

# SOLARNET IV MEETING

## The Physics of the Sun from the Interior to the Outer Atmosphere

The purpose of this conference is to provide a coherent picture of the Sun as a single physical system playing all the underlying physical processes measured and observed in the solar atmosphere to date.

This conference is expected:

- 1) to provide a forum to discuss recent advances in the study of the solar interior, solar dynamics and dynamo, mechanisms of sunspot and active regions formation, and links between the subsurface dynamics, flaring and CME activity;
- 2) to identify the new problems in the study of the solar interior and atmosphere, and of the solar dynamics and magnetism;
- 3) to foster collaborations between researchers working at the study of the Sun's interior and solar atmosphere and to create synergies between solar research programs at different wavelength bands.

### Scientific Organisation Committee:

Elena Khomenko [chair]

María Jesús Martínez González [co-chair]

Alina Donea

Natasha Shchukina

Francesca Zuccarello

Aimee Norton

Lindsey Fletcher

Ineke de Moortel

Emilia Kilpua

Mausumi Dikpati

### Local Organisation Committee:

Elena Khomenko [chair]

María Jesús Martínez González [co-chair]

Iñigo Arregui Uribe-Echevarria

Melania Cubas Armas

Carlos José Díaz Baso

Reza Rezaei

Beatrice Popescu Braileanu

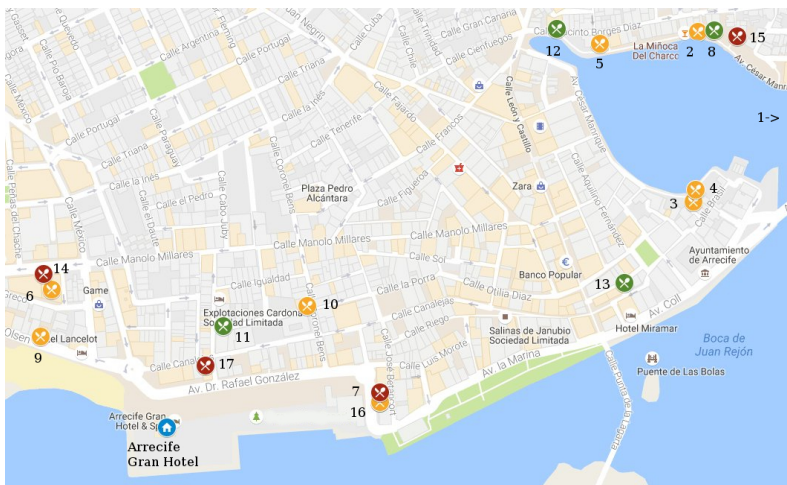
Alberto Escobar Rodríguez

Manuel Collados Vera



The restaurants in the area can be found at:

<https://goo.gl/KLPDIF>



## RESTAURANTS

### Contemporary Canarian food

- 1 Restaurante Lilium [40 €]
- 2 Tasca la Raspa [20-30 €]
- 3 La Tabernita del Charco [20-30 €]
- 4 La Puntilla Colón [20-30 €]
- 5 Naia - Mikel Otaegui [20-30 €]

### Italian food

- 6 El Nuevo Maccheroni [20-30 €]
- 7 Pizzería Dagigi [10-20 €]

8 Divina Italia [20-30 €]

9 Pizzeria Venezia [10-20 €]

### **Mexican food**

10 La Lupe [20-30 €]

### **VEGETARIAN / VEGAN**

11 The V Factor [10-20 €]

12 El veganito del charco [10-20 €]

13 Grapagu [tapas] [10-20 €]

### **FAST FOOD**

### **Tapas**

13 Grapagu [vegetarian / vegan] [10-20 €]

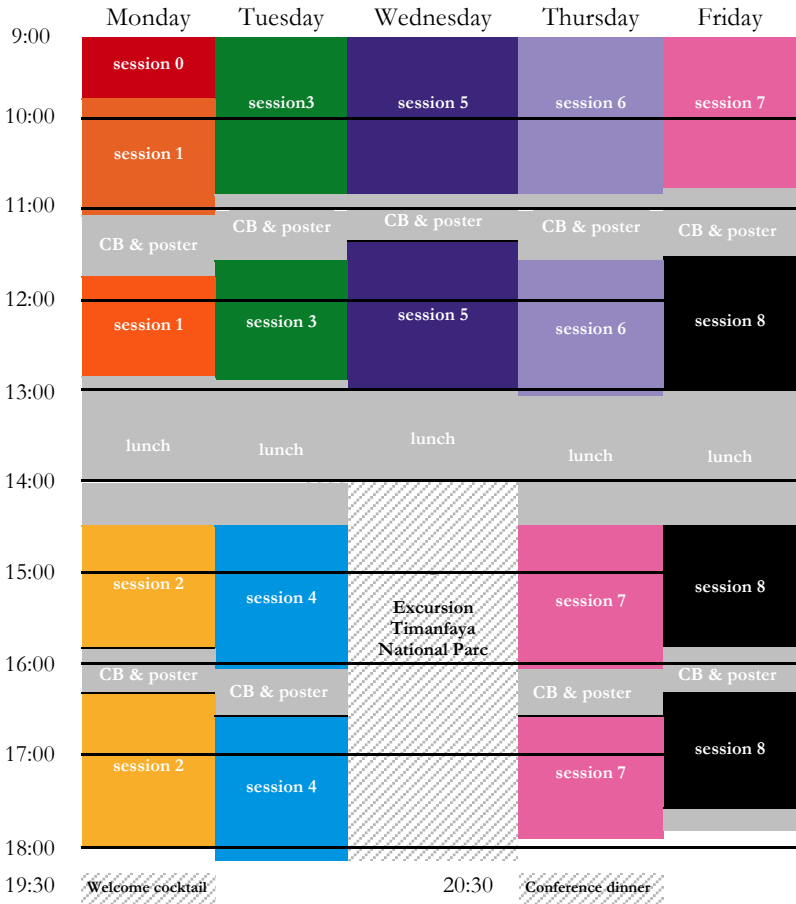
14 El barrilito Tapas y pinchos [20-30 €]

15 La Bulla [20-30 €]

### **Hamburguers**

16 Tabla Arrecife [20-30 €]

17 Superguay [10-20 €]



- SOLARNET
- Solar internal structure from helioseismology
- Solar cycle: convection, rotation, dynamo, flux emergence
- Theoretical radiative transfer and spectropolarimetry
- Photospheric dynamics and magnetism
- Chromospheric dynamics and magnetism
- Corona and transition region: dynamics, magnetic fields and heating mechanisms
- Energetic events, flares and CMEs, and space weather
- Upcoming telescopes and instruments



## MONDAY, JAN 16<sup>th</sup>

09:00 – 09:15	Welcome	Elena Khomenko Marian Martínez
09:15 – 09:45	The SOLARNET project	Manuel Collados

### Session 1: Solar internal structure from helioseismology

**Chair: Elena Khomenko**

09:45 – 10:15	<b>IR:</b> Helioseismic probes of the solar interior	Anne-Marie Broomhall
10:15 – 10:35	<b>ST:</b> Data assimilation as a tool to better understand the solar magnetism	Laurent Jouvé
10:35 – 10:50	Halo formation in realistic 3D MHD simulations	Irina Thaler
10:50 – 11:05	3D hydrodynamical corrections for near surface effects on solar oscillations	Lionel Bigot

### 11:05 – 11:45 Coffee break and poster session

11:45 – 12:05	<b>ST:</b> Forward modeling for local solar seismology	Tobías Felipe
12:05 – 12:20	Formation of sunspots: theory and observations	Illa R. Losada
12:20 – 12:35	A new physical mechanism to explain meridional circulation's cyclic variations	Dário Passos
12:35 – 12:50	Deep meridional flow inversions with spherical born kernels and time-distance helioseismology	Vincent Böning

**12:50 – 14:30 Lunch at the Arrecife Gran Hotel**

## MONDAY, JAN 16<sup>th</sup>

### Session 2: Solar cycle: convection, rotation, dynamo, flux emergence

**Chair: Ada Ortiz**

14:30 – 15:00	<b>IR:</b> Differential rotation and convective dynamo in the solar convective envelope	Yuhong Fan
15:00 – 15:20	<b>ST:</b> Dynamo modes as a mechanism for long-term solar activity variations	Maarit Käpylä
15:20 – 15:35	Confinement of the solar tachocline subject to radiative spreading via a cyclic dynamo magnetic field	Roxane Barnabé
15:35 – 15:50	Understanding dynamo mechanisms and torsional oscillations from 3D convection simulations of the Sun	Jörn Warnecke

### 15:50 – 16:20 Coffee break and POSTER session

16:20 – 16:40	<b>ST:</b> Where are the solar magnetic poles?	Adur Pastor Yabar
16:40 – 17:00	<b>ST:</b> Measurement of the meridional flow: Current developments and results	Ariane Schäd
17:00 – 17:15	Variation of the photospheric temperature gradient with magnetic activity	Marianne Faurobert
17:15 – 17:30	A deep-seated mechanism for cycle-dependent sunspot group tilt angles	Emre Isik
17:30 – 17:45	Solar-like magnetic cycles in 3D turbulent global models of stars	Antoine Strugarek
17:45 – 18:00	Interpreting a millennium solar-like dynamo with the test-field method	Frederick Gent

**19:30 Welcome cocktail**



## TUESDAY, JAN 17<sup>th</sup>

### Session 3: Theoretical radiative transfer and spectropolarimetry Chair: Sarah Gibson

09:00 – 09:30	<b>IR:</b> Non-LTE chromospheric diagnostics and inversions	Jaime de la Cruz
09:30 – 09:50	<b>ST:</b> Sunrise II observations of emergence sites in a solar active region	Rebecca Centeno
09:50 – 10:05	Response functions for NLTE lines	Ivan Milic
10:05 – 10:20	Si I atomic model for NLTE spectropolarimetric diagnostics of the 1082.7 nm line	Natalia Shchukina
10:20 – 10:35	Non-LTE 3D radiative transfer with a Multigrid Solver	Johan Pires Bjørgen
10:35 – 10:50	Helium lines in the solar spectrum: spatial structure in He I 10830 and the anomalous intensity of the resonance lines	Jorrit Leenaarts

### **10:50 – 11:35 Coffee break and poster session**

11:35 – 11:55	<b>ST:</b> Three-dimensional radiative transfer simulations of the scattering polarization	Jiri Stepan
11:55 – 12:10	Spatially resolved Stokes measurements in the Sr I (4607.3 Å) line with FSP at VTT/TESOS	Franziska Zeuner
12:10 – 12:25	The missing 'M' ingredient in 3D photospheric simulations for solar abundances	Damian Fabbian
12:25 – 12:40	A novel radiative transfer investigation of the magnetic micro-activity of the quiet Sun	Javier Trujillo Bueno
12:40 – 12:55	Chromospheric line formation of OI 7772	Hiva Pazira

### **12:55 – 14:30 Lunch at the Arrecife Gran Hotel**

## TUESDAY, JAN 17<sup>th</sup>

### Session 4: Photospheric dynamics and magnetism

Chair: **María Jesús Martínez González**

14:30 – 15:00	<b>IR:</b> Measurements of photospheric magnetic fields	Andreas Lagg
15:00 – 15:20	<b>ST:</b> Emergence of granular-sized magnetic bubbles through the solar atmosphere	Ada Ortiz
15:20 – 15:35	Photospheric counter Evershed flows in the penumbra of sunspots	A. L. Siu-Tapia
15:35 – 15:50	Kinematics and magnetic properties of a light bridge in a decaying sunspot	Mariachiara Falco
15:50 – 16:05	Investigation of straylight in data from the GREGOR Infrared Spectrograph	Morten Franz

### 16:05 – 16:20 Coffee break and poster session

16:20 – 16:40	<b>ST:</b> New insights on penumbra formation	Nazaret Bello
16:40 – 16:55	Numerical simulations of the quiet-sun magnetic field: Beyond MHD	N. Vitas
16:55 – 17:10	Turbulent convection and the dynamic properties of photospheric magnetic fields in the quiet Sun	Fabio Giannattasio
17:10 – 17:25	Multiwavelength study of penumbral decay using GREGOR, VTT, NST, and Hinode	Meetu Verma
17:25 – 17:40	Long-period oscillations of active region patterns: least-square mapping on second-order curves	Gulsun Dumbadze
17:40 – 17:55	Flare-productive active regions: magnetic properties and evolutions	Shin Toriumi

## WEDNESDAY, JAN 18<sup>th</sup>

### Session 5: Chromospheric dynamics and magnetism

Chair: Natasha Shchukina

09:00 – 09:30	<b>IR:</b> Observations and diagnostics of the solar chromosphere	Rob Rutten
09:30 – 09:50	<b>ST:</b> Alfvén wave heating of the solar chromosphere	Tony Arber
09:50 – 10:05	Ellerman bombs in 1-D radiative hydrodynamics	Aaron Reid
10:05 – 10:20	Physical properties of a group of pores as derived from Ca II 854.2 nm observations and inversions	Christoph Kuckein
10:20 – 10:35	On the generation of solar spicules and Alfvén waves	Mats Carlsson
10:35 – 10:50	Slender Ca II H fibrils observed by SUNRISE 2	R. Gafeira

### 10:50 – 11:20 Coffee break and poster session

11:20 – 11:40	<b>ST:</b> 3D simulation of chromospheric jets with twisted magnetic field lines	Haruhisa Iijima
11:40 – 12:00	<b>ST:</b> IRIS diagnostic for lower chromospheric heating	Tiago Pereira
12:00 – 12:15	Structure of chromospheric magnetic field in solar active regions	Sanjay Gosain
12:15 – 12:30	Ellerman bomb emission features in He I D3 and He I 10830: observations and modelling	Tine Libbrecht
12:30 – 12:45	Formation of a stable penumbra in a region of flux emergence	Mariarita Murabito
12:45 – 13:00	Photospheric and chromospheric observations of dynamic features in an arch filament system	S. J. González Manrique

**13:00 – 14:00 Lunch at the Arrecife Gran Hotel**

**14:00 – Excursion to the Timanfaya National Parc**

## THURSDAY, JAN 19<sup>th</sup>

### Session 6: Corona and transition región: dynamics, magnetic fields and heating mechanisms

**Chair: Consuelo Cid**

09:00 – 09:30	<b>IR:</b> Dynamics and diagnostics of the solar corona: unchained magnetism	Sarah Gibson
09:30 – 09:50	<b>ST:</b> Nanoflare properties in the solar corona	Nicki Viall
09:50 – 10:05	IRIS and SDO observations of coronal heating associated with spicules	Ineke De Moortel
10:05 – 10:20	New insights on mass flows in and out of the solar transition region	Pia Zacharias
10:20 – 10:35	Nonlinear force-free coronal magnetic stereoscopy	Iulia Chifu
10:35 – 10:50	A global view of velocity fluctuations in the corona	Richard Morton

### **10:50 – 11:35 Coffee break and poster session**

11:35 – 12:05	<b>IR:</b> Heating of the solar corona	Iñigo Arregui
12:05 – 12:20	Formation and evolution of coronal rain observed by SDO/AIA on February 22, 2012	Zurab Vashalomidze
12:20 – 12:35	Estimation of coronal Solar rotation using 171Å Extreme UV images from SOHO	Shivam Raval
12:35 – 12:50	Bombs, jets and flares at the surface and lower atmosphere	Viggo Hansteen
12:50 – 13:05	Contribution of coupling of Alfvén and kink modes to coronal heating	Paolo Pagano

**13:05 – 14:30 Lunch at the Arrecife Gran Hotel**

## THURSDAY, JAN 19<sup>th</sup>

### Session 7: Energetic events, flares and CMEs, and space weather Chair: Francesca Zuccarello

14:30 – 15:00	<b>IR:</b> Solar eruptions and energetic events	Astrid Veronig
15:00 – 15:20	<b>ST:</b> Magnetic reconnection in twisted magnetic fields in solar flares - heating, particle acceleration and observational signatures	Philippa K. Browning
15:20 – 15:35	Properties of quasi-periodic pulsations in solar flares from a single active region	Chloe E. Pugh
15:35 – 15:50	Could the Hale Sector Boundary help us to anticipate solar flares?	K. Loumou
15:50 – 16:05	Relationship of EIT waves phenomena with Coronal Mass Ejections	V. K. Verma

### **16:05 – 16:35 Coffee break and poster session**

16:35 – 17:05	<b>IR:</b> Solar energetic events and space weather	Consuelo Cid
17:05 – 17:25	<b>ST:</b> Coronal Mass Ejections and Geomagnetic Storms	Marilena Mierla
17:25 – 17:40	Radiative energy budget of solar flares and its scaling with the soft X-ray flare size	Matthieu Kretzschmar
17:40 – 17:55	Examining the drag force on coronal mass ejections	Chia-Hsien Lin
17:55 – 17:55	The Solar event of June 21, 2015: comprehensive Sun-to-Earth analysis	Luca Giovannelli

### **20:30 Conference dinner at “Los Jameos del Agua”**

## FRIDAY, JAN 20<sup>th</sup>

### Session 7: Energetic events, flares and CMEs, and space weather

Chair: Ineke de Moortel

09:00 – 09:15	Propagation of filament and hot plasma through solar atmosphere as observed with ground based and space instruments	A. Kucera
09:15 – 09:30	An alternative cellular avalanche model based on maximum release of energy during solar flares	Nastaran Farhang
09:30 – 09:45	The role of erupting sigmoid in triggering a flare with double set of ribbons	Navin Chandra Joshi
09:45- 10:00	GONG Catalog of large-amplitude oscillations	Manuel Luna
10:00 – 10:15	Coronal loop footpoints threaded with small-scale mixed polarity surface magnetic fields	L. P. Chitta
10:15 – 10:30	Numerical simulation of cool ascending flows in chromosphere	Tatsuki Nakamura
10:30 – 10:45	H $\alpha$ and H $\beta$ emission in a C3.3 solar flare: comparison between observations and simulations	Vincenzo Capparelli

**10:45 – 11:30 Coffee break and poster session**

### Session 8: Upcoming telescopes and instruments

Chair: Nazaret Bello González

11:30 – 12:00	<b>IR:</b> Science with European Solar Telescope	Sarah Matthews
12:00 – 12:20	<b>KT:</b> A science driven update to the Daniel K Inouye Solar Telescope	Valentín Martínez
12:20 – 12:40	<b>KT:</b> Solar Orbiter mission	J. C. del Toro
12:40 – 13:00	<b>KT:</b> Sunrise III project	H.-P. Doerr

**13:00 – 14:30 Lunch at the Arrecife Gran Hotel**

## FRIDAY, JAN 20<sup>th</sup>

### Session 8: Upcoming telescopes and instruments

**Chair: Rebeca Centeno Elliott**

14:30 – 14:50	<b>KT:</b> Results and future of CLASP project	Masahito Kubo
14:50 – 15:05	Prototype characterization and future development of the “Fast Solar Polarimeter”	F. A. Iglesias
15:05 – 15:20	The Heat Rejecter for the GREGOR telescope: a prototype for the European Solar Telescope	F. Berrilli
15:20 – 15:35	SST/CHROMIS: a new window to the solar chromosphere	Goran Scharmer
15:35 – 15:50	Observations of absolute convective blue-shifts with the Laser Absolute Reference Spectrograph at the VTT	Johannes Löhner-Böttcher

### 15:50 – 16:20 Coffee break and poster session

16:20 – 16:35	How does an adaptive optics system work in polarized light?	Marco Stangalini
16:35 – 16:50	The Solar Physics Research Integrated Network Group – SPRING	Markus Roth
16:50 – 17:05	First tests of the Integral Field Unit for GRIS@GREGOR	Andrés Asensio Ramos
17:05 – 17:20	Image restoration of polarimetric slit spectra	Michiel van Noort
17:20 – 17:35	The SOLARNET Solar Virtual Observatory prototype	R. Vansintjan

**17:35 – 17:45 Concluding remarks**

**20:00 End of the Conference**





**SOLARNET Introductory talk:** “The SOLARNET project”**Author(s):** Manuel Collados (Project Coordinator)

**Abstract:** SOLARNET is a EU-funded project aimed at preparing the European Solar Physics research community for the operation of the European Solar Telescope (EST). To achieve this ambitious goal, the project has addressed a number of activities to optimise the use of the major present European high-resolution solar telescopes (GREGOR, SST, THEMIS, VTT) and instruments (IBIS and ROSA operating at DST). The experience gained with these activities will serve as a basis to determine the best way to operate EST and optimise its scientific return to the research community. The following achievements can be mentioned: (1) granting access to world-wide observers to the most powerful European solar observing facilities; (2) implementation of a service mode as a complement to the standard PI-mode; (3) development of standard pipelines for all instruments to produce science-ready data; (4) generation of rules for standard data archiving and retrieval; (5) creation of databases with ground-based data that may be accessed with virtual observatories tools; (6) development of new generation instruments as prototypes for the instrumentation of EST; (7) definition of a global network (SPRING) for continuous ground-based full-sun observations to help prepare and support high-resolution observations; (8) seeing measurements and AO/MCAO optimisation analyses; (9) preparation of the next generation of solar researchers with the organisation of a number of schools and with an efficient student mobility programme; (10) organization of a number of scientific meetings to foster synergies between different research communities; (11) establishment of contacts with the European industry; and (12) disseminate solar research with outreach activities. All these activities will be described in this contribution making emphasis on the importance of SOLARNET for the solar physics community and EST.

**Poster:** “SOLARNET WP20: Integrated operation and exploitation of solar physics facilities and coordination with other research infrastructures”

**Author(s):** Rolf Schlichenmaier (WP leader)

**Abstract:** This work package was aimed to coordinate and advance the concepts and condition for the ground-based European solar physics community. This poster will highlight the various activities: (1) the coordination and implementation of the program of Transnational Access and Services (TAS) via the Time Allocation committee (TAC) of the European Association for Solar Telescopes (EAST), (2) the development of guidelines for data pipelines and data archiving, (3) the study of novel observing strategies. The Forum for Access and Service (FAS), that met annually, was essential for the great achievements of this work package.

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**Poster:** “SOLARNET WP30: Solar Physics Networking”

**Author(s):** Francesca Zuccarello & the SOLARNET Team

**Abstract:** Aim of this work-package was to foster collaborations among different solar physics groups, promote the interaction and cooperation among researchers of different level of expertise, as well as to encourage and promote synergies with other fields. The actions undertaken in this work-package have been: exploitation of ground- and space-based data; enhancement of collaborations with other communities and projects; promotion of collaborations between the new generation of scientists and experienced researchers through short stays and training actions to acquire competences in relevant fields of solar physics. More specifically, the first task of this WP was to organize four Meetings whose objective was to put in contact different solar physics communities and researchers involved in different fields of research. The second task concerned the Mobility of young researchers with the goal to reinforce the contacts between different groups and to allow young researchers to begin early to establish international collaborations. The third task concerned the organization of: a) Summer/Winter

Schools for PhD students and novel post-doc researchers on topics related to the development of new instrumentation for solar observations, diagnostic tools, hot solar research topics and fields of mutual interest for solar and stellar physicists; b) Thematic Workshops matched with the training schools.

