Solar Polarization Workshop 8

Firenze, 12 – 16 September, 2016

Abstracts

Session 1

Physics of polarization

Review talks

Roberto Casini
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Type of contribution: Review talk

Author(s): R. Casini

Title: Egidio Landi: a life in the science and teaching of polarimetry

Abstract:
We highlight the many contributions of Egidio Landi to the advancement and exposure of the science of solar and stellar spectro-polarimetry, over the 40+ years of his career at the University of Florence.

Session 1

Physics of polarization

Standard talks

Véronique Bommier
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Type of contribution: Standard talk

Author(s): Bommier, V.

Title: Non-perturbative theory of radiative scattering in the weak radiation field limit

Abstract:
This work is aimed to the interpretation of the linear polarization spectrum observed in the “Second Solar Spectrum”, likely to provide information on the magnetic field vector or on the medium anisotropy. The lines are formed by scattering. Far wings due to partial redistribution are observed in 30% of the spectral lines (Belluzzi & Landi Degl’Innocenti, 2009, A&A, 495, 577). It will be first shown that the second-order perturbation theory is unable to fully describe the frequency redistribution in the far wings. Rayleigh/Raman scattering appears at fourth order. The development has then to be pursued beyond. It will be shown how this series development can be transformed into an infinite sum, which can then be evaluated at infinity, thus overcoming the Markov approximation. In a second part, addressing the problem of the scattering by multilevel atoms, the different processes entering the redistribution will be discussed, which are namely the Rayleigh/Raman scattering and the coupling between the frequency coherence and the Doppler effect in the laboratory reference frame. These two processes are different, but it will be shown they are weighted by part of the same collisions in the redistribution description. The consequences of this will be discussed, in terms of redistribution model. It will be shown that the statistical equilibrium equations have to be resolved for each atomic velocity class, leading to departures from the Maxwellian distribution in the excited states.

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Type of contribution: Standard talk

Author(s): Frisch Helene

Title: Some analytic results on Rayleigh scattering and resonance polarization

Abstract:
In a plane parallel semi-infinite atmosphere where the scattering of photons follows the Rayleigh scattering law, the emergent intensity in the continuum can be expressed in terms of the two Chandrasekhar functions H_l(\mu) and H_r(\mu), if all the absorbed photons are re-emited (no destruction of photons). It will be explained how starting from a vector radiative transfer equation coupling Stokes I and Stokes Q one can construct two scalar equations with exact solutions. It will also be explained how the emergent intensity for spectral lines can be expressed in terms of an H_matrix satisfying a non linear integral equation, which can be solved numerically.

Egidio Landi Degl'Innocenti
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Type of contribution: Standard talk

Author(s): E. Landi Degl'Innocenti

Title: Relaxation phenomena due to collisons with neutral perturbers in hyperfine structure multiplets

Abstract:
A theoretical scheme is presented for deriving the relaxation properties of the atomic polarization of hyperfine structure (HFS) multiplets under the effect of collisons with neutral perturbers. The theory allows to express in closed form, under the flat spectrum approximation, the polarization expexted from a magnetically split HFS multiplet illuminated by an anisotropic radiation field. Numerical results are presented for the D_2 line of sodium and for the line of ionized scandium at 4247 Å.

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Type of contribution: Standard talk

Author(s): Jirong Mao

Title: Relativistic electrons radiation/polarization in random and small-scale magnetic fields

Abstract:
We present the radiation mechanism of relativistic electrons in random and small-scale magnetic fields. Calculations and results are illustrated under some simple assumptions. Both high-energy and optical polarization properties are given as well. We expect that this radiation process can be applied in solar and astrophysical research fields.

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Type of contribution: Standard talk

Author(s): S. Sahal-Bréchot & V. Bommier

Title: Collisional broadening and collisional depolarization of spectral lines: similarities and differences

Abstract:
The width of a spectral line due to collisions takes part in the relative contribution of the Rayleigh scattering in the line profile. Within the impact approximation, collisional line broadening parameters (widths and shifts), depolarizing rates and polarization transfer rates seem very similar: both include the effect of collisional transitions between the Zeeman sublevels of a given level, or between fine or hyperfine structure levels of a given term. However, there are important differences. On the one hand, for line broadening, the two levels connected by the radiative transition contribute to the broadening. There is also an interference term between the two levels of the line, which can be very important for collisions with neutral hydrogen. On the other hand, only one level or two close levels are concerned in the depolarization. Another difference lies in the fact that "purely" elastic collisions contribute to the line broadening, whereas they do not contribute to the depolarization. The current theory, which has been developed for about 50-60 years, will be briefly outlined at the Conference. Then we will discuss the possibility to find some theoretical relationships or systematic trends concerning depolarization versus collisional broadening. Finally, in the light of a very recent paper, numerical relationships between line widths and level depolarization will be quoted.

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Type of contribution: Standard talk

Author(s): Sowmya K., Nagendra K. N., Sampoorna M., and Stenflo J. O.

Title: Partial frequency redistribution theory with Paschen--Back effect - application to Li I 6708 Å lines

Abstract:
The diagnostically important Li I D lines in the Second Solar Spectrum result from the transitions between the fine structure states and are separated by 0.15A. Since the Li atom possesses a finite nuclear spin, it undergoes hyperfine structure splitting, and hence is governed by the quantum interference processes that take place among the magnetic substates belonging to different fine and hyperfine structure states. This interference gets modified in the presence of a magnetic field. The signatures of this interference in polarization contain information on the nature of the vector magnetic field in the solar atmosphere.
With this motivation, we apply the polarized redistribution matrix including Paschen-Back effect, derived based on the Kramers-Heisenberg scattering matrix approach, to model the polarization profiles of the Li lines observed in the Sun. We make use of the last scattering approximation which is based on the concept that the polarization of the emergent radiation is generated in the last scattering event, before the radiation escapes from the atmosphere.
We present a comparison of the quiet Sun observations of the linear polarization profiles of Li I 6708 Å line system with the theoretical profiles computed using our simple modeling approach. We also present theoretical Stokes profiles in the Paschen-Back regime, to study the sensitivity of these lines to the magnetic field.

Jan Stenflo
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Staff

Type of contribution: Standard talk

Author(s): Jan Stenflo

Title: The Kramers-Heisenberg coherency matrix

Abstract:
Scattering of light is governed by the Kramers-Heisenberg formula, which expresses the scattering probability amplitude. While it provides a well established foundation for scattering theory, its application to the derivation of observable quantities is not straightforward but contains previously overlooked contributions in the case of multi-level atomic systems. One first has to sum over all the possible level combinations that can contribute to the total scattering amplitude matrix and then form the tensor product between these matrix sums, followed by ensemble averaging to construct the coherency matrix that directly relates to observable quantities like the Stokes parameters. The tensor product between the sums generates many cross terms, which represent various kinds of level interferences, but not all of them contribute to the ensemble averages. Here we show how valid, non-zero contributions to the coherency matrix in the form of radiation-induced ground-state coherences have been overlooked in the past, and how these new contributions provide a resolution of long-standing enigmas from both solar and laboratory observations.

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Type of contribution: Standard talk

Author(s): Supriya H. D., Sampoorna M., Nagendra K. N., Stenflo J. O., and Ravindra B.

