EST Science Meeting

Giardini-Naxos – ATAHOTEL Naxos Beach Resort

11 – 15 June 2018

Rationale

The European Solar Telescope (EST), is a 4-metre class aperture telescope designed to investigate our active Sun at very high spatial and temporal resolution and unprecedented polarimetric sensitivity. Equipped with state-of-the-art instrumentation, it will help scientists understand magnetic coupling throughout the solar atmosphere. EST will be installed in the Canary Islands (Spain) to benefit from unique observing conditions. First light is planned for 2027.

The project is promoted by the European Association for Solar Telescopes (EAST) whose aim is to ensure access of European solar astronomers to world-class high-resolution ground-based observing facilities and keep Europe at the forefront of solar physics. Thanks to EU FP7 and H2020 funding, joint research activities have been carried out to determine the most advanced technological solutions that would allow the realization of this state-of-the-art 4-metre telescope. In March 2016, EST was included in the European Strategic Forum on Research Infrastructure (ESFRI) Roadmap and it is now in its Preparatory Phase. During this phase, the Science Requirements are being reviewed by the Science Advisory Group (SAG), taking into account both the advancement in our knowledge of the physics of the Sun and the progress in technology.

This upcoming EST Science Meeting aims at gathering scientists who wish to present their most recent theoretical and observational research in the field. The meeting will highlight the key science cases that will be addressed by the 4-metre class solar telescopes, and the synergies with both current and future ground-based and space-borne facilities. During the EST Science Meeting the main characteristics and science goals of the EST project will be presented to the scientific community to maximize the sharing of knowledge about the project and provide awareness of the potential telescope capabilities. It will also provide an opportunity to contribute to the definition of the telescope Science Requirements.

A Science Requirements Document, describing how and why the unique capabilities of EST will provide answers to several key science questions, will be presented at the meeting. EST will be the heritage of the entire solar physics community, and for this reason it is expected that the scientific community and in particular the EST Science Meeting participants, will contribute with science cases that will then be reflected in the Science Requirement Document.

SOC

L. Belluzzi	*IRSOL*, Switzerland
M. Carlsson	*University of Oslo*, Norway
M. Collados Vera	*Instituto de Astrofísica de Canarias*, Spain
J. Jurčák	*CAS*, Czech Republic
M. Mathioudakis	*Queen's University Belfast*, UK
S. Matthews	*UCL-Mullard Space Science Laboratory*, UK
R. Erdély	*University of Sheffield*, UK
R. Schlichenmaier	**Co-Chair**, *KIS*, Germany
D. Utz	*IGAM*, Austria
F. Zuccarello	**Chair**, *Università degli Studi di Catania*, Italy

LOC

C. Anastasi	*Università degli Studi di Catania*, Italy
G. Bellassai	*INAF–OACT*, Italy
M. Falco	*INAF–OACT*, Italy
M. González	*CSIC/IAA*, Spain
S.L. Guglielmino	*Università degli Studi di Catania*, Italy
A. Martín Gálvez	*Instituto de Astrofísica de Canarias*, Spain
E. Martinetti	*INAF–OACT*, Italy
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G. Santagati	*INAF–OACT*, Italy
F. Zuccarello	**Chair**, *Università degli Studi di Catania*, Italy

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List of Participants

Name	**Institution**	**Country**
ALLCOCK, Matthew	University of Sheffield	UK
ALSINA BALLESTER, Ernest	IRSOL	Switzerland
BELLO GONZÁLEZ, Nazaret	KIS	Germany
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CARLSSON, Mats	University of Oslo	Norway
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COLLADOS VERA, Manuel	IAC	Spain
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GÖMÖRY, Peter	AISAS	Slovakia
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JAIN, Rekha	University of Sheffield	UK

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LIU, Zhong	Fuxian Solar Observatory	China
LO PRESTI Domenico	Università di Catania	Italy
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MARTÍNEZ GONZÁLEZ, Marían	IAC	Spain
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RADZISZEWSKI, Krzysztof	University of Wrocław	Poland
REALE, Fabio	Università di Palermo	Italy
ROMANO, Paolo	INAF–OACT	Italy
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SOBOTKA, Michal	CAS	Czech Republic
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YARDLEY, Stephanie	University of St Andrews	UK
ZUCCARELLO, Francesca	Università di Catania	Italy

Abstracts

Session 1
The State-of-the-Art of the EST Project

The EST status

11 June
9:30 am
Report

Manuel Collados Vera[1] and the EST team

[1]IAC – Instituto de Astrofísica de Canarias, Spain

EST will be the largest solar telescope ever built in Europe. With a 4-metre primary mirror and state-of-the-art technology, it will furnish astronomers with a unique tool to understand the Sun. The main goal of EST is to investigate the structure, dynamics, and energetics of the lower solar atmosphere, where magnetic fields continually interact with the plasma, and magnetic energy is sometimes released in powerful explosions. Understanding these phenomena requires observing fundamental processes at scales of about 30 kilometres on the solar surface and short time scales. To accomplish this goal, EST will be equipped with the most advanced adaptive optics system and a suite of innovative instruments for high-resolution, high-sensitivity, multi-wavelength spectropolarimetric observations. The EST consortium successfully accomplished in 2011 the EST conceptual design, based on novel approaches thanks to the expertise accumulated by the EST partners in building powerful solar telescopes and instruments during the last decades. The inclusion of EST in the ESFRI roadmap in March 2016 represented a key milestone for the project, since it was recognised as a strategic European infrastructure that is expected to be ready for operations in about ten years from now. All these elements have led to the start of the Preparatory Phase of the project as an intermediate phase to consolidate its science goals, technical definition, legal issues and national budget contributions. In this talk, the most relevant aspects related to the present status of EST will be presented: main innovative technical characteristics, timeline, budget, preparatory phase, location of the facility, future legal entity for its construction and operation, as well as the expected involvement of the different European countries.

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11 June
10:00 am
Solicited

EST capabilities

Hector Socas-Navarro[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

In this talk I will discuss briefly the capabilities of the European Solar Telescope, according to its current specifications. The main distinctive feature of this telescope with respect to most other solar observing facilities is its large aperture which may be used to push the spatial resolution to diffraction limit or as a photon bucket for groundbreaking sensitivity. Some compromises are necessary in solar observations. The current plan for the EST instrumentation and its light distribution system allow for the required flexibility to achieve the optimal compromise in each scientific case. Integrated Multi-Congugate Adaptive Optics, polarimetric compensation and 2D spectro-polarimetry are some other outstanding features of the EST..

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11 June
10:20 am
Solicited

EST Multi-wavelength diagnostics

Christoph Kuckein[1]

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany

Over the past decades we have discovered that most of the processes on the Sun are coupled across many layers of the atmosphere. For instance, filaments and arch filament systems are best observed in the chromosphere and corona but are rooted in the photosphere. Another example are the changes in the vector magnetic field during flares which are noticible from the corona down to the photosphere. Furthermore, small magnetic flux emergence has been tracked observationally from the photosphere to the corona. Therefore, it is crucial to have simultaneous observations covering as many atmospheric layers as possible. The next generation of large solar telescopes will focus on the ability to simultaneously observe the Sun in many different wavelengths. Until now, this has been only possible by coordinating different ground and space based telescopes, in order to observe the same area on the Sun with different instruments. In this talk I will present some examples of recent multi-wavelength studies and show how the European Solar Telescope will improve such multi-wavelength observations.

Data centre activities – Towards an EST Science Data Centre

11 June
11:00 am
Solicited

Nazaret Bello González[1]

[1]Kiepenheuer-Institut für Sonnenphysik, Germany

We will present a number of activities on curation, dissemination and visualisation of solar data proposed by the European solar physics community within the framework of the SOLARNET H2020 and ESCAPE H2020 project proposals as a common effort and first steps towards building up a European Solar Data Centre, envisaged for EST.

Integral Field Units

11 June
11:20 am
Solicited

Manuel Collados Vera[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

Integral field units (IFUs) represent the most important instrumental development for solar telescopes in recent times. They aim at obtaining the simultaneous spectral/spectropolarimetric information in all points in a 2D field of view at the best achievable spatial resolution. Present IFU developments are based on three different approaches: image slicers, microlenses, and optical fibres. The first two options have been addressed under the EST framework and very promising results have been obtained up to now. Fibre-based IFUs are being developed for one of the first-light instruments of DKIST. In this talk, the three alternatives will be presented and described, putting especial emphasis on the alternatives developed as prototypes of the future EST instruments. A microlens-based IFU has been developed by MPS and tested at the SST. In parallel, a slicer-based IFU has also been developed by IAC and tested at GREGOR. The latter has been offered to all observers at this telescope to gain experience about its performance, stability and data reduction and analysis. These prototypes are fundamental for the final definition of the EST spectrograph(s) and crucial for the science that will be addressable with EST. IFUs will facilitate, v.g., the study of the fast evolution of small-scale solar structures, high-frequency waves, fast acceleration and heating of the plasma, reconnection events, etc. The present status of these instrument developments will be presented, as well as the future steps for their improvement and their final expected performance if/when installed at EST.

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11 June
11:40 am
Contributed

Collaborative research environment for high-resolution solar physics

Carsten Denker[1], C. Kuckein[1], M. Verma[1], H. Balthasar[1], H. Enke[1], J. Klar[1], S. J. González Manrique[1], A. Dierke[1], E. Dineva[1], and G. Matijevic[1]

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany

The heterogeneous and complex nature of multi-dimensional data arising from high-resolution solar observations provides an intriguing but also a challenging example for "big data" in astronomy. The concept of a Collaborative Research Environment (CRE) for high-resolution solar data is complementary to research infrastructures such as the Virtual Solar Observatory (VSO), which was established to allow easy access of solar data from various space missions as well as from ground-based observatories. The large number and high-resolution of images and spectra, as well as the computational effort for their post-processing, demands capable and efficient structures for storage and data management. To this purpose, we describe a CRE prototype in the context of the European Solar Telescope (EST) as it is implemented for existing data holdings of the GREGOR solar telescope, i.e. for the GREGOR Fabry-Prot Interferometer (GFPI) and the High-Resolution Fast Imager (HiFI). Such a research infrastructure acts as central hub for storage and processing of different data products as well as their distribution among CRE members. The CRE provides data storage space and data access with different levels of authorization, in addition to computational resources and customized tools for analysis and processing. User management and the definition of the users role are also handled by the CRE. Finally, members of the CRE have the option to publish selected and curated "science-read" data for the solar community, including a DOI registration with DataCite. The definition of accurate metadata is essential for database research, where the CRE will offer specialized forms and/or a general SQL interface to query the metadata.

The Science Requirement Document (SRD): an overview

11 June
12:00 am
Report

Rolf Schlichenmaier[1]

[1]Kiepenheuer-Institut für Sonnenphysik, Germany

I will report on the activities of the EST Science Advisory Group (SAG) and give an overview of the SRD for EST. The SAG formed in November 2017 and consists of 23 European scientists. The first top-level goal is to revise the existing SRD that dates back to 2010 and to present the new version at this meeting. Revisiting the design details of EST, the SAG distilled the excellent and unique science that EST can do. I will address the structure and objectives of the SRD. The top-level science goals are split in 7 Sections. Each section forms a session at the meeting. In addition I will elaborate on the scientific uniqueness of the EST Nasmyth focus.

Poster Session 1

Poster

The Broad Band Imager for EST

Matteo Munari[1], S. Scuderi[1], and M. Cecconi[2]

[1]INAF – Osservatorio Astrofisico di Catania, Italy
[2]INAF – Fundación Galileo Galilei, Spain

The BBI (Broad Band Imager) for EST will be one of the 'first light' instruments of the telescope. The scientific objectives will be the the study of fundamental astrophysical processes at their intrinsic scales in the Sun's atmosphere, and this goal will be reached with an instrument able to obtain diffraction limited images over the full field of view of EST at multiple wavelengths and high frame rate. The BBI will cover the 390 to 900 nm wavelength range, using two different arms (390-500 nm and 600-900 nm), and three different channels. Each subchannel will be further split in thre subchannels, each one served by a different 4k $\times$ 4k detector; one subchannel will be dedicated to chromospheric observations with narrow band filters, the second one for photospheric obeservations with wide band filters, and the third one with the same filters, used out of focus for phase recostruction. The total number of foreseen filters will be 11, with bandpasses FWHM from 0.05 to 0.5 nm. The instrument will exploit the diffraction limited quality of the telescope, and will operate in two modalities: maximum field ($2' \times 2'$), and high resolution (better than $0.04''$ at 500 nm).

Session 2
Structure and Evolution of Magnetic Flux

Physics and Diagnostics of Magnetic Flux Emergence

11 June
2:30 pm
Invited

Mark Cheung[1,2], M. Rempel[3], G. Chintzoglou[1,4], F. Chen[5], P. Testa[6], J. Martínez-Sykora[1,7], B. De Pontieu[1], V. Hansteen[8], and M. Jin[1,9]

[1]Lockheed Martin Solar & Astrophysics Laboratory, USA
[2]Stanford University, USA
[3]High Altitude Observatory, National Center for Atmospheric Research, USA
[4]University Corporation for Atmospheric Research, USA
[5]National Solar Observatory, USA
[6]Smithsonian Astrophysical Observatory, USA
[7]Bay Area Environmental Research Institute, USA
[8]Rosseland Centre for Solar Physics, University of Oslo, Norway
[9]SETI Institute, USA

Magnetic flux emergence from the solar convection zone into the atmosphere drives dynamic phenomena observable over a range of temperatures and spatiotemporal scales. In this talk, we review the fundamental physical processes important for flux emergence and relate these processes to observables accessible to ground-based and space borne observatories. We illustrate how continuous spectropolarimetric observations enabled the recent development of data-driven simulations of emerging flux, and how such simulations will improve our understanding of the solar atmosphere. We give suggestions for coordinated studies involving observations by existing and next generation solar telescopes (European Solar Telescope, Daniel K. Inouye Solar Telescope, ALMA and future space missions) and data-driven models. We also explore how machine learning techniques can be applied to perform physical diagnostics of the solar atmosphere.