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**Poster:** “SOLARNET WP40: Innovation Towards Industry: identification of technology transfer opportunities between the astrophysics community and other high tech sectors”

**Author(s):** Richard Seddon, Jesús M. Olaya

**Abstract:** The SOLARNET WP40 Innovation Towards Industry work package has worked to identify common technologies and technology transfer opportunities between the solar astrophysics sector and other industrial sectors. This poster summarises the results of the activities carried out for the identification and development of technological synergies between the solar astrophysics and other high-tech sectors, for the transfer of knowledge and for the identification of common interests between these sectors.

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**Poster:** “SOLARNET WP50: The SOLARNET data pipeline activity”

**Author(s):** Dan Kiselman

**Abstract:** State-of-the art instrumentation of solar telescopes produces multi-dimensional data at a high rate. Streamlined data pipelines with well-characterized data products are required for these instruments to meet their scientific potential. Standard data products can also be incorporated in databases - "virtual observatories" - which can serve a much broader community. All this is standard for space missions but have not been so for European ground-based solar instruments. As part of SOLARNET, data pipelines have been produced for eleven European instruments at several ground-based telescopes (DST, GREGOR, SST, THEMIS,

and VTT). As part of the work, recommendations and standards for the handling and representation of meta data have been produced. We give an overview of the pipeline situation with examples and illustrations.

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**Poster:** “SOLARNET WP60: Advanced Instrumentation development”

**Author(s):** Héctor Socas Navarro (WP leader)

**Abstract:** Here we present the status of SOLARNET work package WP60: "Advanced Instrumentation Development". This WP involves the development of four new instrumental concepts that will be of crucial importance to meet the challenges posed by future solar observations: WP60.1: A large format Etalon system for tuneable, narrow-band spectral imaging; WP60.2: An image slicer for 2D integral field spectroscopy; WP60.3: A new fiberlens-fed spectrograph prototype for 2D integral field spectroscopy; WP60.4: A fast (kHz) rate polarimeter design. The current status and milestones reached by all four subWPs is summarized here.

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**Poster:** “SOLARNET WP70: Turbulence characterisation and correction”

**Author(s):** Manuel Collados, Iciar Montilla, Luz M. Montoya, Francesco Berrilli, Ramón Codina, Ilaria Ermolli, Bernard Gelly, Robert Hammerschlag, Oscar Hartogensis, Dan Kiselman, Fabio Manni, D. Soltau

**Abstract:** SOLARNET WP70 investigates the effects of air turbulence on wavefront distortion and analyses techniques to reduce and correct the optical degradation in order to improve the performance of existing solar telescopes and to optimise the design of EST. The objectives of this WP are divided in three areas: - Characterisation of the daytime atmospheric turbulence at the Canary Islands observatories and its effect (atmospheric seeing) on the wavefront propagation. - Characterisation of the air turbulence

produced at the telescopes environment and validate techniques to predict its effect (local seeing) on the wavefront propagation. Implement an optimized heat rejecter prototype at the GREGOR telescope to reduce the heat load on the telescope primary focus to improve its performance. - Development of numerical simulations to optimize the performance of the adaptive optics systems used to correct the wavefront distortion and implement an adaptive optics system prototype at THEMIS telescope to improve the performance of this facility. This contribution describes all the activities carried out in these three aspects and the results obtained.

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**Poster:** “SOLARNET WP80 - Synoptic observations: Solar Physics Research Integrated Network Group (SPRING)”

**Author(s):** Markus Roth, Frank Hill, Michael Thompson, Sanjay Gosain

**Abstract:** High-resolution telescopes (such as SST, GREGOR and the future EST and ATST) allow observations of only a small fraction of the solar surface. Real-time context data showing the large-scale dynamics and magnetism at different layers of the solar atmosphere are crucial to understand the global behavior of solar phenomena. However, despite the amount of information coming from space and ground-based full-Sun telescopes, real-time information about the variation of important parameters such as velocities, magnetic field and intensity at different solar layers is still lacking. To this aim, a network of telescopes with a small aperture but a large field-of-view can provide useful data to prepare observing campaigns with large-aperture high-resolution telescopes and complement the data taken with them. Distributed in a worldwide network, these small apertures can represent an invaluable supporting tool for coordinated observations with the major infrastructures. Within this Joint Research Activity under Solarnet, the definition of an adequate network of small telescopes, as well as the most suited instrumentation was addressed.

**Poster:** “SOLARNET WP 90: Transnational Access Programme”

**Author(s):** Rolf Schlichenmaier (WP leader)

**Abstract:** The task of this work package was to grant access to the most-advanced solar telescopes and instruments. Under SOLARNET, access was granted to the major European solar telescopes on the Canary Islands: SST, GREGOR, VTT, and THEMIS. Moreover, European scientists were granted with service mode campaigns at the European instruments IBIS and ROSA at the US-American Dunn Solar Telescope. This ACCESS program was most successful which is reflected, e.g., by a large oversubscription rate. This in turn asked for thorough evaluation. Many scientists who do not have access to their 'own' facility took advantage of this program. As a consequence, the community of ground-based solar physics has grown during SOLARNET.

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**Poster:** “SOLARNET WP 100: Access to Science Data Centres. Space missions.”

**Author(s):** Mats Carlsson

**Abstract:** The SOLARNET workpackage 100 provides access to Space data through three Science Data Centres: Hinode and IRIS data through the Hinde Science Data Centre Europe in Oslo, SDO AIA data through the Belgian Web Incessant Screening for SDO Mission in Brussels and SDO HMI data through the German Science Center for the Solar Dynamics Observatory in Göttingen. We here describe the three data centres and usage statistics throughout the SOLARNET period.











**Invited review:** “Helioseismic probes of the solar interior”

**Author(s):** Anne-Marie Broomhall

**Abstract:** Helioseismology uses the Sun’s natural oscillations to probe beneath the surface of the Sun. Over the past several decades helioseismology has proven extremely successful at providing insights into the interior of the Sun: We have learnt about the structure of the solar interior, including the depth of the convection zone, we have learnt about the composition of the Sun, and we have learnt about rotation and other internal flows. I will review our current understanding of the solar interior based upon helioseismic results, and describe how the Sun’s interior varies over timescales commensurate with the solar cycle. For example, although it is difficult to detect solar-cycle related structural changes in the deep interior, variations in rotation have been observed in the form of the torsional oscillation. I will also discuss some of the remaining challenges for helioseismologists to address, including the search for internal gravity modes, whose detection would substantially advance our ability to infer properties of the structure and dynamics of the deep solar core.

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**Solicited talk:** “Data assimilation as a tool to better understand the solar magnetism”

**Author(s):** C.P. Hung, [Lauren Jouve](#), A.S. Brun, A. Fournier

**Abstract:** We present recent studies which aim at implementing variational data assimilation into mean-field solar dynamo models. The main goal of such studies is to prove that the variational approach is a powerful tool to better determine some key ingredients of such models, as for instance the source of poloidal magnetic field or the mean meridional flow. We will present the first work of Jouve et al (2011) in which a classical alpha-Omega model is used to produce the observations with a particular set of parameters. The so-called twin experiments performed in this work enable to reconstruct the alpha function which was used to produce the observations, by minimizing a well-chosen misfit between data

and outputs of the model. The second study which will be presented is a more realistic flux-transport dynamo model in spherical geometry (Hung et al, 2015) in which we intend to infer the meridional flow profile from synthetic observations of the magnetic field. We will then discuss how such data assimilation techniques may improve our ability to forecast the solar magnetic activity.

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**Contributed talk:** “Halo formation in realistic 3D MHD simulations”

**Author(s):** Irina Thaler, Vigeesh G., Roth, M.

**Abstract:** Since the first discovery of acoustic halos around magnetic regions by (Brown 1992, Toner and LaBonte 1993) many observational and theoretical studies have been undertaken to better understand this phenomena. The currently most accepted theory for its formation is the refraction of fast magnetic waves in the solar atmosphere, which then leads to the observed power excess in doppler velocity maps compared to the quiet sun (Khomenko & Collados 2009, e.g. Rijs 2016). Along with that we want to investigate if we can confirm these results with non-linearized wave propagation through a sunspot stripe in fully convective 3D MHD simulations using the STAGGER code.

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**Contributed talk:** 3D hydrodynamical corrections for near surface effects on solar oscillations

**Author(s):** Lionel Bigot

**Abstract:** The most sophisticated standard evolution models of the Sun predict frequencies for the solar oscillations that are too large compared with observations. This shift (up to  $\sim 25$  microHz) cannot be explained using mixing-length. In this poster, I will show how a 3D hydrodynamical simulation of the solar surface coupled with non-adiabatic treatment of solar oscillations can resolve the discrepancy. The formalism is based on a variational approach to

calculate the frequency shifts. I will show that such realistic treatment of the surface layers leads to an agreement of 0.5 microHz.

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**Solicited talk:** “Forward modeling for local solar seismology”

**Author(s):** Tobias Felipe, D.C. Braun, A. D. Crouch, A. C. Birch

**Abstract:** Sunspots are one of the most prominent manifestations of solar magnetic activity and have been studied using local helioseismology for decades. Recent modeling and observational studies indicate that the interpretation of travel-time shifts is still subject to uncertainties regarding the physical causes of the wave perturbations. Numerical wave propagation has proved useful in addressing this problem. In this work, we have analyzed travel-time shifts obtained from three dimensional numerical simulations of wave propagation in a magnetohydrostatic sunspot-like atmosphere. In particular, we isolate the individual effects of the magnetic field and thermal perturbations on the measurements by means of simulations where only one kind of perturbation (magnetic or thermal) is included. The resulting travel-time shift maps, obtained by applying helioseismic holography to the photospheric Doppler signals in the simulated domain, are compared and discussed.

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**Contributed talk:** “Formation of sunspots: theory and observations.”

**Author(s):** Illa R. Losada

**Abstract:** Sunspots are of basic interest in a range of topics within solar physics; from magnetic fields, as activity counter, to source of coronal mass ejections, flares, and motor of space weather. Still their formation is an unresolved problem in nowadays solar physics. Surface observations depict a 2D structure of the spots at the surface, but it is still under debate how to infer deeper structures and properties from local helioseismology. From the theoretical point of view, flux tubes theory manages to explain some of the

observations, but with some drawbacks, like the magnetic field storage mechanism or the survival of a tube rising in a turbulent media. In this talk I will present another theoretical approach to the formation of sunspots: the negative effective magnetic pressure instability, which is able to concentrate magnetic fields in a turbulent stratified medium. This instability suppresses turbulence

and increases the gas pressure, which drags and concentrate the magnetic fields within. In this framework, sunspots ultimately form within the outermost layers of the Sun. From the observational point of view, I will also present some results and approaches from local helioseismology, where we use Hankel analysis to study the pre-emergence phase of sunspots to try to constraint its deep structures and formation mechanism.

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**Contributed talk:** “A new physical mechanism to explain meridional circulation's cyclic variations”

**Author(s):** Dário Passos, Mark Miesch, Gustavo Guerrero, Paul Charbonneau

**Abstract:** Surface observations indicate that the speed of the solar meridional circulation in the surface layers varies in anti-phase with the solar cycle. The current explanation for the source of this variation is that inflows into active regions alter the global surface pattern of the meridional circulation. However, the behaviour of this weak large scale flow, deep inside the convection zone, remains largely unknown. Probing this flow through Helioseismology has proved to be difficult and the long time integration needed to obtain the signal can easily mask certain dynamical behaviours. Also, this flow is one of the main ingredients in the popular axisymmetric flux transport dynamo models and surface flux transport models, that are now tentatively being used for solar cycle predictions. To assess the kind of behaviour that the meridional circulation might present inside the convection zone, where magnetic field strength can achieve considerable values, we use a global 3D MHD model. In this work we examine the dynamics of the meridional circulation

that emerges from a 3D MHD global simulation of the solar convection zone that has a large scale magnetic cycle operating. We find that in most of the convection zone, specially in the regions where the magnetic field accumulates, the meridional circulation cell morphology is highly modified by the action of a magnetic torque that influences the global angular momentum distribution. We show how cyclic variations in the meridional circulation (over the whole convection zone) can be attributed to the combination of magnetically modulated gyroscopic pumping and magneto-thermal wind balance.

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**Contributed talk:** “Deep Meridional Flow Inversions with Spherical Born Kernels and Time-Distance Helioseismology”

**Author(s):** Vincent Böning, Shukur Kholikov, Jason Jackiewicz, and Markus Roth

**Abstract:** In this study, we present first inversion results for deep meridional flow using spherical Born approximation kernels and time-distance helioseismology. The computation of Born approximation kernels for flows has only recently become available in spherical geometry. Compared to the ray approximation, the Born approximation is considered to provide a more realistic model of the advection and scattering processes in the solar interior, which are captured in travel time measurements. We first validate this method using artificial data from a linear 3D simulation of solar interior wave propagation. We find that the prediction of the Born approximation model coincides well with the simulated data. We then perform standard SOLA inversions of the solar meridional flow. First, inversion results of the simulated data are discussed and compared to the original flow profile included in the simulation. Finally, we apply the validated method to GONG data spanning periods of low, medium and high solar activity (2001-2003, 2004-2006, and 2007-2009). The results are discussed and compared to literature.

**Poster:** “Formulations of helioseismic cut-off frequencies compared with MHD simulation results”

**Author(s):** Philippe-A. Bourdin, Irina Thaler, Markus Roth

**Abstract:** Helioseismic analyses discuss atmospheric wave phenomena, where a self-consistent description of the plasma pressure is crucial. Wave phenomena around magnetically active regions are rich of features distinct from the quiet sun. One needs a better understanding of the chromospheric energy budget, as well as the right explanation of local wave phenomena such as halo formation or running penumbral waves, in order to perform helioseismology near active regions. The accurate interpretation of the observed signals requires profound knowledge of the line formation height relative to the  $\beta=1$  level, as well as the magnetic field inclination, which are often not well known nor measurable. Through a 3D-MHD simulation of the solar atmosphere above an active region with some surrounding quiet sun, we are able to compare cut-off frequencies (according to Bel & Leroy 1977) together with plasma parameters like the  $\beta=1$  level and the line formation heights between the simulation and observed signals. We find strong variations in the atmospheric profiles depending on their magnetic environment.

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**Poster:** “From the solar core to the surface through 21 years of exquisite helioseismic data”

**Author(s):** Antonio Eff-Darwich, Sylvain G. Korzennik, Pere Ll. Pallé

**Abstract:** We present state of the art helioseismic eigenfrequencies, derived from over two decades of observations acquired with space-based (HMI, GOLF and MDI) and ground-based (GONG and MARK-I) instruments. The length of the time series, with observations starting all the way back to 1995, and the vast range of frequencies, azimuthal orders and spherical-harmonic angular degrees of the available data sets allow us to study the structure and dynamics of the solar interior from the core to the solar surface



with both high precision and unique resolution. Results for the mean internal structure of the sun, as well as the temporal changes of the solar rotational rate are presented. The impact of the quality of the data on the inferred results about the solar interior are also discussed.











**Invited review:** “Differential rotation and convective dynamo in the solar convective envelope”

**Author(s):** Yuhong Fan

**Abstract:** Significant advances have been made in recent years in global-scale fully dynamic three-dimensional convective dynamo simulations of the solar/stellar convective envelopes to reproduce some of the basic features of the Sun’s large-scale cyclic magnetic field. It is found that the presence of the dynamo-generated magnetic fields may play an important role for the maintenance of the solar differential rotation, without which the differential rotation tends to become anti-solar (with a faster rotating pole instead of the observed faster rotation at the equator). The main driver for the solar-like differential rotation (with faster rotating equator) is a net outward transport of angular momentum away from the rotation axis by the Reynolds stress, and it is found that this transport is enhanced with reduced viscosity and magnetic diffusion. The convective dynamo is also found to produce the emergence of strong super-equipartition flux bundles at the surface, exhibiting properties that are similar to emerging solar active regions.

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**Solicited talk:** “Dynamo modes as a mechanism for long-term solar activity variations”

**Author(s):** Maarit J. Käpylä, Petri J. Käpylä, Nigul Olsperg, Axel Brandenburg, Jörn Warnecke and Frederick A. Gent

**Abstract:** Solar magnetic activity shows both smooth secular changes, such as the modern Grand Maximum, and quite abrupt drops that are denoted as grand minima, such as the Maunder Minimum. Direct numerical simulations (DNS) of convection-driven dynamos offer one way of examining the mechanisms behind these events. In this work, we analyze a solution of a solar-like semi-global wedge magneto convection simulation that has been evolved for nearly 200 magnetic cycles of 4.9 years and where epochs of irregular behavior are detected. A special property of the DNS is the existence of multiple dynamo modes at different depths and

latitudes. The dominant mode is solar-like (equatorward migration at low latitudes and poleward at high latitudes). This mode is accompanied by a higher frequency mode near the surface and at low latitudes, showing poleward migration, and a low-frequency mode at the bottom of the convection zone. The overall behavior of the dynamo solution is extremely complex, exhibiting variable cycle lengths, epochs of disturbed and even ceased surface activity, and strong short-term hemispherical asymmetries. Surprisingly, the most prominent suppressed surface activity epoch is actually a global magnetic energy maximum; during this epoch the bottom toroidal magnetic field obtains a maximum, demonstrating that the interpretation of grand minima-type events is non-trivial. We interpret the overall irregular behavior as being due to the interplay of the different dynamo modes showing different equatorial symmetries, especially the smoother part of the irregular variations being related to the variations of the mode strengths, evolving with different and variable cycle lengths. The abrupt low-activity epoch in the dominant dynamo mode near the surface is related to a strong maximum of the bottom toroidal field strength, which causes abrupt disturbances especially in the differential rotation profile via the suppression of the Reynolds stresses.

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**Contributed talk:** “Confinement of the solar tachocline subject to radiative spreading via a cyclic dynamo magnetic field”

**Author(s):** Roxane Barnabé, A. Strugarek, P. Charbonneau, A. S. Brun

**Abstract:** Understanding the tachocline is important for the overall comprehension of the Sun’s inner working. Since the fundamental paper of Spiegel & Zahn (1992), the question of its relative thinness (less than 5% of the solar radius) is subject to debate in the solar physics community. In this paper, the authors identified the phenomenon of radiative spreading, which leads to the burrowing of the solar differential rotation. By the age of the present-day Sun, this process should have made the differential rotation burrow way deeper in the radiative interior than what the observations show.



The question is therefore to identify which physical process may oppose the differential rotation burrowing and lead to the confinement of the tachocline. We will start by presenting the different hypothesis proposed in the last 25 years in order to explain the tachocline's confinement. We will then focus on the idea that the cyclic dynamo-generated magnetic field known to be present in the convective envelope will penetrate in the upper region of the radiative interior and that the Lorentz force associated with this field could lead to the confinement of the tachocline (Forgács-Dajka & Petrovay, 2001). We will describe a simple reduced (1D) model we developed based on this idea, with two major differences: the inclusion of coherent poloidal and toroidal magnetic fields and of radiative spreading. We will show that if the tachocline is weakly turbulent, it is possible for a cyclic dynamo magnetic field present in the convective envelope to confine a tachocline subject to either viscous diffusion or to radiative spreading to its observed thinness.

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**Contributed talk:** “Understanding dynamo mechanisms and torsional oscillations from 3D convection simulations of the Sun”

**Author(s):** Jörn Warnecke, Petri Käpylä, Maarit Käpylä, Robert Cameron, Axel Brandenburg, Matthias Rheinhardt

**Abstract:** The magnetic field in the Sun undergoes a cyclic modulation with a reversal typically every 11 years due to a dynamo operating under the surface. We simulate a solar-type star, where the interplay between convection and rotation self-consistently drives large-scale magnetic field. We apply the test-field method to characterize the dynamo mechanism acting in this simulation by determining 27 turbulent transport coefficients of the electromotive force, of which 9 are related to the  $\alpha$ -effect tensor. We find that the alpha-effect has a complex nature and does not follow the profile expected from kinetic helicity. Besides the dominant  $\alpha$ - $\Omega$  dynamo, also an  $\alpha^2$  dynamo is locally enhanced. The turbulent pumping velocities significantly alter the effective mean flows acting on the magnetic field and therefore challenge the flux transport dynamo concept. All coefficients are significantly affected due to dynamically

important magnetic fields with quenching as well as enhancement being observed. This leads to a modulation of the coefficients with the activity cycle. We will also present recent results on mechanisms producing torsional oscillations, the cyclic variations of the differential rotation. Besides large-scale Lorentz force also the cyclically varying Maxwell and Reynolds stresses have strong influence in the angular momentum balance. In contrast to previous findings, the small-scale contribution to the mass flux plays a significant role in transporting angular momentum. This gives us important insights on the magnetic field generation and torsional oscillation production in the Sun and other stars.

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**Solicited talk:** “Where are the solar magnetic poles?”

**Author(s):** Adur Pastor Yabar

**Abstract:** In mid ninetens, it was discovered that the Sun had a dipolar global magnetic field, whose temporal evolution followed the Solar Cycle. Polar regions, as well as sunspots that appear in the activity belts, changed their polarity every 11 years: sunspots during each activity minima, and the poles in activity maxima. This fact, made people think that the poles reversal was related to the arrival of opposite polarity magnetic flux dragged from active regions by a meridional flow. Such new flux reduced the dominant polarity at the poles by cancellation, and built the opposite one until next minimum of activity. In our study, we have used the high quality full disc magnetograms, recorded by the HMI instrument onboard the SDO satellite since the beginning of the mission, in april 2010. We perform a deep study of the evolution with time of the line of sight component of the magnetic field at the solar poles. In our data, we see many aspects of the solar cycle as the decay of the dominant polarity of both poles while we approach to the activity maximum. But the main result is the detection of a monthly oscillatory pattern of the pole's magnetic field. Such oscillation, related to solar rotation is a clear evidence of a non-axisymmetric component of the magnetic field. One of the possible explanations is that the global field is tilted with respect to the rotation axis. This rather usual

finding in other stars, here represents a breach of modern solar dynamo theories for the generation and maintenance of the Sun's magnetic field.

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**Solicited talk:** “Measurement of the meridional flow: Current developments and results”

**Author(s):** Ariane Schad

**Abstract:** I will present an overview of the current developments in helioseismology to determine the meridional flow in the solar interior. The profile of the meridional flow in the deep convection zone is important for our understanding of the solar dynamo and its measurement is one of the most challenging problems in helioseismology. In recent times, promising approaches have been developed for solving this problem. The time-distance analysis made large progress in this after becoming aware of and compensating for a systematic effect in the analysis. The origin of this systematic is not clear yet. A different approach is now also available, which directly exploits the distortion of mode eigenfunctions by the meridional flow. These methods have presented us partly surprisingly complex meridional flow patterns, which, however, do not provide a consistent picture of the flow. Resolving this puzzle is part of current research.

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**Contributed talk:** “Variation of the photospheric temperature gradient with magnetic activity”

**Author(s):** Marianne Faurobert, R. Balasubramanian, G. Ricort

**Abstract:** Solar-cycle variations of the quiet-Sun physical structure, such as the temperature gradient, might affect the irradiance. In this talk we shall present a new method that we have developed for measuring the temperature gradient in the low photosphere using high resolution spectroscopic data, together with a first implementation on Hinode SOT/SP data. Comparing the temperature gradient measured at a minimum of the activity cycle in

December 2007 and at a maximum in December 2013 we do find a significantly steeper gradient at the solar maximum, in the Northern hemisphere, whereas we do not detect significant variation in the southern hemisphere. A steepening of the photospheric temperature gradient is obtained in 3D-MHD simulations of the quiet Sun when the ambient magnetic field is increased. Our results agree with MHD simulations if we account for a strong hemispheric asymmetry of the magnetic flux distribution in the quiet Sun at solar maximum.

