Session: Coordinated Heliophysics Science

Ground based: EST

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> METIS Workshop: 21 – 23 November 2018, Goettingen, Germany



- ♦ European Solar Telescope
 (EST)
- ♦ EST and Coronal Science





EST: European Solar Telescope

- <u>Who:</u> EAST: European Association for Solar telescopes
- <u>Why</u>: undertaking the development of a ground-based facility: the European Solar Telescope, to keep Europe on the front line of Solar Physics
- <u>What</u>: EST will observe the layers of the solar atmosphere from the base of the photosphere to the high chromosphere
- <u>Where</u>: The site will be at the Canary Islands
- When: First light in 2027

New Strategic European Infrastructure since March 2016 (ESFRI Roadmap)





EST main objectives is to answer to the following questions

- How does the magnetic field evolve and emerge to the solar surface ?
- How is the energy transported from the photosphere to the chromosphere ?
- How is the energy released deposited in the upper atmosphere ?
- Why does the Sun have a hot chromosphere and a hot corona ?
- What causes the explosive events (flares, filament eruptions, CMEs) ?

EST: European Solar Telescope

- 4-meter diameter
- On-axis Gregorian configuration
- Alt-Az mount



- Simultaneous instrument stations (each with several wavelength channels)
 - Broad-band imager
 - Narrow-band tunable imager
 - Grating spectrograph
- MCAO integrated in the optical path
- Spatial resolution on the solar disk: 30 km (goal 20 km)











Telescope and instrumentation key capabilities

- High precision polarimetric capabilities, for accurate magnetic field determination
- High angular resolution, with AO and MCAO for atmospheric distortion correction
- Simultaneous observation of different layers of the solar atmosphere





EST WILL COMBINE THE BEST OF PRESENT SOLAR TELESCOPES AND LARGELY IMPROVE THEIR PERFORMANCE

EST and Coronal Science

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EST is not optimised to carry out Coronal Science as one of its primary objectives, but it is well suited to providing complementary observations of the underlying photosphere and chromosphere that will significantly advance our understanding of coronal physics in a number of areas.

"...co-ordination with spacebased facilities will be required"

SRD, July 2018



SRD open to the Scientific Community for contributions till the end of October 2018

EST and Coronal Science

Coronal Science

- Sunspot light-bridges
- Light Walls
- Origins of the solar wind
- Probing pre-flare triggers
- Macrospicules/spicules and Transition Regions Quakes (TRQs)
- Ellerman bombs

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Solar Flares and Eruptive Events

- Radiation, structure and evolution of the flare lower atmosphere
- Velocity structure of the flaring atmosphere
- Diagnostics for non thermal particles
- Flare oscillations and Sunquakes
- Large-scale structure and evolution of the magnetic field
- Small-scale structure and evolution of the magnetic field
 - Filaments in flaring active regions
- Coronal Mass Ejections

Orígíns of the solar wind





Debates continue about where in the atmosphere the upflows originate.



Solar Orbiter will provide multivantage points measurements of coronal outflows, but need corresponding chromospheric magnetic field measurements in order to determine the processes that produce them, e.g. **lowaltitude reconnection**, presence of **small-scale open field at AR boundaries**



Orígíns of the Solar Wind

Observing plan aims to explore the role of small-scale photospheric and chromopsheric dynamics in driving the solar wind at the edges of active regions and coronal holes where persistent upflows are observed in coronal lines.

Instrument 2	Broad-band Imagers	
Goal	Detect small-scale photospheric and chrom mation on the surrounding AR/CH.	ospheric activity. Provide context infor-
	Requirement	Goal
Photosphere	G-band	
Chromosphere	Ca II H line core & line wing	+Ca II 854 nm, Hα
FOV	$60'' \times 60''$	$120'' \times 120''$
Spatial resolution	Diffraction limit	
SNR	> 100	
Cadence	5 s	1 s
Notes	See above for co-ordination requirements.	