11 June
3:00 pm
Solicited

Observation of tiny flux tubes in the photosphere

Zhong Liu[1,2], K. Tam[3], and Y. Liu[2]

[1]Fuxian Solar Observatory, China
[2]Yunnan Observatories, CAS, China
[3]Macau University of Science and Technology, China

Tiny flux tubes are very important contributors of the photospheric magnetic flux. It is very difficult to observe tiny flux tubes due to the limitations of spatial resolution and temporal resolution. The scale, lifetime and magnetic flux density of a typical tiny flux tube are the key parameters for the observation. There are many very interesting questions for the observation of tiny flux tubes. For example, can we observe the possible differential velocities inside a single tiny flux tube? We would like to discuss some of these questions and their possible answers in our talk. We will also introduce the present high resolution observations of magnetic bright points by the one meter New Vacuum Solar Telescope (NVST).

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11 June
3:20 pm
Contributed

The small scale magnetic elements on the photosphere: a turbulent story

Dario Del Moro[1], F. Giannattasio[2], A. Caroli[1], L. Giovannelli[1], and F. Berrilli[1]

[1]Università di Roma “Tor Vergata”, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Italy

The study of the dynamics of the photosphere allow us to investigate the physical processes occurring in both the interior of the Sun and in the higher layers of the solar atmosphere due the magnetic coupling between the photosphere and the corona. This field concerns many basic stellar processes such as: global dynamo, turbulent convection and super-hot corona. We report on the recent results on the transport of small scale magnetic field by advection/diffusion as seen on different data-sets from ground-based and space telescopes. We compare those results with simplified advective models that mimic the motion scales observed on the solar surface. We will digress on how the advection of the smallest magnetic elements on the solar surface can affects the toroidal-to-poloidal conversion in the solar cycle, or how it can be used to estimate the possible nano-flare contribution to the coronal heating.

The quest of the horizontal magnetic field

11 June
3:35 pm
Contributed

Oskar Steiner[1,2]

[1]Kiepenheuer-Institut für Sonnenphysik, Germany
[2]Istituto Ricerche Solari Locarno (IRSOL), Switzerland

An important discovery achieved with Hinode's Solar Optical Telescope Spectro-Polarimeter (SOT/SP) was that in the mean, the magnetic field over wide areas of the quiet Sun photosphere is predominantly horizontal, i.e., parallel to the solar surface. This result, however, remained not undisputed because the transversal Zeeman component is much more affected by photon noise than the longitudinal component. This noise may be the source for a gross overestimate of the horizontal field. The present contribution briefly reviews the status of the debate and proposes a bias-free measurement method. Furthermore, the polarimetric accuracy required for a definitive answer of the quest of the horizontal magnetic field is discussed.

Characteristics of Magnetic Bright Points

11 June
3:50 pm
Contributed

Dominik Utz[1], R. Muller[2], A. Veronig[1], José I. Campos Rozo[1], O. Kühner[1], and T. Van Doorsselaere[3]

[1]IGAM/Institute of Physics, Karl-Franzens University Graz, Austria
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Small-scale magnetic fields are of utmost importance for the dynamic and evolution of the solar atmosphere within "quiet" solar surface areas. A typical secondary effect of concentrated kG strong magnetic elements of the solar photosphere are so-called magnetic bright points (MBPs). These solar features are involved in many interesting and important solar physics processes like MHD wave generation and propagation to the higher solar atmosphere, solar irradiance variation over the solar cycle, or magnetic flux balance, and small-scale solar magnetic field dynamos. In this contribution we would like to highlight important static and dynamic parameters of MBPs determined from observations carried out by various telescopes as well as the importance and contribution of MBPs to the afore mentioned topics.

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11 June
4:30 pm
Contributed

The formation of a pore into a pre-existing coronal field

Ilaria Ermolli[1], F. Giorgi[1], S.L. Guglielmino[2], M. Murabito[1], P. Romano[3], M. Stangalini[1], and F. Zuccarello[2]

[1]INAF – Osservatorio Astronomico di Roma, Italy
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We studied the formation of a pore in AR 11462 with IBIS measurements taken at the Dunn Solar telescope on 17th April 2012 at the Fe I 630.1 nm and Ca II 854.2 nm lines, and with simultaneous SDO/HMI magnetograms and SDO/AIA filtergrams. The analysed observations sample the solar atmosphere from the low photosphere to the low corona. The photospheric data show that the pore is formed from emergence of new magnetic flux and its subsequent reorganization from interaction with the surrounding plasma.The chromospheric and higher atmosphere data display arch filament systems and intense brightening due to magnetic interactions of the new emerging flux with the pre-existing coronal field. We investigated the connectivity throughout the solar atmosphere of the processes observed in the evolving region at different atmospheric heights, and the role of the overlying pre-existing fields in the formation of the pore.

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11 June
4:45 pm
Contributed

Magnetic topology of the north solar pole

Adur Pastor Yabar[1], M.J. Martínez González[2], and M. Collados Vera[2]

[1]Kiepenheuer-Institut für Sonnenphysik, Germany
[2]IAC – Instituto de Astrofísica de Canarias, Spain

The magnetism at the poles is similar to that of the quiet Sun in the sense that no active regions are present there. However, the polar quiet Sun is somewhat different from that at the activity belt as it has a global polarity that is clearly modulated by the solar cycle.

We study the polar magnetism near an activity maximum when these regions change their polarity, from which it is expected that its magnetism should be less affected by the global field. To fully characterise the magnetic field vector, we use deep full Stokes polarimetric observations of the 15648.5 Å and 15652.8 Å Fe I lines. We observe the north pole as well as a quiet region at disc centre to compare their field distributions. In order to calibrate the projection effects, we observe an additional quiet region at the east limb.

We find that the two limb datasets share similar magnetic field vector distributions. However, we infer a new population of magnetic field distributions at the limbs that are different from the distribution inferred at disc

centre. We propose that this new population at the limbs is due to the observation of unresolved magnetic loops as seen close to the limb. This is the first (indirect) evidence of small-scale magnetic loops outside the disc centre and would imply that these small-scale structures are ubiquitous on the entire solar surface.

The proper characterisation of this new population of magnetic fields imposes strong observational constraints. First, quiet Sun magnetism shows very faint polarisation signals. Second, very high spatial resolution is required to resolve them. Finally, since the inferred unresolved loops show a polarity imbalance, bigger fields-of-view are necessary to address whether it is due to a statistical fluctuation or it is related with the solar magnetic cycle. Currently, these goals cannot be achieved by any solar telescope and EST would be an excellent candidate to accomplish them.

Structure and evolution of magnetic flux in the solar atmosphere (WG1)

11 June
5:00 pm
Report

Luis R. Bellot Rubio[1]

[1]CSIC/IAA – Instituto de Astrofísica de Andalucía, Spain

Magneto-convection is an ubiquitous process in the solar surface. The interaction of magnetic fields and granular convection leads to the formation of magnetic features and a broad range of flows and waves on very small spatial and temporal scales. This makes the photosphere highly dynamic and the place where heating of the upper solar atmosphere could be initiated via small-scale flux emergence, flux cancellation, braiding of magnetic field lines, or generation and upward propagation of waves.

These proceses need to be studied at their intrinsic spatial and temporal scales, of order 100 km and 10 s, respectively. Small-scale magnetic fields in the photosphere and chromosphere are weak, producing small polarization signals. To detect them, high polarimetric sensitivity is needed. The three requirements have been difficult to meet with existing telescopes and, as a result, temporal resolution has usually been sacrificed. Thus, our knowledge of the short-time evolution of surface magnetic fields is very limited. With its large primary mirror and dedicated suite of instruments, EST will for the first time provide the necessary sensitivity and spatial resolution to study the structure, dynamics, and evolution of the fields pervading the quiet solar surface at much faster cadences than never before.

Here I will present examples of the science cases worked out by the SAG to investigate the structure and evolution of magnetic flux in the solar atmosphere, highlighting how the unique capabilities of EST will serve to advance our knowledge in this area.

Poster Session 2

Poster

Modelling the solar photospheric plasma and magnetic field dynamics studying the temporal evolution of the velocity distributions

José I. Campos Rozo[1], S. Vargas Domínguez[2], D. Utz[1], and A. Veronig[1]

[1]IGAM/Institute of Physics, Karl-Franzens University Graz, Austria
[2]Observatorio Astronomico Nacional / Universidad Nacional de Colombia, Colombia

The emergence of convective flows define the dynamics on the solar surface, transporting plasma, energy as well as magnetic field from the solar interior. These emergences display flow convective patterns so-called granulation on different spatial and temporal scales depending of how they are organized. On the photosphere it is also possible to observe the arrangement of magnetic field at different scales, from small-scales, like Magnetic Bright Points (MBP), as well as large-scale magnetic concentrations such as sunspots or Active Regions (AR). The interaction between the plasma and the magnetic field has been studied before by several authors. In this work we made a detailed study employing two different distributions applied to the flow velocities during the emergence and prior evolution of AR 11190 on 11-April-2010. The velocity fields are computed from intensity as well as LOS magnetograms by using Local Correlation Tracking (LCT) techniques. The velocity flow fields show that they can be modelled by a mixture of two different statistical distributions. Firstly, a Rayleigh distribution, that shapes the background velocities as well as the general behavior of the velocity distributions, plus another component that recreates the fast changes within the field of view. We propose two different distributions as the second component for our model. The model shows a strong correlation between the plasma motions and the movements of magnetic elements except during time instances where strong and fast magnetic flux starts to appear within the region of interest.

Background-subtracted solar activity maps

Poster

Carsten Denker[1], and M. Veerma[1]

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany

Solar activity in all its facets has its origin in the temporal variability of the Sun's magnetic field. We introduce the concept of a Background-subtracted Solar Activity Map (BaSAM) as a new quantitative tool to assess and visualize the temporal variation of the photospheric magnetic field and the EUV λ 160 nm intensity. The method utilizes data of the Helioseismic and Magnetic Imager (HMI) and the Atmospheric Imaging Assembly (AIA), which are part of the Solar Dynamics Observatory (SDO). The availability of high-cadence synoptic full-disk data with a moderate spatial resolution of about one second of arc and with a temporal cadence well below one minute is the prerequisite for our method to assess variations in magnetic-field and EUV-imaging data. However, the technique can be easily adapted to other types of data, wavelengths, and instruments. Instead of exploring the rms-contrast of two- dimensional magnetic-field or intensity maps, we explore the temporal variation of the magnetic field and the EUV intensity at a certain location on the solar disk, i.e. for each pixel in a full-disk magnetogram/image or in a region- of-interest. Thus, the implementation of BaSAM resembles common rms-measurements. The background- subtracted variation of the magnetic field strength and the EUV intensity are computed for time-series data after correction of differential rotation, and if needed, geometrical foreshortening and center-to-limb variation.

We present representative examples of full-disk maps obtained during solar maximum and minimum conditions, summary activity maps for dynamic features (sunspots with moat flow, emerging flux regions, sunspot rotation, and flares), solar activity indices for the period 20112018, and a parameter study aiding in selecting the most appropriate implementation for a given science case. Solar activity maps allow target selection for high-resolution solar observations, as expected from the European Solar Telescope (EST), and complement high-resolution data by relating them quantitatively to solar activity.

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11 June
e-Poster

Reconnection between emerging and pre-existing magnetic fields observed with IRIS: a case study for EST observations

Salvo L. Guglielmino[1], F. Zuccarello[1], P.R. Young[2], P. Romano[3], and M. Murabito[4]

[1]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
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[4]INAF – Osservatorio Astronomico di Roma, Italy

We report multi-wavelength ultraviolet observations taken with the IRIS satellite, concerning the emergence phase in the upper chromosphere and transition region of an emerging flux region (EFR) embedded in the unipolar plage of active region NOAA 12529.

These data are complemented by full-disk, simultaneous observations of the Solar Dynamics Observatory satellite, relevant to the photosphere and the corona. The photospheric configuration of the EFR is also analyzed by measurements taken with the spectropolarimeter aboard the Hinode satellite, when the EFR was fully developed.

Recurrent intense brightenings that resemble UV bursts, with counterparts in all coronal passbands, are identified at the edges of the EFR and in the region of the arch filament system (AFS) cospatial to the EFR. Jet activity is also found at chromospheric and coronal levels, near the AFS and the observed brightness enhancement sites. The analysis of the IRIS line profiles reveals the heating of dense plasma in the low solar atmosphere and the driving of bi-directional high-velocity flows with speeds up to 100 km/s at the same locations.

Comparing these signatures with previous observations and numerical models, we suggest evidence of several long-lasting, small-scale magnetic reconnection episodes occurring between the emerging bipole and the ambient field. This process leads to the cancellation of a pre-existing photospheric flux concentration of the plage with the opposite polarity flux patch of the EFR. Moreover, the reconnection appears to take place higher in the atmosphere than usually found in UV bursts, explaining the observed coronal counterparts.

These observations provide a case study for the EST science requirements, as higher spatial and temporal resolution are necessary to better understand and characterize the onset and development of such small-scale reconnection events.