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**Contributed talk:** “A deep-seated mechanism for cycle-dependent sunspot group tilt angles”

**Author(s):** Emre Isik

**Abstract:** The cycle-averaged tilt angle of sunspot groups is an important quantity in determining the magnetic flux diffusing across the equator in a given cycle, which is highly correlated with the strength of the subsequent cycle. This quantity has recently been reported to be anti-correlated with the strength of the solar cycle. I suggest that a deep-seated thermodynamic cycle in phase with the activity cycle can be responsible for the observed correlation. Motivated by helioseismic indications, I calculate the effect of cooling of the convective overshoot region on the stability and dynamics of magnetic flux tubes. I find that cycle-to-cycle variations in the range 5-20 K at the base of the convection zone can explain the observed range of tilt angle fluctuations among different cycles. This mechanism can play a role in the nonlinear saturation and amplitude fluctuations of the solar dynamo.

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**Contributed talk:** Solar-like magnetic cycles in 3D turbulent global models of stars

**Author(s):** [Antoine Strugarek](#), P. Beaudoin, P. Charbonneau, A.S. Brun, P. Smolarkiewicz, S. Mathis

**Abstract:** Global simulations of the convective dynamo of the Sun

and solar-type stars have exhibited in the past decade a rich variety of magnetic self-organization, from small-scale turbulent fields; stable magnetic structures; to periodically reversing large-scale magnetic fields. These promising results were obtained using different approximations, from the geometry of the system to the way of modelling convective turbulence. Both aspects are thought to play an important role in the large-scale organization of the magnetic field of stars. Hence, careful cross-comparisons of these results against the different (numerical and physical) approximations are today mandatory to assess their robustness and their applicability to the Sun. I will first give a brief tour of the present status of non-linear dynamo simulations in deep stellar convection zones, with a particular focus on results obtained using implicit large eddy simulations (ILES) for a solar-like, cyclic, turbulent dynamos. I will report on an ongoing benchmarking effort, which aims at comparing convective turbulent dynamo solutions obtained with large eddy simulations (LES) and ILES using the ASH and EULAG codes. Thanks to this comparison, the effect of the subgrid-scales treatment on the large-scale organization is assessed, partly explaining the differences obtained using the two methodologies. I will finally present a series of 3D global simulations where the periods of the simulated magnetic cycle systematically varies with the rotation rate and luminosity of the star, shedding a new light on non-linear dynamo processes in solar-like stars.

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**Contributed talk:** “Interpreting a millennium solar-like dynamo with the test-field method”

**Author(s):** [Frederick Gent](#), Maarit Käpylä, Matthias Rheinhardt, Petri Käpylä and Jörn Warnecke

**Abstract:** Direct numerical simulations (DNS) of stellar dynamo have recently succeeded in emulating many key features of the magnetohydrodynamics (MHD) observed in stars, such as solar-like differential rotation profiles, cyclic variation in the magnetic field and field reversals, equatorward migration of the field, and episodic grand minima. The complexity of the processes in the models and

stars themselves makes it difficult to interpret the results. Statistical analysis is useful to identify trends and describe patterns in the models and observations, but to understand the physics other analytical tools are required. One such method is the mean-field approximation, by which the induction equation governing the evolution of the magnetic field is reduced to mean and fluctuation equations. The electromotive force (EMF), which controls the evolution of the mean-field, can then be expressed as a sum of tensors acting on the mean magnetic field or current, each representing identifiable physical processes. Investigation of these tensorial terms, if the mean-field approximation is valid, can help us to understand how the dynamo operates and how changes in parameters influence the dynamo. We must know the composition of these tensors, in order to use the mean-field method. Typically, for complex systems applying in stars, it is not possible to derive these tensors analytically, but we might obtain them numerically by applying the test-field method to DNS. We consider the application of the test-field method to a millennium dynamo simulation, exhibiting solar-like long term variability of the magnetic cycle.

**Poster:** “Global MHD Simulations of the Solar Wind over cycle 22”

**Author(s):** Victor Réville, Allan Sacha Brun, Antoine Strugarek

**Abstract:** The geometry of the photospheric magnetic field strongly varies over the solar cycle, going from dipolar to multipolar between minimum and maximum of activity. The structure of the solar wind, particularly the spatial distribution of the slow and fast wind components shows a strong correlation with the structure of the magnetic field in the low-corona. For instance, the fast wind appears to be anti-correlated with the expansion factor, which is a consequence of the dynamics of the open and closed regions. We study the evolution of the solar coronae over the 22nd cycle with 3D MHD simulations. We constrain the photospheric magnetic field with synoptic magnetic maps obtained through observations at the Wilcox Observatory. We obtain 12 different simulations corresponding to quasi-static solutions of the solar coronal structure every year between 1989 and 2000. These simulations allow to compute expansion factor in a better fashion than the usual potential field source surface model and can be compared to remote and in-situ measurements of the solar wind, through Ulysses data for instance. We also compare our results to emission measurements made by the SOHO/EIT instrument thanks to synthetic images post-processed from our simulations.

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**Poster:** “The dependence of the [FUV-MUV] colour index on solar cycle”

**Author(s):** M. Lovric, F. Berrilli, C. Cagnazzo, E. Pietropaolo, D. Del Moro, L. Giovannelli

**Abstract:** The dependence of solar UV variability on solar cycle is investigated using far UV (115-180nm) and middle UV (180-310nm) fluxes from SOLSTICE/SORCE experiment and Mg II index from Bremen composite. The SOLSTICE [FUV-MUV] colour is introduced to study the solar UV spectral slope during the cycle. The calculated colour is corrected from aging effects due to an

efficiency reduction of SOLSTICE FUV irradiance. In order to extract the 11-year scale variation, the Empirical Mode decomposition (EMD) is applied on the data sets. We found that the [FUV-MUV] colour strongly correlates with the Mg II index.

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**Poster:** “The barycenter of the Solar System, its different links with the activity of the Sun”

**Author(s):** Maxime Pélerin

**Abstract:** Sun cycles like used nowadays seem to obey some sort of rules. In this work I present only a lot of observations that show that all its activity and its magnetic pole fields flip is linked by the center of mass of its planetary system and permit a precised defined cycle. It's only observations that have to be grounded by mathematical and physical more deeper examinations that could conduct to the simple and incredible fact, in a real concordance way to the Musica Universalis, that the sun is like a dynamo supply by the center of mass of its own planetary system.











**Invited review:** “Non-LTE chromospheric diagnostics and inversions”

**Author(s):** Jaime de la Cruz

**Abstract:** The chromosphere is transparent to most of the radiation that is emitted in the photosphere and only a few spectral lines have sufficient opacity to sample the chromosphere. It is very challenging to infer the physical state of chromospheric plasmas because non-local/non-equilibrium physics are usually required to model the observations: Ca II H&K, Ca II 8542, Mg II h&k, H $\alpha$ , He I 10830. Non-LTE inversion codes allow to construct 3D empirical models from spectropolarimetric observations. In this talk I will review the current status of chromospheric observations and inversion methods in the chromosphere.

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**Solicited talk:** “Sunrise II Observations of Emergence Sites in a Solar Active Region”

**Author(s):** [Rebecca Centeno](#), J. Blanco Rodriguez, J.C. Del Toro Iniesta and the Sunrise II Team

**Abstract:** In June 2013, the two scientific instruments onboard the second Sunrise mission witnessed, in detail, a small-scale magnetic flux emergence event as part of the birth of an active region. The Imaging Magnetograph Experiment (IMaX) recorded two small ( $\approx 5''$ ) emerging flux patches in the polarized filtergrams of a photospheric Fe I spectral line. Meanwhile, the Sunrise Filter Imager (SuFI) captured the highly dynamic chromospheric response to the magnetic fields pushing their way through the lower solar atmosphere. The serendipitous capture of this event offers a closer look at the inner workings of active region emergence sites. In particular, it reveals in meticulous detail how the rising magnetic fields interact with the granulation as they push through the Sun's surface, dragging photospheric plasma in their upward travel. The plasma that is burdening the rising field slides along the field lines, creating fast downflowing channels at the footpoints. The weight of this material anchors this field to the surface at semi-regular spatial

intervals, shaping it in an undulatory fashion. Finally, magnetic reconnection enables the field to release itself from its photospheric anchors, allowing it to continue its voyage up to higher layers. This process releases energy that lights up the arch-filament systems and heats the surrounding chromosphere.

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**Contributed talk:** “Response functions for NLTE lines”

**Author(s):** Ivan Milic, Michiel van Noort

**Abstract:** Response functions for Stokes parameters are an important diagnostics tool for solar atmospheric parameters, and an essential ingredient of inversion codes. Spectral lines formed in non-local thermodynamic equilibrium (NLTE) are particularly interesting, as they generally probe higher layers of the solar atmosphere, and can also exhibit so called scattering polarization. However, in NLTE, atomic level populations have a non-local dependence on atmospheric parameters, which makes the computation of the response functions difficult. In this contribution we present an analytic solution to this problem. We take an analytic derivative of the statistical equilibrium equation, and follow the dependencies until we end up with a linear system which couples all atomic levels and spatial points in the atmosphere. By solving this linear system we get the response of all the populations to all the atmospheric parameters. We illustrate accuracy and speedup provided by this method on several example spectral lines and then turn our attention to scattering polarization. If the scattering polarization is determined mainly by the anisotropy of radiation the response functions for the intensity directly yield responses for the anisotropy and thus responses for the scattering polarization. We discuss the applicability of this approach to Hanle node-based inversion and show response functions of some interesting Hanle-sensitive lines.

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**Contributed talk:** “Si I atomic model for NLTE spectropolarimetric diagnostics of the 1082.7 nm line”

**Author(s):** Natalia Shchukina, J. Trujillo Bueno, A. V. Sukhorukov

**Abstract:** The SiI 1082.7 nm line is commonly used for the spectropolarimetric diagnostics of the solar atmosphere. First, we aim to quantify the sensitivity of all four Stokes parameters of this line to NLTE effects. Second, we aim to facilitate its NLTE diagnostics by reducing a full, comprehensive silicon model atom to a simplest one with no significant changes in the calculated line Stokes parameters. We investigate the impact of the NLTE effects by means of the multilevel radiative transfer calculations in a three-dimensional model atmosphere taken from the magneto-convection simulations with the small-scale dynamo action. We find significant departures from LTE in the SiI 1082.7nm line not only for the intensity but also for the linearly and circularly polarization. At wavelengths around 0.01 nm, where most of the Stokes Q, U, and V amplitudes of this line are formed, the differences between the NLTE and LTE Stokes profiles are comparable with the Stokes amplitudes themselves. The deviations from LTE are increasing with increasing Stokes Q, U, and V signals. For the circularly polarized radiation, the NLTE effects correlate with the magnetic field strength in the layers where this radiation is formed. We conclude that the NLTE effects should be necessarily taken into account when diagnosing the emergent Stokes I profiles as well as the Stokes Q, U, and V profiles of the SiI 1082.7 nm line. The sixteen-level silicon model atom with six radiative bound-bound transitions is sufficiently accurate to describe the physics of formation of this line with no significant changes in its emergent Stokes profiles.

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**Contributed talk:** “Non-LTE 3D radiative transfer with a Multigrid Solver”

**Author(s):** Johan Pires Bjørgen, J. Leenaarts

**Abstract:** Increase in high-resolution observation in future instruments/telescopes (SST/CHROMIS, DKIST 4-meters), require robust non-LTE 3D radiative transfer diagnostics tools to

analyze spectra from MHD calculations and compare it with observation. With increase high-resolution realistic atmosphere, non-LTE radiative transfer becomes CPU heavy. In recent years, there have been a focus on Gauss-Seidel/SOR and Multigrid for solving radiative transfer and have shown to be efficient but not been tested on a realistic problem: MHD model atmosphere and complicated atoms. We have implemented a nonlinear multigrid scheme into an existing 3D non-LTE radiative transfer, Multi3D with MALI and applied it on a MHD snapshot from Bifrost, 504x504x496 with a six-level hydrogen atom. We obtain a factor  $\sim 4.5$  speed-up, compared to MALI. Here we also present our recent modeling using a high-resolution model atmosphere from Bifrost, 768<sup>3</sup> grid points with 32 km horizontal grid spacing, with timing and results. We present preliminary formation properties of the Ca II H & K lines.

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**Contributed talk:** “Helium lines in the solar spectrum: spatial structure in He I 10830 and the anomalous intensity of the resonance lines”

**Author(s):** [Jorrit Leenaarts](#), Thomas Golding, Mats Carlsson

**Abstract:** In this talk we will discuss the formation of the He I 10830 line, an important diagnostic of the upper chromosphere. The formation of the line in one-dimensional models is well understood, but the influence of the complex 3D structure of the chromosphere and corona has not been investigated. We discuss this using 3D radiation-MHD simulations and 3D non-LTE radiative transfer calculations, and show that the small-scale spatial variation of the optical thickness of the line-forming region is mainly set by variations of the EUV flux from the transition region and not by the more smoothly varying radiation from the corona. We also discuss the resonance lines from He I and He II. Jordan (1975) found that the observed intensity of these lines were an order of magnitude larger than derived values based on emission measure models. We show that we can reproduce this effect using non-equilibrium non-LTE radiative transfer. We identify the cause to be



non-equilibrium ionization effects, which leads to the presence of He I and He II at higher temperatures than expected based on equilibrium ionisation.

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**Solicited talk:** “Three-dimensional Radiative Transfer Simulations of the Scattering Polarization”

**Author(s):** Jiri Stepan

**Abstract:** Forward modeling of the intensity and polarization of spectral lines is the classical discipline that led to number of essential discoveries in the solar physics. From the simple limit of LTE in the solar photosphere, to more complicated NLTE solutions in the chromosphere, to optically thin corona, the confrontation of the observations and models has led to great progress in our understanding of the Sun. The forward modeling process is an inevitable part of all the inversion codes that helped to refine our quantitative knowledge of the solar atmosphere in the regions where the physics is sufficiently simple for the inversion procedure. At the onset of the new-generation solar telescopes, we should not only aim at refining our present knowledge of the relatively well known solar structures. Instead, we face a scientific challenge to uncover the physics of the regions that are notoriously difficult to diagnose, such as the quiet solar chromosphere, the quiescent prominences, or solar flares. These regions, in which the line formation is difficult due to the complex spatial distribution of the plasma properties and due to the limited usability of the Zeeman effect, 3D NLTE modeling becomes essential. Instead of neglecting the complexity of the real solar atmosphere and of the physical mechanisms affecting the emergent spectra, the 3D NLTE modeling aims at incorporating as much of physics as possible into the calculations. The qualitative and quantitative comparisons of such calculations with actual observations is perhaps the most promising way to uncover the new secrets of the physics of the upper solar atmosphere.

**Contributed talk:** “Spatially resolved Stokes measurements in the Sr I (4607.3 Å) line with FSP at VTT/TESOS”

**Author(s):** Franziska Zeuner, Alex Feller, Francisco Iglesias, Ivan Milic, Sami K. Solanki

**Abstract:** Scattering polarization signals at spatial scales in the 0.1"-1" regime are a very promising complementary diagnostic for the Sun's atmosphere and magnetism at small spatial scales. So far, for the Sr I line at 4607.3 Å, which exhibits a large scattering polarization signal, only theoretical predictions for the strength and spatial distribution of linear polarization signals at sub-arcsecond scales are available, whereas observational feedback has been missing. Here, we present results of two VTT/TESOS campaigns in May 2015 and June 2014. In May 2015, we measured the center-to-limb variation of the spatially averaged Stokes Q profiles to test the ability to measure scattering polarization using the prototype of the Fast Solar Polarimeter. To obtain the spatial distribution of the Stokes vector, we have observed the Sr I line in the quiet Sun at  $\mu=0.6$  from the north solar limb in June 2014, with a spatial sampling of 0.08" and noise levels as low as 0.6% per pixel for linearly polarized signals with 1.25 s integration time. To obtain the theoretically required lower noise levels ( $< 0.1\%$ ), while conserving sufficient spatial resolution to resolve the solar granulation, we carefully performed spatial and temporal averaging. Our analysis of the images indicates a strong correlation of the line core Stokes Q signals with the intensity of the nearby continuum.

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**Contributed talk:** “The missing 'M' ingredient in 3D photospheric simulations for solar abundances”

**Author(s):** Damian Fabbian

**Abstract:** Present-day three dimensional (3D) magneto-hydrodynamic (MHD) solar simulations have reached a high level of maturity and can accurately predict many observables, thus finding vast applications in solar physics. However, failure to use the resulting temporal snapshots in favour of those from the

simpler, pure hydrodynamic case as far as chemical abundance determinations are concerned, can introduce significant systematics due to both direct and indirect effects of the presence of magnetic fields on absorption line profiles. The signature of magnetic fields in the properties and distributions of different Stokes parameters can help discern the best models among those derived using different MHD codes and/or different initial setups. Another field where the use of more realistic 3D photospheric models which include magnetic fields may have a significant impact is that of exoplanet detection thanks to a better description of stellar magnetoconvection "noise".

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**Contributed talk:** "A novel radiative transfer investigation of the magnetic micro-activity of the quiet Sun via the Hanle effect in the Sr I 460.7 nm line"

**Author(s):** Javier Trujillo Bueno, T. del Pino Alemán et al.

**Abstract:** The planning and interpretation of the high-resolution spectropolarimetric observations that solar telescopes like DKIST and EST will make feasible require detailed radiative transfer simulations of the spectral line polarization produced by scattering processes and the Hanle and Zeeman effects in increasingly realistic 3D models of the solar atmosphere. One of the key research topics in solar physics is the small-scale magnetic activity of the quiet regions of the solar disk, which cover most of the solar surface at any given time during the solar activity cycle. Recent magnetoconvection simulations with small-scale dynamo action have provided 3D models of the quiet solar photosphere characterized by a high degree of magnetic microactivity, similar to that found through theoretical interpretation of the scattering polarization observed in the Sr I 4607 Å line. Here we present the results of an investigation of the Sr I 4607 Å line polarization, based on radiative transfer calculations in a 3D magneto-convection model with most of the convection zone magnetized close to the equipartition and a mean field strength of 160 G at the model's visible surface. Some of the questions we consider are the following: 1) Is the height-

variation of the model's mean magnetization suitable to explain the available (low-resolution) scattering polarization observations ? 2) How are the polarization signals of the Sr I 4607 Å line at high spatial resolution, in the absence and in the presence of the model's magnetic field ? 3) Is the standard deviation of the horizontal fluctuations of the scattering polarization signals sensitive to the mean field strength? Which are the minimum spectral and spatial resolutions needed to detect them ? Here we provide answers to these questions, which are important for improving our understanding of the quiet Sun magnetism and for designing the instrumentation of the new generation of solar telescopes.

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**Contributed talk:** “Chromospheric line formation of OI 7772 Å”

**Author(s):** [Hiva Pazira](#), Dan Kiselman, Jorrit Leenaarts

**Abstract:** SST/CRISP observations show that chromospheric off-limb emission of neutral oxygen at 7772 Å can be observed with this instrument. Line core images reveal dark gaps between the limb and the maximum off-limb emission in the lower chromosphere. Using the RH code in spherical geometry mode with FAL-C as the atmospheric model, we demonstrate that the dark gap is caused by variation in opacity rather than in the source function. Our work shows that there is a strong downward cascade from the continuum. We have also investigated the importance of neutral hydrogen collisions, charge transfer with hydrogen, and the Ly- $\beta$  pumping/suction in the formation of the 7772 Å line.











**Invited review:** “Measurements of photospheric magnetic fields”

**Author(s):** Andreas Lagg

**Abstract:** Large-aperture solar telescopes, advances in detector technology, sophisticated adaptive optics systems, powerful data analysis tools: These are the key elements for the tremendous progress achieved in this millennium in measuring the photospheric magnetic field at highest spatial resolution. It is now possible to replace indirect methods for determining the magnetic field of small-scale structures on the solar surface by direct measurements, resolving the details of the prevailing physical processes within these structures. In this review I present selected highlights of such high-resolution measurements, covering the wide range from quiet-sun magnetism to the strongest field regions in sunspot umbrae and penumbrae. In addition, I discuss open questions in the understanding of the photospheric magnetism and outline promising approaches to resolve them.

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**Solicited talk:** “Emergence of Granular-sized Magnetic Bubbles through the Solar Atmosphere”

**Author(s):** Ada Ortiz-Carbonell

**Abstract:** Recently we have published a trilogy of papers devoted to the flux emergence and rise of granular-sized magnetic bubbles through the solar atmosphere. In this talk I will focus on Papers I and III of the series, where the evolution and fate of such events is followed in great detail. In the first work we report on 3D semi-spherical bubbles which differ from previously reported linear loop-shaped emergence cases. High resolution full Stokes observations taken with the CRISP spectropolarimeter at the Swedish 1 m Solar Telescope of the two photospheric FeI 630 nm lines and the chromospheric CaII 854.2 nm line at a resolution of 0.14" allow us to study a flux emergence case in July 2009. Several phenomena typically associated to the flux emergence process occur simultaneously, but perhaps the most characteristic one is the observation of a dark bubble in intensity maps constructed from the

wings of the CaII 854.2 nm line. We can infer how the bubble rises through the solar atmosphere as we see it progressing from the wings to the core of the CaII 854.2 nm line. We describe the dynamic and magnetic properties of the magnetic bubble as it rises from the photosphere to the mid-chromosphere. The magnetized plasma rises with a mean velocity of 2 km/s through the photosphere. To aid the interpretation of the observations, we use the Bifrost code to carry out 3D numerical simulations of the evolution of a horizontal magnetic flux tube injected in the convection zone, 2.5 Mm below the photosphere. In the modeled chromosphere the rising flux tube produces a large, cool and magnetized bubble. We compare our observed bubble with that given by the numerical simulations. In Paper III of these series, we extend our study from the photosphere and chromosphere up to the transition region and corona by combining imaging and spectroscopic information at the highest spatial, spectral and temporal resolution of spectral lines sensitive to upper layers. In order to achieve these goals we count on multi-wavelength observations obtained simultaneously with the SST, the IRIS spacecraft and the SDO spacecraft. We obtain the signatures of the rising plasma at several heights: lifetimes of the magnetic bubbles, temporal delays between the passage through different points and vertical velocities. Strong intensity enhancements and energy release are observed whenever the new emerging flux interacts with the ambient pre-existing loops. We believe that flux emergence is an important mechanism of transporting energy and magnetic flux from subsurface layers to the transition region and corona.

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**Contributed talk:** Photospheric counter Evershed flows in the penumbra of sunspots

**Author(s):** A. L. Siu-Tapia, A. Lagg, S. K. Solanki, M. van Noort, M. Rempel

**Abstract:** The Evershed effect, an almost radial and horizontal outflow of material seen in the penumbra of sunspots at the photospheric layers, is a common characteristic of well-developed

penumbrae. On the contrary, counter Evershed flows (i. e. photospheric radial inflows in the penumbra) are extraordinary events, but they have been observed in few occasions along singular penumbral filaments of sunspots leading to flares. We investigate the dynamic properties of the main sunspot of the AR NOAA 10930. This sunspot displays the normal Evershed outflow, but it also harbors a fast inflow of material over a large area of the disk-center-side penumbra at the photospheric layers. To investigate this anomalous counter Evershed flow, we have inverted the spectropolarimetric data from HINODE using the SPINOR 2D inversion code. Similarities and differences between the normal and the counter Evershed flows are presented. In addition, we analyze recent results of high-resolution sunspot simulations based on the MURaM radiative MHD code which reproduce a number of transient regions with counter Evershed flows at photospheric heights. The analysis of this simulated setup allows us to study the dynamics of the flows at constant geometrical heights, which is an important advantage over the observations for determining the origins and the dominant driving forces of the flows.