Instrument 1	IFU spectropolarimeters	
Goal	Determine magnetic field topology and dynamics of the photosphere and chromo- sphere at active region and coronal hole boundaries as a function of height. Combine with UV/EUV imaging and spectroscopic observations of TR and coronal response using Solar Orbiter EUI/SPICE and/or Solar C EUVST.	
	Requirement	Goal
Photosphere	FeI 525.02, FeI 630, FeI 1565 nm	+Si I 1082.7 nm
Chromosphere	CaII H ₂ 396.8, CaII 854, He I 1083 nm +Na I D ₂	
FOV	$10'' \times 10''$	As large as possible
Spatial resolution	0.05"	
SNR	2000	
Integration time/tile	5 s	
Cadence	60 s	30 s
Notes	These observations need to be co-ordinated with space platforms to enable the connection to the TR and corona to be made. For Solar Orbiter this should be done at conjunction. This OP links to OP 3.3.1 on spicule ac- celeration on disk, so could potentially be merged, and is very similar to DKIST SUC-61 created by Louise Harra. Appropriate Solar Orbiter SOOPs, as listed in SUC-61 are L_BOTH.HIRES+LCAD_CH_Boundary_Expansion; L_SMALL_HIRES_HCAD_SlowWindConnection; L_SMALL_HRES_HCAD_Fast_Wi L_SMALL_HRES_HCAD_SlowWindConnection; R_SMALL_HRES_MCAD_PolarOb EST can potetially provide greater multi-height coverage.	

Erderly, Mathiudakis, Matthews, SRD

It will measure the magnetic field strength and direction from the photosphere to the upper chromosphere using spectropolarimetry, and the plasma dynamics using 2D spectroscopy to determine intensity, line widths, and line of sight velocities.

Measurements should be coordinated with servations, space platforms to provide the link to coronal spectroscopy, and ideally with insitu measurements of plasma composition.

Flares: The parad to of the magnetic coupling of the solar atmosphere

The main question of flare physics is to understand:

How the energy, previously stored in a stressed coronal magnetic field \rightarrow

is released so rapidly,
transported through the atmosphere of the Sun,
converted into the kinetic energy of the non-thermal particles and into the flare's radiation output.

Their relation to CMEs (yes/no, before/after).



Chromospheric footpoint UV/optical emission, fast electrons/ions

Fletcher, 2014

Probing pre-flare triggers

• This observing plan aims to explore the role of small-scale photospheric and chromopsheric dynamics in the period before flare/CME onset and its relationship to TR and coronal dynamics.

Instrument 2	Broad-band Imagers	
Goal	Detect small-scale photospheric and chromospheric activity around the neutral line, including flux emegernce, cancellation. Provide context information on the surround-ing AR.	
	Requirement	Goal
Photosphere	G-band	
Chromosphere	Ca II H line core & line wing	+Ca II 854 nm, Hα
FOV	$60'' \times 60''$	$120'' \times 120''$
Spatial resolution	Diffraction limit	
SNR	> 100	
Cadence	5 s	1 s
Notes	See above for co-ordination requirements.	

T () 1		
Instrument I	IFU spectropolarimeters	
Goal	Determine magnetic field topology and dy	namics of the photosphere and chromo-
	sphere within the vicinity of the neutral line	in an active region as a function of height.
	Combine with UV/EUV imaging and spect	roscopic observations of TR and coronal
	response using Solar Orbiter EUI/SPICE an	d/or Solar C EUVST.
	Requirement	Goal
Photosphere	FeI 525.02, FeI 630, FeI 1565 nm +SiI 1082.7 nm	
Chromosphere	Ca II H 396.8, Ca II 854, He I 1083 nm	+NaI D ₂
FOV	$30'' \times 30''$	As large as possible
Spatial resolution	0.05''	
SNR	2000	
Integration time/tile	10 s	
Cadence	100 s	30 s
Notes	These observations would have to be a	TOO but need to be co-ordinated with
	space platforms to enable the connection	to the TR and corona to be made. For
	Solar Orbiter this could be done either at	conjunction or quadrature, with quadra-
	ture providing a 3D view of the overlying corona, particularly if combined with	
	Solar C EUVST. Relevant SOOPs: L_FULL_HRES_HCAD_Coronal_Dynamics;	
	R_SMALL_HRES_HCAD_AR_Dynamics; R_SMALL_HRES_HCAD_RSburst:	
	L_FULL_HRES_HCAD_Eruption_Watch	

It will measure the magnetic field strength and direction from the photosphere to the upper chromosphere using spectropolarimetry, and the plasma dynamics using 2D spectroscopy to determine intensity, line widths, and line of sight velocities.