Flux emergence in the quiet Sun, from the photosphere to the corona

Poster

Ioannis Kontogiannis[1], G. Tsiroupola[2], and K. Tziotziou[2]

[1]Research Center for Astronomy and Applied Mathematics, Academy of Athens, Greece
[2]Institute for Astronomy, Astrophysics, Space Applications and Remote Sensing, National Observatory of Athens, Greece

We report preliminary results on the evolution of a small-scale bipolar magnetic feature, from its emergence at the photosphere to its brightening at the corona. We use imaging and spectral observations from the space-born Hinode (SOT/BFI, SOT/SP, EIS & XRT), TRACE (1550 Å, 1600 Å, 1700 Å) and SoHO (MDI hi-res) as well as the ground-based Dutch Open Telescope (G-band, Ca II H, and five positions along the Hα profile). The small-scale feature emerges adjacent to the chromospheric network. The magnetic flux density increases, reaching a maximum value while fine-scale Ca II H brightenings coalesce forming clusters of positive and negative polarity footpoints of a bipolar feature. The emerging magnetic flux tubes make their way to the chromosphere, pushing aside the ambient magnetic field, producing Doppler-shifted absorption features. At the upper chromosphere and transition region, imaged by Hinode/EIS, the emission gradually increases. The connectivity of the quiet-Sun network gradually changes, and part of the existing network connects to the newly emerged bipole. A few minutes after the bipole has reached its maximum magnetic flux density, it brightens in soft X-rays forming a coronal bright point. The brightening is observed in all EIS transition region and coronal windows and is accompanied by Doppler-shifted Hα features.

Magnetic Reconnection at the Earliest Stage of Solar Flux Emergence

Poster

Tanmoy Samanta[1], H. Tian[1], X. Zhu[2], H. Peter[3], J. Zhao[4], and Y. Chen[1]

[1]Peking University, China
[2]National Astronomical Observatories, Chinese Academy of Sciences, China
[3]Max-Planck Institute for Solar System Research (MPS), Germany
[4]Purple Mountain Observatory, China

On 2016 September 20, the Interface Region Imaging Spectrograph observed an active region during its earliest emerging phase for almost 7 hr. The Helioseismic and Magnetic Imager on board the Solar Dynamics Observatory observed continuous emergence of small-scale magnetic bipoles with a rate of $\sim 10^{16}$ Mx/s. The emergence of magnetic fluxes and interactions

between different polarities lead to the frequent occurrence of ultraviolet (UV) bursts, which exhibit as intense transient brightenings in the 1400 Å images. In the meantime, discrete small patches with the same magnetic polarity tend to move together and merge, leading to the enhancement of the magnetic fields and thus the formation of pores (small sunspots) at some locations. The spectra of these UV bursts are characterized by the superposition of several chromospheric absorption lines on the greatly broadened profiles of some emission lines formed at typical transition region temperatures, suggesting heating of the local materials to a few tens of thousands of kelvin in the lower atmosphere by magnetic reconnection. Some bursts reveal blue- and redshifts of $\sim$ 100 km/s at neighboring pixels, indicating the spatially resolved bidirectional reconnection outflows. Many such bursts appear to be associated with the cancellation of magnetic fluxes with a rate of the order of $\sim 10^{15}$ Mx/s. We also investigate the three-dimensional magnetic field topology through a magnetohydrostatic model and find that a small fraction of the bursts are associated with bald patches (magnetic dips). Finally, we find that almost all bursts are located in regions of large squashing factor at the height of $\sim$ 1 Mm, reinforcing our conclusion that these bursts are produced through reconnection in the lower atmosphere.

Poster

Testing the Gallavotti-Cohen Fluctuation Theorem on the Solar Photosphere

Giorgio Viavattene[1], F. Berrilli[1], G. Consolini[2], D. Del Moro[1], F. Giannattasio[3], and L. Giovannelli[1]

[1]Università di Roma “Tor Vergata”, Italy
[2]Istituto di Astrofisica e Planetologia Spaziali (IAPS-INAF)
[3]Istituto Nazionale di Geofisica e Vulcanologia, Italy

The understanding of fluctuations in systems far from equilibrium is one of the key issues of non-equilibrium statistical thermodynamics. The Fluctuation Theorem of Gallavotti and Cohen (1995) [GCFT] portrays some symmetry features of entropy production rate and deviations in non-linear and far from equilibrium regime. In this framework, the turbulent solar convection, observed in the photosphere and viewed as a dissipative non-equilibrium system near a steady state, provides an incomparable laboratory where to attempt a test the GCFT. In fact, solar convection flows emerge in the photosphere in terms of a structured pattern: the granulation. High resolutions spectro-polarimetric data acquired with Interferometric BIdimensional Spectropolarimeter (IBIS) instrument installed at the Dunn Solar Telescope (DST) are used to perform this analysis. Here, we present a preliminary analysis of the validity of the GCFT in the solar convection field. The statistical features of entropy production rate, which is at the core of the

irreversibility, is estimated through the vertical heat flux. The vertical heat flux along the line of sight (LOS), in its turn, is evaluated using temperature and LOS velocity map obtained with spectro-polarimetric inversion using the NICOLE code and with the simplest center of gravity method.

Session 3
Wave Coupling throughout the Solar Atmosphere

Torsional Alfvén waves in magnetic flux tubes of the solar atmosphere

12 June
8:45 am
Invited

Valery Nakariakov[1]

[1]University of Warwick, UK

In the solar atmosphere, the perpendicular spatial scale of Alfvén waves is typically much shorter than the parallel scale, and hence the waves appear in the torsional form. Similar to the linearly polarised plane Alfvén waves, torsional waves nonlinearly induce compressive perturbations by the ponderomotive force. The modification of the local plasma density and magnetic field strengths, and hence the Alfvén speed, leads to the nonlinear self-interaction of Alfvén waves, accompanied by the nonlinear cascade and enhanced damping. In the case of torsional waves, the ponderomotive effect is much richer than in the case of plane Alfvén waves, as torsional waves are essentially oblique due to their intrinsic dependence on the radial coordinate. The ponderomotive force leads to the induction of compressive flows in the perpendicular direction. Also, the radial non-uniformity of the torsional wave amplitude makes the wave speed dependent on the radial coordinate too, which causes phase mixing. In waveguiding magnetic flux tubes, nonlinearly induced compressive perturbations are found to be of three types: the longitudinal flows propagating at the Alfvén and tube speeds, respectively, and transverse flows propagating at the Alfvén speed outside the flux tube. The efficiency of the nonlinear cascade in torsional wave could be significantly weaker than in plane Alfvén waves. We also discuss the typical observational signatures of torsional waves that are important for their identification in the EST data, with implications for the coronal heating problem and MHD seismology.

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12 June
9:15 am
Contributed

The Magnetic Response of the Solar Atmosphere to Umbral Flashes

David Jess[1], S. Houston[1], A. Asensio Ramos[2], S. Grant[1], C. Beck[3], A. Norton[4], and K. Prasad[1]

[1]Queen's University Belfast, UK
[2]IAC – Instituto de Astrofísica de Canarias, Spain
[3]National Solar Observatory, USA
[4]Stanford University, USA

Previous research has documented the ubiquitous presence of non-linear shocks that are introduced by upwardly propagating magneto-acoustic waves in sunspot umbral atmospheres. In recent years, extensive analyses have been undertaken to examine the effect of these shocks on the surrounding magnetically-dominated plasma, with previous work identifying line-of-sight modulations of the magnetic field strengths and temperature enhancements on the order of several hundred degrees Kelvin. We employ simultaneous slit-based spectro-polarimetry and spectral imaging observations of the chromospheric He I 10830 Å and Ca II 8542 Å lines to examine full vector fluctuations in the umbral magnetic field caused by the steepening of magneto-acoustic waves into umbral flashes. Following the application of the HAZEL inversion routine, we find evidence to support the scenario that umbral shock events cause expansion of the embedded magnetic field lines due to the increased adiabatic pressure, hence providing increased transversal magnetic field fluctuations up to ~ 200 Gauss. Through comparisons with non-linear force-free field extrapolations, we demonstrate how the development of umbral flashes can deflect the quiescent magnetic field geometry by up to 8 degrees in both inclination and azimuthal directions.

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12 June
9:30 am
Contributed

Alfvén Wave Dissipation in the Solar Chromosphere

Samuel Grant[1], D. Jess[1], T. Zaqarashvili[2], C. Beck[3], H. Socas-Navarro[4], M. Aschwanden[5], P. Keys[1], D. Christian[6], S. Houston[1], and R. Hewitt[1]

[1]Queen's University Belfast, UK
[2]IGAM/Institute of Physics, Karl-Franzens University Graz, Austria
[3]National Solar Observatory, USA
[4]IAC – Instituto de Astrofísica de Canarias, Spain
[5]Lockheed Martin Solar & Astrophysics Laboratory, USA
[6]California State University Northridge, USA

The elusive Alfvén wave has been at the centre of atmospheric heating studies for decades, due to its unique incompressible nature making it an ideal energy transporter. However, the viability of Alfvén waves as a heating mechanism in the chromosphere, and beyond, depends on efficient

thermalisation of the wave energy, which has previously been undetectable. We combine high resolution spectral imaging with advanced inversion techniques to uncover the first evidence of Alfvén wave energy conversion, in the form of non-linear shock fronts in a sunspot umbra. Observed local temperature enhancements of 5% are observed in regions where conventional umbral flash formation is inhibited, providing a unique and unprecedented insight into Alfvén wave behaviour in the solar atmosphere. Importantly, this work also provides avenues for future research with next generation telescopes and observations.

How much can the damping of the observed power spectrum of transverse waves contribute to coronal heating?

12 June
9:45 am
Contributed

Paolo Pagano[1], and I. De Moortel[1]

[1]University of St Andrews, UK

Observations of coronal loops have long revealed ubiquitous, transverse velocity perturbations, that undergo strong damping as they propagate. Observational estimates show that these perturbations contain significant amounts of energy and a clear power spectrum for these transverse oscillations has been identified, composed of three distinct distributions: one for long periods, one for near 5 minutes oscillations and one for short periods.

We have previously demonstrated that the damping of transverse waves can be understood in terms of coupling of the transversal modes (kink) with azimuthal modes (Alfvén) in the inhomogeneous boundaries of the loops. Moreoever this process strongly depends on the wavelength of the kink modes, where short wavelength oscillations are more efficiently damped, but carry less energy.

However observed wave damping does not automatically imply dissipation and hence heating. To investigate under which circumstances this process can contribute to coronal heating and to what extent the heating rate is sustainable, we perform 3D numerical experiments modelling the observed power spectrum of transverse oscillations including the effects of resistivity and thermal conduction. By means of this simulation, we can address to what extent the observed power spectrum of transverse oscillations can contribute to coronal heating and how the simultaneous propagation of long and short period wavelengths affects the heat deposition distribution. In addition, we will address what high resolution instruments can reveal about this mechanism if the structure of the heating deposition is resolved and how to extend the modelling of this mechanism from isolated loops to complex loop systems as observed in active regions.

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12 June
10:00 am
Contributed

Fast MHD waves in a cylindrical magnetic arcade and solar coronal loop oscillations

Rekha Jain[1], and B.W. Hindman[2]

[1]University of Sheffield, UK
[2]University of Colorado, Boulder, USA

Many observed oscillations of solar coronal loops have been attributed to transverse, standing kink mode of oscillations. We theoretically investigate coronal loop oscillations in a cylindrical magnetic arcade as fast MHD modes of oscillations by arguing that the entire 3D magnetic arcade in which the loops reside participates in the oscillation. Thus, considering the true wave cavity as multi-dimensional. We discuss fast MHD modes as superposition of waves generated by localised sources of short impulsive nature and continuous stochastic sources. The oscillatory signal arising from a localised, short-duration source is interpreted as a pattern of interference fringes produced by waves that have travelled different routes of different path-lengths through the waveguide. The talk will also address how fast waves can resonantly couple to the Alfvén waves, leading to resonant absorption.

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12 June
10:15 am
Contributed

Flow-twist coupling in the solar atmosphere

Youra Taroyan[1], and T. Williams[1]

[1]Aberystwyth University, Wales, UK
[2]University of Central Lancashire, Preston, UK

The ubiquity of magnetic twists and plasma flows, as well as their importance in generating the dynamic behaviour of the Sun has become apparent only recently due to improvements in spectral, temporal and spatial resolution of instrumentation. I will demonstrate how energy is transferred from plasma flows into magnetic twists and vice-versa. The dynamic and energetic consequences of coupling between plasma flows and magnetic twists in the solar atmosphere will be addressed using time-dependent modelling in 1.5 dimensions. These consequences include the excitation of large amplitude propagating Alfven waves, the subsequent generation of slow and fast shocks due to nonlinear coupling, the formation of globally twisted structures that may become unstable. The implications of the coupling process and the twist amplification will be discussed in the contexts of Evershed flows, intergranular downdrafts, and chromospheric evaporation in coronal loops.