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**Contributed talk:** “Kinematics and Magnetic Properties of a Light Bridge in a Decaying Sunspot”

**Author(s):** Mariachiara Falco, J. M. Borrero, S. L. Guglielmino, P. Romano, F. Zuccarello, S. Criscuoli, A. Cristaldi, I. Ermolli, S. Jafarzadeh, L. Rouppe van der Voort

**Abstract:** High spatial and spectral resolution data of the solar photosphere were acquired by the CRISP Imaging SpectroPolarimeter at the Swedish Solar Telescope on 6 August 2011. We analysed a large sunspot with a light bridge (LB) observed in NOAA AR 11263. These data are complemented by simultaneous Hinode Spectropolarimeter (SP) observation in the Fe I 630.15 nm and 630.25 nm lines. The continuum intensity map shows a discontinuity in the radial distribution of the penumbral filaments in correspondence with the LB, which shows a dark lane ( $\approx 0.3''$  wide and  $\approx 8.0''$  long) along its main axis. The line-of-sight

(LOS) velocity of the plasma along the LB derived from the Doppler effect shows motions towards and away from the observer up to 0.6 km/s that are lower in value than the LOS velocities observed in the neighbouring penumbral filaments. Moreover, the available data were inverted with the Stokes Inversion based on Response functions (SIR) code and magnetic field strength and temperature maps were obtained. The noteworthy result is that we find motions towards the observer of up to 0.6 km/s in the dark lane where the LB is located between two umbral cores, while the LOS velocity motion towards the observer is strongly reduced where the LB is located between an umbral core at one side and penumbral filaments on the other side. Statistically, the LOS velocities correspond to upflows or downflows, and comparing these results with Hinode/SP data, we conclude that the surrounding magnetic field configuration (whether more or less inclined) could have a role in maintaining the conditions for the process of plasma pile-up along the dark lane. The results obtained from our study confirm and support outcomes of recent magneto-hydrodynamic simulations showing upflows along the main axis of an LB.

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**Contributed talk:** “Investigation of straylight in data from the GREGOR Infrared Spectrograph”

**Author(s):** Morten Franz, Juan Borrero, Manolo Collados, Sami Solanki, Andreas Lagg, Wolfgang Schmidt

**Abstract:** The amount of penumbral return flux is important for our understanding of Sunspots. In the past, 3-lobe Stokes V profiles of spectral lines in the visible have been used to detect the signatures of 'hidden' magnetic fields of opposite polarity (Franz 2011, Ruiz Cobo & Asensio Ramos 2013, Scharmer et al. 2013). In Franz & Schlichenmaier (2013), we demonstrated that a large fraction of these penumbral return fields are located in deep photospheric layers. In Franz et al. (2016), we performed a systematic analysis of a large number of high quality data sets from the GREGOR Infrared Spectrograph (GRIS). We obtained a

significantly smaller amount of 3-lobe Stokes V profiles in the infrared (IR) when compared to data sets in the visible. As of yet, there is no conclusive explanation for this unexpected lack of penumbral return fields detected in IR data. In this contribution, we investigate to which degree straylight influences our results. To this end, we use the synthesis module of the SIR code (Ruiz-Cubo & del Toro Iniesta 1992) to perform radiative transfer calculations in a 3D-MHD model atmosphere of a full sunspot (Rempel 2012). We convolve the resulting Stokes spectra spatially and spectrally with theoretical point spread functions (PSF) as well as a PSF obtained during the Mercury transit (Collados 2016) and compare the results to GRIS observations.

Ruiz Cobo & del Toro Iniesta, (1992) *ApJ.*, 398, 375

Collados et al. (2016), private communication

Franz, M. (2011) PhD, Kiepenheuer Institut Freiburg

Franz, M. & Schlichenmaier, R. 2013, *A&A*, 550, 97

Franz, M., Collados, M., Bethge C. et al. 2016 (accepted) Rempel, M. (2012) *ApJ*, 750, 62

Ruiz Cobo, B. & Asensio Ramos, A. (2013), *A&A* 549L, 4

Scharmer, G. B., de la Cruz Rodriguez, J., Sütterlin, P. & Henriques, V. M. J. (2013) *A&A* 549L 4R

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**Solicited talk:** “New insights on penumbra formation”

**Author(s):** Nazaret Bello Gonzalez

**Abstract:** Fully-fledged penumbra is by now a well-characterised phenomenon from an observational point of view. Also, very sophisticated MHD simulations are providing us with good insights on the physical mechanisms possibly running behind the observed processes. Yet, how this penumbral magneto-convection sets in is still an open question. Due to the fact that penumbra formation is a relatively fast process (of the order of hours), it has eluded its observation with sufficient spatial resolution by both, space- and ground-based solar observatories. Only recently, some authors have witnessed the onset of both orphan and sunspot penumbrae. We

are one of those. In July 2009, we observed the early stages of the NOAA 11024 leading sunspot while developing its penumbra. The spectro-polarimetric data lead us to new observational findings. In this contribution, we put into context our and other authors' results to draw the overall picture of sunspot formation. Most important, the comparison on the properties of orphan and sunspot penumbrae lead us to the conclusion that the formation of penumbra is not just one mechanism. Rather, observations show that flux emergence is behind the formation of orphan penumbra while flux fallen from chromospheric layers leads to the formation of penumbra in sunspots. A major conclusion follows: the sole responsible for penumbral magneto-convection to set in are stably inclined fields. The mechanisms generating inclined fields differ. This conclusion is a crucial step forward to our understanding on the coupling of solar plasmas and magnetic fields in penumbral atmospheres.

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**Contributed talk:** “Numerical simulations of the quiet-sun magnetic field: Beyond MHD”

**Author(s):** Khomenko, E., [Vitas, Nikola](#), Collados, M., de Vicente, A.

**Abstract:** At any time at least 90% of the solar surface is covered by the quiet-sun component. High-resolution high-sensitivity observations reveal that this component is characterized by ubiquitous weak magnetic field. The energy budget of the quiet sun is thus crucial to explain the thermal structure of the solar atmosphere. Despite substantial theoretical efforts, the origin of the quiet sun magnetic field is still under debate. We apply our numerical code MANCHA3D to address the question of magnetogenesis in the solar photosphere. The code solves a set of time-dependent coupled equations (MHD equations, equation of state, radiative transfer equation) on a 3D Cartesian grid with realistic boundary conditions. The novelty of our code is that it explicitly includes the effects of the partial ionization and charge separation. Our results describe a self-consistent realistic model of

the quiet sun magnetic field within the constraints of the numerical modeling approach.

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**Contributed talk:** “Turbulent convection and the dynamic properties of photospheric magnetic fields in the quiet Sun”

**Author(s):** Fabio Giannattasio, Del Moro, D.; Berrilli, F.; Consolini, G.; Caroli, A.; Gosic, M.; Bellot Rubio, L.

**Abstract:** The features observed in the solar photosphere at a wide range of spatial (between tens of kilometers to global scales) and temporal (between tens of seconds to about 22 years) scales are the result of turbulent convection and its nonlinear interaction with the magnetic fields. Nowadays, an exhaustive theory of turbulent convection is still lacking, and MHD simulations are able to reproduce the photospheric features only in a small range of scales due to computational limits. We instead follow a Lagrangian approach, which consists in tracking small-scale magnetic fields (magnetic elements, MEs) under the hypothesis that they are passively transported by the plasma flows. This approach allows us to reveal the dynamic properties of MEs, the scaling properties of the underlying velocity field and the scales at which magnetic fields organize in the quiet Sun. The use of a 24-hr uninterrupted sequence of magnetograms acquired by SOT-NFI onboard Hinode at high spatial (0.3 arcsec) resolution with a 90s cadence and targeted at the disk center allows us to investigate the diffusive nature of MEs, pointing out different dynamic regimes at different scales (from sub-granular to supergranular) and environments in the quiet Sun, setting constraints on turbulent convection and on the organization and amplification of magnetic fields in the solar photosphere.

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**Contributed talk:** “Multiwavelength study of penumbral decay using GREGOR, VTT, NST, and Hinode”

**Author(s):** Meetu Verma, C. Denker, H. Balthasar, C. Kuckein, Reza Rezaei, M. Sobotka, N. Deng, H. Wang, A. Tritschler, M.

Collados, A. Diercke, S.J. González Manrique

**Abstract:** The solar magnetic field is responsible for all aspects of solar activity. Sunspots are the main manifestation of the ensuing solar activity. Combining high-resolution and synoptic observations has the ambition to provide a comprehensive description of the sunspot growth and decay process. Active region NOAA 12597 emerged on 22 September 2016 in southern hemisphere. The region was observed two days later on 24 September 2016 with GREGOR, VTT, NST, and Hinode during a campaign organized as part of the SOLARNET initiative for coordinated observing campaigns. The leading spot of the region was observed for the next four days. We obtained high-resolution imaging, spectroscopic, and spectropolarimetric data in various spectral lines covering the photosphere as well as the chromosphere. These data were complemented by synoptic line-of-sight magnetograms and continuum images obtained with the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) and slit-jaw images from the Interface Region Imaging Spectrograph (IRIS). We will present the dataset taken on 24 September 2016 containing the leading spot. The sunspot was at its maximum growth and slowly started to disintegrate at the time of GREGOR and VTT observations followed by the observations from Hinode and NST a few hours later. We will discuss the photospheric and chromospheric flow fields along with the magnetic fields during the penumbral decay of a large penumbral sector. The penumbral filaments do not simply vanish but intermingle with the nearby granules and even temporarily form darkened areas resembling umbral cores filled with umbral dots.

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**Contributed talk:** “Long-period oscillations of active region patterns: least-square mapping on second-order curves”

**Author(s):** Gulsun Dumbadze, B.M. Shergelashvili, V. Kukhianidze, G. Ramishvili, T.V. Zaqarashvili, M. Khodachenko, E. Gurgenashvili, S. Poedts and P. De Causmaecker



**Abstract:** Active Regions (ARs) are main sources of a variety in solar dynamic events. Automated detection and identification tools need to be developed for solar features for a deeper understanding of the solar cycle. We studied the oscillatory dynamics of two ARs: NOAA 11327 and NOAA 11726 using two different methods of pattern recognition. We developed a novel method of automated AR border detection and compared it to an existing method for the proof-of-the-concept. The first method uses least-square fitting on the smallest ellipse enclosing the AR, while the second method applies regression on the convex hull. After processing the data, we found that the axes and the inclination angle of the ellipse and the convex hull oscillate in time. These oscillations are interpreted as the second harmonic of the standing long-period kink oscillations (with the node at the apex) of the magnetic flux tube connecting the two main sunspots of the ARs. We also found that the inclination angles oscillate with the characteristic periods of 4.9 hours in AR 11726 and 4.6 hours in AR 11327. In addition, we discovered that the lengths of the pattern axes in the ARs oscillate with similar characteristic periods and these oscillations might be ascribed to standing global flute modes. In both ARs we have estimated the distribution of the phase speed magnitude along the magnetic tubes (along the two main spots) by interpreting the obtained oscillation of the inclination angle as the standing second harmonic kink mode. After comparison of the obtained results for fast and slow kink modes, we conclude that both of these modes are good candidates to explain the observed oscillations of the AR inclination angles, as in the high plasma  $\beta$  regime the phase speeds of these modes are comparable and on the order of the Alfvén speed. Based on the properties of the observed oscillations, we detected the appropriate depth of the sunspot patterns, which coincides with estimations made by helioseismic methods.

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**Contributed talk:** “Flare-productive Active Regions: Magnetic Properties and Evolutions”

**Author(s):** Shin Toriumi, Carolus J. Schrijver, Louise K. Harra, Hugh Hudson, Kaori Nagashima

**Abstract:** Strong flares and CMEs are often produced from active regions (ARs). To better understand the magnetic properties and evolutions of such ARs, we conducted statistical investigations on the SDO data of all flare events with GOES levels  $>M5.0$  within 45 deg from the disk center for 6 years from May 2010 to April 2016. Out of the total of 51 flares from 29 ARs, more than 80% show delta-sunspots and about 15% violate Hale's polarity rule. Depending on the magnetic properties, these ARs can be categorized into several groups, such as spot-spot, in which a sheared polarity inversion line is formed between two large sunspots, and spot-satellite, where a newly emerging flux next to a mature sunspot triggers a compact flare event. We also obtained several key findings including (1) the flare duration is linearly proportional to the separation of the flare ribbons (i.e., scale of reconnecting magnetic fields) and (2) CME-eruptive events have smaller sunspot areas. These results point to the possibility that magnetic structures of the ARs determine the characteristics of flares and CMEs. In the presentation, we will also show new results from the systematic flux emergence simulations of delta-sunspot formation and discuss the evolution processes of flaring ARs.

**Poster:** “Center-to-limb variation of the velocity field in and around a sunspot with light-bridges”

**Author(s):** Carsten Denker, M. Verma, H. Balthasar, A. Diercke, S.J. González Manrique, J. Löhner-Böttcher, C. Kuckein, M. Sobotka

**Abstract:** The disk passage of active region NOAA 12121 was observed with the 1.5-meter GREGOR solar telescope during the time period 2014 July 22-30. On 2014 July 25 and 28, the seeing conditions were excellent so that longer time-series were recorded approaching the diffraction limit of the telescope. The seeing conditions on the other days were variable ranging from mediocre to very good so that only snapshots of high-quality images and imaging spectroscopy were possible. On each day, data were acquired with the GREGOR Fabry-Pérot Interferometer (GFPI), initially in the spectral line Fe I  $\lambda 630.15$  nm and on the last two days in the spectral line Fe I  $\lambda 617.34$  nm. Imaging spectroscopy based on spectral scans restored with Multi- Object Multi-Frame Bild Deconvolution (MOMFBD) delivered high-resolution line-of-sight (LOS) velocity maps for a field-of-view (FOV) of  $50'' \times 38''$ . In addition, we present speckle reconstructed images obtained with a G-band filter ( $\lambda 430.7$  nm) in the Blue Imaging Channel (BIC) of the GFPI. These images cover a FOV of  $75'' \times 93''$  and were obtained with a cadence of  $\sim 30$ s. These data serve as input for Local Correlation Tracking (LCT) to investigate horizontal proper motions in and around the sunspots. The high-resolutions data are complemented by data from the space missions Solar Dynamics Observatory (SDO) and Interface Region Imaging Spectrograph (IRIS). We study the evolution of the sunspots with an emphasis on growth and decay of individual sunspots, formation and dissolving of (rudimentary) penumbrae, and fine structure of light-bridges and umbral dots.

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**Poster:** “A (new) entropy approach on the diffusion scaling features of photospheric magnetic elements”

**Author(s):** Fabio Giannattasio; Consolini, G.; Del Moro, D.;

Berrilli, F.; Gossip, M.; Bellot Rubio, L.

**Abstract:** High-resolution observations revealing the motion and the scales of organization of magnetic elements (MEs) in the quiet Sun are helpful to detect their diffusive nature as tracers in a turbulent convective medium. For this reason, a number of studies in the last decades focused on the determination of the diffusion scaling features. Those studies were based on variance analysis, being this quantity defined as the ensemble average of the squared displacement of MEs, when following a Lagrangian approach and under the hypothesis of passive transport. Here we present an alternative method of analysis based on entropy, and apply it to a long magnetogram time series. We find robust scaling exponents and discuss the results in light of previous literature.

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**Poster:** “Velocity fields in sunspots derived from observations with the GREGOR Fabry-Pérot Interferometer”

**Author(s):** H. Balthasar, C. Denker, S.J. González Manrique, C. Kuckein, M. Verma, J. L.

**Abstract:** Two sunspot groups at different states of their evolution have been observed on 2014 August 24 with the GREGOR Fabry-Pérot Interferometer (GFPI) at the GREGOR solar telescope in Tenerife. The first active region NOAA 12146 consisted of two major spots with new flux emerging between them. The second active region NOAA 12148 was in its decaying phase when it was separated into two small sunspots with light bridges and several pores. To probe velocities in the mid photosphere, the magnetically insensitive spectral line Fe I 709.04 nm with an excitation potential of 4.23 eV was selected. In this presentation we show the Doppler velocities in different parts of the sunspots and their surroundings, especially we will study the velocities in the area of emerging flux in NOAA 12146. Observations from the Solar Dynamics Observatory serve as context data.

**Poster:** “Flux emergence rate in the quiet Sun from Sunrise data

**Author(s):** H. N. Smitha, L. S. Anusha, S. K. Solanki, T. L. Riethmueller

**Abstract:** The small-scale internetwork (IN) features are thought to be the major source of fresh magnetic flux in the quiet Sun. The balloon-borne observatory Sunrise, during its first flight in 2009, captured images of the magnetic fields in the quiet Sun at a high spatial resolution. For the first time, features with fluxes as low as  $9 \times 10^{14}$  Mx were detected, which is nearly an order of magnitude smaller than those detected from Hinode observations. In this work, we measure the rate at which flux is brought to the solar surface by accounting for such small fluxes. By considering the features with fluxes in the range  $10^{15} - 10^{18}$  Mx, we measure a flux emergence rate (FER) of  $1100 \text{ Mx cm}^{-2} \text{ day}^{-1}$ . This is an order of magnitude higher than the FER from Hinode. A wider comparison with the literature shows, however, that the exact technique of determining the FER can lead to results that differ by up to 2 orders of magnitude, even when applied to similar data. The causes of this discrepancy will be discussed.

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**Poster:** “SOLARNET Mobility of Young Researchers Program: Bright Points dynamics from a VTT G-band dataset”

**Author(s):** L. Giovannelli, S. Hoch, D. Del Moro, F. Berrilli and O. von der Lühe

**Abstract:** We present the Bright Points (BPs) analysis from Vacuum Tower Telescope (VTT) dataset, performed in the framework of the SOLARNET Mobility of Young Researchers Program. A fast CMOS camera was used to acquire a G-BAND dataset of the AR 12390 at the VTT on July 27 2015. The KISIP speckle reconstruction algorithm was used to obtain a reconstructed frame from every burst of 100 images. The reconstructed dataset has a cadence of 8 s, a duration of 44 minutes and field of view of  $53.8 \text{ Mm} \times 45.4 \text{ Mm}$ , the pixel scale is  $0.029 \text{ arcsec/pixel}$ . In order to detect the BPs in the dataset we used the Multi Level Technique

(MLT 4) and then applied the Two level Structure Tracking to study BPs dynamical properties. We report on the area distribution, life times, velocity distribution and the displacement spectrum of the 3238 tracked BPs and compare with literature values.

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**Poster:** “Flare induced changes of the photospheric magnetic field in a delta-spot deduced from ground-based observations.”

**Author(s):** Peter Gömöry, H. Balthasar, C. Kuckein, A. Kučera, S.J. González Manrique, P. Schwartz, A.M. Veronig, A. Hanslmeier

**Abstract:** We present a study of the physical parameters of a delta-spot within active region NOAA 11865 derived from spectropolarimetric inversions before, during and after an M-class flare. The analysed near-infrared spectropolarimetric measurements of high angular resolution were obtained in two spectral lines (Fe I 1078.3 nm and Si I 1078.6 nm) with the Tenerife Infrared Polarimeter at the Vacuum Tower Telescope in Tenerife on October 15, 2013. Acquired full Stokes spectra were inverted using the code 'Stokes Inversions based on Response functions' (SIR) which allowed us to study the morphology, the magnetic field strength and inclination, and the velocity field of the observed delta-spot. Properties of the related M-class flare were derived using EUV and UV filtergrams provided by Atmospheric Imaging Assembly (AIA) instrument on-board the Solar Dynamics Observatory satellite.

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**Poster:** “Two Spectra of Turbulence of the Sun”

**Author(s):** R. Kostik, L. Kozak, and O. Cheremnykh

**Abstract:** Observations obtained at the 70-cm vacuum tower telescope (VTI) at Izaña (Tenerife, Spain) are analyzed to show that turbulent processes in the solar photosphere have two distinct spectra of turbulence. The first is the well-known Kolmogorov spectrum, which describes plasmas with a zero mean magnetic field, and the second is the Kraichnan spectrum with a nonzero mean

magnetic field. The transition from one spectrum type to another is found to occur at a scale of 3 Mm. This scale is consistent with the typical size of mesogranular structures, which indicates a transition to large-scale self-organizing magnetic structures.

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**Poster:** “Monitoring program of selected Fraunhofer lines over the 11-year cycle of solar activity”

**Author(s):** S. Osipov, R. Kostik, N. Shchukina

**Abstract:** Investigations of long-term changes of selected Fraunhofer lines is aimed at understanding the solar activity cycle and the solar irradiance changes. The research is based on high ( $R = 330,000$ ) spectral resolution observations of the quiet Sun using the horizontal solar telescope ACU-5 of the Main Astronomical Observatory of the National Academy of Sciences of Ukraine. The telescope has a spectrograph with a double pass system. It maintains a high precision stability of the the solar spectrum registration on long time scales. The diagnostics of the solar cycle variation include spectral lines of neutral and ionized chemical elements (C I, Ca I, Cr I, Mn I, Fe I, Fe II, Ti II) in nine spectral regions from 393 nm to 657 nm. The formation heights of these lines cover the large portion of the photosphere, the temperature minimum and the lower chromosphere. Since 2012 we perform observations at different positions on the solar disk and observation of the Sun as a star.

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**Poster:** “Magnetic and thermodynamic structure of a sunspot light bridge”

**Author(s):** T. Felipe, M. Collados, E. Khomenko, C. Kuckein, A. Asensio Ramos

**Abstract:** We study the three dimensional configuration of a sunspot and in particular its light bridge during one of the last stages of its decay. The magnetic and thermodynamical stratification of the sunspot have been inferred from full Stokes inversions of the photospheric Si I 10827 Å and Ca I 10839 Å lines obtained with the

GREGOR Infrared Spectrograph of the GREGOR telescope at Observatorio del Teide, Tenerife, Spain. The sunspot shows a light bridge with penumbral continuum intensity that separates the central umbra from a smaller umbra. We find that in this region the magnetic field lines form a canopy with lower magnetic field strength in the inner part. The photospheric light bridge is dominated by gas pressure (high-beta), as opposed to the surrounding umbra where the magnetic pressure is higher. A convective flow is observed in the light bridge. This flow is able to bend the magnetic field lines and to produce field reversals. The field lines close above the light bridge and become as vertical and strong as in the surrounding umbra. This magnetic configuration may be related to the dynamic activity in the chromosphere of light bridges reported by previous works.

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**Poster:** “Fast-to-Alfvén Mode Conversion Mediated by the Hall Current. II. Warm Plasma Simulations.”

**Author(s):** Pedro A. González-Morales, Elena Khomenko and Paul S. Cally.

**Abstract:** Solar atmospheric plasma near the temperature minimum it is in a weakly ionised state with a low ionisation fraction. These are good conditions for a coupling between magneto-acoustic waves and Alfvén waves through the Hall term, present both in the induction and the energy equations. In this contribution we present some results derived from numerical experiments considering a quasi-realistic solar stratification with different magnetic field configuration. These experiments are in agreement with the theoretical work, showing that the coupling fast-Alfvén is more intense for small angles between the magnetic field and the wave vector, for high frequency and when the intensity of the magnetic field is similar to the quiet sun.

