WP07000 - Instruments that best suit the science requirements (Broad-Band Imager, Tunable filter spectropolarimeters, Grating spectropolarimeters, Detectors)
- WP08000 - Site characterization (short and large baseline SHABAR)
- WP09000 - Design solution for pier, dome and building
- WP10000 - Data acquisition and control



(a) (b)

**Fig. 2.** (a) Wavefront reconstruction with 10 Zernike modes. (b) The same wavefront reconstructed with 10 Karhunen-Loeve modes. It is worth to note that the Karhunen-Loeve reconstruction already contains very high spatial frequency features.

**Table 1.** List of Italian Institutions and Industry involved in the EST Project

| | Institute | Work Package Number |
|---|---|---|
| INAF | | |
| | IFSI | WP 5000 |
| | OAA | WP 6000, 7000, 10000 |
| | OACt | WP 7000, 10000 |
| | OAR | WP 7000, 10000 |
| | OATs | WP 10000 |
| University | | |
| | UniAq | WP 10000 |
| | UniCal | WP 8000 |
| | UniCt | WP 7000 |
| | UniFi | WP 2000 |
| | UniToV | WP 5000, 6000, 7000 |
| Industry | | |
| | SRS | WP 5000 |

– WP11000 - Financial feasibility

## 4. The Italian contribution to the EST project

In Fig. 1 a schematic breakdown of the Work packages is reported: besides the sub-Work packages in which each WP is divided, it is possible to see the scientific institutions leading each WP and sub-WPs.

In the same Figure the WPs or sub-WPs leaded by Italian Institutions are evidenced by red characters. Moreover, in Table 1 these Institutions are listed, together with the relevant WPs in which they are involved.

As an example of the contribution of the Italian scientists to the project, we report the results obtained from the Tor Vergata team on the wavefront reconstruction with 10 Zernike modes (Fig. 2 (a)) and with 10 Karhunen-Loeve modes (Fig. 2 (b)).

In conclusion, the presence of the Italian institutions (and specifically, of 27 researchers) in the Design Study of EST, indeed witnesses the strong interest and support of the Italian researchers involved in ground-based solar physics to the development of a next generation large European solar telescope.