Three-dimensional simulations of solar magneto-convection including effects of partial ionization

12 June
11:00 am
Contributed

E. Khomenko[1], Nikola Vitas[1], and M. Collados Vera[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

In this contribution we will discuss the importance of partial ionization effects for the energy balance of the solar chromosphere. Over the last decades, realistic 3D radiative-MHD simulations have become the dominant theoretical tool for understanding the complex interactions between the plasma and the magnetic field on the Sun. Most of such simulations are based on approximations of magnetohydrodynamics, without directly considering the consequences of the very low degree of ionization of the solar plasma in the photosphere and bottom chromosphere. The presence of large amount of neutrals leads to a partial decoupling of the plasma and the magnetic field. As a consequence of that, a series of non-ideal effects (ambipolar diffusion, Hall effect and battery effect) arises. The ambipolar effect is the dominant one in the solar chromosphere. Here we report on the first three-dimensional realistic simulations of magneto-convection including ambipolar diffusion and battery effects. The simulations are done using Mancha3D code. Our results reveal that ambipolar diffusion causes measurable effects on the amplitudes of waves excited by convection in the simulations, on the absorption of Poynting flux and heating and on the formation of chromospheric structures. We provide a low bond on the chromospheric temperature increase due to the ambipolar effect using the simulations with battery-excited dynamo fields. We will discuss the possible observational implications of these effects, taking advantage of the high spatial and temporal resolution to be achieved by EST telescope.

Automated Swirl Detection Algorithm (ASDA) and Its Application to Simulation and Observational Data

12 June
11:15 pm
Contributed

Jiajia Liu[1], C.J. Nelson[1,2], R. Erdély[1,3]

[1]University of Sheffield, UK
[2]Queen's University Belfast, UK
[3]Eötvös Loránd University, Budapest, Hungary

Swirling motions in the solar atmosphere have been widely observed in recent years and suggested to play a key role in channeling energy from the photosphere into the corona. In this talk, we will present a newly-developed Automated Swirl Detection Algorithm (ASDA) and discuss its applications. ASDA is found to be very proficient at detecting swirls in a

variety of synthetic data with various levels of noise, implying our subsequent scientific results are astute. Applying ASDA to photospheric observations with a spatial resolution of 39.2 km sampled by the Solar Optical Telescope (SOT) on-board Hinode, suggests a total number of 1.62×10^5 swirls in the photosphere, with an average radius and rotating speed of $\sim$ 290 km and $<$ 1.0 km/s, respectively. Comparisons between swirls detected in Bifrost numerical MHD simulations and both ground-based and space-borne observations, suggest that: 1) the spatial resolution of data plays a vital role in the total number and radii of swirls detected; and 2) noise introduced by seeing effects could decrease the detection rate of swirls, but has no significant influences in determining their inferred properties. All results have shown that there is no significant difference in the analysed properties between counter-clockwise or clockwise rotating swirls. About 70% of swirls are located in intergranular lanes. Most of the swirls have lifetimes less than twice of the cadences, meaning future research should aim to use data with much higher cadences than 6 s. Our results suggest very promising detection of more small-scale and short-lived swirls using higher resolution and cadence observations provided by the EST or DKIST in the future.

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12 June
11:30 am
Report

SRD: Report from WG2

Mats Carlsson[1]

[1]Rosseland Centre for Solar Physics, University of Oslo, Norway

The SRD Working Group 2 has worked within the theme *Wave Coupling Throughout the Solar Atmosphere*. This report will cover the sample science cases the WG2 has worked on, including observing programs and a discussion of trade-offs needed and possible instrument configurations to optimize the science return.

Spectropolarimetric investigation of MHD waves in a sunspot

12 June
e-Poster

M. Stangalini[1], M. Murabito[1], and Ilaria Ermolli[1]

[1]INAF – Osservatorio Astronomico di Roma, Italy

Very long and high temporal cadence multi-line spectropolarimetric observations of the solar atmosphere are ideal for the investigation of MHD waves. In May 2016, AR 12546, one of the largest magnetic structures appeared on the solar disk in the past 20 years (diameter larger than 40 arcsec), was observed continuously for more than three hours by IBIS at the Fe I 617.3 nm and Ca II 854.2 nm spectral lines, under good seeing conditions. The length of the data set, its high temporal cadence (48 s), together with the high resolution and the spectropolarimetric capabilities of the instrument represent a unique combination.

In this contribution we present preliminary results of the spectropolarimetric investigation of MHD waves that reveal the co-existence of a combination of global and surface modes in the same structure.

Session 4
Chromospheric Dynamics and Heating

Modeling chromospheric heating and dynamics: What do we understand?

12 June
11:30 am
Invited

Viggo Hansteen[1]

[1]Rosseland Centre for Solar Physics, University of Oslo, Norway

Three-dimensional (3D) radiative MHD numerical simulations now reproduce many properties of the outer solar atmosphere. When including a domain from the convection zone into the corona, a hot chromosphere and corona are found to be self-consistently maintained and reproduce many observational diagnostics measured in the real Sun. Concentrating on the chromosphere, in this talk we study a number "realistic" models, with different simulated areas, magnetic field strength and topology. We analyze the heating at both large and small scales and find that heating is episodic and highly structured in space, but occurs along loop-shaped structures. We discuss which observations are critical in order to bridge the gaps between models and observations; to measure magnetic and velocity fields at hight cadence and at high spatial resolution. This to answer the questions such as: How energy is transported from the photosphere? What is the importance of flux emergence? and How much wave energy is generated in the photosphere, and how much is able to traverse the chromosphere? At what scales does reconnection occur, is microphysics important, and at what scale?

Magnetic bright point dynamics and its relations to the generation of chromospheric jets

12 June
3:00 pm
Contributed

Tanmoy Samanta[1], H. Tian[1], and V. Yurchyshyn[2]

[1]Peking University, China
[2]Big Bear Solar Observatory, USA

On 2016 September 20, the Interface Region Imaging Spectrograph observed an active region during its earliest emerging phase for almost 7 hr. The Helioseismic and Magnetic Imager on board the Solar Dynamics Observatory observed continuous emergence of small-scale magnetic bipoles with a rate of $\sim 10^{16}$ Mx/s. The emergence of magnetic fluxes and interactions between different polarities lead to the frequent occurrence of ultraviolet

(UV) bursts, which exhibit as intense transient brightenings in the 1400 Å images. In the meantime, discrete small patches with the same magnetic polarity tend to move together and merge, leading to the enhancement of the magnetic fields and thus the formation of pores (small sunspots) at some locations. The spectra of these UV bursts are characterized by the superposition of several chromospheric absorption lines on the greatly broadened profiles of some emission lines formed at typical transition region temperatures, suggesting heating of the local materials to a few tens of thousands of kelvin in the lower atmosphere by magnetic reconnection. Some bursts reveal blue- and redshifts of $\sim$ 100 km/s at neighboring pixels, indicating the spatially resolved bidirectional reconnection outflows. Many such bursts appear to be associated with the cancellation of magnetic fluxes with a rate of the order of $\sim 10^{15}$ Mx/s. We also investigate the three-dimensional magnetic field topology through a magnetohydrostatic model and find that a small fraction of the bursts are associated with bald patches (magnetic dips). Finally, we find that almost all bursts are located in regions of large squashing factor at the height of $\sim$ 1 Mm, reinforcing our conclusion that these bursts are produced through reconnection in the lower atmosphere.

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12 June
3:15 pm
Contributed

Chromospheric heating by magneto-acoustic waves – a science case for EST

Michal Sobotka[1], M. Švanda[1], and P. Heinzel[1]

[1]Astronomical Institute of the Czech Academy of Sciences, Ondřejov, Czech Republic

An EST science case concerning the possible heating of solar chromosphere by magneto-acoustic waves is elaborated. The case is based on observations of intensity, polarisation, and Doppler velocity of selected spectral lines with high temporal resolution to detect fluctuations with frequencies up to 40 mHz. The required observing parameters, including the list of proposed spectral lines, together with the tools for velocity and magnetic-field measurements are described. An important point is the determination of time-dependent and time-averaged model atmospheres under the non-LTE conditions in quiet and magnetic regions. These models are used to calculate the energy flux transported by magneto-acoustic waves and net radiative cooling rates at different heights in the atmosphere. Finally, an example of a comparison between acoustic energy fluxes and radiative losses in quiet and magnetised chromosphere is given.

Analysis of 3D plasma motions in a chromospheric jet formed due to magnetic reconnection

12 June
3:30 pm
Contributed

Gary Verth[1], V. Fedun[1], J. González-Áviles[2], S. Shelyag[3], and S. Regnier[3]

[1]University of Sheffield, UK
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[3]Department of Mathematics Physics and Electrical Engineering, Northumbria University, UK

Within the framework of resistive MHD, using the C7 equilibrium atmosphere model and a realistic 3D potential magnetic field configuration based on potential extrapolation of a bipolar model of solar photospheric magneto-convection, we simulate formation of a collimated structure with the morphology, upward velocity up to 130 km/s and timescale formation between 60 and 90 s, similar to those expected for Type II spicules. Our results suggest that 3D magnetic reconnection within a realistic atmosphere and magnetic field models, can trigger formation of the jet. By calculating the vorticity and analyzing the vector velocity field, we find that there is rotational motion in the jet-structure region and we can see propagation of the velocity field away from it, which suggests generation of waves. For the study of possible torsional motion we draw the path lines of the fluid elements around the jet. Unlike idealized models of displacement of plasma, in our scenario the realistic properties of the jet allow to diagnose a single cycle of the propagation and the energy carried by the waves.

A long-duration quiet-Sun small-scale vortex

12 June
3:45 pm
Contributed

Kostas Tziotziou[1], G. Tsiroupola[1], I. Kontogiannis[2], and E. Scullion[3]

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[2]Research Center for Astronomy and Applied Mathematics, Academy of Athens, Greece
[3]Department of Mathematics Physics and Electrical Engineering, Northumbria University, UK

Vortex flows have been extensively observed over a large range of spatial and temporal scales in different lines and hence layers of the solar atmosphere and widely found in numerical simulations. However, they have never been reported so far in observations in the α line centre. High spatial and temporal resolution observations obtained with the CRISP instrument at the Swedish 1-m Solar Telescope in several wavelengths along the α and Ca II 8542 Å line profiles reveal the existence of a persistent 1.7-hours small-scale vortex flow in contrast to short-lived such structures reported so far in literature. We discuss the appearance, characteristics, structure and dynamics

of this vortex flow in these two lines as well as in simultaneous UV and EUV SDO/AIA channels and HMI magnetograms. Our analysis includes visual inspection and comparison of simultaneous or near-simultaneous observations in the different spectral lines and channels, study of Doppler velocities derived from the α line profiles and detailed investigation of the vortex appearance, characteristics and dynamics using time slices along linear and circular slits. It reveals the existence of a funnel-like expanding structure with height that is possibly rotating rigidly or quasi-rigidly and exhibits significant substructure within it, manifested as several individual intermittent chromospheric swirls with typical sizes and durations. We further investigate oscillations within the vortex area using a wavelet analysis, phase differences using a cross-wavelet analysis and search for signatures of waves. We also discuss the possible generating physical mechanisms behind this unusual persistent vortex flow and try to understand its relation to previously reported short-duration small-scale magnetic swirls.

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12 June
4:30 pm
Contributed

Temporal evolution of arch filaments as seen in He I 10830 Å

Sergio J. González Manrique[1], C. Kuckein[2], M. Collados Vera[3], C. Denker[2], S.K. Solanki[4], P. Gömöry[1], M. Verma[2], H. Balthasar[2], A. Lagg[4], and A. Dierke[2]

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[3]IAC – Instituto de Astrofísica de Canarias, Spain
[4]Max-Planck Institute for Solar System Research (MPS), Germany

We aim to study the evolution of an arch filament system (AFS) and of its individual arch filaments to learn about the processes occurring in them. We observed the AFS at the GREGOR solar telescope on Tenerife at high cadence with the very fast spectroscopic mode of the GREGOR Infrared Spectrograph (GRIS) in the He I 10830 Å spectral range. The He I triplet line profiles were fit with analytical functions to infer line-of-sight (LOS) velocities to follow the plasma motions within the AFS. We tracked the temporal evolution of an individual arch filament over its entire lifetime as seen with the He I 10830 Å triplet. The studied individual arch filament expands in height and extends in length (from 13″ to 21″). The lifetime of this arch filament is about 30 min. About 11˜min after the arch filament is seen in He I, the loop top starts to rise with an average LOS velocity of 6 km/s. Only two minutes later, plasma drains down with supersonic velocities towards the footpoints reaching peaks up to 40 km/s in the chromosphere. The temporal evolution of He I 10830 Å profiles near the leading pore showed almost ubiquitous dual red components of the He I triplet, indicating strong

downflows, along with material nearly at rest within the same resolution element during the whole observing time. We follow the arch filament as it carries plasma during its rise from the photosphere to the corona. The material then drains toward the photosphere, reaching supersonic velocities, along the legs of the arch filament. Our observational results support theoretical AFS models and will serve to improve future models. The consequences of observations such as AFS for EST will be deduced. Also recommendations about EST performance and its instrumentation will be presented.

High Cadence Observations of the Solar Flares in the Hα Line

12 June
4:45 pm
Contributed

Krzysztof Radziszewski[1], and P. Rudawy[1]

[1]Astronomical Institute, University of Wroclaw, Poland

The Hα emission of chromospheric plasma in solar flares is powered mostly by high energy particle beams and conduction. Particles (mostly electrons) transfer energy from the reconnection region in a fraction of second, while conduction front is much slower, and its contribution reached maximum some tens of seconds after energy release in the solar corona. Energy deposed in the chromosphere causes immediately variations of the hard X-ray emission and after 1-2 seconds correlated variations of the emission of the flaring kernels in the Hα line.