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**Poster:** “High-resolution modeling of the solar photosphere with the ANTARES RHD code”



**Author(s):** P. Leitner, A. Hanslmeier, B. Lemmerer, A. Veronig, T. Zaqarashvili, F. Kupka and H. Muthsam

**Abstract:** The ANTARES code simulates near solar surface convection in detail unequaled by direct observation. It considers full radiative transfer and realistic microphysics including e.g. the thermodynamics of mixtures as well as realistic opacities based on the opacity distribution functions of the ATLAS-9 package to determine bin-averaged opacities and source functions. We study the photospheric flow kinematics and vertical stratification on small scales focusing on the quiet sun. This study is soon to be complemented by an MHD upgrade of ANTARES, such that the influence of the magnetic field on the photospheric dynamics is revealed. One such small-scale phenomenon we study from the high resolution modeling are intergranular jets that are characterized by a short lifetime of roughly a minute and a high local vorticity. We discuss their dynamics and their potential role in heating upper layers by advection or stimulation of Poynting flux through their associated horizontal kinetic energy flux.

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**Poster:** “Filamentary Oscillations in the Penumbra of Sunspots”

**Author(s):** Ana Belén Griñón Marín

**Abstract:** The issue of long-term (on scales of several hours to days) morphological changes in sunspots, and particularly the possible existence of apparent rotational motions and oscillations, has drawn attention since the early 20th Century. This kind of study requires data with high spatial resolution and good temporal sampling and coverage. The HMI instrument on board the Solar Dynamics Observatory routinely measures the full magnetic field vector in sunspots and allows us to track them with consistent image quality and high cadence during their entire disk passage. It is the ideal instrument to analyze the evolution of sunspots, and in particular the azimuthal component of the penumbral magnetic field. We carried out an analysis (Griñón-Marín et al. 2016 - Submitted-) looking for torsional oscillations in the penumbra of

sunspots that led to no evidence of this kind of oscillation in the 25 sunspots analyzed. However, we detected filamentary-like oscillations in some areas of the penumbra with periods of several hours. In this contribution I will show their morphological analysis and discuss the possible sources for such oscillations.

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**Poster:** “Canonical  $B_{\text{ver}}$  value on umbra/penumbra boundaries”

**Author(s):** Jan Jurcak, Nazaret Bello González, Rolf Schlichenmaier, Reza Rezaei

**Abstract:** We review past and upcoming studies related to the canonical value of the vertical component of the magnetic field on stable umbra/penumbra boundaries of sunspots,  $B_{\text{ver}}^{\text{stable}}$ . The remarkable stability of the  $B_{\text{ver}}$  value on UP boundaries of stable sunspots was found by Jurcak (2011) in a small sample of sunspots. Jurcak et al. (2015) described how the canonical value of  $B_{\text{ver}}^{\text{stable}}$  establishes by analysing observations of a forming penumbra. Jurcak et al. (2016, submitted) confirmed the importance of strong enough  $B_{\text{ver}}$  for formation of stable UP boundary. With  $B_{\text{ver}} < B_{\text{ver}}^{\text{stable}}$  the protrusion of penumbral grains into the pore area is not blocked, a stable pore-penumbra boundary does not establish, and the pore is fully overtaken by the penumbral magneto-convective mode. We also present a preliminary results of a statistical analysis of  $B_{\text{ver}}$  values on umbra/penumbra boundaries of more than 100 sunspots by Rezaei et al. (2017, in preparation).









**Invited review:** “Observations and diagnostics of the solar chromosphere”

**Author(s):** Rob Rutten

**Abstract:** Solar chromosphere research is booming thanks to the advent of high-resolution ground-based Fabry-Pérot observing, of ultraviolet spectroscopy with IRIS, and of Bifrost-class simulations. I will showcase new observations and treat various diagnostics, including expectations for ALMA.

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**Solicited talk:** “Alfvén Wave Heating of the Solar Chromosphere”

**Author(s):** Tony Arber

**Abstract:** By driving Alfvén and kink waves into an expanding flux tube we demonstrated that with a Poynting flux on  $2 \times 10^7$  erg/s/cm<sup>2</sup> we can reproduce a heating profile broadly consistent with the mid to upper chromosphere. The heating mechanism is through either ponderomotive or geometric coupling of Alfvén waves to shock and it is these shocks which dissipate and heat the chromosphere. These same shocks also produce jets of chromospheric material with properties similar to spicules (Type-I).

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**Contributed talk:** “Ellerman Bombs in 1-D Radiative Hydrodynamics”

**Author(s):** [Aaron Reid](#), Mihalis Mathioudakis, Gerry Doyle

**Abstract:** Ellerman Bombs (EBs) are small-scale, impulsive photospheric brightenings with estimated energies comparable to micro-flares. Recent IRIS observations show EB signatures in lines sensitive to transition region temperatures, hinting that the photosphere is superheated to transition region temperatures during these events. We use the 1 dimensional RADYN code to simulate the effect of the atmosphere due to the sudden deposition of energies across the photosphere and chromosphere. We use the MULTI line synthesis code to obtain the resultant EB diagnostic

lines of H $\alpha$  and Ca II 8542A from these models to find that EB line profiles are most likely formed when the energy is deposited around the temperature minimum region, resulting in temperature enhancements of  $\sim 2000\text{K}$ . We also use the RH line synthesis code to obtain Mg II h & k line profiles, to compare the models to the IRIS observations. We show that a scenario where Mg II h & k lines show enhancement, while maintaining traditional EB line profiles in H $\alpha$  and Ca II 8542 A is not possible with the described model setup, implying that EB atmospheres are not yet fully understood.

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**Contributed talk:** “Physical properties of a group of pores as derived from Ca II 854.2 nm observations and inversions at GREGOR”

**Author(s):** Christoph Kuckein, H. Balthasar, C. Denker, A. Diercke, S. J. González Manrique, J. Löhner-Böttcher, A. Pastor Yabar, M. Sobotka, and M. Verma

**Abstract:** The GREGOR Fabry-Perot Interferometer (GFPI) is installed at the 1.5-meter GREGOR telescope on Tenerife, Spain. The coatings of the etalons of the GFPI have a high reflectivity in the wavelength range between 530-860 nm. Therefore, during a 50-day first-science campaign in 2014 the chromospheric Ca II 854.2 nm line was observed with the GFPI in spectroscopic mode. The target was a group of pores close to disk center in active region NOAA 12149 on 2014 August 26. A non-equidistant wavelength spacing to scan through the broad Ca II 854.2 nm line was used. Narrower step sizes were taken close to the line core. Each of the 20 scans comprised 36 steps. Four images with an exposure time of 80 ms were acquired per step. We will present some physical properties of the group of pores derived from the inversions of the Ca II 854.2 nm intensity profiles using the non-LTE radiative transfer code NICOLE. This code is especially useful to infer atmospheric parameters from chromospheric lines formed under non-LTE conditions.



**Contributed talk:** “On the generation of solar spicules and Alfvén waves”

**Author(s):** Juan Martinez –Sykora, B. De Pontieu, M. Carlsson, V. Hansteen, L. Rouppe van der Voort, T. Pereira

**Abstract:** In the lower solar atmosphere, the chromosphere is permeated by jets, in which plasma is propelled at speeds of 50-150 km/s into the Sun’s atmosphere or corona. Although these spicules may play a role in heating the milliondegree corona and are associated with Alfvén waves that help drive the solar wind, their generation remains mysterious. Our study uses simulations created with the Bifrost code (Gudiksen et al. 2011). We implemented in the code the effects of partial ionization using the generalized Ohm’s law. This code also solves the full MHD equations with non-grey and non-LTE radiative transfer and thermal conduction along magnetic field lines. The ion-neutral collision frequency is computed using recent studies that improved the estimation of the cross sections under chromospheric conditions (Vranjes & Krstic 2013). Self-consistently driven jets (spicules type II) in magnetohydrodynamic simulations occur ubiquitously when magnetic tension is amplified and transported upwards through interactions between ions and neutrals, and impulsively released to drive flows, heat plasma and generate Alfvén waves. This mechanism explains how spicular plasma can be heated to millions of degrees and how Alfvén waves are generated in the chromosphere.

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**Contributed talk:** “Slender Ca II H fibrils observed by SUNRISE 2”

**Author(s):** R. Gafeira, A. Lagg, S. K. Solanki, S. Jafarzadeh, M. van Noort, and Sunrise team

**Abstract:** The special observing conditions of the SUNRISE observatory allow to obtain observations in the UV with unprecedented temporal stability and spatial resolution. On its second scientific flight, the Sunrise Filter Imager (SuFI) was used to

record a time series of narrow-band intensity images in the Ca II H line for approximately one hour at a cadence of 7 seconds. This unique data set enabled us to characterize the morphological properties of 598 slender Ca II H fibrils, such as width, length and lifetime. In addition, the fibril tracking algorithm delivered an average backbone of every fibril which allowed for the study of width and intensity oscillations at several positions along the fibril. A wavelet analysis applied to these oscillations reveals their periods, phase relations and the phase speeds. We find that a majority of the fibrils exhibits a clear relation between the width and intensity oscillation which can be interpreted as the signature of a sausage mode.

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**Solicited talk:** “Three-dimensional simulation of chromospheric jets with twisted magnetic field lines in the chromosphere”

**Author(s):** Haruhisa Iijima and Takaaki Yokoyama

**Abstract:** A study on the chromospheric jet formation by three-dimensional radiation MHD simulations with our code named RAMENS is presented. The aim of this study is to investigate the effects of three-dimensionality on the scale of chromospheric jets. We have newly developed the Radiation Magnetohydrodynamics Extensive Numerical Solver (RAMENS) for this study. The code includes the effect of non-local radiative transfer in the photosphere and optically thin radiative cooling in the upper layer. The Spitzer-type thermal conduction and latent heat of partial ionization are also taken into account. We find that the top of generated chromospheric jets reaches the height of 10—11 Mm. The twisted magnetic field lines are formed below the tall jets. This magnetic field structure helps to drive these tall chromospheric jets through the Lorentz force. Note that the produced chromospheric jets form a cluster with the diameter of several Mm with finer strands of several hundreds km, which is consistent with the multi-threaded nature of observed spicules.

**Solicited talk:** “IRIS diagnostic for lower chromospheric heating”

**Author(s):** Tiago M. D. Pereira

**Abstract:** The IRIS mission is providing an unprecedented amount of rich, high-resolution UV spectra from its seeing-free, stable platform. These have opened up a range of different diagnostics for the chromosphere and transition region. However, the journey from spectra to diagnostics is not always straightforward, and this is the subject of this talk. We used 3D rMHD simulations to study the formation of IRIS spectral lines. By comparing the synthetic spectra with physical quantities from the simulations, we gather statistics on how different spectral signatures correlate with atmospheric conditions. Of particular interest are the Mg II h&k and triplet lines, which together are formed over column mass ranges of 0.1 to approx  $10^{-6}$  g cm<sup>-2</sup>, or a formation height from 0.5 to 4 Mm. While the Mg II h&k profile shapes carry a signature of chromospheric heating, the Mg II triplet lines change dramatically in the presence of strong temperature increases in the lower chromosphere. In addition, profile shapes and shifts offer robust diagnostics of atmospheric velocities. I will show how different spectral signatures have been observed by IRIS and what they tell us about heating in events such as UV bursts or Ellerman bombs, and how different IRIS diagnostics can be used together.

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**Contributed talk:** “Structure of Chromospheric Magnetic Field in Solar Active Regions: Results from SOLIS/VSM Ca II 854.2 nm observations”

**Author(s):** [Sanjay Gosain](#), Valentin-Martinez Pillet, Jack Harvey, and SOLIS Team

**Abstract:** We will present full-disk spectropolarimetric observations of the Sun taken in chromospheric Ca II 854.2 nm spectral line. In particular we show that the NLTE inversion can fit properly the variety of Stokes profiles in different structures in active regions such as penumbra, umbra, plage, quiet sun, neutral lines etc. The chromospheric vector magnetograms of solar active regions,

derived by performing non-LTE inversions of the Stokes profiles using NICOLE (Non-LTE inversion code), will be presented. Chromospheric vector magnetograms have several advantages over photospheric ones because the field is more closer to force-free approximation at this height as compared to photospheric layer. We will present a critical analysis of this argument. These observations have recently become part of the core program of the synoptic observing program of National Solar Observatory, meaning that these observations are taken on daily basis, weather permitting.

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**Contributed talk:** “Ellerman bomb emission features in He I D<sub>3</sub> and He I 10830: observations and modelling”

**Author(s):** [Tine Libbrecht](#), J. Joshi, J. de la Cruz Rodríguez, J. Leenaarts, A. Asensio Ramos

**Abstract:** Ellerman Bombs (EBs) are short-lived emission features observed in the wings of Balmer lines of hydrogen. We aim to study the signature of EBs in neutral helium triplet lines using SST/TRIPPEL raster scans, featuring the H $\beta$ , He I D<sub>3</sub> and He I  $\lambda$ 10830 spectral regions, IRIS raster scans and the SDO/AIA 1700 Å channel. We have found for the first time a distinct EB signature in helium lines: three of the EBs in our data show emission signatures in He I D<sub>3</sub>. In some cases, there are some weaker emission effects in He I  $\lambda$ 10830 as well. The helium lines have two components: a broadened and blueshifted emission component, associated with the EB, and an absorption component, caused by the overlying canopy. With HAZEL, we disentangle the two components in the spectra. The observed EBs show enhanced signal in IRIS lines Mg II h&k and the triplet, and the Si IV doublet as well. Recently, there has been a discussion on the nature of IRIS bombs and Ellerman Bombs observed in the Si IV 1400 Å spectral lines with IRIS. It has been suggested that Ellerman Bombs are possibly much hotter than previously thought. An order of magnitude estimate places the temperatures of our observed EBs between  $2 \times 10^4 - 10^5$  K. This is an order of magnitude higher than obtained from forward modelling of H $\alpha$  lines, as attempted by

many authors. Synthesis of EB helium profiles in 1D and 3D will shed more light on the physical conditions causing helium emission in a reconnecting atmosphere.

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**Contributed talk:** “Formation of a stable penumbra in a region of flux emergence”

**Author(s):** Mariarita Murabito, Romano P., Guglielmino S. L., Zuccarello F.

**Abstract:** We studied the formation of the first penumbral sector around a pore in the following polarity of the Active Region (AR) NOAA 11490. We used a high spatial, spectral, and temporal resolution data acquired by the Interferometric BIdimensional Spectrometer (IBIS), mounted at NSO/DST, on 2012 May 28 from 14:20 UT to 14:38 UT, in the Fe I 6173 nm and Ca II 8542 nm. To follow the evolution of the penumbral sector, we also used data taken by the Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory satellite. We found that on the side towards the leading polarity, elongated granules in the photosphere and an arch filament system (AFS) in the chromosphere were present. From the inversion of the spectropolarimetric data, we noted that before the formation of the penumbral sector the magnetic field showed a sea-serpent configuration, indicating a region of magnetic flux emergence. We also found that the formation of a stable penumbra in the following polarity of the AR began in the area facing the opposite polarity, located below the AFS, i.e. in the flux emergence region, differently from what found by Schlichenmaier et al (2010). In particular, the formation of this penumbral sector occurred from 15:00 UT to 20:00 UT on 28 May 2012. During this time the area of the umbra was not constant but it increased as well as the negative magnetic flux did.

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**Contributed talk:** “Photospheric and chromospheric observations of dynamic features in an arch filament system”

**Author(s):** S. J. González Manrique, C. Kuckein, A. Pastor Yabar,

M. Collados, C. Denker, M. Verma, A. Diercke, P. Gömöry, H. Balthasar, M. Cubas Armas, A. Lagg, S.K. Solanki, and K.G. Strassmeier

**Abstract:** The new generation of solar instruments provides better spectral, spatial, and temporal resolution, which is essential to investigate the physical processes that take place on the Sun. High-resolution observations often show double- or even multiple-component spectral profiles. This is particularly true for observations of the near-infrared He I 10830 Å triplet. These spectral lines provide information on the velocity and magnetic fine structure of the upper chromosphere. We present observations of an emerging flux region (EFR), including two small pores visible in the photosphere and an arch filament system (AFS) in the chromosphere. The data were taken on 2015 April 17 with the very fast spectroscopic mode ( $\sim 1$  min for a full scan of 180 steps) of the GREGOR Infrared Spectrograph (GRIS), one of the post-focus instruments of the 1.5-meter GREGOR solar telescope located at the Observatorio del Teide, Tenerife, Spain. Simultaneous spectroscopic observations were taken with the GREGOR Fabry-Pérot Interferometer (GFPI) of the photospheric Fe I 6302 Å line. On the island of La Palma, the Swedish Solar Telescope (SST) observed the same EFR using the CRisp Imaging Spectro-Polarimeter (CRISP), which recorded spectropolarimetric data in the photospheric Fe I 6173 Å and the chromospheric Ca II 8542 Å lines. The observed AFS connects the two opposite magnetic polarities of newly emerging flux. Supersonic downflows up to  $100 \text{ km s}^{-1}$  were measured in the He I triplet, which occur near both footpoints of dark filaments, whereas loop tops rise with about  $1.5\text{--}20 \text{ km s}^{-1}$ . The aim of this work is to track locations of high velocities within the footpoints of the arch filaments down to the photosphere. A special question arises, if the plasma contained in chromospheric structures, which exhibits supersonic LOS downflows near the footpoints of the AFS even reaches the photosphere.

**Poster:** “Polarization of kink waves in the solar chromosphere”

**Author(s):** Marco Stangalini, F. Giannattasio, R. Erdélyi, G. Consolini, S. Jafarzadeh, S. Criscuoli, I. Ermolli, F. Zuccarello

**Abstract:** In recent years, new high spatial resolution observations of the solar atmosphere have revealed the presence of a plethora of small-scale magnetic elements down to the resolution limit of current cohort of solar telescopes. These small magnetic field concentrations are advected and diffused at the solar surface and act like energy conduits for the MHD waves. In this work, exploiting the high spatial and temporal resolution chromospheric data acquired with SST/CRISP, we show for the first time the presence of polarized kink oscillations in small magnetic elements in the solar chromosphere, with an energy flux in excess of the required amount needed to heat both the chromosphere itself and the corona.

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**Poster:** “Probing the lower solar atmosphere with CRSIP-SST Data”

**Author(s):** Arnold Hanslmeier, B. Lemmerer, M. Roth, J. Staiger

**Abstract:** The still pending question in high resolution solar physics is to understand the dynamics from the higher photosphere to the lower chromosphere, since a detailed knowledge about these layers will contribute to a better understanding of upwards propagation disturbances related to chromospheric heating mechanisms. We present first results from our observing run on May 13 2016 with the Swedish solar telescope using CRISP. The CRSIP Imaging Polarimetric Spectrometer has been installed in 2008 at the 1 m Swedish solar telescope. We made time series of images taken at a sampling rate of 12.39 sec. The angular pixel size was 0,057 arcsec/px. The individual frames consisted of 983 x 985 pixels and data were obtained in the H-Alpha line at 656.3 nm and the Ca II line at 854.2 nm. These lines cover different height regions in the upper solar photosphere and lower chromosphere. The H-Alpha line profile was scanned at 14 wavelength positions, the Ca-II line profile at 26 wavelength positions. In the first analysis we provide

samples of correlation analysis of (i) residual intensities at the line core, (ii) intensities near the continuum and (iii) intensities near line center velocities. The correlations were calculated between the two different lines as a function of time. Main results: The correlation between H-Alpha and Ca II is about .25 for the line core intensities. The correlation between H-Alpha and Ca II becomes very weak in the case of continuum intensities. The correlation between H-Alpha and Ca-II for the line center velocities is above 0.6 In all cases, the correlation coefficient shows a periodic behavior reflecting oscillations. The oscillations are very weak for the line center velocities.

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**Poster:** “Unraveling the photospheric-chromospheric coupling in sunspot light bridges”

**Author(s):** Rohan Eugene Louis

**Abstract:** Light bridges (LBs) are bright bands observed in the umbral core of pores and sunspots. Their convective origin represents a strong perturbation to the umbral magnetic field. A variety of chromospheric and coronal phenomena are associated with LBs, such as jets, brightness enhancements, plasma ejections, flare ribbons, etc. The presence of small-scale, velocity and magnetic inhomogeneities in the photosphere suggests a causal relationship with the observed chromospheric activity, although the exact mechanism remains speculative. In this talk I will present observations from various ground and space-based instruments in order to clarify the dynamic nature of sunspot LBs.

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**Poster:** “Atmosphere models of solar magnetic structures derived from high resolution spectro-polarimetric observations”

**Author(s):** [Alice Cristaldi](#), Ermolli, I., Stangalini, M., Giorgi, F.

**Abstract:** Most advanced solar irradiance models employ outcomes of spectral synthesis performed on one-dimensional (1D) static atmosphere models to reproduce the radiative output of magnetic



and quiet features observed over the solar photosphere. However, recent results derived from analysis of high resolution observations and magnetohydrodynamic simulations have raised some concern about the accuracy of 1D models employed in solar irradiance reconstructions. High resolution spectro-polarimetric solar observations offer rather unexplored data to further test and improve such models. Within this framework, we analysed spectro-polarimetric ground-based observations to derive the average properties of various solar atmosphere regions. We discussed the obtained results with respect to several 1D models presented in the literature and widely employed in SI reconstructions.

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**Poster:** On the ultraviolet contrast of solar magnetic features  
**Author(s):** Romaric Gravet, Matthieu Kretzschmar, and Thierry Dudok de Wit

**Abstract:** The knowledge of solar irradiance and its temporal variations is essential for climate modeling and space weather. Measuring irradiance being difficult, one often relies on models and their different assumptions. In this study, we aimed at providing observational constraints on these models by studying the contrast of magnetic features at ultraviolet (UV) wavelengths. We used SDO magnetograms, visible, and UV images at 1600Å and 1700Å from the HMI and AIA instruments onboard SDO, to quantify and characterize the contrast of features versus the strength of the magnetic field, the positions on the solar disk, and in time. We found no significant variations of the contrast with the solar cycle. As expected, we found that magnetic features have stronger contrast in UV than at visible wavelengths. Additionally, by considering features used in irradiance models such as quiet-Sun, spots and faculae, we have identified structures that are quiet-Sun like at visible wavelengths but have faculae-like contrast in UV. We will also discuss the impact of spatial resolution (i.e., pixel's filling factor) on our results.

**Poster:** “Waves at Tilted Interfaces”

**Author(s):** Eleanor Vickers

**Abstract:** We investigate the characteristics of magnetoacoustic surface waves propagating at a single density interface, in the presence of an inclined magnetic field. An exact dispersion relation is obtained and analytical solutions are derived for a small angle inclination. In order to understand the effect of the inclination (compared to the well-known parallel case), we analysed the variation of phase speed of waves with the plasma-beta and density ratio. The inclination of the field renders the frequency of waves to be complex, where the imaginary part describes a weak damping or growth.