Title: Effects of lower-level polarization and partial frequency redistribution on Stokes profiles

Abstract:
The theory of polarized radiative transfer including the effects of partial frequency redistribution (PRD) for a two-level and two-term atom is formulated in the scattering matrix approach. However there exist several enigmatic features in the Second Solar Spectrum which can not be explained based on the above said approach. The reason for this lies in the approximations made in this approach.
One such approximation is the assumption that the lower level of the atom involved in the scattering process is unpolarized. There are alternative approaches based on the density matrix formalism to relax this assumption. It was shown that the inclusion of the polarization of all the atomic levels involved in the scattering process is important. In our recent studies, the collisionless redistribution matrix including the effects of both PRD and lower-level polarization (LLP) was derived starting from the Kramers-Heisenberg scattering formulation. We proposed a simple numerical technique namely, the correction method, to solve the problem of polarized radiative transfer with PRD and LLP.
Here we apply this technique to different atomic systems and discuss the effects of PRD and LLP on the emergent Stokes profiles.

Session 2

Modeling of polarization in the atmospheres of the Sun and other stars

Review talks

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Type of contribution: Review talk

Author(s): K. N. Nagendra

Title: Polarized Line Formation: Methods and Solutions

Abstract:
In this talk I briefly review few methods that we have developed over the past several years for solving polarized line transfer problems of different degrees of complexity. I describe the way in which the complexity of the transfer problem increases as one introduces the physics of partial frequency redistribution, magnetic field, multi-level coupling, multi-D effects, and finally the velocity fields in the line forming region. Examples are given to demonstrate how the methods are applied after suitable modifications. The methods are qualitatively compared in terms of their numerical performance. Some sample results are shown to demonstrate the usefulness of these methods in theoretical modeling of the solar polarimetric data. The results discussed are Hanle effect, the J and F state quantum interference effects, the effects of angle-dependent partial frequency redistribution, transfer effects in multi-D geometry, and finally the effects of macroscopic velocity fields on the spectral lines formed in the solar atmosphere.

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Staff

Type of contribution: Review talk

Author(s): Javier Trujillo Bueno

Title: The last twenty years: a review on optically polarized atoms in the solar atmosphere

Abstract:
This Solar Polarization workshop in honor of Egidio Landi Degl'Innocenti is a unique opportunity to review the last twenty years of research on the generation and transfer of spectral line polarization produced by optically pumped atoms in the solar atmosphere. Many investigations have been carried out since 1997, when Egidio and I published our first joint letter in The Astrophysical Journal, arguing that lower-level depopulation pumping is a key physical mechanism for understanding some of the enigmatic spectral features of the Second Solar Spectrum. Here I provide an overview of the research carried out since then on optically polarized atoms in the solar photosphere, chromosphere and transition region, with emphasis on applications based the quantum theory of spectral line polarization to which Egidio Landi Degl'Innocenti has made so many pioneering and fundamental contributions.

Session 2

Modeling of polarization in the atmospheres of the Sun and other stars

Standard talks

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Type of contribution: Standard talk

Author(s): Ernest Alsina Ballester, Luca Belluzzi, Javier Trujillo Bueno

Title: The transfer of resonance line polarization with PRD in the general Hanle-Zeeman regime

Abstract:
Probably, the main reason why spectropolarimetry is a key diagnostic window to investigate the solar atmosphere is because the magnetic field information is encoded in the spectral line polarization. In general, to infer correctly such information we need to deal with the non-equilibrium problem of the generation and transfer of polarized radiation in magnetized plasmas. This problem can be particularly complex, especially when the interest lies in some resonance lines that originate in the solar chromosphere. Here we present a theoretical framework and the numerical methods of solution of the problem's equations taking into account partial redistribution in frequencies (PRD) and the joint action of scattering polarization and the Hanle and Zeeman effects, for spectral lines whose polarization can be investigated using the two-level atom model. We show some applications to a few resonance lines.

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Type of contribution: Standard talk

Authors: Belluzzi, L., Trujillo Bueno, J., Landi Degl'Innocenti, E., Del Pino Alemán, T., and Bianda, M.

Title: Modeling the enigmatic scattering polarization signal of the NaI D1 line

Abstract:
For nearly two decades, the modeling of the scattering polarization signal observed by Stenflo & Keller (1997) in the core of the NaI D1 line has represented one of the most challenging and debated problems in theoretical spectropolarimetry. In this talk, we show that a polarization signal similar to the observed one is obtained if the detailed spectral structure of the pumping radiation field, as calculated by solving the full non-LTE radiative transfer problem of the second kind in semi-empirical models of the solar atmosphere, is taken into account. We show that our modeling does not require the presence of atomic polarization in the lower level, and that the ensuing signal is only slightly modified if a realistic amount of lower level polarization is considered. New observations of this polarization signal, obtained with ZIMPOL at IRSOL, will also be presented.

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Type of contribution: Standard talk

Author(s): Flavio Calvo

Title: Linear polarization of the solar continuum spectrum

Abstract:
Linear polarization of the solar continuum spectrum (which results from symmetry breaking) exhibits a centre-to-limb variation. This variation can be extracted both in a semi-empirical way and with 1D simulations of the solar photosphere. However, this latter approach neglects local inhomogeneities introduced by convective motions of the plasma, which induce additional symmetry breaking. To take this into account, and to provide realistic predictions, we consider more general non-magnetic 3D hydrodynamic models of the solar photosphere. These models are currently employed to determine the factors that are most relevant for the centre-to-limb variation. In particular, we focus both on microscopic physical processes in which light interacts with matter and macroscopic effects due to the solar convection and the geometry of the problem.

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Type of contribution: Standard talk

Author(s): E.S. Carlin

Title: Modelling of chromospheric Hanle and Zeeman polarization in time and space

Abstract:
The fast temporal evolution of the solar chromosphere leads to well-known challenges for measuring the light that is emitted by these layers. In this contribution we illustrate how chromospheric motions cooperate with other physical actors for shaping the scattering polarization in different dimensions, so altering our inference of magnetic fields through the Hanle and Zeeman effects. How large is the contribution of solar dynamics to the second solar spectrum and to the forward-scattering signals? Should we really account for plasma motions when modeling the Hanle effect in the spectral line polarization? For posing and answering these and other similar fundamental questions we will show some results concerning the synthetic temporal evolution of the scattering, Hanle and Zeeman polarization in state-of-the-art Radiation-MHD models of the solar chromosphere. Our results yield a real fit between theory and observations of scattering polarization in a chromospheric line (CaI 4227 Å), after considering its temporal, spatial and spectral variations as well as the instrumental degradation. Several remarks and open questions arise from this work in relation to the interpretation of the second solar spectrum and the measurement of magnetic fields in dynamic solar layers.

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Type of contribution: Standard talk

Author(s): Tanausú del Pino Alemán, Javier Trujillo Bueno, Jiri Stepan

Title: A theoretical investigation of the scattering polarization in far ultraviolet lines with different sensitivities to the Hanle effect

Abstract:
In order to probe the magnetism of the upper solar chromosphere and transition region it is important to measure and model the linear polarization caused by anisotropic radiation pumping in ultraviolet resonance lines having different sensitivities to the Hanle effect. For example, the critical magnetic field for the onset of the Hanle effect in the HI Lyman-alpha line at 121.57 nm is 53 G, while it is 290 G for the SiIII line at 120.65 nm and 75 G for the SiIV line at 139.83 nm. Interestingly, the Chromospheric Lyman-alpha Spectro-polarimeter (CLASP) has successfully measured scattering polarization in the first two spectral lines mentioned above, and it is important to theoretically investigate how the scattering polarization in these resonance lines is produced with the aim of clarifying whether or not they can be safely combined to determine the magnetic field of the chromosphere-corona transition region by exploiting their different magnetic sensitivities. Here we present the first step of such theoretical investigation, with emphasis on the SiIII and SiIV lines. We choose one-dimensional (1D) semi-empirical models of quiet and plage regions of the solar atmosphere and solve the problem of the generation and transfer of scattering polarization accounting for their different magnetic sensitivity to the Hanle effect. We aim at clarifying how exactly the scattering polarization signals of these spectral lines are produced in the absence and the presence of magnetic fields.