Basic properties of the emissions in the Hα line induced by particles and frons, geometrical properties of the magnetic loops in the chromosphere and basic properties of the energy deposition layers were already investigated by us using – inter alia – Multi-Channel Subtractive Double Pass (MSDP) observations having spatial, spectral and high time resolutions. More detailed observations, collected with high cadence in broad spectral ranges and with sub-arcsec spatial resolution, as offered by EST telescope, are necessary for detailed studies of interactions of the non-thermal electrons accelerated during impulsive phases of flares with chromosphere.

On the basis of our fast-cadence (20 images per second) observations of the flaring kernels collected with MSDP imaging spectrograph we discuss new opportunities offered by the EST telescope in investigations of the feet of the flaring loops, with a special interest in stratification of the energy deposit in the different depths into the chromosphere and its emission in thick chromospheric lines during the impulsive phase of the solar flares.

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12 June
5:00 pm
Report

Report from WG3: Chromospheric dynamics, magnetism, and heating

Ada Ortiz Carbonell[1], J. Leenaarts[2], M. Carlsson[1], C. Kuckein[3], and P. Gömöry[4]

[1]Rosseland Centre for Solar Physics, University of Oslo, Norway
[2]Institute for Solar Physics – University of Stockholm, Sweden
[3]Leibniz Institute for Astrophysics Potsdam (AIP), Germany
[4]Astronomical Institute Slovak Academy of Sciences (AISAS), Slovakia

The chromosphere is the interface between the photosphere and the corona. In the chromosphere the dynamics change from gas-pressure driving to magnetic-force driving, radiation transport changes from optically thick to optically thin, the gas state changes from neutral to ionized, and from local thermodynamic equilibrium to non-equilibrium conditions. The magnetic field is the key quantity in the physics of the chromosphere. Understanding its physics thus requires determination of the magnetic field at all locations of the chromosphere.

The chromosphere is relatively difficult to study compared to the photosphere: evolution timescales are shorter, chromospheric lines are broad and deep, and thus have a relatively small photon flux, magnetic flux densities and polarization signals are weaker and fundamental spatial scales are expected to be very small.

In this talk I will introduce the science that SG3 has planned for EST, some selected examples of observing plans and the requirements that we think EST should deliver in order to be able to carry out the mentioned science.

Two types of surge-like activity above sunspot light bridges

12 June
e-Poster

Tanmoy Samanta[1], J. Zhang[1], and H. Tian[1]

[1]Peking University, China

We analyzed the surge-like oscillatory activity above sunspot light bridges using data taken by the Interface Region Imaging Spectrograph (IRIS) and the 1.6-m Goode Solar Telescope (GST). From the IRIS 2796 slit-jaw images, we detected surge-like activity above the entire light bridge at any time. The 1400 slit-jaw images reveal an oscillatory bright front ahead of the surges. The wavelength-time diagrams of the Mg II 2796.35 Åline within the surges show clear "Z" patterns, suggesting that the oscillations are highly nonlinear and likely caused by shocks. We also find a positive correlation between the acceleration and maximum velocity of the moving front, which is consistent with numerical simulations of upward propagating slow-mode shock waves. These results, together with the fact that the oscillation period stays almost unchanged over a long duration, lead us to propose that the surge-like activity above LBs is mainly caused by shocked p-mode or magnetoacoustic waves leaked from the underlying photosphere. In observations of another sunspot, similar surge-like activity is seen in the Halpha core images taken by GST. Some surges appear to reach larger distances and they are clearly associated with fast jets visible in the Halpha wing images, which occasionally occur at selected locations in the light bridge. Many of these jets are found to have an inverted Y-shape and rooted in transient brightenings with line profiles typical of UV bursts, indicating the occurrence of magnetic reconnection at the footpoints of the jets. In conclusion, our analysis clearly shows that the surge-like activity above light bridges has two components: the ever-present short surges likely to be related to the upward leakage of magneto acoustic waves from the photosphere, and the occasionally occurring long and fast surges that are obviously caused by the intermittent reconnection jets.

Session 5
Large Scale Dynamic Structures: Sunspots, Prominences and Filaments

New insights on sunspot formation

13 June
9:00 am
Invited

Nazaret Bello González[1]

[1]Kiepenheuer-Institut für Sonnenphysik, Germany

How do sunspots form? How is this large amount of magnetic flux gathered? Why do certain pores become sunspots? Why some large pores never develop penumbra? How is penumbra formed? What is the role of light bridges during sunspot formation? What is hidden in the dark umbrae? How do sunspots decay? What is the role of the moat flow?

We will review our current understanding on sunspot formation, evolution and decay addressing these and other questions.

Lessons from SST: What can EST learn?

13 June
9:30 am
Solicited

Dan Kiselman[1], and J. Leenaarts[1]

[1]Institute for Solar Physics – University of Stockholm, Sweden

The Swedish 1-m Solar Telescope has been operating on La Palma since 2002. Before that, the Swedish solar observatory hosted other solar telescopes for almost 20 years. From this experience we will formulate a number of conclusions that we believe are relevant for the EST.

These points will touch upon telescope and instrument design, telescope operations, and the science that could or should be made with EST. Finally we will try to answer the question "When is the seeing good?"

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13 June
9:50 am
Contributed

Umbral filaments: a conundrum to be solved by EST?

Salvo L. Guglielmino[1], P. Romano[2], B. Ruiz Cobo[3,4], F. Zuccarello[1] and M. Murabito[5]

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[2]INAF – Osservatorio Astrofisico di Catania, Italy
[3]IAC – Instituto de Astrofísica de Canarias, Spain
[4]ULL – Departamento de Astrofísica, Univ. de La Laguna, Spain
[5]INAF – Osservatorio Astronomico di Roma, Italy

Recent observations have shown the presence of bright filamentary structures that intrude sunspot umbrae, different in morphology, evolution, and magnetic configuration from light bridges that are usually observed in sunspots. Such structures have been called umbral filaments (UFs). In this context, we characterise an UF inside the umbra of the big sunspot in active region NOAA 12529. We analysed high-resolution observations taken in the photosphere with the spectropolarimeter aboard the Hinode satellite and in the upper chromosphere and transition region with the IRIS telescope. These observations were complemented with data from the Solar Dynamic Observatory satellite and from the INAF-OACT equatorial spar to study the evolution of this structure. The maps of the vertical component of the photospheric magnetic field indicate that a portion of the feature has a polarity opposite to that of the hosting sunspot. Furthermore, in the entire UF the horizontal component of the magnetic field is about 2500 G, substantially stronger than in the surrounding penumbral filaments. In the upper atmospheric layers, the UF is co-spatial to one of the footpoints of a small filament, which appears to be rooted in the sunspot umbra. Therefore, we have interpreted the UF as the photospheric counterpart of a flux rope touching the sunspot and giving rise to penumbral-like filaments in the umbra. New observations from the photosphere to the corona with higher spatial resolution, like those which will be provided by EST, are required to shed light on the nature of these structures.

Absolute velocity measurements in sunspot umbrae

13 June
10:05 am
Contributed

J. Löhner-Böttcher[1], W. Schmidt[1], Rolf Schlichenmaier[1], H.-P. Doerr[2], T. Steinmetz[3], and R. Holzwatrh[3]

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[2]Max-Planck Institute for Solar System Research (MPS), Germany
[3]Max-Planck-Institut fur Quantenoptik / Menlo Systems GmbH, Germany

In sunspot umbrae, the upward motion of hot gas is suppressed by the strong magnetic field. Previous measurements reported on a negligible convective flow. Based on this, numerous studies have taken the umbra as zero reference to calculate Doppler velocities of the ambient active region. To clarify the amount of convective motion in the darkest part of umbrae, we directly measured Doppler velocities with an unprecedented accuracy and precision.

We performed spectroscopic observations of sunspot umbrae with the Laser Absolute Reference Spectrograph (LARS) at the German Vacuum Tower Telescope. A laser frequency comb supported the high-resolution spectrograph and enabled an absolute wavelength calibration for 13 observation sequences. A thorough spectral calibration, including the measurement of the reference wavelength, yielded Doppler shifts of the spectral line Ti I 5713.9 $\mathring{A}$ with a spectral accuracy of around 5 m s^{-1}. A bisector analysis gave the depth-dependent line asymmetry.

The measured Doppler shifts are a composition of umbral convection and magneto-acoustic waves. For the analysis of convective shifts, we temporally average each sequence to reduce the superimposed wave signal. Compared to convective blueshifts of up to -350 m s^{-1} in the quiet Sun, sunspot umbrae yield a strongly reduced convective blueshifts around -30 m s^{-1}. By applying statistical analyses, we find that the velocity in a sunspot umbra correlates significantly with the magnetic field strength, but also with the umbral temperature defining the depth of the Ti I 5713.9 $\mathring{A}$ line. The vertical upward motion decreases with increasing field strength. Extrapolating the linear approximation to zero magnetic field reproduces the measured quiet Sun blueshift. In the same manner, we find that the convective blueshift decreases as a function of increasing line depth. We propose a novel approach of substantially increasing the accuracy of the Doppler velocities of a sunspot region by its magnetic field context.

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11 June
10:20 am
Contributed

3D structure, waves, and brightening in a large and mature spot

Mariarita Murabito[1], M. Stangalini[1], F. Giorgi[1], and I. Ermolli[1]

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[2]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
[3]INAF – Osservatorio Astrofisico di Catania, Italy

We analyzed spectropolarimetric data in the Fe I 617.3 nm and Ca II K 854.2 nm lines of the sunspot in AR 12546 observed with the IBIS at the Dunn Solar Telescope on 20th May 2016 and co-temporal filtergrams by IRIS and SDO/AIA. The observed sunspot is one among the largest such features occurred over the last solar cycle. The IBIS data, taken under excellent seeing conditions that lasted more than three hours, were restored for seeing-induced degradations not accounted for during observations, and inverted with the NICOLE code, in order to retrieve the temperature, magnetic field, and plasma velocity of the studied sunspot as a function of optical depth and time. The umbral and penumbral regions are for the most part stable in the photosphere, while co-spatial chromospheric areas show waves in the umbra-penumbra boundary and intense brightening along penumbral filaments. We explored the origin of these chromospheric processes and their relation to changes in the 3D magnetic structure of the observed sunspot.

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13 June
11:00 am
Contributed

Chromospheric jets above sunspots

Jan Jurčák[1], and L. Rouppe van der Voort[2]

[1]Astronomical Institute of the Czech Academy of Sciences, Czech Republic
[2]Rosseland Centre for Solar Physics, University of Oslo, Norway

In recent years, various chromospheric jet-like phenomena have been discovered in sunspots. There are impulsive penumbral and umbral microjets and slower, longer-lived, and more ubiquitous sunspot dynamic fibrils. Furthermore, surges and jest observed above sunspots light bridges. There have been strong indications that magnetic reconnection is the driving mechanism of the impulsive type of these phenomena. The more regular and cyclic occurring type of jets are attributed to magneto-acoustic waves leaking into the higher atmosphere. Comprehensive studies demonstrate the need for further multi-height investigation of the magnetic and dynamic structure through the photosphere and chromosphere, in order to identify heating mechanisms and the height at which energy is deposited. EST will be optimised for this type of analyses as it will provide simultaneously high spatial and temporal resolution observations of multiple spectral lines sampling different layers of the solar photosphere and chromosphere. Combined with high-sensitivity

spectro-polarimetry, we will be able to fully characterise the different types of jets in sunspots and address their formation mechanisms.

Observations of the uncoupling of ionized and neutral species in solar prominences

13 June
11:15 am
Contributed

E. Khomenko[1], and Manuel Collados Vera[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

The aim of this work is to measure possible differences in the dynamics of the ionized and neutral components of the solar plasma, as a manifestation of partial ionization effects due to an incomplete collisional coupling, causing deviations from ideal MHD. Here we report the detection of differences in ion and neutral velocities in prominences using very high temporal resolution spectral data obtained in 2012 at the German VTT (Observatorio del Teide, Tenerife). A time series of scans of a small portion of a solar prominence was obtained simultaneously with a high cadence using spectral lines of two elements with different ionization states, namely the Ca II 8542 Å and the He I 10830 Å. Displacements, widths and amplitudes of both lines were carefully compared to extract dynamical information about the plasma. Many dynamical features are detected, such as counterstreaming flows, jets and propagating waves. In all the cases we find a very strong correlation between the parameters extracted from the lines of both elements, confirming that both trace the same plasma. Nevertheless, we also find short-lived transients where this correlation is lost. These transients are associated with ion-neutral drift velocities of the order of several hundred m/s. The patches of non-zero drift velocity show coherence on time-distance diagrams. We continue and expand this initial study with another set of data, also obtained under similar conditions at the VTT in 2016, this time including He I D3 5876 Å, Hα, and Ca II 8542 Å, measured simultaneously. The new dataset has an advantage of including two lines of neutral elements with different atomic mass, together with one line of an ionized element. The importance of such kind of simultaneous observations for detecting partial ionization effects will be emphasized. The EST instrumentation should be designed to make possible these type of observations with the highest temporal cadence and spatial resolution.

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13 June
11:30 am
Report

SRD: Report from WG4

María J. Martínez González[1], C. Díaz Baso[1], and A. Asensio Ramos[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

In this talk, I will review the more recent advances on the understanding of the magnetic nature of chromospheric structures, focusing on prominences and filaments. By so doing, I will introduce the science cases chosen by the Working Group 4 for the scientific document of the European Solar Telescope.