Measurements should be coordinated with space platforms to provide the link to coronal spectroscopy.

Erderly, Mathioudakis, Matthews, SRD

CMEs sources and temporal relations with flares

There are still some difficulties in determining the relationship between flares and CMEs, due to the use of different instruments needed to observe phenomena on the disk and in the outer corona.

Instrument 1	SP_vis & SP_ir	
Goal	Search for any brightening or flaring emiss rally correlated with a CME. Infer the mag involved in the eruption leading to the coror	tion which could be spatially and tempo- gnetic field configuration of the flux rope nal mass ejection.
	Requirement	Goal
Photosphere	Fe I 1565	+Si 1 1082.7 nm
Chromosphere	Сан 854 nm, На, Ван 455	+He1 1083 nm
Wavelength samples	15	20 for chromospheric lines
FOV	$60^{\prime\prime} \times 60^{\prime\prime}$	$120'' \times 120''$
Spatial resolution	0.'05	
SNR	200	
Cadence	5 s	
Notes	Raster scans with slit parallel to the magnetic flux rope axis to look for plasma mo- tions and for brightenings in the surroundings.	

Instrument 2	BB_vis & BB_ir	
Goal	Detect flare signatures at photospheric and chromospheric heights. Context infor- mation on the active region morphology before, during and after the flare - CME occurrence.	
	Requirement	Goal
Photosphere	G-band	+CN bandhead
Chromosphere	Ca II H line core & line wing	Hα
Wavelength samples		
FOV	$120'' \times 120''$	As large as possible
Spatial resolution	0.1	
SNR	> 100	
Cadence	10 s	5 s
Notes	These observations should be complem	nented with data acquired by coronagraphs.

This circumstance can have different implications, like for instance the fact that there can be a loss of information during the time when the plasma is travelling within the region covered by the occulting disk of the coronagraph.

Fletcher, Zuccarello, Kuckein, Danilovic, SRD

EST and METIS: Synergies and complementarities:

 How energy is deposited in the polar regions where the fast solar wind is generated and accelerated ?

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- Which are the sources of the slow solar wind at lower latitudes ?
- How does the global corona evolve and how does give birth to the huge coronal mass ejections characteristic of solar activity ?



Previous experience, advantages and limitations

Ground-based telescopes:

Higher angular resolution
 Possibility to repair, upgrade instruments
 Change of the target in real time
 Unique observations in the Hα line (often patrol observations, but low spatial resolution)

Wavelength range límíted by Earth atmosphere
 Data Acquisition strongly dependent on seeing conditions
 Day/night constraints

Prevíous experíence, advantages and límítatíons

Satellite Instruments:

No seeing problems
 Public release data
 Pipelines (for instance, Solar Software, almost immediately available
 Data archives and repository well organized

Telemetry and data transfer limitation
Effects of energetic particles during solar explosive events
Difficulty to upgrade or repair
Lost of satellite control (see, e.g. SOHO)
Limited time interval of satellite observations (10 y ?)

Conclusions

- EST: a ground-based 4-m solar telescope optimized for spectropolarimetric observations of the photosphere and chromosphere
- EST is not optimised to carry out Coronal Science as one of its primary objectives, but it is well suited to providing complementary observations of the underlying photosphere and chromosphere
- Several Science Cases (and relevant OPs) concerning Coronal Science and the main objectives of METIS are already present in the Science Requirement Document
- SRD: need of complementary observations.

Thanks for your attention

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