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Type of contribution: Standard talk

Author(s): Gioele Janett and Oskar Steiner

Title: Numerical methods for the formal solution of the radiative transfer equation for polarized light

Abstract:
We revisited two well-known numerical "families" for the integration of the radiative transfer equation for polarized light, which are the DELO method and the Runge-Kutta integration. Different formal solvers have been analyzed in terms of stability, convergence rate and computational cost.
We also briefly discuss integration involving the evolution operator method and plan how to deal with integration of the RTE in discontinuous media.

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Type of contribution: Standard talk

Author(s): N.M.Kostogryz, S.V.Berdyugina, D.Gisler, M.Bianda, T.M. Yakobchuk, I. Milic

Title: Center-to-limb continuum polarization in solar and stellar atmosphere.

Abstract:
Stellar intrinsic polarization from scattering is an important effect for investigating physical and geometrical properties of stars and stellar environments. The scattering and absorption processes in stellar atmospheres affect center-to-limb variations of the intensity (CLVI) and the linear polarization (CLVP) of the radiation. We model the CLVI and CLVP in continuum spectra, taking into account different contributions of scattering and absorption opacity for a variety of spectral type stars with plane-parallel and spherical PHOENIX atmosphere models. We show how the polarization depends on effective temperature and surface gravity of a star and how the considered geometry of stellar atmosphere affects the polarized signal. For Sun, we present absolute polarimetric measurements at different limb angles and wavelengths obtained with ZIMPOL instrument at IRSOL. By fitting these measurements with our theoretical predictions for different solar models (FALA, FALC, FALP, HSRA, and Phoenix), we find that the HSRA model describes the best the solar atmosphere in considered wavelength range in continuum.
The CLVI and CLVP of stellar atmospheres are also needed to interpret the light curves of transiting exoplanets. Here we present variation of polarization in exoplanetary systems caused by transits, grazing transits and starspots and show how the considered geometry of stellar atmosphere models affect the transit curves of exoplanets.

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Type of contribution: Standard talk

Author(s): R. Manso Sainz, T. del Pino Alemán, R. Casini

Title: Magnetic Field Diagnostics with Strong Chromospheric Lines

Abstract:
Strong lines such as the Mg II h&k doublet, the Ca II H&K doublet and IR triplet, or the H I Lyman and Balmer systems, are essential for observationally accessing the tenuous and highly dynamic solar chromosphere; spectropolarimetry in these lines promises to open a window to the direct observation of magnetic fields all the way up to the transition region. But the formation of their complex spectropolarimetric patterns involves many different physical mechanisms and their modelling is a theoretical challenge. We developed a numerical polarization radiative transfer code that implements partially coherent scattering by polarized multi-term atoms, in arbitrary magnetic fields, for planeparallel stellar atmospheres. We present results of the Mg II h-k doublet in magnetized atmospheres that confirm the importance of partial redistribution effects in the formation of these lines, as previously pointed out for the non-magnetic case. We show that a magnetic field produces measurable modications of the broadband linear polarization even for relatively small field strengths while the circular polarization remains well represented by the magnetograph formula. The interplay between partial redistribution in the H-K doublet of Ca II and metastable level polarization in its IR triplet allow diagnosing the chromospheric magnetic field at different layers and strengths. Our results suggest several new avenues to investigate empirically the magnetism of the solar chromosphere.

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Type of contribution: Standard talk

Author(s): M. Sampoorna and K. N. Nagendra

Title: Comoving Frame Methods for Polarized PRD Line Transfer with Velocity Fields

Abstract:
Solution of the transfer equation in moving atmospheres is a classical problem. Whereas the low-velocity regime can be handled in a simpler manner using the rest frame method, the regime of high velocity requires comoving frame technique to be applied. We show that even in the low velocity regime (like that prevailing in the solar atmosphere) we require the comoving frame method when linear polarization together with partial frequency redistribution (PRD) in line scattering is considered. This situation arises because of the numerical difficulties that we encounter in the rest frame method, namely, the heavy demand on the angle, frequency, and depth grids when transfer of polarized radiation with PRD and velocity field are considered. These difficulties can be overcome through an application of comoving frame technique. In this talk, we present the details of the comoving frame technique and its applications to solar like conditions.

Session 2

Modeling of polarization in the atmospheres of the Sun and other stars

Posters

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Type of contribution: Poster

Authors: L. S. Anusha & K. N. Nagendra

Title: Spatial structuring in the scattering polarization line profiles in the solar chromosphere

Abstract:
Linear polarization produced by scattering of light and its magnetic field modification (namely, Hanle effect) in spectral lines are useful for understanding the structuring of the solar atmosphere and the physical processes that produce and modify the linear, scattering polarization signals. Synthesizing the line polarization in spectral lines using model solar atmospheres can give information on the less understood solar chromosphere, where these lines are formed. To synthesize these spectral lines the solution of polarized radiative transfer equation is required. Although solution is easier in one-dimension, to be more realistic we must use multi-dimensional geometries. The wings of these chromospheric lines are formed by the partial frequency redistribution (PRD) scattering mechanism which is rather complicated to include in radiative transfer computations. Here we present the results of computations of the fractional scattering polarization profiles of the Ca II K line at 3933 Å, and O I line at 1302 Å, using two-dimensional polarized radiative transfer with PRD (c.f. Anusha & Nagendra 2013, Anusha et al. 2014).

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Type of contribution: Poster

Authors: Stanislav Gunár, Duncan H. Mackay, Petr Heinzel, Javier Trujillo Bueno

Title: 3D Whole-Prominence Fine Structure model as a test case for verification and development of magnetic field inversion techniques

Abstract:
The 3D whole-prominence fine structure (WPFS) model (Gunar & Mackay 2015) allows to simulate entire prominences including their numerous fine structures. It combines a 3D magnetic field configuration of an entire prominence obtained from NLFF simulations, with a detailed description of the prominence plasma located in magnetic dips and distributed along hundreds of fine structures. It has realistic density and temperature distributions including the PCTR. The WPFS model thus provides consistent information on the 3D distribution of the magnetic field vector and prominence plasma.
Prominences simulated by such model can serve as a complex but well controlled environment for testing of inversion techniques used for the inference of the magnetic field. For example, the configuration of the individual fine structures in simulated prominences provides a realistic 3D plasma environment that can be used for analysis of the radiative transfer effects including symmetry-breaking on the synthetic spectro-polarimetric data. In turn, such data can be used as an input for 1D inversion techniques. A comparison between the results of such forward modelling & inversion process and the known conditions provided by the model could be used to improve the reliability of the inversion techniques.
Here we aim to present the abilities of the 3D WPFS model and its potential for serving as a testing ground for the verification and further development of the magnetic field inversion techniques.

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Type of contribution: Poster

Title: Modeling the scattering polarization of the hydrogen Ly-alpha and Si III lines observed by CLASP in a filament channel

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Abstract:
The 400 arcsec spectrograph slit of CLASP crossed predominantly quiet regions of the solar chromosphere, from the limb towards the solar disk center. Interestingly, in the CLASP slit-jaw images and in the SDO images of the He I line at 304 Å, we can identify a filament channel extending over more than 60 arcsec crossing the spectrograph slit. In order to interpret the peculiar spatial variation of the Q/I and U/I signals observed by CLASP in the hydrogen Ly-alpha line (1216 Å) and in the Si III line (1206 Å) in such a filament channel, it is necessary to perform multi-dimensional radiative transfer modeling. In this contribution, we show the first results of the two-dimensional calculations we are carrying out in given filament models. Our aim is to determine the filament magnetic magnetic field by comparing the theoretical and the observed polarization signals.