Poster Session 5

Comparison of different populations of granular features in the solar photosphere

13 June
e-Poster

Mariachiara Falco[1], G. Puglisi[2], S.L. Guglielmino[3], P. Romano[1], I. Ermolli[4], and F. Zuccarello[3]

[1]INAF – Osservatorio Astrofisico di Catania, Italy
[2]Dipartimento di Matematica e Informatica – Università di Cagliari, Italy
[3]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
[4]INAF – INAF – Osservatorio Astronomico di Roma, Italy

One of the most visible manifestations of convective motions occurring in the uppermost layers of the solar convection zone is the granulation. Strong magnetic fields hinder the convective motions, but the appearance of bright structures such as umbral dots (UDs) and light bridges (LBs) in sunspots also shows that in strong magnetic field regions, the convection is not completely suppressed. To improve the current knowledge of the mechanism behind the appearance of the different bright structures in sunspots, we investigate the properties of the granules identified by a new segmentation algorithm in regions characterized by different magnetic field strength.

We analyzed data relevant to a large sunspot with a LB observed in AR NOAA 11263. The data were acquired by the CRisp Imaging SpectroPolarimeter at the SST on 6 August 2011. We applied a new segmentation algorithm to the data acquired along the Fe I 630.15 nm line.

We found that the granules in the LB have a diameter between 0.22″ and 0.99″, being smaller than the granules in a nearby plage region (PL) and similar to those of the UDs. The values of the mean continuum intensity, between 0.42 Ic and 0.98 Ic for the LB granules, are similar to those of the UDs. PL granules have higher values of continuum intensity, probably reflecting different conditions of the plasma convection. Mean Doppler velocity and mean magnetic field strength have similar values between LB granules and UDs as well.

Different values for the physical properties analyzed have been found between the granules of the PL and LB granules of the three analyzed solar regions, suggesting that PL and sunspot granules have different physical properties. This clearly depends on the different physical conditions of the regions where these two types of granular structures are embedded and confirms the recent findings on the similarity between granules in PL and quiet Sun regions. Finally, a noteworthy result is that the granules observed in the faint LB have physical properties similar to those found for UDs.

Poster

Recent insights on the penumbra formation process

Mariarita Murabito[1], S.L. Guglielmino[2], P. Romano[3], F. Zuccarello[2]

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[2]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
[3]INAF – Osservatorio Astrofisico di Catania, Italy

Using high-resolution spectropolarimetric data acquired by IBIS, as well as SDO/HMI observations, we studied the penumbra formation in AR NOAA 11490 and in a sample of twelve ARs appeared on the solar disk on 2011 and 2012, which were characterized by β-type magnetic field configuration. The results concerning the leading polarity of AR NOAA 11490 show that the onset of the classical Evershed flow occurs in a very short time scale, 1-3 hours, while the penumbra is forming to the side away from the opposite polarity of the AR. Conversely, studying the formation of the first penumbral sector around the following proto-spot, we found that a stable penumbra forms in the area facing the opposite polarity, which appears to be co-spatial with an AFS, i.e. in a flux emergence region, in contrast with the results of Schlichenmaier et al. (2010). Analyzing the sample of twelve ARs, we noticed that there is not a preferred location for the formation of the first penumbral sector. We also observed before the penumbra formation an inverse Evershed flow, which changes its sign when the penumbra appears. This confirms the observational evidence that the appearance of the penumbral filaments is correlated with the transition from the inverse Evershed to the classical Evershed flow. Furthermore, the analysis suggests that the time needed to form the penumbra may be related to the location where the penumbra first appears. New high-resolution observations, like those that will be provided by the European Solar Telescope, are expected to increase our understanding of the penumbra formation process.

Session 6
The Solar Corona

Investigating the footpoints of the magnetically structured solar corona

14 June
9:00 am
Invited

Daniele Spadaro[1]

[1]INAF – Osservatorio Astrofisico di Catania, Italy

Observations of the solar corona during the past decades have clearly shown that this region of the solar atmosphere is bound to follow the structure and evolution of the solar magnetic fields. They form in the sub-photospheric convection zone and subsequently emerge in the photosphere, chromosphere and corona, so characterizing the entire atmosphere as a highly coupled system.

The physical properties of various coronal structures (loop systems, coronal holes, streamers, prominences, etc.) indeed depend on the intensity and configuration of the magnetic fields filling the corona. The topology of such fields, in turn, is bound to follow the driving provided by photospheric flows. Significant and rapid changes of the magnetic topology, on the other hand, can cause high energy explosive events occurring in the solar corona, such as flares and eruptive prominences, that in turn may give rise to coronal mass ejections, phenomena with high impact on the space weather.

This presentation will concentrate on some typical coronal structures whose physical understanding and modeling is crucially related to a detailed knowledge of the flow fields and magnetic fields, and of their interaction, at the bottom boundary. It will also attempt to put into evidence the role that a 4-m class aperture solar telescope can have in addressing these science topics, thanks to its optical design capable of investigating the active Sun at very high spatial and temporal resolution, and unprecedented polarimetric sensitivity.

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14 June
9:30 am
Solicited

Simulating the coronal evolution and eruption of bipolar active regions

Stephanie Yardley[1], D. Mackay[1], and L. Green[2]

[11]University of St Andrews, UK
[12]UCL-Mullard Space Science Laboratory, UK

To gain a better understanding of the formation and evolution of the pre-eruptive structure of CMEs requires the direct measurement of the coronal magnetic field, which is currently very difficult. An alternative approach, such as using the photospheric magnetic field as a boundary condition to simulate a time series of the coronal field must be used to infer the pre-eruptive magnetic structure and coronal evolution prior to eruption. The evolution of the coronal magnetic field of a small sub-set of bipolar active regions is simulated by applying the magnetofrictonal relaxation technique of Mackay et al. (2011). A sequence of photospheric line-of-sight magnetograms produced by SDO/HMI are used to drive the simulation and continuously evolve the coronal magnetic field of the active regions through a series of non-linear force-free equilibria. The simulation is started during the first stages of active region emergence so that the full evolution from emergence to decay can be simulated. A comparison of the simulation results with SDO/AIA observations show that many aspects of the observed coronal evolution of the active regions can be reproduced, including the majority of eruptions associated with the regions. To better constrain these models requires the use of accurate vector magnetic field measurements with high polarimetric precision as the initial condition such as those that will be produced by EST.

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14 June
9:50 am
Solicited

Parker's dilemma: Do flares provide enough energy to heat the quiet corona?

Luca Giovannelli[1], D. Del Moro[1], F. Berrilli[1], R. Foldes[1], and D. Cicogna[1]

[1]Università di Roma "Tor Vergata", Italy

Flares are fast and powerful events that increase by orders-of-magnitude the solar electromagnetic output, especially the shorter-wavelength part of the spectrum. General consensus has that their trigger is the magnetic re-connection, which releases the energy stored in the magnetic field configuration, causing the heating of the plasma, the acceleration of particles and the emission in a broad part of the electromagnetic spectrum.

The probability distribution function of the flare energy shows a typical power law shape, which suggest that the so called 'nano-flares' may have a primary role in the heating of the solar corona. Due to the very faint emission of the nano-flares, and the limited sensitivity of current instrumentation,

there is still debate on how much of the needed energy budget is deposited in the Corona by flares.

In this talk, we present the analysis of the whole GOES detected flare sample (1979-2018), computing the power law of the flare energy for different periods of solar activity. To complement this result, we present a toy-model to extend the power law into the nano-flare energy regime and thus estimate the possible contribution to the coronal heating. Taking into account the measured magnetic flux emergency rate in the Quiet Sun, this model suggests that the amount of energy released by flares is such that an efficiency of $\sim 10\%$ in the deposition rate is enough to justify the million degree hot Corona.

Observing The Internal Kink Instability In The Solar Corona Using SDO/AIA

14 June
10:10 am
Contributed

Chris J. Nelson[1,2], J. Liu[2], B. Snow[2], M. Mathioudakis[1], and R. Erdély[1,3]

[1]Queen's University Belfast, UK
[2]University of Sheffield, UK
[3]Eötvös Loránd University, Budapest, Hungary

The presence of magnetic twist in the solar corona is rarely observed; however, the conversion of such twist (or magnetic free energy) to thermal energy is often cited as a potential solution for heating the corona. One mechanism which is often linked to the conversion of magnetic twist to thermal energy is the internal kink instability, an ideal magneto-hydrodynamic phenomenon which acts upon twisted magnetic flux ropes and can cause flurries of magnetic reconnection during its non-linear phase. Despite numerous successful attempts at forward modelling the signatures of the internal kink instability, little observational evidence has been found to confirm its occurrence in the solar corona. In this talk, we present observational evidence of the release of magnetic twist in the solar corona using the Solar Dynamics Observatory's Atmospheric Imaging Assembly. The initial twist can be detected during the on-set of the reconnection in imaging data (including in the 17.1 nm, 19.3 nm, and 21.1 nm channels) before a relatively wide loop arcade forms indicating the more potential nature of the field following the event. These signatures agree well with the forward modelled signatures of the internal kink instability in the solar corona. The heating associated with this event is detectable for around one hour before the structure fades from view. Non-linear force-free magnetic field extrapolations confirm the presence of twist prior to the feature and its reduction after the initial reconnection confirming the reduction in magnetic free energy. Finally, we will discuss the possibilities for studying the internal kink instability in the future using data collected by the European Solar Telescope.

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14 June
10:45 am
Contributed

Preliminary Results from a Coronal Oscillations Instrument during the 2017 Total Eclipse

Pawel Rudawy[1]

[1]Astronomical Institute, University of Wroclaw, Poland

An instrument using fast-frame cameras has been used during several recent total solar eclipses to search for oscillations in the green-line coronal emission. A much more sophisticated version of the instrument was prepared, tested, and successfully used during the August 21, 2017 total eclipse from a location in the Rocky Mountains, Idaho, USA. A pair of cameras, one observing the corona through a narrow-passband green line filter (wavelength 530.3 nm), and the other the white-light corona, was mounted on a 20 cm f/10 Celestron telescope on a Sky-Watcher EQ8 mounthead. During the 122 s of totality, 428 images in a field-of-view that included approximately two-thirds of the corona were obtained in the 530.3 nm Fe XIV line with an Andor iXon3 885 camera working at approximately 3.5 frames per second. The image format was 1004×1002, with a scale of 1.6 arcsec (1200 km) per pixel. The field-of-view included the loop system making up the flare-prolific active region AR12672 which was near the Sun's east limb. Emission is recognizable out to a distance of 150,000 km, and the brightest structures in the active region loop have a strong signal (500-2000 DN) that enables a search to be made for oscillations and other rapid fluctuations. This compares with a maximum signal of about 60 DN with a frame rate of 40 frames per second in a similar (negative) search by a previous version of this instrument during the 2001 total eclipse visible from central Africa. After dark-current subtraction and flat-fielding, a careful analysis of jitter and drifting motion of the images has enabled the solar coronal images to be placed on a frame that is stable to only 0.1 pixel, or 0.15 arcsec. An in-depth wavelet analysis of the collected data is under way. Meanwhile, analysis of the white-light channel data is proceeding. These images cover the entire low corona over the whole solar limb and include the loop structures of AR12672 as well as other loop systems around the limb, polar plumes, and two bright prominences. The emission from these will allow searches to be made for rapid intensity changes.

Impulsive coronal heating from large-scale magnetic rearrangements: observations with SDO/AIA

14 June
11:00 am
Contributed

Fabio Reale[1], A. Petralia[2], and P. Testa[3]

[1]Università di Palermo, Italy
[2]INAF – Osservatorio Astronomico di Palermo, Italy
[3]Smithsonian Astrophysical Observatory, USA

IRIS has observed bright spots at the transition region footpoints. These spots showed significant blueshifts in the Si IV line at 1402.77 Å (T $\sim 10^{4.9}$ K). Such blueshifts could not be reproduced by coronal loop models assuming heating by thermal conduction only, but were consistent with electron beam heating, highlighting for the first time the possible importance of non-thermal electrons in the heating of non-flaring active regions (Testa et al. 2014, Science). Here we report on the coronal counterparts of these brightenings observed in the hot channels of the Imaging Atmospheric Assembly on board the Solar Dynamics Observatory. We show that the IRIS bright spots are the footpoints of very hot and transient coronal loops which clearly experience strong magnetic rearrangements, thus confirming the impulsive nature of the heating and providing important constraints for physical interpretation (Petralia et al., this meeting).

Impulsive coronal heating from large-scale magnetic rearrangements: MHD modeling

14 June
11:15 am
Contributed

Antonino Petralia[1], F. Reale[2], and P. Testa[3]

[1]INAF – Osservatorio Astronomico di Palermo, Italy
[2]Università di Palermo, Italy
[3]Smithsonian Astrophysical Observatory, USA

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14 June
11:30 am
Report

Report from WG5: Coronal Science

Robertus Erdély[1,2], S. Matthews[3], and M. Mathioudakis[4]

[1]University of Sheffield, UK
[2]Eötvös Loránd University, Budapest, Hungary
[3]UCL-Mullard Space Science Laboratory, UK
[3]Queen's University Belfast, UK

Here, we report on what EST may offer towards making a leap in coronal sciences. After a brief introduction on the aims and objectives of WG5, we will outline the currently proposed observing programmes that is associated with WG5. These programmes, by no means, are final and it is highly encouraged that anyone who may feel to have contribution, should do so by contacting the WG Team (R. Erdelyi, S. Matthews and M Mathioudakis). The currently elaborated and proposed specific observing programmes, in the context of coronal studies, include e.g., sunspot light-bridges/light walls, solar spicules/macrospicules, coronal upflows and outflows, probing the pre-flare triggers, observables on constraining the coronal magnetic field, what we can gain towards understanding forbidden coronal lines, and exploring the limits of MHD. A particularly interesting aspect is the synergies with DKIST, Solar C EUVST, Solar Orbiter and other potential missions that overlap with the operation of EST.