**Invited review:** Dynamics and diagnostics of the solar corona: Unchained magnetism

**Author(s):** Sarah Gibson

**Abstract:** Coronal dynamics and magnetism are intrinsically linked. The three-dimensional coronal magnetic field shapes coronal plasma and channels its flow, storing energy in twists and tangles that ultimately drives massive eruptions. Quantifying and analyzing this magnetic field is thus a critical, but extremely difficult problem to solve. Since different types of multiwavelength coronal data probe different aspects of the coronal magnetic field, these data can be used together in an inverse calculation to validate and constrain specifications of that field. Such a task requires three things: a means of specifying the physical state (e.g., the distribution of density, temperature, velocity, and magnetic field), a well-defined forward calculation (i.e., the physical process relating the physical state and the observations), and the observations themselves.

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**Solicited talk:** “Nanoflare Properties in the Solar Corona”

**Author(s):** Nicholeen Viall

**Abstract:** We investigate the properties of coronal heating using a systematic analysis of EUV light curves. We use data taken with the Atmospheric Imaging Assembly on-board the Solar Dynamics Observatory and make maps of emission time lags - how the evolution of emission formed at one temperature correlates with the evolution of emission formed at other temperatures. Our technique computes these time lags of coronal and transition region plasma on a pixel-by-pixel basis and has the advantage that it analyzes all of the emission along the line of sight, including the diffuse emission between and around identifiable 'coronal loops'. We examine the coronal heating occurring in quiet Sun locations and active regions on the Sun that exhibit a myriad of different properties, and compare the observations with those predicted from our coronal heating models. We find that the majority of quiet Sun and active region coronal plasma is undergoing dynamic heating and cooling

cycles. The cooling phase dominates the emission, with the heating phase relatively invisible, which is consistent with theories of impulsive heating, or nanoflares. Further, with the statistics of the pixel-by-pixel measurements, we are able to test theoretical distributions of nanoflares and to determine the typical time between subsequent nanoflares on individual flux tubes, i.e. the reheat time.

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**Contributed talk:** “IRIS and SDO observations of coronal heating associated with spicules”

**Author(s):** Ineke De Moortel, Bart De Pontieu

**Abstract:** We use high-resolution observations of the chromosphere and transition region with the Interface Region Imaging Spectrograph (IRIS) and of the corona with the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) to show evidence of the formation of coronal structures as a result of spicular mass ejections and subsequent heating of plasma first to transition region and later to coronal temperatures. Our observations suggest that much of the highly dynamic loop fan environment associated with plage regions may be the result of the formation of such new coronal strands, a process that previously had been interpreted as the propagation of transient propagating coronal disturbances (PCD)s. Our results suggest that heating and strong flows play an important role in maintaining the substructure of loop fans, in addition to the waves that permeate this low coronal environment.

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**Contributed talk:** “New insights on mass flows in and out of the solar transition region”

**Author(s):** Pia Zacharias, Jorrit Leenaarts, Viggo Hansteen

**Abstract:** We have performed 3D radiation MHD simulations with the Bifrost stellar atmosphere code to study the temporal evolution of mass flows into and out of the solar corona. By adding tracer



particles, so-called corks, to the simulations and analysing their behaviour over time, we are able to provide new insights on the physical processes driving these mass flows and on their role in the chromosphere-corona mass cycle. The corks allow for a thorough tracking of magnetic field lines over time. We have analysed several different sets of magnetic field structures with respect to their mass loading and mass draining from the corona and will present first results on how the behaviour of high-reaching coronal loops differs from that of cooler, low-lying loops.

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**Contributed talk:** “Nonlinear force-free coronal magnetic stereoscopy”

**Author(s):** [Iulia Chifu](#), Thomas Wiegelmann, Bernd Inhester

**Abstract:** In the past, two completely different methods were used for deriving the 3D structure of the solar coronal magnetic field: 1) Nonlinear force-free field (NLFFF) extrapolations, which use photospheric vector magnetograms as boundary condition and 2) Stereoscopy of coronal magnetic loops visible in images from different view directions. Both approaches have their limitations and, as a consequence, for the same observational data, the computed 3D magnetic field with the two methods do not necessarily coincide. We extended the NLFFF optimization code by the inclusion of stereoscopic constrains. The extended method (called S-NLFFF) contains an additional term that minimizes the angle between the local magnetic field direction and the orientation of the 3D coronal loops reconstructed by stereoscopy. The method was successfully tested with synthetic data and within this work we apply the newly developed code to a combined data-set from SDO/HMI, SDO/AIA and the two STEREO spacecraft. We find that prescribing the shape of the 3D stereoscopically reconstructed loops, the S-NLFFF method could lead to a stabilization of the coronal NLFFF model and it could recover a magnetic field which agrees also with the coronal observations.

**Contributed talk:** “A global view of velocity fluctuations in the corona”

**Author(s):** Richard Morton

**Abstract:** The last few years has seen the ubiquity of transverse MHD wave modes established throughout the solar atmosphere. These waves are often put forward as a candidate responsible for the heating of the solar atmospheric plasma and the acceleration of the solar wind. However, it is still unclear whether these waves carry enough energy and whether they can dissipate it in the locations required, in order to play a significant role in determining the dynamics of the atmosphere. I will discuss recent observations using the Coronal Multi-channel Polarimeter that provide insight the propagation of transverse waves through the corona, evidence for their generation via mode-coupling to p-modes, and their relative energy flux in distinct magnetic geometries.

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**Invited review:** “Heating of the solar corona”

**Author(s):** Iñigo Arregui

**Abstract:** In spite of decades of research, the coronal heating problem remains a recurrent issue. A number of mechanisms are believed to contribute to the heating: the direct dissipation of magnetic energy by processes such as magnetic reconnection, current cascades, viscous turbulence or magnetic field braiding; the dissipation of wave energy; or the mass flow cycle between chromosphere and corona are some suggestions. Observations provide ample motivation for pursuing all of them, so a discussion in terms of mutually exclusive explanations is beside the point. Instead, we focus on a number of recent advances in observations and theory. They are pointing towards a better understanding of aspects such as plasma and field dynamics at increasingly smaller spatial scales, the coupled photosphere-chromosphere-corona system, the possible relevance of the underlying partially ionised plasma, multi-scale physical processes through the use of large scale MHD numerical experiments, or the relative contribution of

multiple processes through forward modelling and comparison to observations.

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**Contributed talk:** “Formation and evolution of coronal rain observed by SDO/AIA on February 22, 2012”

**Author(s):** Zurab Vashalomidze; Kukhianidze, V.; Zaqarashvili, T. V.; Oliver, R.; Shergelashvili, B.; Ramishvili, G.; Poedts, S.; De Causmaecker, P.

**Abstract:** *Context.* The formation and dynamics of coronal rain are currently not fully understood. Coronal rain is the fall of cool and dense blobs formed by thermal instability in the solar corona towards the solar surface with acceleration smaller than gravitational free fall.

*Aims:* We aim to study the observational evidence of the formation of coronal rain and to trace the detailed dynamics of individual blobs.

*Methods:* We used time series of the 171 Å and 304 Å spectral lines obtained by the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamic Observatory (SDO) above active region AR 11420 on February 22, 2012.

*Results:* Observations show that a coronal loop disappeared in the 171 Å channel and appeared in the 304 Å line more than one hour later, which indicates a rapid cooling of the coronal loop from 1 MK to 0.05 MK. An energy estimation shows that the radiation is higher than the heat input, which indicates so-called catastrophic cooling. The cooling was accompanied by the formation of coronal rain in the form of falling cold plasma. We studied two different sequences of falling blobs. The first sequence includes three different blobs. The mean velocities of the blobs were estimated to be 50 km s<sup>-1</sup>, 60 km s<sup>-1</sup> and 40 km s<sup>-1</sup>. A polynomial fit shows the different values of the acceleration for different blobs, which are lower than free-fall in the solar corona. The first and second blob move along the same path, but with and without acceleration, respectively. We performed simple numerical simulations for two consecutive blobs, which show that the second blob moves in a

medium that is modified by the passage of the first blob. Therefore, the second blob has a relatively high speed and no acceleration, as is shown by observations. The second sequence includes two different blobs with mean velocities of  $100 \text{ km s}^{-1}$  and  $90 \text{ km s}^{-1}$ , respectively. *Conclusions:* The formation of coronal rain blobs is connected with the process of catastrophic cooling. The different acceleration of different coronal rain blobs might be due to the different values in the density ratio of blob to corona. All blobs leave trails, which might be a result of continuous cooling in their tails.

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**Contributed talk:** “Estimation of Coronal Solar Rotation using  $171\text{\AA}$  Extreme UV images from SOHO”

**Author(s):** Shivam Raval, Hari Om Vats

**Abstract:** Rotation of the Sun is traditionally estimated by observing the motion of certain features on the solar surface e.g. sunspots, plages, filaments etc. Recent advances have allowed us to precisely monitor the rotation of the sun using the means of spectroscopy and flux modulation approach. In the present work, we analyze the  $171 \text{ \AA}$  extreme UV solar images from the SOHO Extreme ultraviolet Imaging Telescope (EIT) for the period of 20 years (January 1997 to August 2016) using the flux modulation approach to estimate the Sidereal Rotation Period of the Corona and analyze its present variation as a function of solar latitude for the estimation. This involves the techniques of Digital Image Processing to precisely observe the variation of average intensity in a small width at each latitude throughout the year. We perform time series analysis and observe that the periodic nature of auto-correlation plot of the intensities reveals the rotation period at a given latitude. We find the evidence of some important features such as the Differential Rotation as a function of latitude and the North-South Asymmetry in the Rotation Period of the Sun. We also substantiate that the variation of solar rotation rate with latitude has to be of a cubic form to incorporate the asymmetric effects in the Differential Rotation.

**Contributed talk:** “Bombs, jets and flares at the surface and lower atmosphere of the Sun”

**Author(s):** Viggo Hansteen & Vasilis Archontis

**Abstract:** A spectacular manifestation of solar activity is the appearance of transient brightenings in the far wings of the H $\alpha$  line, known as Ellerman bombs (EBs). Recent observations obtained by the Interface Region Imaging Spectrograph (IRIS) have revealed another type of plasma “bombs” (UV bursts) with high temperatures of 8Å~104 K within the cooler lower solar atmosphere. Realistic numerical modeling is needed to produce these solar bombs and explain their nature. Here, we report on 3D radiative magneto-hydrodynamic simulations of magnetic flux emergence in the solar atmosphere. We find that ubiquitous reconnection between emerging bipolar magnetic fields can trigger EBs in the photosphere, UV bursts in the mid/low chromosphere and small (nano- and micro-) flares (10<sup>6</sup> K) in the upper chromosphere. These results provide new insights on the dynamics and heating of the solar surface and lower atmosphere.

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**Contributed talk:** “Contribution of coupling of Alfvén and kink modes to coronal heating”

**Author(s):** Paolo Pagano, Ineke De Moortel, Patrick Antolin

**Abstract:** Recent observations of coronal loops reveal ubiquitous transverse velocity perturbations, that undergo strong damping as they propagate. Observational estimates show that these perturbations contain significant amounts of energy. We have previously demonstrated that this observed rapid damping can be understood in terms of coupling of different wave modes in the inhomogeneous boundaries of the loops: this mode coupling leads to the coupling of the transversal (kink) mode to the azimuthal (Alfvén) mode, observed as the decay of the transverse kink oscillations. However, an important point to note here is that (observed) wave damping does not automatically imply dissipation, and hence heating. To investigate under which circumstances this

process can contribute to the coronal heating and to what extent the heating rate is sustainable, we perform 3D numerical experiments modelling the observed, transverse oscillations including the effects of resistivity and thermal conduction. We first analyse the contribution from a single monochromatic pulse, and then we extend the study by investigating different sizes and structures of the boundary layer and a continuous driver.

**Poster:** “Coronal density structure and its role in wave damping in loops

**Author(s):** Ineke De Moortel, P.J. Cargill, G. Kiddie

**Abstract:** It has long been established that gradients in the Alfvén speed, and in particular the plasma density, are an essential part of the damping of waves in the magnetically closed solar corona by mechanisms such as resonant absorption or phase mixing. While models of wave damping often assume a fixed density gradient, the self-consistency of such calculations is assessed by examining the temporal evolution of the coronal density. We show conceptually that for some coronal structures, density gradients can evolve in a way that the wave damping processes are inhibited. For the case of phase mixing we argue that: (a) wave heating cannot sustain the assumed density structure and (b) inclusion of feedback of the heating on the density gradient can lead to a highly structured density, although on long timescales. In addition, transport coefficients well in excess of classical are required to maintain the observed coronal density. Hence, the heating of closed coronal structures by global oscillations may face problems arising from the assumption of a fixed density gradient and the rapid damping of oscillations may have to be accompanied by a separate (non-wave based) heating mechanism to sustain the required density structuring.

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**Poster:** “Magnetic evolution of emerging active region 11856 using a potential field model”

**Author(s):** Autumn Rolling, Stéphane Régnier

**Abstract:** Active region 11856 was observed on the solar disk in October 2013. It provides an example of emerging flux in an already established active region – the distribution of the photospheric magnetic field shows an initial bipolar configuration, into which a second bipolar field emerges over the following days. The timing of this event coincided with the production of several C-class flares. The active region is studied using a newly developed and fast

potential field algorithm to construct the coronal magnetic field from the SDO/HMI magnetogram data. By applying this method over the time period in which the flux emergence occurred, the changes in the magnetic field caused by the emerging flux can be revealed with a focus on the topological changes due to the interaction between the newly emerged and pre-existing bipoles. This then allows for a quantitative comparison of the expected magnetic energy of the region as it evolves.

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**Poster:** “Discovery of Ubiquitous Fast Propagating Intensity Disturbances by CLASP/SJ”

**Author(s):** M. Kubo, Y. Katsukawa, Y. Suematsu, R. Kano, T. Bando, N. Narukage, R. Ishikawa, H. Hara, G. Giono, S. Tsuneta, S. Ishikawa, A. Winebarger, K. Kobayashi, F. Auchere, J. Trujillo Bueno

**Abstract:** High cadence observations by CLASP/SJ reveal ubiquitous intensity disturbances that recurrently propagate in either the chromosphere, transition region, or both at a speed much higher than the sound speed. The CLASP/SJ instrument provides a time series of two-dimensional images taken with broadband filters centered on the Ly-alpha line at a 0.6 s cadence. The multiple fast propagating intensity disturbances appear in the quiet Sun and in an active region, and they are clearly detected at least in 20 areas in the field of view of 527”x 527” during the 5-minute observing time. The apparent speeds of the intensity disturbances range from 150 to 350 km/s, and they are comparable to the local Alfvén speed in the transition region. The intensity disturbances tend to propagate along bright elongated structures away from areas with strong photospheric magnetic fields. This suggests that the observed fast propagating intensity disturbances are related to the magnetic canopy structures. The maximum distance traveled by the intensity disturbances is about 10”, and the widths are a few arcseconds, which are almost determined by the pixel size of 1.03”. The timescale of each intensity pulse is shorter than 30 s. One possible explanation for the fast propagating intensity disturbances observed



by CLASP is magnetohydrodynamic fast mode waves. We will also report temporal evolution of the shape of the Ly-alpha line while the fast propagating intensity disturbances across the slit of CLASP.

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**Poster:** “Comparison of damping mechanisms for transverse waves in coronal loops.”

**Author(s):** M. Montes-Solís, I. Arregui, M. Collados

**Abstract:** Damping of transverse waves in different solar coronal structures is a commonly observed property and a source of information about coronal conditions. Although resonant damping seems to be the most accepted mechanism for damping of transverse waves, there are other possible mechanisms. We have carried out a Bayesian analysis comparing three different models which could explain the damping in coronal loops. Our results indicate that resonant absorption is the most probable mechanism for low ratios between damping time and wave period, while the wave leakage mechanism is the best candidate for high ratios. Nonetheless, the evidence for one model against another shows a strong dependence on the data errors.

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**Poster:** “Behavior of Eigenfrequencies in a System of Coronal Loops Oscillation: Multi-stranded Loops Interaction Approach”

**Author(s):** Shahriar Esmaceli, Neda Dadashia, Mojtaba Nasiria, and Hossein Safaria

**Abstract:** The study of the Sun is developing through the combination of observational data and numerical simulation which clarify physical mechanism. The bundles of loops were observed in active regions led to study the collective oscillations and internal fine structures of the loops. We studied the MHD oscillations of a system of magnetized loops under the zero- $\beta$  condition and the stratification of density along the radial (step function) and the loops axis ( $z$ ). A single partial differential equation as the wave equation, for  $z$  component of the perturbed magnetic field, is

numerically solved based on finite element method by employing the appropriate boundary conditions. Eigenfunctions and eigenfrequencies are extracted for a system of loops with various number of multi-stranded loops inside the hypothetical monolithic loop (Fig. I). Results show that the interactions of multi-stranded loops are roughly correlated with their spatial configuration and density topology. The ratios of frequencies  $\tilde{\omega}_{sys}/\tilde{\omega}_{mono}$  are extracted in order to studying the interaction influence of the loops on their collective oscillations. It is inferred that for a system of loops, the ratios of frequencies are found in large quantities than a system of loops with many tubes inside the equivalent monolithic loop. It is also concluded that for a system with a few number of loops, the density configuration possesses asymmetric topology inside the monolithic tube. While, by adding the loops inside the hypothetical tube and notifying the equivalent density are kept in the same quantity, the density structure tends to have symmetric topology. In this case the, the ratios of frequencies are lower [1].

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**Invited review:** “Solar eruptions and energetic events”

**Author(s):** Astrid Veronig

**Abstract:** Coronal mass ejections (CMEs) and flares are the most energetic phenomena in our solar system, and are thus the main drivers for severe disturbances of the space weather near Earth. In this review, we will discuss recent advances on the initiation and dynamics of flare/CME events and associated phenomena, such as large-scale shock waves and coronal dimmings. We will also draw attention on confined versus eruptive flares. Finally, we will discuss the relation between the early CME dynamics and the energy release in the associated flare, and the propagation of CMEs in interplanetary space.

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**Solicited talk:** “Magnetic reconnection in twisted magnetic fields in solar flares - heating, particle acceleration and observational signatures”

**Author(s):** Philippa K. Browning and M Gordovsky

**Abstract:** Twisted magnetic fields are reservoirs of free magnetic energy in the solar corona, and represent a basic building block of non-potential fields. Energy release through magnetic reconnection may be triggered by the onset of kink instability, leading to plasma heating and acceleration of non-thermal particles. This may be manifest as a confined flare in a loop. We describe modelling with coupled 3D magnetohydrodynamic and test-particle simulations, and determine the possible observational signatures of energy release in twisted magnetic fields, including microwave polarisation patterns. We also show that instability in one twisted thread may trigger energy release in a stable neighbour, with enhanced heating as the threads reconnect and merge. A model of this process based on relaxation theory is presented.

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**Contributed talk:** “Properties of quasi-periodic pulsations in solar flares from a single active region”

**Author(s):** Chloe E. Pugh, V. M. Nakariakov, A.-M. Broomhall

**Abstract:** Quasi-periodic pulsations (QPPs) in solar flares have been widely observed, and can be used as a coronal plasma diagnostics tool. A total of 181 GOES class solar flares have been identified from a single active region (best known as NOAA 12192), which can be tracked for at least three Carrington rotations. Many of these flares show evidence of quasi-periodic pulsations, which can be detected in the power spectra, and so a statistical study is being undertaken using X-ray and microwave observations from GOES, RHESSI, Fermi and Nobeyama Radioheliograph. The aim of this investigation is to determine whether there is any variation of the QPP properties which correlates with the evolution of the active region.

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**Contributed talk:** “Could the Hale Sector Boundary help us to anticipate solar flares?”

**Author(s):** K. Loumou, I.G. Hannah, H. Hudson

**Abstract:** The interplanetary magnetic field is structured into large-scale domains, a pattern that extends back to the photospheric magnetic field. This field is concentrated in each solar hemisphere where the change in magnetic sector polarity is the same as the change in polarity between the leading and following sunspots. These parts of the sector boundary are called the Hale Sector Boundary (HSB). In this study we demonstrate the positive relationship between its presence and the occurrence of flares. We use the polarity change at the Earth as a proxy (5.5 days beforehand) for when the HSB is at the solar meridian. We then analysed the location of solar flares, obtained by RHESSI, identifying those occurring near the HSB. We reconfirm that for cycle 23 the flares occur preferentially in the predicted hemisphere (Svalgaard, Hannah and Hudson 2011) although for cycle 24 this relation was not as clear. We therefore investigated the behaviour of the HSB for the past 6 solar cycles, finding that the sector starts well organised at solar minimum but becomes more disorganised by



solar maximum. We extend this work using photospheric magnetic field extrapolations as a way to confirm the HSBs and also investigate their relationship to a larger number of flares.

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**Contributed talk:** “Relationship of EIT Waves Phenomena with Coronal Mass Ejections”

**Author(s):** V. K. Verma

**Abstract:** In the present paper we have studied the relationship of Extreme Ultraviolet Imaging Telescope (EIT) waves phenomena with coronal mass ejections (CMEs) events. This study is a part of our research work to understand the origin of CMEs and its relationship with EIT waves phenomena. To carry out this study we have used EIT waves list (March 25, 1997-June 17, 1998) published by Thompson & Myers (2009) and CMEs data for the same period observed by LASCO/ SOHO. The EIT/ SOHO instrument recorded 176 EIT events during above period and after matching with CMEs phenomena we find that corresponding to 84 EIT wave events, no CMEs events were recorded and thus we excluded 84 EIT wave events from present study. Out of 176 EIT wave events only 92 are accompanied by CMEs phenomena. The correlation study of speed of EIT wave events and CMEs events of 92 events shows poor correlation  $r=0.21$  indicate that the EIT wave and CMEs events does not have common mechanism of origin. Earlier Verma & Pande (1989), Verma (1998) indicated that the CMEs may have been produced by some mechanism, in which the mass ejected by solar flares or active prominences, gets connected with the open magnetic lines of CHs (source of high speed solar wind streams) and moves along them to appear as CMEs. The results obtained in the present are discussed in the view of recent scenario of heliophysics.

References:

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**Invited review:** “Solar energetic events and space weather”

**Author(s):** Consuelo Cid

**Abstract:** The terrestrial environment is under a dynamic equilibrium which strongly depends on solar activity. When a solar energetic event occurs, several changes take place in the space environment, particularly in the region between the Earth and Sun, defining what it is labelled as space weather. Disturbances of the terrestrial environment, or space weather events, include a large range of phenomena extending from geomagnetic storms to energetic particle events or to ionospheric disturbances. This presentation reviews the kind of space weather events and how they depend on the solar trigger and on the energy transfer to the terrestrial environment. The relevance of the solar wind signatures reaching the Earth, often arising from the interaction of solar ejections, and the transient phenomena at the magnetosphere will be also described.

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**Solicited talk:** “Coronal Mass Ejections and Geomagnetic Storms”

**Author(s):** Marilena Mierla

**Abstract:** Coronal mass ejections (CMEs) are huge expulsions of plasma and magnetic field from the Sun into the interplanetary space. When interacting with the Earth's magnetosphere they can create major geomagnetic storms which can have a direct impact on our technological life. In this presentation a summary on the recent results regarding the propagation of CMEs and their impact on the magnetosphere will be given. The limitations of the actual observations and models used for forecasting the arrival time of the CMEs to the Earth will be also outlined.