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Type of contribution: Poster

Author(s): Zhiliang Yang, Jiangchuan Zheng

Title: The Relation between the magnetic field and rotation of sunspots.

Abstract:
The polarization measurement is contributed to the observation of the magnetic field of sunspots. With the data from HMI/SDO, we study the relation of magnetic polarity and rotational tendency of the sunspot groups. The sunspot having negative magnetic polarity tends to rotate clockwise, and the sunspot having posity magnetic polarity tends to rotate countclockwise. The rotation of the relatively large and stable preceding sunspots located in the same hemisphere have opposite directions in 2003 and 2014, the two different solar cycle. The results may help us to understand the secret of magnetic field of sunspots.

Session 3

Polarimetry as a diagnostic tool for stellar atmospheres

Review talks

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Type of contribution: Review talk

Author(s): S. V. Berdyugina

Title: Polarized Scattering due to Molecules, Particles and Biopigments in Stellar and Planetary Atmosphere

Abstract:
Polarized scattering in stellar and planetary atmospheres is computed in the context of exoplanetary systems. The problem of polarized radiative transfer is solved for a general case of absorption and scattering, while Rayleigh and Mie polarized scattering are considered as most relevant examples. We show that (1) relative contributions of single and multiple scattering depend on the stellar irradiation and opacities in the planetary and stellar atmosphere; (2) particle physical parameters can be deduced from the wavelength-dependent measurements of the continuum polarization and from a differential analysis of molecular band absorption; (3) polarized scattering in molecular bands increases the reliability of their detections in exoplanets; (4) photosynthetic life can be detected on other planets in visible polarized spectra with high sensitivity. These examples demonstrate the power of spectropolarimetry for stellar and exoplanetary research for searching for life in the universe.

Session 3

Polarimetry as a diagnostic tool for stellar atmospheres

Standard talks

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Staff

Type of contribution: Standard talk

Author(s): Andrés Asensio Ramos

Title: Modern inversion codes for Stokes parameters

Abstract:
The revolution that nonlinear inversion codes for the Stokes parameters introduced in Solar Physics is undeniable. They allowed us to quantitatively infer the thermodynamic, dynamic and magnetic properties of solar plasmas, from the photosphere to the chromosphere. The time has come to push the inversions further to deal with the data that future facilities like EST and DKIST will provide. In this contribution, I present different strategies (2D inversions, nodeless inversions, different regularization techniques, etc.) that we are pursuing to improve the inversion codes and use up all the information available in the Stokes parameters.

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Type of contribution: Standard talk

Author(s): Hao, Li

Title: Polarization of coronal forbidden line

Abstract:
The coronal forbidden line polarimetry, which is only sensitive to the direction of magnetic field not the strength was suggested by Charvin to diagnose the magnetic field in the solar corona. Here, we investigate the polarization of green line Fe XIV 530.3nm during a solar cycle with a potential field model. We thought that the polarization of forbidden line is the best diagnostic tool for the polarity reversal.

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Type of contribution: Standard talk

Author(s): M. J. Martínez González, T. Vieu, A. Pastor Yabar, A. Asensio Ramos

Title: Measuring the global field of the Sun and other stars with the Hanle effect

Abstract:
The presence of a magnetic field over a stellar surface brakes the symmetry limitations of pure scattering processes. Hanle effect signals depend on the orientation of the magnetic field with respect to the line of sight and on the geometry of the scattering event. Then, a perfect cancellation of linear polarisation signals when averaging the stellar disc is very unlikely. After deriving the exact expressions for the intensity and polarisation produced by scattering and the Hanle effect in the presence of a dipolar field, we consider the possibility of diagnosing the global field of the Sun (and of other stars). The interesting point is that the polarisation signals depend on the inclination of the dipole with respect to the Sun's (star) rotation. This allows the possibility to check recent claims that the solar global field is inclined with respect to the solar rotation axis.

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Type of contribution: Standard talk

Author(s): Ivan Milic, Michiel van Noort

Title: Response function for NLTE lines

Abstract:
Response functions are an important tool in understanding spectral line formation. They are also an essential ingredient of spectropolarimetric inversion codes. Computation of the response functions for lines formed in non-local thermodynamic equilibrium (NLTE) is complicated because level populations have both non-local and non-linear dependence on atmospheric quantities.
Here we propose an novel method to compute response functions for these lines. We express the response function of emergent intensity through the response function of level populations at all points in the atmosphere. We then take the analytical derivative of the rate equations and follow through the dependencies until we end up with a linear system coupling all atomic levels and points in the atmosphere. Solution of the linear system yields a response of all level populations at all depths to the perturbation of given atmospheric quantity.
We show that our method is in excellent agreement with response functions computed using finite differences, while obtaining at least an order of magnitude speedup. We then use this approach to study the response functions of emergent intensity and radiation anisotropy to Temperature and discuss on potential application of this method to node-based NLTE Hanle inversion.

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Type of contribution: Standard talk

Author(s): N. E. Raouafi, P. Riley, S. Gibson, S. Fineschi, S. K. Solanki

Title: Diagnostics of Coronal Magnetic Fields Through the Hanle Effect in UV and IR Lines

Abstract:
The plasma thermodynamics in the solar upper atmosphere, particularly in the corona, are dominated by the magnetic field, which controls the flow and dissipation of energy. The relative lack of knowledge of the coronal vector magnetic field is a major handicap for progress in coronal physics. This makes the development of measurement methods of coronal magnetic fields a high priority in solar physics. The Hanle effect in the UV and IR spectral lines is a largely unexplored diagnostic. We use magnetohydrodynamic (MHD) simulations to study the magnitude of the signal to be expected for typical coronal magnetic fields for selected spectral lines in the UV and IR wavelength ranges, namely the H I Ly-α and the He I 10830 Å lines. We show that the selected lines are useful for reliable diagnosis of coronal magnetic fields. The results show that the combination of polarization measurements of spectral lines with different sensitivities to the Hanle effect may be most appropriate for deducing coronal magnetic properties from future observations.

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Type of contribution: Standard talk

Author(s): C. Scalia, F. Leone, M. E. M. Gangi

Title: Measuring the effective magnetic field of cold active star Eps Eri using the slope method.

Abstract:
We obtain high resolution (R=55000) spectropolarimetric observations of the cold (T_eff=5084 K) active star Epsilon Eridani using CAOS (Catania Astrophysical Observatory Spectro-polarimeter). We develop a code for the measurement of the effective magnetic field based on the slope method. We apply this technique for the first time to high resolution spectra of active stars. We measure the effective magnetic field of Eps Eri for all the available spectropolarimetric observations in the archives. We report the periodically variation of longitudinal field of the star probably due to the dynamo process.

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Type of contribution: Standard talk

Author(s): H. N. Smitha, S. K. Solanki

Title: Measurement of solar magnetic fields using mutli-pair Stokes V line ratios

Abstract:
The magnetic line ratio method was introduced nearly four decades ago to estimate the magnetic field strength using the line pair at 5247-5250 A. Since then, this method has been greatly exploited to measure the photospheric magnetic fields. The only two other line pairs used for this method are the 6301-6302 A in the visible, and the 15648-15652 A in the infrared. The robustness of the former line pair has been under debate with some works concluding in favour and some against the pair. This leaves us with a single ìidealî line pair in the visible range. Following a detailed search, we have identified a new line pair in the visible range suitable for the line ratio method. In this work, we demonstrate the uniqueness and robustness of this new pair, in comparison with the others, using a three dimensional magneto-hydrodynamic cube representative of the quiet Sun atmosphere.