Poster Session 6

Energetic budget for a nanoflare heated solar upper atmosphere

14 June
e-Poster

Luca Giovannelli[1], D. Del Moro[1], and F. Berrilli[1]

[1]Università di Roma "Tor Vergata", Italy

The investigation of dynamics of the small scale magnetic field on the Sun photosphere is necessary to understand the physical processes occurring in the higher layers of solar atmosphere due to the magnetic coupling between the photosphere and the chromospheric-coronal layers. We present a simulation able to address these phenomena investigating the statistics of magnetic loops reconnections. The simulation is based on a N-body model approach and is divided in two computational layers. We adopt a simplified convection model, interpreting the largest convective scales as the result of the collective interaction of downflows of granular scale. Such an advection model is the base to generate a synthetic time series of nanoflares produced by reconnecting magnetic loops. The reconnection of magnetic field lines results from the advection of their footpoints dragged by the velocity field.

We compute the energy released in the different layers of the solar atmosphere, which is highly dependent on the magnetic loop emergence rate. The emergence rate has been constrained using observations from the HINODE satellite. Further improvement in the model will be possible once the window on emergence of magnetic flux tubes on scales below the 30 km will be opened by EST.Moreover we plan to include information on the fine scale magnetic flux tube coming from future observations at different heights in photosphere and cromosphere. The model gives a quantitative estimate of the energy released by the reconfiguration of the magnetic loops in a quiet Sun area as a function of height in the solar atmosphere, from hundreds of Km above the photosphere up to the corona.

The CoMP-S and SCD spectropolarimeters at the Lomnicky Peak Observatory as supporting instrumentation to EST

Poster

Peter Gömöry[1], J. Rybák[1], P. Schwartz[1], A. Kučera[1], J. Ambróz[1], M. Kozák[1], J. Koza[1], S. Tomczyk[2], S. Sewell[2], P. Aumiller[2], D. Gallagher[2], R. Summers[2], L. Sutherland[2], A. Watt[2]

[1]Astronomical Institute Slovak Academy of Sciences (AISAS), Slovakia
[2]High Altitude Observatory, National Center for Atmospheric Research, USA

We present actual status and observing possibilities of the Coronal Multichannel Polarimeter (CoMP-S) and Solar Chromospheric Detector (SCD) installed at the Lomnicky Peak Observatory. The CoMP-S is a dual beam spectropolarimeter developed to detect full Stokes parameters of prominent coronal and chromospheric spectral lines in order to estimate magnetic and velocity fields in the solar corona and in prominences. The SCD is a single beam spectropolarimetric instrument designed for on disk measurements of Stokes parameters in the chromosphere. Both instruments were designed and manufactured by HAO/NCAR (Boulder, USA). We present technical parameters of the instruments and the acquired data which can serve as complementary observing material to high resolution measurements taken by the European Solar Telescope (EST).

Poster

Dynamics and magnetic properties in coronal holes using high-resolution multi-instrument solar observations

Kilian Krivova[1], D. Utz[1], A. Veronig[1], S. Hofmeister[1], and M. Temmer[1]

[1]IGAM/Institute of Physics, Karl-Franzens University Graz, Austria

Using high-resolution solar observations from the Hinode Instruments SOT/SP, EIS and XRT as well as IRIS from a coronal hole on the 26th of September 2017, we are investigating the dynamics within the coronal hole. Further satellite data support is given by full disc images from SDO with the AIA and HMI instruments. EIS and IRIS data provide us crucial information about the plasma and energy flow from the Sun's chromosphere into the corona using the EUV and UV spectra and images. Investigating the magnetic configuration as well as the dynamics and changes within the coronal hole by using the SOT/SP data gives us crucial insides about the physical processes leading to the corresponding changes in the higher atmosphere. We compare the Hinode data with AIA and HMI data to get a firm comprehensive picture about the connection from high resolved photospheric fields and its dynamic with the higher layers. In this poster contribution we will outline the state of the art of this investigation and give an overview of the further steps necessary. The data were obtained during a recent GREGOR campaign with the joint support of IRIS and Hinode (HOP 338).

Session 7
Solar Flares and Eruptive Filaments

Pre-Eruption Conditions in Solar Active Regions: Operations to Research and a Meaningful EST Role

14 June
2:30 am
Invited

Manolis K. Georgoulis[1]

[1]Research Center for Astronomy and Applied Mathematics, Academy of Athens, Greece

Understanding the physics of solar eruptive activity is a key pursuit of solar physics that continues unabated for at least half a century. Over the past two decades, however, solar eruptions are studied from an additional angle, aiming to generate the necessary operational knowledge to predict them. This has been dictated by recent, vivid interest in space weather forecasting. Moving from understanding to forecasting is a paradigm of research-to-operations (R2O), via which one builds comprehensive databases of quantitative parameters of solar active regions at various stages prior to eruptions. Ranking these parameters in terms of forecasting significance enables another, equally meaningful, step, namely that of operations to research (O2R). In this action, one focuses on the best performing parameters to understand the physics of their (absolute or relative) success. The EU FLARECAST project has managed to collect more than a hundred solar flare (and coronal mass ejection) predictors for each of tens of thousands solar photospheric magnetograms acquired by the Helioseismic and Magnetic Imager (HMI) of the Solar Dynamics Observatory (SDO). With a number of ranking exercises complete, we single out a few of these parameters, whose physics and ramifications for the active-region photosphere and the photosphere-chromosphere coupling we present and discuss. This physics can be boosted from future, ultra high-resolution observations that EST will obtain at high cadence. Therefore, among its other objectives, EST can use existing knowledge to fine-tune its scientific targets, aiming to break ground on the understanding of solar eruptions, potentially even identifying and observing their actual trigger(s). The question of the existence, or lack thereof, of unambiguous eruption precursors is also one of central importance, which EST could successfully put to rest.

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14 June
3:00 pm
Solicited

Solar flare initiation and signatures: What can EST tell us about the role of the magnetic field?

Kévin Dalmasse[1]

[1]Research Institute in Astrophysics and Planetology (IRAP), France

Solar flares and eruptive events are driven by the 3D evolution of current-carrying magnetic fields in the solar atmosphere. The magnetic energy of such magnetic fields is slowly built up through photospheric plasma flows that braid coronal magnetic field lines and the emergence of twisted/sheared magnetic fields into the corona. While several mechanisms have been identified, we still do not know which ones are really responsible for the trigger of these flaring phenomena. This is because our knowledge of the 3D magnetic field in the solar atmosphere mostly rely on the approximate 3D solution obtained from force-free coronal magnetic field extrapolations of the 2D photospheric measurements. The European Solar Telescope will provide magnetic field measurements of the solar photosphere and chromosphere with unprecedented polarimetric sensitivity and very high spatial and temporal resolution. Such measurements will provide original information for better constraining the 3D magnetic field in the solar atmosphere. In this talk, I will discuss how EST measurements may help us identifying the mechanisms triggering solar flares and eruptive events, and how the 3D magnetic field properties control the flare signatures.

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14 June
3:20 pm
Contributed

Modelling of Electron and Proton Beams in a White-light Solar Flare

Ondrej Prochazka[1], A. Reid[1], R. Milligan[2], P. Simões[2], J.C. Allred[3], and M. Mathioudakis[1]

[1]Queen's University Belfast, UK
[2]University of Glasgow, UK
[3]NASA Goddard Space Flight Centre, USA

Observations of an X1 white-light solar flare on 11 July 2014 showed an extraordinarily weak emission in hydrogen lines, extremely hard X-ray spectrum and indications for proton beams. We have used the radiative hydrodynamic code RADYN to model the response of the solar atmosphere with a grid of models that was based on electron and proton beam parameters that may be most appropriate for this type of event. We then use the radiative transfer code RH to synthesise line profiles from these atmospheres to compare to observations. We selected those models that agree best with the RHESSI/Fermi, ground-based spectra (350 – 440 nm) and HMI white-light continuum data. Our analysis shows that the observed

atmospheric response could be reproduced with a relatively weak particle beam with a high low energy cut-off. We found that both electron and proton beams can generate the observed flare emission but it is easier for the protons to penetrate deeper into the atmosphere and deliver their energy in the lower chromosphere where the excess white-light continuum emission originates. Observations of such events with higher spatial resolution at shorter wavelengths would allow more accurately determine the flaring area and the nature of WL emission.

High-resolution Ca II 8542 observations of an M-class solar flare

14 June
3:35 pm
Contributed

Christoph Kuckein[1], and M. Collados Vera[2]

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany
[2]IAC – Instituto de Astrofísica de Canarias, Spain

An M3.2 flare was observed in 2013 May 17 with the Vacuum Tower Telescope (VTT, Tenerife, Spain) at a heliocentric angle of 0.8. The observations covered the activation, impulsive, and relaxation phases of the flare. Intensity spectra were acquired with the Echelle slit-spectrograph with a spectral sampling of 8.2 mÅ/pixel and an exposure time of 1 s. This work is an extension of the already published work from Kuckein et al. (2015, ApJL, 799, L25), which was based on photospheric changes during this flare. In this work, we concentrate on the changes in the chromosphere, analyzing the Ca II 8542 Å line during the M-class flare. Large emission peaks are present during the flare and relaxation phases. Strong asymmetries of the intensity profiles are detect in the red wing during the flare, which indicates strong downflows. Temperatures and velocities were inferred from selected profiles using the inversion code NICOLE. Our results add to the few earlier studies concerning flare observations in the Ca II infrared line. Observing flares from ground-based telescopes is very challenging. Recommendations about instrumentation will be presented including possible strategies for flare observations with the European Solar Telescope (EST) in the chromosphere.

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14 June
3:50 pm
Contributed

Shear flows and head-on collision of new and pre-existing flux – On the origin of two X-class flares in NOAA 12673

Meetu Verma[1]

[1]Leibniz Institute for Astrophysics Potsdam (AIP), Germany

The flare-prolific active region NOAA 12673 produced consecutive X2.2 and X9.3 flares on 6 September 2017. The immediate succession of two major flares motivated this work. We scrutinized the morphological, magnetic, and horizontal flow properties associated with these flares using seven hours of data taken by the Solar Dynamics Observatory (SDO). The enhanced flare activity has its origin in the head-on collision of newly emerging flux with an already existing sunspot, creating a long and curved polarity inversion line (PIL) centered on a δ-spot. This PIL was the fulcrum of all the activity. The white-light flare emission differed for both flares, while the X2.2 flare displayed localized, confined flare kernels, the X9.3 flare exhibited a two-ribbon structure. Horizontal proper motions were computed using the differential affine velocity estimator for vector magnetograms (DAVE4VM). Persistent flow features included (1) strong shear flows along the polarity inversion line, where the negative, parasitic polarity tried to bypass the majority, positive-polarity part of the δ-spot in the north, (2) a group of positive-polarity spots, which moved around the δ-spot in the south, moving away from the δ-spot with significant horizontal flow speeds, and (3) intense moat flows partially surrounding the penumbra of several sunspots, which became weaker in regions with penumbral decay. These two flares represented a scenario, where the first confined flare acted as precursor, setting up the stage for the more extended flare. The improved spatial resolution of European Solar Telescope (EST) will allow to make observations of fine-scale flare precursors possible in practice on an unprecedented scale and on a routine basis.

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14 June
4:30 pm
Contributed

Pre-flare dynamics of the flaring Active Regions in the solar atmosphere

Marianna Korsós[1], and R. Erdély[1,2]

[1]University of Sheffield, UK
[2]Eötvös Loránd University, Budapest, Hungary

We present our method where we focus on the pre-flare evolution of the 3D magnetic field skeleton of flaring ARs. The 3D magnetic structure is based on PF/NLFFF extrapolations and PENCIL MHD code simulations to encompassing a vertical range from the photosphere through the chromosphere and transition region into the low corona. The basis of our proxy

measure of activity prediction is the so-called weighted horizontal gradient of magnetic field (WG_M) defined between opposite polarities in the entire delta-type sunspot. The temporal variation of the distance of the barycenter of theopposite polarities is also found to possess potentially important diagnostic information about the flare onset time estimation as function of height. We found that at a certain height in the lower solar atmosphere the onset time may be estimated much earlier than at the photosphere or at any other heights. Therefore, we present a tool and recipe that may potentially identify the optimum height for flare prognostic in the solar atmosphere allowing to improve our flare prediction capability and capacity. This kind of application would be a new example how to exploit high-resolution ground-based observations with our future facilities, like EST.

Observation of magnetic reconnection around a 3D null point

14 June
4:45 pm
Contributed

Paolo Romano[1], S.L. Guglielmino[2], M. Falco[1], and M. Murabito[3]

[1]INAF – Osservatorio Astrofisico di Catania, Italy
[2]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
[3]INAF – Osservatorio Astronomico di Roma, Italy

We describe high-resolution observations of a GOES B-class flare observed at the Dunn Solar Telescope with IBIS and ROSA instruments. The flare was characterized by a circular ribbon at chromospheric level and was interpreted as a consequence of a magnetic reconnection event that occurred at a three-dimensional (3D) coronal null point located above a supergranular cell. We highlight some interesting observational aspects that need to be explained by models. We observe a bundle of loops corresponding to the outer spine that becomes brighter a few minutes before the onset of the flare. The circular ribbon was formed by several adjacent compact kernels with a size of $1'' - 2''$ and brightening sequentially in clockwise direction. We note that the kernels with a stronger intensity emission were located at the outer footpoint of the darker filaments, departing radially from the center of the supergranular cell. The site of the 3D null point and the shape of the outer spine were also detected by RHESSI in the low-energy channel between 6.0 and 12.0 keV. We ascribe the low intensity of the flare to the low amount of the involved magnetic flux and to its symmetric magnetic configuration.