**Contributed talk:** “Radiative energy budget of solar flares and its scaling with the soft X-ray flare size”

**Author(s):** Matthieu Kretzschmar

**Abstract:** Solar flares radiate energy at all wavelengths, but are best observed at « hot » (coronal) wavelengths where the contrast is larger. Consequently, the flare classification relies on soft X-ray observations made by the GOES 0.1nm-0.8nm passbands. There are however evidences that most of the flare energy is radiated by

the colder layers of the Sun, in particular in the chromosphere, and at longer wavelengths. We used high-cadence TSI measurements and chromospheric extreme-ultraviolet (EUV) observations (by SDO/EVE) of many flares to investigate the radiative energy budget of flares and its evolution with the soft X-ray flare size. We found evidences for a larger contribution of the chromospheric radiation when considering smaller soft X-ray flares. In other words, the ratio of chromospheric to coronal emission appears to increase when going from X-class flares to smaller flares. This study opens the way for a contribution of small flares to solar irradiance variations and questions the traditional flare model. We will detail our analyses and discuss their limitations and implications.

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**Contributed talk:** “Examining the drag force on coronal mass ejections”

**Author(s):** Chia-Hsien Lin, James Chen

**Abstract:** Coronal mass ejections (CMEs) are highly energetic solar eruptive events. They are the main driver of space weather disturbance. If they reach Earth, they can cause hazard and disruptions to modern life. Therefore, the prediction of their arrival at Earth is an important subject in the space weather research. An accurate prediction of when and whether a CME would reach Earth relies on a correct formulation of the equation that governs its motion. One commonly used prediction method is drag-based model. It is formulated under the assumption that the CME

propagation through the interplanetary space is governed by drag forces alone, with all other forces negligible. This assumption has never been justified, and may not be valid because any object that experiences only drag force would eventually stop relative to the background medium. The objective of this work is to test the validity of this assumption, and to clarify the role the drag force plays in the CME kinematics. We use a physical model implemented with a complete equation of motion to compute the forces acting on a CME fluxrope during its propagation from the Sun to Earth. The results can reveal how different forces change with the distance from the Sun.

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**Contributed talk:** “The Solar event of June 21, 2015: comprehensive Sun-to-Earth analysis.”

**Author(s):** Mirko Piersanti, Tommaso Alberti, Alessandro Bemporad, Francesco Berrilli, Roberto Bruno, Vincenzo Capparelli, Vincenzo Carbone, Giuseppe Consolini, Alice Cristaldi, Alfredo Del Corpo, Dario Del Moro, Simone Di Matteo, Ilaria Ermolli, Silvano Fineschi, Fabio Giannattasio, Fabrizio Giorgi, Luca Giovannelli, Salvatore Luigi Guglielmino, Monica Laurenza, Fabio Lepreti, Maria Federica Marcucci, Matteo Martucci, Matteo Mergè, Ermanno Pietropaolo, Paolo Romano, Roberta Sparvoli, Marco Stangalini, Antonio Vecchio, Massimo Vellante, Umberto Villante, Francesca Zuccarello, B. Heilig, J. Reda, J. Lichtenberger

**Abstract:** A full-halo coronal mass ejection left the sun on June 21, 2015 from the active region NOAA 12371 encountering Earth on June 22, 2015, generating a G3 strong geomagnetic storm. The CME was associated with an M2 class flare observed at 01:42 UT, located near the center disk (N12E16). Using satellite data from solar, heliospheric, magnetospheric missions and ground-based instruments, we performed a comprehensive Sun-to-Earth analysis. In particular, we analyzed the active region evolution using ground-based and satellite instruments (BBSO, IRIS, HINODE, SDO/AIA, RHESSI -- H $\alpha$ , EUV, UV, X), the AR magnetograms, using data from SDO HMI, the relative particle

data, using PAMELA instruments and the effects of interplanetary perturbation on cosmic ray intensity. We also evaluated the 1-8 Å soft X-ray and low-frequency ( $\approx 1$  MHz) Type III radio burst time-integrated intensity (or fluence) of the flare in order to make a prediction of the associated Solar Energetic Particle (SEP) event by using the model developed by Laurenza (2009). In addition, using ground based observations from lower to higher latitudes (INTERMAGNET – EMMA, etc.), we reconstructed the ionospheric current system associated to the geomagnetic Sudden Commencement. Furthermore, SuperDARN measurements are used to image the global ionospheric polar convection during the SSC and during the principal phases of the geomagnetic storm.

Moreover, we investigated the dynamics of the plasmasphere during the different phases of the geomagnetic storm by examining the time evolution of the radial profiles of the equatorial plasma mass density derived from field line resonances detected at the EMMA network ( $1.5 < L < 6.5$ ). Finally, we presented the general features of the geomagnetic response to the CME, by applying innovative data analysis tools that allow to investigate the time variation of ground-based observations of the Earth's magnetic field during the associated geomagnetic storm.

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**Contributed talk:** “Propagation of filament and hot plasma through solar atmosphere as observed with ground based and space instruments”

**Author(s):** Vaskova, R., Kucera, A., Gomory, P., Rybak, J.

**Abstract:** Dynamical characteristics of filament and hot plasma propagation through chromosphere, corona and near surrounding of the Sun are presented. The filament movement and subsequent coronal mass ejection were associated with M5.4 solar flare that appeared on July 13, 2004 near the north-west limb of the Sun. We observed the event with German VTT, TRACE, RHESSI, SOHO/EIT, SOHO/CDS, SOHO/MDI and SOHO/LASCO instruments. Filament and hot plasma velocities in the plane-of-sky

were measured in front of the solar disc before the flare onset and after its eruption using VTT and TRACE data. Doppler velocities of the hot plasma were measured with CDS spectrograph and using SOHO/LASCO data, tracking of the event above the limb was done. Prior to eruption, the filament undergoes a slow movement within a velocity range of  $\approx 5 - 30$  km/s. Then it erupted and accelerated to a speed of  $\approx 180$  km/s according to VTT H-alpha and  $\approx 200$  km/s in TRACE 195 Å. The CDS spectra exhibits double components what reveal the superposition of a relatively stationary plasma volume and plasma elements moving up with high velocities up to  $\approx 340$  km s<sup>-1</sup>. The last part of the propagation of the filament and hot plasma near surrounding of the Sun was measured from SOHO/LASCO data. The velocities estimated here were around 500 km/s. Evidence of an acceleration process through the solar atmosphere and filament behaviour are discussed.

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**Contributed talk:** “An Alternative Cellular Avalanche Model, Based On Maximum Release Of Energy During Solar Flares”

**Author(s):** Nastaran Farhang, M. S. Wheatland, and H. Safari

**Abstract:** Prediction of solar flares based on analysis of observational time series is an important problem, and has been subjected to wide study. Various models have been used to describe solar flares, but each has some imperfections, in particular in application to predicting the occurrence of solar flares. We present a new statistical avalanche model based on a maximum release of energy during each avalanche event. We assume that among all possible burst candidates (unstable nodes) magnetic re-connections (i.e. an avalanche) only take place at nodes maximizing the amount of released energy. This constraint provides a controlling switch over the number of bursts. Statistical study of energy distribution shows promising results to predict solar flares more precisely.

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**Contributed talk:** “The role of erupting sigmoid in triggering a flare with double set of ribbons”

**Author(s):** Navin Chandra Joshi, Chang Liu, Xudong Sun, Haimin Wang, Tetsuya Magara, Y.-J. Moon

**Abstract:** We present observations and analysis of an interesting sigmoid formation, eruption, and their rope in triggering a flare with two different sets of ribbons (parallel ribbons and a large-scale quasi-circular ribbon) occurred on 2014 April 18. SDO/AIA, SDO/HMI, GOES, RHESSI data have been used for the present study. Several observational evidence and nonlinear force-free field extrapolation results reveal the presence of a large-scale fan-spine type magnetic field configuration with a sigmoid lying under the eastern section of the fan dome. The whole event can be understood with the following two different phases. During the preflare phase, we observed the formation and appearance of the sigmoid via tether-cutting reconnection between the two sets of sheared fields under the fan dome. The second, main flare phase features the eruption of the sigmoid, the subsequent flare with parallel ribbons, and a quasi-circular ribbon. We propose the following multi-stage successive reconnection scenario for the main flare. First, tether-cutting reconnection is responsible for the formation and the eruption of the sigmoid structure. Second, the reconnection occurring in the wake of the erupting sigmoid produces the parallel flare ribbons on the both sides of the circular polarity inversion line. Third, the null-type reconnection higher in the corona, possibly triggered by the erupting sigmoid, leads to the formation of a large quasi-circular ribbon. To the best of your knowledge, for the first time, we suggest a possible scenario for this type of solar flare with double set of ribbons.

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**Contributed talk:** “GONG Catalog of Large-Amplitude Oscillations in Solar Filaments”

**Author(s):** Manuel Luna, J. L. Ballester, P. F. Chen, M. Dumbović, H. Gilbert, J. Karpen, N. Maygar, M. Ruderman, J. Terradas, B. Vršnak, A. Adrover, J. Čalogović and Y. Ouyang

**Abstract:** Solar filaments exhibit a variety of oscillations. Large-

Amplitude oscillations involves periodic motions with velocities larger than 20 km/s. A large portion of the filament move in phase and the oscillations are triggered by an energetic event as flares or jets. The key point is that this kind of motions are just most appropriate motions for the purpose of determining the large-scale filament structure. In the literature these kind of oscillations have been considered as rare with scarce scientific reports. In this work we analyze the H $\alpha$  images from GONG network and we have created a large catalog of oscillations with hundreds of events. The results of this study will be presented and general characteristics of these oscillations will be shown.

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**Contributed talk:** “Coronal loop footpoints threaded with small-scale mixed polarity surface magnetic fields”

**Author(s):** L. P. Chitta, H. Peter, and S. K. Solanki

**Abstract:** Coronal loops are the direct signatures of a magnetically coupled solar atmosphere. The details of the magnetic environment and its evolution at the footpoints of coronal loops are crucial to understanding the processes of mass and energy supply to the solar corona. Traditionally, both 1D and 3D coronal loop models assume that there is a direct magnetic connection between the regions of opposite polarities that constitute the loop footpoints. The observed magnetograms with moderate spatial resolution do support this assumption. In this talk, I will present high resolution observations of an active region obtained from the Sunrise balloon-borne observatory that reveal a complex magnetic environment at the footpoints of coronal loops that is different from the traditional picture. The magnetograms from the Imaging Magnetograph eXperiment onboard Sunrise show an abundance of small-scale mixed polarity magnetic field at the coronal loop footpoints. Further, photospheric magnetic flux cancellation and chromospheric jets are observed at the base of coronal loops. I will present some preliminary results from the Swedish 1-m Solar Telescope observations that show similar mixed polarity magnetic elements at coronal loop footpoints. I will discuss these results and



their implications in the context of mass and energy supply into the corona.

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**Contributed talk:** “Numerical simulation of cool ascending flows in chromosphere”

**Author(s):** Tatsuki Nakamura, Kazunari Shibata

**Abstract:** Solar flare is an explosive phenomenon on the sun and the most intense phenomenon in the solar system. It is originated in the short-time release of magnetic energy stored in corona, which is the upper solar atmosphere. There are layers called photosphere and chromosphere under corona, and solar flare brightens them. They are also observed in the stellar flares. Therefore the amplitude of light is the key to the understanding of energy release processes in solar/stellar flares. However, there are still many unsolved problems on the energy transport from corona to photosphere or chromosphere. Hot ascending flows ( $\sim 10^6$  K) and cool descending flows ( $\sim 10^4$  K) are known to occur near the chromosphere after the solar flare. This phenomena has been studied with hydrodynamic numerical simulations including thermal conduction or high energy particle beam (Nagai(1980), Nagai and Emslie(1984)). However, recently cool ascending flows ( $\sim 10^4$  K) were discovered before the hot ascending ones (Tei, 2016). This phenomenon cannot be explained with current flare model intuitively. To explore this flow, we developed 1D numerical MHD simulation code including the heating by thermal conduction and high energy electron beam and empirically introduced radiative cooling. The numerical calculation showed the following facts: The plasma in the interior of the chromosphere was heated by the high energy electron beam and pushed out into the corona. Radiative instability made its density increase keeping its temperature low. As a result, cool and dense ascending flow was generated in the solar atmosphere. We explained cool ascending flows observed in the early stage of flares with high energy electron beam and radiative cooling as a result of the above research.

**Contributed talk:** “H $\alpha$  and H $\beta$  emission in a C3.3 solar flare: comparison between observations and simulations”

**Author(s):** Vincenzo Capparelli, F. Zuccarello, P. Romano, L. Fletcher, P. J. A. Simoes, D. Kuridze, M. Mathioudakis, P. Keys, and G. Cauzzi

**Abstract:** In this work we describe the results obtained from the analysis of high resolution images acquired at the Dunn Solar Telescope during an observing campaign carried out during April 2014. Using the Interferometric Bi-dimensional Spectrometer (IBIS) instrument, images along the H $\alpha$  line profile were acquired during a C3.3 flare (SOL2014-04-22T15:22) that occurred in Active Region NOAA 12305. At the same time, using the Rapid Oscillations in the Solar Atmosphere (ROSA) instrument, images in the core of the H $\beta$  line, as well as in the Ca II K line and in the G band were acquired. The data acquired in the H $\alpha$  and H $\beta$  lines allow us to investigate the flare evolution at two different heights of the solar chromosphere and constitute a rare sample of flare simultaneous observations at these wavelengths. In particular, we attempted to characterize the intensity evolution at both wavelengths and compare the results with those retrieved from non-LTE simulations obtained from the RADYN code.

**Poster:** “Combined Global NLFFF simulations and MHD simulations of flux rope ejections”

**Author(s):** Paolo Pagano, Duncan Mackay, Anthony Yeates, Farid Goryaev, Vladimir Slemzin, Gordon Gibb

**Abstract:** Magnetic flux ropes ejections are considered a progenitor of Coronal Mass Ejections (CMEs) from the Solar Corona and their occurrence usually follows a long lasting equilibrium in the solar corona. Magnetic flux ropes form in the solar corona due to the evolution the coronal magnetic field driven by photospheric motions and flux emergence events and when magnetic flux ropes become unstable their ejection may turn into a CME releasing plasma and magnetic flux into the interplanetary space. The different time scales of formation and ejection of magnetic flux ropes pose a significant challenge to theoretical models and for this reason we couple the Global Non-Linear Force-Free Field (GNLFFF) - tailored to describe the slow magnetic evolution of the corona with 3D MHD simulations - a general approach and can effectively model a fast flux rope ejection -. We present here two applications of the coupling. In the first one we model magnetic flux rope ejections in the global corona and the implications on Space Weather in terms of plasma and magnetic field injected in the solar wind. In the second one we use this technique to model the magnetic flux rope ejection observed on August, 2nd 2011 and to describe the early stage of the following CME. We also present the potential applications on of our technique in the Space Weather forecast context.

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**Poster:** “A Database of Flare Ribbons Observed By Solar Dynamics Observatory”

**Author(s):** Maria D. Kazachenko

**Abstract:** Flare ribbons are emission structures observed during flares in transition-region and in chromospheric. They typically straddle a polarity inversion line (PIL) of the radial magnetic field at the photosphere, and move apart as the flare progresses. The ribbon

flux - the amount of unsigned photospheric magnetic flux swept out by flare ribbons - is thought to be related to the amount coronal magnetic reconnection, and hence provides a key diagnostic tool for understanding the physical processes at work in flares and CMEs. Previous measurements of the magnetic flux swept out by flare ribbons required time-consuming co-alignment between magnetograph and intensity data from different instruments, explaining why those studies only analyzed, at most, a few events. The launch of the Helioseismic and Magnetic Imager (HMI) and the Atmospheric Imaging Assembly (AIA), both aboard the Solar Dynamics Observatory (SDO), presented a rare opportunity to automatically compile a complete dataset of flare-ribbon events. Here we present a dataset of both flare ribbon positions and reconnection fluxes, as a function of time, for all C-class flares within 45 degrees of disk center observed by the SDO.

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**Poster:** “Magnetic field changes in sunquakes - smoking gun or red herring?”

**Author(s):** Sarah A. Matthews, Deborah Baker, Gherardo Valori, Sergei Zharkov, Connor Macrae, Lucie M. Green

**Abstract:** Flare related acoustic emission, or so-called sunquakes, have now been observed in association with flares as small as C-class, suggesting the phenomena may be more common than previously thought. However, the question of what drives the acoustic disturbance remains open, with characteristics of recently observed events unable to definitively distinguish between potential mechanisms. Recent simulations by Russell et al. (2016) explore further the possible role of the re-configuration of the coronal magnetic field as a driver for sunquakes, predicting changes in magnetic tilt and horizontal magnetic field strength at the location of the acoustic source, which may be accompanied by signatures of Alfvén wave heating and enhanced photospheric currents. In this work we re-visit a small sample of previously observed sunquake events to determine whether they display signatures consistent with these predictions.

**Poster:** “Space Weather services for flare and CME forecasting supported by a multi instrument database”

**Author(s):** Berrilli F., Casolino M., Dario Del Moro, Forte R., Giovannelli L., Martucci M., Merge` M., Napoletano G., Narici L., Pietropaolo E., Pucacco G., Rizzo A., Scardigli S., Sparvoli R.

**Abstract:** The Sun continuously releases energy into space in the form of electromagnetic and particle radiation (e.g., CMEs, flares, and Solar Energetic Particles). These emissions can vary very quickly and dramatically change the Sun-Earth environment, i.e., the Space Weather. Understanding Space Weather is extremely important for our technological society, since it can damage or destroy satellites, GNSS, communication, and power distribution systems. In the framework of supporting the regional, national and EU resilience to these effects, the Space Weather Team at University of Rome Tor Vergata is realizing a database for ground-based and space-born instrument with specific capabilities for the Space Weather activity. On top of this database, we have implemented an automated flare detection and forecasting system based on the detection of magnetic active regions and associated flare probability estimation. Also, we have realized and tested an evolution of the Drag Based Model for CME propagation. We present here the concept of a service which capitalize on all these contributions to provide the likelihood of a CME to hit Earth and the relative time of arrival and velocity at 1AU. Regional and European funds support the development and realization of the database.

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**Poster:** “Continuum emission enhancements in solar flares observed by ROSA and IRIS”

**Author(s):** Francesca Zuccarello, V. Capparelli, M. Mathioudakis, P. Keys, O. Prochazka, M., Falco, M. Murabito

**Abstract:** During solar flares, magnetic energy can be converted into electromagnetic radiation from radio waves to  $\gamma$  rays. In the most energetic events, enhancements in the continuum at visible

wavelengths may be present (WL flare), probably due to energetic electrons heating directly the chromosphere and indirectly, through radiative backwarming, the photosphere. Recently the WL emission has been correlated with enhancements in the FUV and NUV passbands. We describe the results obtained from the analysis of data acquired by ground-based (ROSA@DST) and satellite (IRIS) instruments, concerning a WL flare observed in NOAA 12205 on 7 November 2014, and the role played by the evolution of some delta sunspots on the flare triggering.

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**Poster:** “Polarization signatures in the chromosphere during an X1.6 flare”

**Author(s):** Guglielmino S. L., Zuccarello F., Murabito M., Romano P.

**Abstract:** Measurements of the magnetic fields in the chromosphere still present large uncertainties, in particular during solar flares. Very few studies addressed this question, due to the scarcity of spectropolarimetric data from the ground. We report on full spectropolarimetric observations acquired by the IBIS/DST along the Ca II 8542 line together with spectroscopic measurements along the H $\alpha$  line and photospheric spectroscopic measurements along the Fe I 6173 line during SOL2014-10-22T14:28. This flare was classified as X1.6 and occurred in the complex active region NOAA 12192. We analyze polarization signatures along the Ca II line profile to derive new information on the chromospheric magnetic properties of flares.

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**Poster:** “ Successive Magnetic Reconnections Observed during Sympathetic Eruptions”

**Author(s):** Navin Chandra Joshi, Brigitte Schmieder, Tetsuya Magara, Yang Guo, Guillaume Aulanier

**Abstract:** The nature of various plausible causal links between sympathetic events is still a controversial issue. In this work, we

present multiwavelength observations of sympathetic eruptions, associated flares and coronal mass ejections occurring on 2013 November 17 in two close-by active regions NOAA 11893 and 11900. Two filaments i.e., F1 and F2 are observed in between the active regions. Successive magnetic reconnections, caused by different reasons (flux cancellation, shear and expansion) have been identified during the whole event. The first reconnection occurred via flux cancellation between the sheared arcades overlying a filament F2 creating a flux rope and leading to the first double ribbon solar flare. During this phase we also observed some partial eruption of overlaying arcades and coronal loops. The second reconnection is believed to occur between the expanding flux rope of F2 and the overlying arcades of the filament F1. We suggest that this reconnection destabilized the equilibrium of filament F1, which further facilitated its eruption. The third stage of reconnection occurred in the wake of the erupting filament F1 between the legs of overlying arcades. This may create a flux rope and the second double ribbon flare. The fourth reconnection was between the expanding arcades of the erupting filament F1 and the nearby ambient field, which produced the bi-directional plasma flows towards both upward and downward. Observations and a nonlinear force-free field extrapolation confirm the possibility of reconnection and the casual link between the magnetic systems. The series of eruptions and flares can thus be considered as a good example in which many of the formerly proposed theories accounting for sympathetic flares can be at work in a single event.













**Invited review:** “Science with European Solar Telescope”

**Author(s):** Sara Matthews and the EST team

**Abstract:** EST is a 4-metre class solar telescope concept that is planned to see first-light in 2026. It will be the first solar telescope to incorporate multi-conjugate adaptive optics from inception, enabling diffraction-limited observations with a spatial resolution of 25 km, less than the photon scattering mean-free path in the photosphere. EST will be optimised for state-of-the-art studies of the magnetic coupling between the deep photosphere and upper chromosphere of the Sun; the regions where the solar magnetic field emerges from the interior and undergoes the most rapid evolution. In particular, it will provide the most sensitive diagnostics of the thermal, dynamic and magnetic properties of the chromospheric plasma of any solar telescope either on the ground or in space. In this presentation we will describe how EST will be able to directly contribute to answering the following questions: “What are the causes, consequences and predictability of solar magnetic variability and the solar cycle?” and “What are the structures, dynamics and energetics of the Sun?”

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**Keynote talk:** “A science driven update to the Daniel K Inouye Solar Telescope

**Author(s):** Valentin Martinez Pillet, T. Rimmele, J. McMullin and the DKIST team

**Abstract:** In conjunction with the broader solar community, the National Solar Observatory (NSO) is building the Daniel K Inouye Solar Telescope (DKIST) at the summit of Haleakala (Maui, Hawai’i). This presentation provides a science driven update on the status of the telescope and its post focus instrumentation. NSO is articulating the early science of the facility in the context of the Critical Science Plan (CSP) activity and its science use cases. The two first year of the operations of the facility (2020/21) will execute the CSP in close collaboration with the solar community. Starting from the particular science use cases described in the CSP, we

provide an update on the DKIST capabilities and its current status, from the telescope structure under assembly at the summit to the state of the first light instrumentation. We also discuss other key aspects driven by the science goals of the facility such as the polarimetric calibration of the telescope and its coronagraphic capabilities.