Session 3

Polarimetry as a diagnostic tool for stellar atmospheres

Posters

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Type of contribution: Poster

Author(s): Gabriel I. Dima, Jeffrey R. Kuhn, Svetlana V. Berdyugina

Title: Hanle coronal magnetometry using permitted HeI 1083nm and forbidden SiX 1430.1nm IR emission lines

Abstract:
With a model of the coronal Hanle effect, and by measuring the linear polarization of permitted and forbidden lines, it is possible to determine the magnetic field in the emission region. This technique is useful in the corona because of the discovery of faint HeI emission, possibly due to a non-equilibrium population of HeI atoms originating on coronal dust grains. Coronal HeI 1083nm generally lies in the permitted Hanle regime so that the polarization amplitude and orientation of the emission are sensitive to both the orientation and strength of the magnetic field. To break this degeneracy we use one of several Infrared forbidden lines, like FeXIII 1074.9 or SiX 1430.1nm. These are sensitive to different coronal temperature regimes. We discuss magnetic field uncertainties inherent to this measurement technique, and present the first polarized measurements of the SiX1430nm line, obtained during an eclipse and using the SOLARC telescope on Haleakala. This is an off-axis 40 cm telescope fitted with an IR imaging spectropolarimeter. It is a precursor to the coronal magnetometry that the 4-m DKIST will achieve in 2019.

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Type of contribution: Poster

Author(s): C. Beck, D. Fabbian, R. Rezaei, and K. G. Puschmann

Title: Internetwork magnetic flux density in 3D magneto-hydrodynamic simulations and observations

Abstract:
Before employing the results of three-dimensional magneto-hydrodynamical (3D MHD) simulations of the solar photosphere in the determination of chemical abundances, one should ensure that the amount of total magnetic flux present in the simulations themselves is realistic, since the presence of magnetic fields affects the formation of spectral lines which the abundance determinations are based on.
We compare the polarization signals induced by the Zeeman effect in the presence of photospheric magnetic fields in disc-centre observations and in 3D MHD-based snapshots to find the simulation run that best matches the observed polarization properties. We determine characteristic quantities of full Stokes profiles in observations of photospheric spectral lines in the visible (630 nm) and in the near-infrared (1560 nm), and in corresponding synthetic spectra obtained from numerical 3D MHD simulations. To reproduce the observed polarization signals, the total unsigned vertical magnetic flux density in the simulations should be about 30 G on average. Linear polarization signals are found to be closely related to co-spatial or near-by circular polarization signals and trace canopy fields of magnetic flux concentrations.

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Type of contribution: Poster

Author(s): M. Cubas-Armas, D. Fabbian, and N. Vitas

Title: Physical and observable parameters derived from 3D magneto-convection simulations of the Sun's photosphere

Abstract:
We present our results on three-dimensional magnetohydrodynamic (3D MHD) simulations of a plage. The latter were obtained with the MURaM and STAGGER numerical codes, whose results are compared in the MHD case for the first time. We used similar setups and a vertical magnetic field of ~ 200 G.
Using several snapshots of each simulation series, we first compared the atmospheric physical parameters (temperature, magnetic field and velocity). Subsequently, we performed spectral synthesis calculations using the NICOLE code, assuming local thermodynamical equilibrium (LTE). We computed the continuum intensity in the visible and near infrared (400-1600 nm), as well as the Fe I 630.1 nm and 630.2 nm spectral lines. We compared the computed lines in terms of line-core intensity, equivalent width, full width at half maximum (FWHM), and area and amplitude asymmetry for the Stokes V profile.
We highlight similarities and differences found in the results we obtained based on the snapshots representing the regimes of the solar magnetized plasma simulated with the two codes.

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Type of contribution: Poster

Authors: Manuele Gangi, Francesco Leone, Cesare Scalia

Title: Detection of liner polarization in strong metal lines of 89 Herculis

Abstract:
We use spectropolarimetric data collected at the 3.6 m Canadian-France-Hawaii Telescope with the high resolution spectropolarimeter ESPADONS (R=68000) to study the polarized spectrum of the post-AGB binary system 89 Herculis. We discover the existence of linear polarization in the strongest metal absorption lines with low excitation potentials of the low level. Signals are characterized by complex Q and U morphologies varying in time. According to the optical pumping model, we show that these evidences could be ascribed to the anisotropy of the radiation field induced by the dynamics of the system.

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Type of contribution: Poster

Authors: A. Megha, M. Sampoorna, K. N. Nagendra, and K. Sankarasubramanian

Title: Polarized scattering matrix for magnetic dipole transitions

Abstract:
Coronal forbidden emission lines which are difficult to produce in the laboratories arise due to the magnetic dipole (M1) transitions in the highly ionized atoms present in the solar corona. The polarization of these lines is the result of anisotropic excitation of the ions present in the corona. The measurement of polarization of the forbidden emission lines is the most direct method of determining the direction of magnetic fields in the solar corona. A classical oscillator model for the magnetic dipoles was proposed by Casini & Lin (2002, ApJ, 571, 540). Based on this model Lin & Casini (2000, ApJ, 542, 528) derived the polarization properties of the coronal forbidden emission lines in the limiting case of strong-field regime (saturated Hanle regime). In this poster we consider the more general case of magnetic dipole transitions in an arbitrary strength magnetic field. In particular we derive the scattering matrix for the magnetic dipole transitions using the classical M1 model of Casini & Lin (2002) and applying the scattering matrix approach of Stenflo (1998, A&A, 338, 301). The scattering matrix derived by this approach covers all the various cases, in a continuous way, from saturated Hanle, to intermediate Hanle-Zeeman, to purely longitudinal Zeeman effect.

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Type of contribution: Poster

Authors: Vieu T., Martínez González M. J., Pastor Yabar A., Asensio Ramos A.

Title: How to infer the Sun's global magnetic field using the Hanle effect

Abstract:
We present a new approach to determine the characteristics of the global magnetic field of stars and in particular of the Sun, based on the study of the Hanle signals. The Hanle effect of a stellar dipole produces a surface asymmetric pattern of linear polarization that depend on the strength and geometry of this global field. Moreover, if the dipole is misaligned with respect to the rotation, the Hanle signals are modulated following the rotational period. We explore the possibility to retrieve those characteristics by comparing the computed theoretical signatures with actual observations. We show that this is possible, in the case of the Sr I line of the Sun, with a photon noise below 10^-5 - 10^-6, either using the maps of resolved signals and in particular the spread of values obtained along different directions on the stellar disk, or using the integrated signals.

Session 4-I

Ground-based polarization measurements: observations, analysis and interpretation

Standard talks

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Type of contribution: Standard talk

Author(s): H. Balthasar, P. Gömöry, S. González Manrique, C. Kuckein, et al.

Title: Spectropolarimetric Observations of an Arch Filament System with GREGOR

Abstract:
We observed an arch filament system (AFS) in a sunspot group with the GREGOR Infrared Spectrograph (GRIS) attached to the GREGOR telescope. The AFS was located between the leading sunspot of negative polarity and several following pores of positive polarity. We recorded five spectro-polarimetric scans of this region. The spectral range included the spectral lines Si I 1082.7 nm, He I 1083.0 nm and Ca I 1083.9 nm, among others. The photospheric calcium line is inverted with the code 'Stokes Inversion based on Response functions' (SIR) to obtain the magnetic field vector and the line-of-sight velocities. Between the following pores, we encounter an area of negative polarity that is decreasing during the five scans. We interpret this by new emerging positive flux in this area canceling out the negative flux. The chromospheric helium line is inverted with the code 'Hanle and Zeeman Lines' (HaZeL). High chromospheric velocities of 30 km/s and more are detected using a Lorentzian fit procedure. Context data from the Solar Dynamics Observatory (SDO) complete our study.