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14 June
5:00 pm
Report

SRD: Report from WG6

Lyndsay Fletcher[1]

[1]University of Glasgow, UK

The European Solar Telescope offers unique and novel opportunities for solving some of the long-standing problems related to solar flares, such as the slow evolution of the stored energy preceding the flare, the rapid deposition in the chromosphere during the flare impulsive phase, and the response of the chromosphere as the atmosphere responds. The focus of EST on the solar chromosphere - where flare radiation is intense and flare-related magnetic changes likely to be significant, will lead to unique insights. This talk will overview the progress and recommendations of Working Group 6 on Solar Flares and Eruptive Events.

Statistical investigation of CMEs properties and their correlation with flares during Solar Cycles 23 and 24

Poster

Alessio Compagnino[1]

[1]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy

The Large Angle Spectrometric Coronagraph (LASCO), onboard the Solar and Heliospheric Observatory (SOHO) provided us observations extending for the two Solar Cycles 23 and 24 (31 July 1996 – 31 March 2014) that allow one to compare some properties (speed, acceleration, polar angle, angular width, and mass) of Coronal Mass Ejection (CMEs). The Coordinated Data Analysis Workshops (CDAW) Data Center datasets uses manual identification for the detection of the CMEs, while the Computer Aided CME Tracking software (CACTus) datasets uses an automatic detection algorithm. Some important results found in this analysis, for both dataset, are that there are more CMEs during the maximum of Solar Cycle 24 than during the maximum of Solar Cycle 23, although the photospheric level and magnetic activity of the Sun during Cycle 24 was weaker than during Cycle 23. Peaks of CMEs observed by CACTus are of the same order of magnitude in the two cycles, but the distribution of CMEs observed by CACTus exhibits a long lasting peak during the Solar Cycle 24. The discrepancy between the CACTus and CDAW results may be due to an observer bias giving origin to different definition of CMEs in CDAW catalog. In order to investigate the correlation between Flares and CMEs, during the Solar Cycles 23 and 24 we used the Geostationary Operational Environmental Satellite (GOES) datasets that contain observations of 19811 flares of C-, M-, and X-class and found 11441 flares temporally correlated with CMEs for CDAW and 9120 for CACTus. We also found some characteristics of the mean velocity and acceleration of the CMEs associated with flares and the CMEs not associated with flares. The most important results of this statistical analysis is a log-log relationship between the flux of the flares integrated from the start to end in the 0.1 – 0.8 nm range and the CME mass, valid not only when we consider the energy released by the flare during the whole events, but also considering the flux emitted at the peak of the corresponding flares and the mass ejected by the CMEs.

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14 June
e-Poster

Continuum emission enhancements in flares observed by ROSA and IRIS

Francesca Zuccarello[1], V. Capparelli[1], M. Mathioudakis[2], P. Keys[2], L. Fletcher[3], S. Criscuoli[4], M. Falco[5], S.L. Guglielmino[1], and M. Murabito[6]

[1]Dipartimento di Fisica e Astronomia – Università degli Studi di Catania, Italy
[2]Queen's University Belfast, UK
[3]University of Glasgow, UK
[4]National Solar Observatory, USA
[5]INAF – Osservatorio Astrofisico di Catania, Italy
[6]INAF – Osservatorio Astronomico di Roma, Italy

During solar flares, magnetic energy can be converted into electromagnetic radiation from radio waves to rays. In the most energetic events, enhancements in the continuum at visible wavelengths may be present (white-light [WL] flares). Recently, the WL emission has also been correlated with enhancements in the FUV and NUV passbands. In this context, we describe observations acquired by ground-based (ROSA@DST) and satellite (IRIS) instruments during two consecutive C7.0 and X1.6 flares occurred in active region NOAA 12205 on 2014 November 7.

The results of the analysis of these data show the presence of continuum enhancements during the evolution of the events, observed both in ROSA images and in IRIS spectra. Moreover, we analyze the role played by the evolution of the δ sunspots of the active region in the flare triggering, discussing the disappearance of a large portion of penumbra around these sunspots as a further consequence of these energetic flares. We expect that high-resolution observations acquired during the EST operations will enable us to extend our knowledge about the physical process that determines WL emission during solar events like those discussed here.

Session 8
Scattering Physics and Hanle-Zeeman Diagnostics

Experimental testing of scattering polarization models

15 June
9:00 am
Invited

Roberto Casini[1], S. Tomczyk[1], and W. Li [1]

[1]High Altitude Observatory, National Center for Atmospheric Research, USA

We realized a laboratory experiment to study the polarization of the Na I doublet at 589.3 nm in the presence of a magnetic field. The purpose of the experiment is to test the current theory of scattering polarization for illumination conditions typical of solar plasmas. This work was stimulated by solar observations of the Na I doublet that have proven particularly challenging to reproduce with current models of polarized line formation, even casting doubts on our very understanding of the physics of scattering polarization on the Sun. The experiment has confirmed the fundamental correctness of our theoretical framework for modeling polarized line formation, providing compelling evidence that the "enigmatic" polarization of those observations is exclusively of solar origin. In this talk, I will review the basic facts about the currently adopted framework for the description of line polarization phenomena, and the various modeling aspects that had to be tackled in order to reproduce the experimental results.

Si I 1082.7 nm line as a probe of photospheric magnetic fields

15 June
9:30 pm
Contributed

Nataliia Shchukina[1]

[1]Main Astronomical Observatory, National Academy of Sciences, Ukraine

Scientific interest for the spectral region around 1083 nm is growing over the last years following advances in theory as well as in IR instrumentation. Such facilities require further development of diagnostic tools. The aim of our study is to analyze the validity of the weak field approximation for measuring photospheric magnetic fields using Si I 1082.7 nm line. We solve the NLTE formation problem of the Si I 1082.7 nm line by means of multilevel radiative transfer calculations in a 3D snapshot model taken from the magnetoconvection simulations with small-scale dynamo action. The spectral images of

the snapshot were degraded because of the Earth's atmospheric turbulence and light diffraction by the telescope aperture. We apply the weak field approximation both to the spatially unsmeared and smeared Stokes I, Q, U, V profiles supposing that they represent "real Sun" observations. We compare the longitudinal and transverse components of the magnetic field that one would expect from observations of the Si I 1082.7 nm line under perfect spatial resolution and under different seeing conditions of the observations done with the VTT, GREGOR and EST (DKIST) telescopes. We conclude that the weak field approximation applied to smeared profiles of this line gives us an opportunity to "trace" only the low limit of magnetic field along the middle and upper photosphere. In order to obtain the reliable field the speckle-reconstructed observations of the Si I 1082.7 line are required.

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15 June
9:45 am
Contributed

What can we learn from infrared Iron lines?

Ivan Milic[1], S. Narayanamurthy[1], A. Lagg[1], and M. Van Noort[1]

[1]Max-Planck Institute for Solar System Research (MPS), Germany

Observations of iron lines around 15600 angstrom provide us with the information about the deep photospheric layers. Large wavelengths are beneficial since the Zeeman splitting increases, but, on the other hand, the seeing effects are more pronounced. In this contribution we test the limits of our current capabilities for inference. We synthesize Stokes profiles of these lines from a state-of-the art MURAM simulation of the quiet Sun and apply different amounts of spatial degradation and noise to them. We then invert these synthetic observations and discuss the differences between the original and the inverted atmospheres. Most notably, we find that even at "decent" spatial resolution of 0.15 arcseconds, a lot of small-scale structure of the atmosphere simply cannot be seen, even though we have needed "depth" resolution provided by the infrared lines. We discuss possible advances that can be made with upcoming telescopes and scientific implications of the diagnostics we propose.

The diagnostic value of the Mn I spectral lines in the era of large solar telescopes

15 June
10:00 am
Contributed

Nikola Vitas[1]

[1]IAC – Instituto de Astrofísica de Canarias, Spain

Manganese has nuclear spin I = 5/2 and thus many spectral lines of Mn I are widely broadened by hyperfine structure. This additional broadening significantly affects the formation of these lines in the solar photosphere and modifies their sensitivity to the temperature and magnetic field in respect to the similar spectral lines without hyperfine structure. Although these lines had been intensively studied, their usage has been limited due to computationally expensive algorithm for calculating the hyperfine splitting in the presence of magnetic field. Here we present a new rapid and accurate approach for computing these lines and demonstrate how they can be used to infer the solar parameters from observations. To compare the diagnostic value of the Mn I lines relative to the commonly used lines of Fe I, we synthesize observations with the spatial resolution comparable to the resolution of European Solar Telescope. In the numerical tests we use snapshots from the local-dynamo quiet Sun simulations initiated by the Biermann's battery seed performed with the MANCHA code.

Magnetic sensitivity of the scattering polarization signal in the wings of the Ca I line at 4227 Å

15 June
10:15 am
Contributed

Ernest Alsina Ballester[1], L. Belluzzi[1], and J. Trujillo Bueno[1]

[1]Istituto Ricerche Solari Locarno (IRSOL), Switzerland
[2]IAC – Instituto de Astrofísica de Canarias, Spain

The scattering polarization signal of the Ca I line at 4227 Å shows a peculiar triple-peak profile, with a sharp peak in the line core and broader peaks in the wings. This structure is due to frequency coherence in line scattering processes and cannot be modeled under the assumption of CRD. Since the Hanle effect operates in the line core region only, it has generally been thought that the amplitude of the scattering polarization wing lobes is insensitive to the presence of weak magnetic fields. However, recent theoretical investigations have shown that such wing lobes are in fact sensitive to the magnetic field through another physical mechanism, namely the magneto-optical effects that rotate the plane of linear polarization as radiation propagates through the solar atmosphere. Here, the expected signatures of such mechanism are discussed, focusing on the implications for magnetic field diagnostics in quiet or weakly magnetized regions.

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15 June
11:00 am
Report

SRD: Report from WG7

Luca Belluzzi[1], A. Feller[2], and J. Trujillo Bueno[3]

[1]Istituto Ricerche Solari Locarno (IRSOL), Switzerland
[2]Max-Planck Institute for Solar System Research (MPS), Germany
[3]IAC – Instituto de Astrofísica de Canarias, Spain

The chapter *Scattering polarization and Hanle-Zeeman diagnostics* of the EST Scientific Requirement Document (SRD) collects a series of observing programs (OPs) focused on scattering polarization signals of particular interest either because of their diagnostic potential for the investigation of the magnetism of the solar atmosphere (especially in domains that are not accessible through the Zeeman effect), or because their theoretical interpretation is still unclear. The OPs are specifically designed so as to exploit the specific advantages of the EST, in particular the combination of high polarimetric sensitivity and high spatio-temporal resolution. In this talk, we review the status of this chapter of the SRD, and we present in detail some of the observing programs that have been proposed so far.

Poster Session 8

Comparison of bisectors with inversions based on response functions to infer line-of-sight velocities of the Si I 10827 Å line

Poster

Sergio J. González Manrique[1], and C. Kuckein[2]

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We compare two methods to compute the Doppler shifts and infer the line-of-sight (LOS) velocities of the largely used photospheric Si I 10827 Å line. This line yields information about the upper photosphere. The first method consisted of computing the height-depend bisectors of the line. The second method required much longer computational time since an inversion code was used. For this purpose we used the Stokes inversion based on response function (SIR) code, which provided height-dependent information, in an optical depth scale, of the LOS velocities. The used data set of this study was observed on 2015 April 17 with the very fast spectroscopic mode of the GREGOR Infrared Spectrograph (GRIS). Small pores and large quiet Sun areas were within the field of view. Two different data sets at different times were exploited for this study. The wavelength positions of the bisectors were computed in 10%-steps of the line depth using linear interpolation in both line wings. The output model from the SIR code covered 55 optical depth positions which range between $1.4 \geq \log \tau \geq -4.0$. These LOS velocity maps from SIR at different $\log \tau$ were compared with those originated from the bisector method at different percentages. The comparison between both methods allowed us to associate the bisector percentages to a specific optical depth. We associated nine LOS velocity bisector maps, in 10% steps of the line depth, starting from the lowest value at 10% and ending at the highest value of 80%. The bisector and SIR velocity maps were compared using the Pearson linear correlation coefficient. Each of the LOS velocity bisector maps was compared and correlated with the SIR LOS velocity maps. High linear correlations in the range of 95-98% were found. Bisector velocities obtained deeper in the line correspond to lower optical depths. The best correlation (97.8%) was achieved for the SIR velocity map at $\log \tau = -2.6$, which corresponds to a bisector of 20%. The inferred correspondence between bisector percentage and optical depth can be used to quickly obtain information about the LOS velocity stratification versus optical depth.

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Solar large-scale magnetic field variations from HMI data

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Solar observations by SDO/HMI offer a unique possibility to analyse a long-term spectro-polarimetric dataset, spanning a large fraction of the present solar cycle. We use this dataset in order to analyse the large-scale solar magnetic field, retrieving the dipolar, quadrupolar, and octupolar contributions from spectro-polarimetric inversion, using the COSSAM code on the integrated solar signal. We explore possible correlations between our results and activity indices.

This work may complement future observations by the EST, which will concentrate on the small-scale magnetic field on the solar surface, adding information about the behaviour of the large-scale solar magnetic fields during the activity cycle.

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