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**Keynote talk:** “Solar Orbiter mission”

**Author(s):** Jose Carlos del Toro

**Abstract:**

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**Keynote talk:** “Sunrise III project“

**Author(s):** Hans-Peter Doerr for the Sunrise Team

**Abstract:** Sunrise is a balloon-borne solar observatory dedicated to the investigation of the physics of the magnetic field and the convective plasma flows in the lower solar atmosphere. The Sunrise observatory is designed for operation in the stratosphere (at heights up to 40 km) in order to avoid the image degradation due to turbulence in the Earth’s lower atmosphere and to gain access to the UV spectral range. The first science flights of Sunrise, in June 2009 and June 2013, led to many new results described in roughly 80 papers that have appeared or have been submitted to refereed journals. This success has shown the huge potential of the Sunrise approach. The recovery of the largely intact payload *offers* an opportunity for a third flight. Sunrise III will have greatly extended capabilities, in particular to measure weaker magnetic field over a greater range of heights (covering both photosphere and chromosphere). To this end, Sunrise III will carry two new instruments as well as upgrades of its present instruments. The new instrument is a novel UV spectropolarimeter that will explore and exploit the rich spectral range between 300 and 430 nm, which is poorly accessible from the ground. A near-infrared spectropolarimeter will sensitively sample both, the photosphere

and chromosphere. The existing imaging magnetograph, IMAx, will be upgraded to greatly increase its speed and to allow it to access multiple spectral lines (compared with a single one so far). The new instrumentation will allow new regimes of the solar magnetic field to be explored. This includes the field in the poorly understood chromosphere, which is the key interaction region between magnetic field, waves, and radiation and plays a central role in transporting energy to the upper solar atmosphere. In addition, the presence of many spectral lines sensitive to the Hanle effect in the spectral regions covered by the new Sunrise instruments will allow Sunrise III to be sensitive to weak magnetic fields as found in the quiet Sun and in the chromosphere.

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**Keynote talk:** “Results and future of CLASP project”

**Author(s):** Masahito Kubo, R. Kano, R. Ishikawa, A. Winebarger, D.E. McKenzie, F. Auchere, J. Trujillo Bueno, N. Narukage, K. Kobayashi, L. Rachmeler, T. Bando, Y. Katsukawa, S. Ishikawa, G. Giono, H. Hara, Y. Suematsu, M. Yoshida, T. Shimizu, T. Sakao, S. Tsuneta, K. Ichimoto, M. Goto, J. Cirtain, P. Champey, B. De Pontieu, R. Casini, C. Bethge, R. Manso Sainz, A. Asensio Ramos, J. Stepan, L. Belluzzi, M. Carlsson, T. del Pino Aleman, E. Alsina Bellester

**Abstract:** The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP), for the first time, detected the scattering polarization in the hydrogen Lyman-alpha line (121.57 nm) originating in the solar chromosphere and transition region. The CLASP observations were performed during 5-minute ballistic flight on September 3, 2015. The observed scattering polarization near the solar limb is of the order of 0.1% in the core of the Ly-alpha line and a few percent in the wings, which is consistent with theoretical predictions. One surprising result on the observed scattering polarization is that the line-center Q/I signal does not show any clear CLV, in contrast with the Q/I signals calculated using the available 1D and 3D models of the solar atmosphere. We also find that modifications of the scattering polarization in the cores of Ly-alpha line and Si III

line (120.65 nm) are observed in the network regions but not observed in the inter-network regions. A plausible explanation of these results is the operation of the Hanle effect. The first flight of CLASP gives us a new diagnostic tool of the magnetism in the upper chromosphere and the transition region. A second flight of CLASP (CLASP2: Chromospheric LAYER Spectro-Polarimeter 2) has been proposed in order to further study polarization measurements in the upper chromosphere. We will refit the existing CLASP instrument to measure all four Stokes parameters in the Mg II h and k lines near 280 nm. The cores of these lines form about 100 km below the Ly-alpha core; they were chosen because circular polarization can be detected in addition to linear polarization. We will describe the CLASP 1 data and the second CLASP mission, which has a proposed launch in 2019.

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**Contributed talk:** “Prototype characterization and future development of the Fast Solar Polarimeter”

**Author(s):** F. A. Iglesias, A. Feller, S. K. Solanki and F. Zeuner

**Abstract:** Due to the differential and non-simultaneous nature of temporally-modulated polarization measurements, the spurious signals and image aberrations induced by atmospheric seeing or instrument jitter can easily counterbalance the benefits of ground-based observatories. To tackle the above-named issues we are developing the Fast Solar Polarimeter (FSP), which aims for high-spatial-resolution and high-sensitivity spectropolarimetric measurements in the 390 to 860 nm spectral range by combining fast modulation frequency with high frame rate. The FSP prototype is based on a high sensitivity (QE>80%), low-noise (~3.6 e-rms), high frame-rate (400 fps) pnCCD camera and ferroelectric liquid crystals. The fast polarization modulation (100 full-Stokes sets per second) and high duty cycle (>98%), have the double benefit of reducing seeing induced crosstalk and improving the final spatial resolution by providing an optimal regime for the application of post-facto image reconstruction techniques. In this talk we describe the characterization of the FSP prototype and the first



measurements acquired from 2013 to 2015 at the VTT. We also present the status and future plans for the second, improved version of the instrument based on a larger 1k x 1k pnCCD and a dual-beam polarimetric configuration.

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**Contributed talk:** “The Heat Rejecter for the GREGOR telescope: a prototype for the European Solar Telescope”

**Author(s):** Berrilli F., Manni F., Del Moro D., Giovannelli L., Fischer A., von der Lühe O., Soltau D., Mainella G., Caroli A.

**Abstract:** In a solar telescope the internal air turbulence, due to convective flows created by optical/mechanical hot parts over the integrated optical path, produces a wavefront distortion (internal seeing) which is a major contributor to image degradation. An innovative heat-rejecter (HR), based on jet impingement technology (JIT), has been designed, realised and tested. The HR-JIT can replace the liquid-cooled HR currently installed at the primary focus of the GREGOR telescope and represents an operative prototype for the future European Solar Telescope. Thermographic imaging, using the TNG thermal camera FLIR i40, was employed to evaluate current HR thermal environment and investigate future performances of HR-JIT. The results of hydraulic and thermal tests of HR-JIT are presented and discussed.

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**Contributed talk:** “SST/CHROMIS: a New Window to the Solar Chromosphere”

**Author(s):** Goran Scharmer

**Abstract:** Observations of the Sun in the cores of the Ca II H and K lines are of fundamental importance for advancing our understanding of the structure and dynamics of the upper solar chromosphere. Because of the low intensities in these deep lines combined with the need to spectrally resolve the emission peaks, and the severe image degradation from telescope aberrations and seeing at short wavelengths, such observations are extremely

demanding. We present a novel instrument for high spatial resolution (0.1 arc second) and high spectral resolution (FWHM 80 mÅ) observations of the chromosphere in the Ca II H and K lines: CHROMIS. This instrument is installed on the blue beam of the Swedish 1- meter Solar Telescope and can be used independently of and in parallel with CRISP on the red beam. CHROMIS is a dual Fabry-Perot system similar to CRISP but uses separate filter wheels for its narrowband and wideband re-imaging system. The wideband system of CHROMIS was installed in April 2016 and demonstrated the outstanding image quality of SST at short wavelengths. The narrowband CHROMIS system was installed at the end of August 2016. We will describe the design of the system and show the first CHROMIS data.

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**Contributed talk:** “Observations of absolute convective blue-shifts with the Laser Absolute Reference Spectrograph at the VTT”

**Author(s):** Johannes Löhner-Böttcher

**Abstract:** The Laser Absolute Reference Spectrograph (LARS) is a novel scientific instrument for solar observations with the Vacuum Tower Telescope (VTT) on Tenerife. It works as a combination of the high-resolution Echelle Spectrograph of the VTT with an state-of-the-art, ultra-precise Laser Frequency Comb. The solar spectrum is then calibrated by the Frequency Comb spectrum on an absolute scale. Resulting Doppler shifts of spectral lines reach an accuracy of m/s. In this talk, I will present systematic observations of the convective blue-shift in the solar photosphere. The recent data reveal the absolute velocities and the center-to-limb variation for several spectral lines in the visible spectral range. I will present the bisectorial C-shape profiles and systematical variations for e.g. the Fe I lines at 630.15nm, 630.25nm, and 525.0nm. On behalf of the SOLARNET project, I want to encourage the audience to perform Service-Mode operations with LARS. Co-observations with other telescopes and instruments would provide e.g. spectro-polarimetric solar observations on an absolute wavelength scale.

**Contributed talk:** “How does an adaptive optics system work in polarized light?”

**Author(s):** Marco Stangalini, F. Pedichini, F. Giorgi, I. Ermolli

**Abstract:** The European Solar Telescope (EST) will be best suited for very high accuracy polarization measurements. Indeed, its optical design is such that the telescope as a whole does not modify the polarization state of the incoming light. For this reason, the adaptive optics system must be optimized for high precision polarimetry. In this contribution we study the behavior of an adaptive optics system in polarized light. More in depth, after showing the results of laboratory measurements aimed at characterizing and estimating its induced polarization, we discuss possible optimal calibration strategies to be adopted in order to guaranteed the EST expected performances.

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**Contributed talk:** “The Solar Physics Research Integrated Network Group – SPRING”

**Author(s):** Markus Roth, Frank Hill, Michael Thompson, Sanjay Gosain

**Abstract:** SPRING is a project to develop a geographically distributed network of instrumentation to obtain synoptic solar observations. Building on the demonstrated success of networks to provide nearly-continuous long-term data for helioseismology, SPRING will provide data for a wide range of solar research areas. Scientific objectives include internal solar dynamics and structure; wave transport in the solar atmosphere; the evolution of the magnetic field over the activity cycle; irradiance fluctuations; and space weather origins. Anticipated data products include simultaneous full-disk multi-wavelength Doppler and vector magnetic field images; filtergrams in H-Alpha, CaK, and white light; and PSPT-type irradiance support. The data will be obtained with a duty cycle of around 90% and at a cadence no slower than one minute. The current concept is a multi-instrument platform installed in at least six locations, and which will also provide context

information for large-aperture solar telescopes such as EST and the DKIST. There is wide support for the idea within the EU and the US solar research communities. The project has completed a science requirement study and a technical feasibility study as a Joint Research Activity under Solarnet. The results of those will be presented during this presentation.

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**Contributed talk:** “First tests of the Integral Field Unit for GRIS@GREGOR”

**Author(s):** Andrés Asensio Ramos

**Abstract:** The observation of the highly dynamic events in the chromosphere with current slit or filter spectropolarimeters is not adequate. With the sake of increasing the time, spectral and spatial coherence of the data, an integral field unit prototype has been developed for the GRIS spectrograph on the GREGOR telescope. In this talk, we present the first tests of the prototype.

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**Contributed talk:** “Image restoration of polarimetric slit spectra”

**Author(s):** Michiel van Noort, Alex Feller, Hans Peter Doerr, Jaime de la Cruz, Dan Kiselman

**Abstract:** A new technique is presented that allows for the recovery of the spatial resolution of spectro-polarimetric data recorded from the ground with a traditional slit-spectrograph. The process is based on a synchronized slit-jaw camera, that is used to record images of the slit, from which the wavefront error introduced by the atmospheric seeing on the slit is obtained for each recorded spectrum. The resulting PSF is then applied to the degraded slit-spectra, to map them back to the undegraded solar coordinates, yielding high spatial resolution spectral scans. This technique has been applied to spectro-polarimetric data obtained with TRIPPEL at the SST in June 2016.

**Contributed talk:** “The SOLARNET Solar Virtual Observatory prototype”

**Author(s):** B. Mampaey, R. Vansintjan, V. Delouille

**Abstract:** As part of the FP7 SOLARNET project a new Solar Virtual Observatory (SVO) is being developed at the Royal Observatory of Belgium. The goal of the SVO is to make data from European ground based telescopes such as GREGOR, SST, THEMIS, VTT, DST as well as data from space missions such as SDO and PROBA2 easily available to the scientific community. Our aim is to make the SVO user friendly while also providing advanced options for more in depth searches.

**Poster:** Probing the solar atmosphere with Hellride

**Author(s):** A. Hanslmeier, B. Lemmerer, M. Roth, J. Staiger

**Abstract:** HELLRIDE (Helioseismic Large Regions Interferometric Device) is an Etalon based 2-D Spectrometer. 2-D spectrograms of up to 32 photospheric, low chromospheric lines can be obtained with a high time cadence. We present analysis of Sep 2015 observations: time intervall 1 min, FOV 100 arcsec, 512 x 512 pixel. We present a correlation analysis of line center velocities deduced from several lines. The correlation between the line center velocities decreases with increasing core formation height difference. The correlation coefficient falls below 0.5 for height differences larger than 500 km indicating the decoupling of the velocity field between the photosphere and low chromosphere. Also data from a run in 2016 are presented which are less noisy. The Kolmogorof spectra indicate the turbulent character of the motions.

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**Poster:** "A data reduction pipeline for the GREGOR Fabry-Perot Interferometer (GFPI) and the imaging systems at GREGOR"

**Author(s):** C. Kuckein, C. Denker, M. Verma, H. Balthasar, S. J. Gonzalez Manrique, R. E. Louis, and A. Diercke

**Abstract:** During the "Early Science Phase" of the 1.5-meter GREGOR telescope in 2014 and 2015, a huge data volume has been acquired with the GREGOR Fabry-Perot Interferometer (GFPI), large-format facility cameras, and since 2016 with the High-resolution Fast Imager (HiFI). These data are processed in a standardized procedure with the aim of providing science-ready data for the solar physics community. For this purpose, we have developed a user-friendly data reduction pipeline called "sTools" based on the Interactive Data Language (IDL). The pipeline delivers reduced and image-reconstructed data with a minimum of user interaction. Furthermore, quick-look data are being generated, as well as a webpage with an overview of the observations and their statistics. All the processed data are stored online at the GREGOR GFPI and HiFI data archive of the Leibniz Institute for

Astrophysics Potsdam (AIP). We will describe the principles of the pipeline and present selected high-resolution spectral scans and images processed with sTools and acquired with the GFPI and HiFI instruments. sTools is licensed under a creative commons license.

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**Poster:** “The SOLARNET data pipeline activity”

**Author(s):** D. Kiselman

**Abstract:** State-of-the art instrumentation of solar telescopes produces multi-dimensional data at a high rate. Streamlined data pipelines with well-characterized data products are required for these instruments to meet their scientific potential. Standard data products can also be incorporated in databases - "virtual observatories" - which can serve a much broader community. All this is standard for space missions but have not been so for European ground-based solar instruments. As part of SOLARNET, data pipelines have been produced for eleven European instruments at several ground-based telescopes (DST, GREGOR, SST, THEMIS, and VTT). As part of the work, recommendations and standards for the handling and representation of meta data have been produced. We give an overview of the pipeline situation with examples and illustrations.

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**Poster:** “JP3D compression of solar data-cubes: photospheric imaging and spectropolarimetry”

**Author(a):** Dario Del Moro, Luca Giovannelli, Francesco Berrilli, Ermanno Pietropaolo, Ilaria Ermolli and Dan Kiselman

**Abstract:** Hyperspectral imaging is an ubiquitous technique in solar physics observations and the recent advances in solar instrumentation enabled us to acquire and record data at an unprecedented rate. The huge amount of data which will be archived in the upcoming solar observatories press us to compress the data in order to reduce the storage space and transfer times. The correlation present over all dimensions, spatial, temporal and

spectral, of solar data-sets suggests the use of a 3D base wavelet decomposition, to achieve higher compression rates. In this work, we evaluate the performance of the recent JPEG2000 Part 10 standard, known as JP3D, for the compression of several types of solar data-cubes.

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**Poster:** “The Laser Absolute Reference Spectrograph (LARS) at the VTT”

**Author(s):** Johannes Löhner-Böttcher, Wolfgang Schmidt

**Abstract:** The Laser Absolute Reference Spectrograph (LARS) is a novel scientific instrument for solar observations with the Vacuum Tower Telescope (VTT) on Tenerife. It works as a combination of the high-resolution Echelle Spectrograph of the VTT with an state-of-the-art, ultra-precise Laser Frequency Comb. The solar spectrum is then calibrated by the Frequency Comb spectrum on an absolute scale. Resulting Doppler shifts of spectral lines reach an accuracy of m/s. With this poster, I will present the optical design of the instrument and its versatility for solar and stellar observations as well as atomic and molecular studies. I will guide the visitor through the poster and want to encourage to perform Service-Mode operations with LARS. Since the instrument is unique for spatial solar observations, it can provide an absolute wavelength calibration e.g. for spectro-polarimetric co-observations with other telescopes and instruments.

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**Poster:** “SOLARNET: Turbulence characterisation and correction”

**Author(s):** M. Collados, I. Montilla, L. Montoya, F. Berrilli, R. Codina, , I. Ermolli, B. Gelly, R. Hammerschlag, O. Hartogensis, D. Kiselman, F. Manni, D. Soltau

**Abstract:** SOLARNET WP70 investigates the effects of air turbulence on wavefront distortion and analyses techniques to reduce and correct the optical degradation in order to improve the performance of existing solar telescopes and to optimise the design



of EST. The objectives of this WP are divided in three areas: - Characterisation of the daytime atmospheric turbulence at the Canary Islands observatories and its effect (atmospheric seeing) on the wavefront propagation. - Characterisation of the air turbulence produced at the telescopes environment and validate techniques to predict its effect (local seeing) on the wavefront propagation. Implement an optimized heat rejecter prototype at the GREGOR telescope to reduce the heat load on the telescope primary focus to improve its performance. - Development of numerical simulations to optimize the performance of the adaptive optics systems used to correct the wavefront distortion and implement an adaptive optics system prototype at THEMIS telescope to improve the performance of this facility. This contribution describes all the activities carried out in these three aspects and the results obtained.

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**Poster:** “MOTH II calibration pipeline and data merging with SDO/HMI and SDO/AIA.”

**Author(s):** Roberta Forte, Jefferies, S., Pietropaolo, E., Scardigli, S., Giovannelli, L., Del Moro, D., Berrilli, F.

**Abstract:** The development of the numerical pipeline for the automatic calibration and registration of the zero level images obtained from the solar telescope Magneto Optical filters at Two Heights (MOTH) is the aim of my research grant at Università degli Studi di Roma Tor Vergata. The MOTH telescope, located at the Mees Observatory (Maui, USA) and operated by IfA - University of Hawaii and Georgia State University, consists in a dual channel equipment, each mounting magneto-optical filters (MOF) at 589 nm (Na D2-line) and 770 nm (K I-line), respectively. The aim of the MOTH solar full disk observations is the study of the magnetic evolution and dynamics of the solar low atmosphere by mean of the line-of-sight measure of velocity and magnetic field, at two different levels of the solar atmosphere. The MOTH data can be merged with magnetic and velocity field data from Helioseismic and Magnetic imager (HMI) on the satellite Solar Dynamic Observatory (SDO), to obtain a three-heights characterization of the solar

magnetic evolution, in order to identify signature parameters of solar eruptive events, useful for flare forecasting. Within the Solarnet Programme “Mobility for Young Researchers” I had the opportunity to spend 7 weeks at Harvard- Smithsonian Center for Astrophysics, where I discussed the calibration of SDO/HMI and SDO/AIA (Atmospheric Imaging Assembly) data with the Solar and Stellar X-ray group (SSXG) and I worked on variations in the polarity inversion line (PIL) in active regions. It has also been evaluated the possibility of matching magnetograms from MOTH and HMI and images from AIA for a preliminary statistics of a flare forecasting model. Moreover, it has been examined the possibility of incorporating MOTH data, also available in a future SWERTO database in Tor Vergata, into a flux rope model developed in collaboration between Harvard-Smithsonian CfA and MIT Laboratory for Nuclear Science.

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**Poster:** “SPRING: A new synoptic network for solar and space weather research”

**Author(s):** [Sanjay Gosain](#), Markus Roth and Frank Hill

**Abstract:** Solar Physics Research Integrated Network Group (SPRING ) is a proposal to build next generation global network of identical telescopes for providing synoptic observations. SPRING will enable us to obtain uninterrupted full disk observations of the Sun's magnetic and velocity field at different heights in the solar atmosphere (multi-wavelength approach) and at a temporal cadence adequate enough to (i) probe solar interior via helioseismology, and (ii) study evolution of magnetic fields in solar atmosphere leading to flares, CMEs and filament eruptions. Further, the long-term operation of the SPRING (multiple solar cycles, at least two) will allow detailed study of solar interior and atmosphere in response to 22 year magnetic solar cycle. We will present the science goals and proposed design concepts for SPRING.

**Poster:** “IBIS-A The IBIS solar spectropolarimetric data Archive”

**Author(s):** Ilaria Ermolli, Silvio Giordano, Fabrizio Giorgi, Vincenzo Guido, Alessandro Marassi, Antonio Volpicelli, Paolo Di Marcantonio, Francesca Zuccarello

**Abstract:** We review the efforts undertaken to set up and operate the IBIS-A archive of ground-based solar spectropolarimetric observations, in the VSO (Virtual Solar Observatory) framework, by using IBIS data, SOAP/XML Web Services, and Usage-Centered Design approach. The IBIS (Interferometric BIdimensional Spectropolarimeter) is a high cadence, dual Fabry-Perot interferometer spectropolarimeter constructed by a consortium of italian institutes and installed at the Dunn Solar Telescope of the US National Solar Observatory in New Mexico. The instrument allows for spectropolarimetric observations of the solar photosphere and chromosphere at high spatial, spectral, and temporal resolution, within the 550-860 nm range. The IBIS-A is realized in the framework of the FP7 SOLARNET High-resolution Solar Physics Network project that aims at integrating the major European infrastructures in the field of high-resolution solar physics, as a step towards the realization of the 4m EST European Solar Telescope.

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**Poster:** “A large diameter Capacitance Stabilized Etalon for European Solar Telescope”

**Author(s):** Berrilli F., Del Moro D., Giovannelli L., Gallieni D., Lazzarini P., Greco V., Cauzzi G., Scharmer G.

**Abstract:** Next generation solar telescopes, e.g., DKIST or EST, optimised for spectro-polarimetric imaging, will require large diameter (100-300 mm) tuning filters. The Capacitance Stabilized Etalon (CSE) represents the most suitable instrument to be implemented to operate in the visible/near-infrared range with fast cadence. A tunable, large Fabry-Perot etalon engineering prototype has been designed and realised to be tested by interferometer to demonstrate the feasibility of the optomechanical design and qualify the cavities and substrate coating. The 150 mm CSE prototype uses

a new geometry to minimise statical and dynamical stresses of the optical surface and guarantee the cavity error budget with different mechanical configurations. The final design of the prototype is the result of several iterations based on FE simulations and cross checks with the manufacturer of the optics and control electronics, the ICOS ltd. Company. The new design approach is discussed with respect to the classical ICOS design. The first spectral stability test and cavity error maps acquired with a novel technique using Zygo interferometers is presented.

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**Poster:** “MiHI: a Microlensed Hyperspectral Imager”

**Author(s):** Michiel van Noort

**Abstract:** MiHI is an integral field spectrograph specifically intended for high spectral and high spatial resolution solar observations. As it is based on diffraction rather than filtering, the instrument contains no scanning device and is able to simultaneously capture a spectrum with a spectral range of approximately 0.5nm, for each critically sampled image element in an 8"x8" field of view, which greatly enhances the photon efficiency of the instrument. The instrument was designed as a plug-in for the TRIPPEL spectrograph at the SST, and was successfully tested at the SST in October 2016.