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Type of contribution: Standard talk

Author(s): M. Bianda, R. Ramelli, D. Gisler, L. Belluzzi

Title: Second Solar Spectrum observations with ZIMPOL

Abstract:
Observations performed with ZIMPOL3 are presented. In particular we summarize the state of the art observing the Second solar spectrum in several lines. The Na I D1 D2 lines, in particular the D1, are showing spatial variations in polarization signatures, the interpretation of which is always a crucial issue. The Sr I 4607 Å line is showing scattering polarization spatial variations; however, we have not yet succeed to resolve the sub-granular scale. The current state of the Li I 6708 Å observations is also presented, where the observed amplitude is down to few 10-5. ZIMPOL can be used also at GREGOR, results and perspectives are reported.

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Type of contribution: Standard talk

Author(s): Linhua Deng

Title: New Vacuum Solar Telescope Observations of Solar Fine-scale Structures in the Lower Atmosphere

Abstract:
The heating of the upper solar atmosphere to high temperatures is a long-standing problem in solar physics. Many ultra-fine magnetic structures in the photosphere and chromosphere of the Sun, including magnetic bright points, umbral dots, and penumbral filaments, hold the key to many poorly understood aspects of solar magnetism (e.g., coronal heating, local turbulent dynamo, total solar irradiance, and so on). Based on the high-resolution, high-cadence, and multi-wavelength observations with the modern one-meter New Vacuum Solar Telescope located at Fuxian Solar Observatory of P.R. China (FSO/NVST; Liu et al., RAA, 2014, 14, 705-718), we study the intrisic dynamics and topogical evolution of the above solar small-scale magnetic structures in the Hα-off and TiO-band filtergrams.
The following works are studied: 1) comparison of general properties (size and area, coverage ratio, intensity, eccentricity) of magnetic bright points in both active and quite Sun; 2) difference of horizontal motion, diffusion index and dynamical behavior of magnetic bright points for their varying magnetic environments (with the help of SDO/HMI magnetograms); 3) physical connection of magnetic bright points with umbral dots, Ellerman bombs, and microflare in the different atmospheric layers. Our analysis results indicate that solar ultra-fine magnetic structures should be useful for understanding the physical processes of solar magnetic energy from the lower and the upper atmosphere.

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Type of contribution: Standard talk

Author(s): C.J. Díaz Baso, M. J. Martínez González, A. Asensio Ramos

Title: Inference of magnetic fields in an active region filament

Abstract:
Active region (AR) filaments are dense structures of cold plasma suspended at chromospheric heights, present in or close to active regions. A magnetic field mostly parallel to the surface is what seems to hold these structures. However, there are only a few measurements of the magnetic field in AR filaments, hence its topology is still a matter of debate. In this talk, we will show spectropolarimetric observations in 1083 nm taken with GRIS in the GREGOR telescope. The spectral range contains the photospheric Si I 1082.7 nm and the chromospheric He I 1083.0 nm triplet that nicely traces a filament close to a sunspot. To study the magnetic field accurately, we have used two inversion codes - HAZEL and SIR - to infer the magnetic and thermal properties of the filament and the photospheric context. In the inversion process, we have used a Bayesian approach to look for possible degeneracies and ambiguous solutions. We will present preliminary results on the magnetic topology at this active region filament, focusing on the need for more complex models given the complexity of the observed Stokes profiles.

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Type of contribution: Standard talk

Author(s): Haisheng Ji

Title: The results from NST's observation --- Magnetic activities

Abstract:
In this talk, I would like to present some important results of He I 1083 nm narrow band imaging observed with NST at BBSO. The results strongly suggest the importance of high-resolution He I 1083 nm polarimetry for understanding magnetic activities of various scales.

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Type of contribution: Standard talk

Author(s): Jan Jurcak, Jiri Stepan, Michele Bianda, Javier Trujillo Bueno

Title: The intensity and polarization of the Ca II 8542 line in the quiet Sun: spectropolarimetric observations vs. 3D radiative transfer modelling

Abstract:
We present an analysis of the intensity and polarization profiles of the Ca II 8542 line. We compare the disk-center observations of a quiet Sun region, taken with the ZIMPOL instrument at IRSOL, with the synthetic 8542 line profiles computed with the PORTA code in a 3D model of the solar chromosphere resulting from a well-known radiation MHD simulation. The Ca II 8542 line is of great interest for magnetic field diagnostics of the solar chromosphere, both in active and quiet regions. In the quiet regions, the Stokes Q and U signals are generally the result of the joint action of scattering processes and the Hanle and Zeeman effects. 1D semi-empirical models of the quiet solar atmosphere predict very weak disk-center scattering signals, between 10^-4 and 10^-3 for Q/I and U/I, while Zeeman signals can be expected to be typically of the same order of magnitude. Even though the spatial sampling of the ZIMPOL observations is only 1.43 arcsec/pixel, we detect polarization signals of the order of 10^-3 in Q/I and U/I. Our synthetic line profiles have been obtained by solving the full 3D NLTE radiative transfer problem taking into account the symmetry breaking effects due to the horizontal inhomogeneities and gradients of the macroscopic velocity. After spatial and spectral degradation, we obtain similar amplit7udes to the observed ones by only taking into account scattering polarisation and the Hanle effect. We discuss also the role of the Zeeman effect on the line polarization.

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Type of contribution: Standard talk

Author(s): Murabito M., Romano P., Gugliemino S. L., Zuccarello F., Solanki S. K.

Title: Formation of the penumbra and start of the Evershed flow

Abstract:
We analyze high-resolution observations of Active Region NOAA 11490, acquired on 2012 May 28 and 29. Spectropolarimetric measurements along the Fe I 617.3 nm and 630.25 nm photospheric lines were taken with the Interferometric BIdimensional Spectrometer (IBIS), mounted on NSO/DST, during about 30 minutes for each day. To study the evolution of the physical parameters during the entire time interval, we also used data taken by SDO/HMI.
We used the SIR code to invert the Stokes profiles observed with IBIS, using different initial models to take into account the physical conditions of the plasma in the region of umbra, penumbra, and quiet Sun.
From the analysis of the SIR results, we found that, before the formation of the penumbra, the annular zone is characterized by downflows in the inner part. Furthermore, we observed that the onset of the classical Evershed flow occurs in a very short time scale, 1-3 hours, while the penumbra is forming.
In order to investigate the conditions that lead to the establishment of the classical Evershed flow, we analyzed the evolution of the continuum intensity, LOS velocity, inclination and strength of the magnetic field in a segment in the north-western part of the leading spot. In about 1 hour, we noted a clear evolution from redshift to blueshift in the penumbral filaments.
We propose a scenario in which the penumbra is formed by magnetic flux dragged down from the canopy surrounding the initial pore: the Evershed flow starts when the sinking magnetic field dips below the solar surface and magnetoconvection sets in.

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Type of contribution: Standard talk

Author(s): Pastor Yabar, A.; Martínez González, M. J.; Collados, M.

Title: Magnetic topology of the North solar pole

Abstract:
The magnetism at the poles is similar to that of the Quiet Sun, meaning that no Active Regions are present there. However, polar Quiet Sun is somehow different from that at the Activity Belt as it is modulated by the solar cycle. We study the magnetism at three different regions of the solar disk near a maximum of activity. We use deep full Stokes polarimetric observations of the 15648.5Å and 15652.8Å FeI lines close to a maximum of solar activity (i.e. when polar regions change their polarity). Full Stokes polarisation allows the inference of the various magneto-thermodynamical properties of the atmosphere. It is shown that the North polar regions exhibit a population of strong magnetic fields that are not seen neither at disk centre nor at West limb. This component shows magnetic fields inclined around 40º from the vertical to the surface. The polarity of this new population is that previous to the polarity reversal of the North polar region. The behaviour seen at the West limb Quiet Sun rejects projection effects as the source for these magnetic fields.

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Type of contribution: Standard talk

Author(s): L.A. Rachmeler, C. Guennou, D.B. Seaton, S.E. Gibson, F. Auchere

Title: Coronal polarization of pseudostreamers and the solar polar field reversal

Abstract:
The reversal of the solar polar magnetic field is notoriously hard to pin down due to the extreme viewing angle of the pole. In Cycle 24, the southern polar field reversal can be pinpointed with high accuracy due to a large-scale pseudostreamer that formed over the pole and persisted for approximately a year. We tracked the size and shape of this structure with multiple observations and analysis techniques including PROBA2/SWAP EUV images, AIA EUV images, CoMP polarization data, and 3D tomographic reconstructions. We find that the heliospheric field reversed polarity in February 2014, whereas in the photosphere, the last vestiges of the previous polar field polarity remained until March 2015. We present here the evolution of the structure and describe its identification in the Fe XII 1074nm coronal emission line, sensitive to the Hanle effect in the corona.

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Type of contribution: Standard talk

Author(s): Reza Rezaei, Rolf Schlichenmaier, & GREGOR team

Title: The fine-structure of a faint sunspot light bridge

Abstract:
We study light bridges in a large sunspot close to disk center through the solar atmosphere with the GREGOR Infrared Spectropolarimeter (GRIS) and the Atmospheric Imaging Assembly (AIA) onboard SDO.
The flow velocity, magnetic field, and thermal stratification in the photosphere were derived from an simultaneous inversion of Stokes spectra of four photospheric lines in the 1565 nm wavelength range. We compare the properties of a thick, a thin, and an umbral light bridge. With decreasing intensity, their values for field strength, inclination, and azimuth approach those of the surrounding umbra. In faint areas of the light bridge linear polarisation signals disappear. All AIA filtergrams of the upper atmosphere show a persistent activity in the light bridge areas for several hours before and after the GRIS observations.
The canopy configuration of the magnetic field in a light bridge can only be seen in strong light bridges. Weak light bridges are presumably produced by less vigorous convection. Its weak-field plasma is located beneath the formation of the spectral lines. Yet, shear flows may exist within the light bridge that drag field lines along the light bridge. Such motions generate gradients and rotation of B in higher layers, and thus may produce electric currents which can be seen as emissions in the chromosphere and transition region, implying that there are no observable imprints in the mid photosphere.

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Type of contribution: Standard talk

Author(s): Tessore B, Josselin J, Lebre A, Morin J, Auiere M, Lopez-Ariste A

Title: Spectropolarimetric study of red supergiant stars

Abstract:
With the spectropolarimeter Narval at TBL we have initiated in spring 2015 a Large Program (LP) dedicated to a sample of cool and evolved stars, including red supergiant stars (RSGs). Our two aims are to study the surface magnetic field and the linear polarisation of non magnetic origin.
In the Sun, linear polarisation is due to anisotropy of the radiation field induced by limb darkening. It is maximal when it is seen parallel to the limb and it vanishes when it is integrated over the spherically-symmetric solar disk. Therefore for distant stars, which present spherical symmetry, linear polarisation signatures are very difficult to observe.
However we report strong linear polarisation signatures in LSD (*least square deconvolution) profiles as well as in specific spectral lines in some RSGs, known to have a very complex atmospheric dynamics. Those linear polarisation signatures are presumably related to symmetry-breaking effects induced by giant convective cells lying at the surface of RSGs. Therefore, the analysis of these signatures can give us new constrains about the atmospheric dynamics of these stars.
Here I briefly present the results obtain so far with this LP and the status of the magnetism of RSGs and then focus on the interpretation of linear polarisation features.

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Type of contribution: Standard talk

Author(s): Yan Xiaoli

Title: The change of photospheric magnetic fields before filament formation and eruptions

Abstract:
To better understand solar filaments, we study the change of photospheric magnetic fields before filament formation and eruption. It is found that the shear motion often appear along polarity inversion line and is associated with the increase of the transverse magnetic fields before the filament formation. Prior to the filament eruptions, the transverse magnetic fields begin to decrease. These results imply that the filament formation and eruption is closely related to the change of photospheric magnetic fields.

Session 4-I

Ground-based polarization measurements: observations, analysis and interpretation

Posters

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Type of contribution: Poster

Author(s): M. Verma, H. Balthasar, C. Denker, et al.

Title: Near-infrared spectropolarimetry of the trailing sunspots of NOAA 12396

Abstact:
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 processes. The active region NOAA 12396 emerged on 2015 August 3 and was observed three days later with the 1.5-meter GREGOR solar telescope on 2015 August 6. High-resolution spectropolarimetric data from the GREGOR Infrared Spectrograph (GRIS) are obtained in the photospheric Si I 1082.7 nm and Ca I 1083.9 nm lines, together with the chromospheric He I 1083.0 nm triplet. These near-infrared spectropolarimetric observations were complemented by synoptic line-of-sight magnetograms and continuum images obtained with the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO) and slit-jaw images from the Interface Region Imaging Spectrograph (IRIS). We will present the steps involved in the calibration of GRIS spectra and discuss the results based on the "Stokes Inversion based on Response functions" (SIR) code. SIR Maps from the photospheric lines depicting various physical parameters such as line-of-sight velocities, and magnetic field parameters will be shown. We will discuss the results in context of continuous flux emergence and evolution of sunspots in the trailing region.

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Type of contribution: Poster

Author(s): Nazaret Bello González

Title: New insights on penumbra formation - The origin of the counter-Evershed flow

Abstract:
We will present results on the origin of the counter-Evershed flow preceding penumbra formation as seen in photospheric layers. For that purpose, we analysed 4.5 hours of high-resolution spectro-polarimetric data during the formation of the leading sunspot in NOAA11024 observed at the VTT (Tenerife) in June 2009.

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Type of contribution: Poster

Author(s): Demidov M.L., Kiselev A.V.

Title: On the Time Variations of Magnetic Strength Ratios in Different Combinations of Spectral Lines

Abstract:
Magnetic strength ratio (MSR) is a good indicator of the relationship between strong (order of kG) and weak (no more than some hectoG) components of solar magnetism. Many studies are devoted to explore spatail and temporal variations of MSR in different combinations of spectral lines for diagnostics of solar magnetic fields properties. In this investigation we use long-time (1999-2016) multi-lines Solar Mean Magnetic Field (SMMF) observations, made on STOP telescope at the Sayan Solar observatory (SSO). SMMF is important global parameter of solar magnetism which closely connected with activity cycle and distribution of large-scale quiet magnetic fields across solar disk. It was possible to expect that MSR SMMF should provide solar cycle variations due to different contribution from sunspots. However, observations show only tiny cycle variations. A reason of that not clear yet and new observations are necessary. Additionally, the results of cross-comparison of SSO and Wilcox Solar observatory (WSO) SMMF data sets are presented. Despite of two observatories use the same spectral line (Fe I 525.0 nm), their regression coefficients undergo some time variations. Possible reasons of that are discussed in this report as well.

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Type of contribution: Poster

Author(s): Y. Hanaoka, T. Sakurai, and IRMag Group

Title: Statistical Study of the Magnetic Field in Solar Filaments

Abstract:
We carried out a statistical study of the magnetic field orientation in solar filaments based on our daily full-Sun, full-Stokes spectropolarimetric observations with the He I 10830 line. The analysis of more than 400 filaments revealed that the magnetic field of the filaments shows a certain shear with respect to the filament axis, and that the direction of the shear (chirality), particularly that of the quiescent ones, strongly depends on the hemisphere where the filaments appear. The hemispheric pattern seen in the filament magnetic field is consistent with the well-known chirality pattern of the fine structure seen in filaments. On the other hand, the filament chirality is known to be opposite to that of the coronal magnetic field above the filaments. This contradiction can be understood by considering that filaments are located at the bottom of a flux rope, which is often observed in coronal mass ejections. Spectropolarimetric observations of the filament magnetic field give us important clues to study how filaments are formed and how they erupt.

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Type of contribution: Poster

Author(s): David Hiriart, Erika Benítez, Jochen Heidt, Raul Mujica, & Manuel Lopez

Title: Long Term Photopolarimetric Monitoring of Bright Blazars at San Pedro Mártir Observatory

Abstract:
In this work we present the current status on the data reduction of photopolarimetric observations in the R-band of 37 bright blazars. The observing program spanned from 2008 to 2016. Blazars were observed with the 0.84-m telescope at the San Pedro Mártir National Astronomical Observatory in Mexico and the optical polarimeter POLIMA.

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Type of contribution: Poster

Author(s): R. Ramelli, M. Setzer, M. Enegelhard, M. Bianda, F. Paglia, J. O. Stenflo, G. Kü, R. Plewe

Title: Atlas of the solar intensity spectrum and its center to limb variation

Abstract:
The solar limb darkening function is well known and is widely employed in models of the solar atmosphere. However there has been a lack of systematic spectrally resolved measurements. Therefore we recently decided to start an observing campaign with the Gregory Coudé telescope at IRSOL in Locarno in order to produce a spectral atlas obtained at 10 different heliocentric angles “theta”, chosen so that mu=cos(theta) covers the interval from 0.1 to 1.0 in step of 0.1. The measurments carried out till now include the spectral range from 439 nm to 638 nm.
The collected data provide information about the anisotropy of the emergent radiation field on the solar surface, allowing a better modeling of the Second Solar Spectrum. In addition the data give observational constraints that shuold be taken into account when modeling the solar atmosphere.

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Type of contribution: Poster

Author(s): R. Ramelli, M. Bianda, S. Berdyugina, L. Belluzzi, L. Kleint

Title: Measurement of the evolution of the magnetic field of the quiet photosphere during a solar cycle

Abstract:
The solar photosphere is filled by a magnetic field which is tangled on scales much smaller than the resolution scale of solar telescopes. This hidden magnetic field can be investigated via the Hanle effect. In 2007 we started a synoptic program to explore if the magnetic flux of the quiet photosphere varies with the solar cycle. For this purpose we applied a differential Hanle effect technique based on observations of scattering polarization in C2 molecular lines around 514.0 nm, taken generally every month. Our results now span almost one complete solar cycle.

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Type of contribution: Poster

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

Title: Polarization measurements: observations, analysis and interpretation Fast Solar Polarimeter (prototype): preliminary results of Stokes measurements in the Sr I (4607 Å) line at VTT/TESOS

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 is very sensitive to scattering polarization, 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 so far.
Here, we present preliminary results of a VTT/TESOS campaign in May 2015. We have observed the Sr I line in the quiet Sun using the prototype of the Fast Solar Polarimeter, with a spatial sampling of 0.08" and noise levels significantly below 1% per pixel for linear polarized signals with 1.25 s integration time. To obtain lower noise levels (< 0.1%), while conserving sufficient spatial resolution to resolve the solar granulation, we carefully used spatial, spectral and temporal averaging as well as a MOMFBD restoration. We compare our findings in the Sr I line with the neighbouring, but not scattering sensitive Fe I line at 4607.6 Å.

Session 4-II

Space-borne polarization measurements: observations, analysis and interpretation

Review talks

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Type of contribution: Review talk

Author(s): Silvano Fineschi

Title: Coronal Polarimetry: Future prospects for space- and ground-based observations

Abstract:
This presentation gives an overview of the near-future prospects of ultraviolet (UV) and visible-light and infrared (VIR) spectro-polarimetric instrumentation for probing coronal magnetism from space-based and ground-based observatories.
Spectro-polarimetric imaging of VIR forbidden emission-lines provides an important diagnostics, via the Hanle effect, of the plane-of-the-sky direction of the magnetic field in corona. A prospect for ground-based polarimetry of the corona, described here, is the Torino Coronal Magnetograph (CorMag) for spectro-polarimetric observations of the FeXIV, 530.3 nm, and FeXIII 1074.4 nm, forbidden emission-line with a liquid crystal (LC) Lyot filter and a LC linear polarimeter. CorMag has been recently selected for the Italian-French experiment ESCAPE to be installed in 2017 in Antarctica at the Concordia base.
The Hanle effect of the linear polarization by resonance scattering of permitted UV line-emission yields information on the strength and line-of-sight direction of coronal magnetic fields. Space-based UV spectro-polarimeters would provide a diagnostics for coronal magnetic fields complementary to that from VIR spectro-polarimetry. This presentation describes the future upgrade of the Sounding-rocket Coronagraphic Experiment (SCORE) to include the imaging polarimetry of the HI Lyman-alpha, 121.6 nm. SCORE has flown successfully in 2009 and a second lauch is scheduled for 2017.

Session 4-II

Space-borne polarization measurements: observations, analysis and interpretation

Standard talks

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Type of contribution: Standard talk

Author(s): L. S. Anusha, Johann Hirzberger, Alex Feller, Sami, K. Solanki

Title: Evolution of quiet-Sun small scale magnetic features using Sunrise observations

Abstract:
Here we analyze small-scale magnetic features in the quiet Sun, using the high resolution, seeing-free observations from the Sunrise balloon borne solar observatory. Our aim is to understand the contribution of different physical processes, such as splitting, merging, emergence and cancellation of magnetic fields to the rearrangement, addition and removal of magnetic flux in the photosphere. We find that the total flux gained in unipolar appearance is an order of magnitude larger than the total flux gained in emergence. On the other hand, the bi-polar cancellation contributes nearly an equal amount to the loss of magnetic flux as unipolar disappearance. The total flux lost in cancellation is nearly 6-8 times larger than the total flux gained in emergence. One big difference between our study and previous similar studies is that, the higher spatial resolution of Sunrise we can track features with fluxes as low as 9×10^{14} Mx. This flux is one to two orders of magnitude lower than the smallest fluxes of the features tracked in previous studies based on Hinode data. The area and flux of the magnetic features follow power-law type distribution, while the lifetimes show either power-law or exponential type distribution depending on the exact definitions used to define various birth and death events.

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Type of contribution: Standard talk

Author(s): J.C. del Toro Iniesta, I. S. Requerey, L.R. Bellot Rubio, V. Martínez Pillet, S.K. Solanki, & W. Sch

Title: On the role of convectively driven sinks on magnetic field evolution in the quiet Sun

Abstract:
We study the relation between mesogranular flows, convectively driven sinks and magnetic fields using high spatial resolution spectropolarimetric data acquired with the Imaging Magnetograph eX- periment on board Sunrise. We obtain the horizontal velocity flow fields of two quiet-Sun regions (31.2 x 31.2 Mm2) via local correlation tracking. Mesogranular lanes and the central position of sinks are identified by using passively advected tracers. We find 3.1 x 10^-3 sinks Mm^-2 minute^-1 located at the mesogranular vertices. These sinks are associated to (1) horizontal velocity flows converging to a central point and (2) long-lived downdrafts. The spatial distribution of magnetic fields in the quiet Sun is also examined. The strongest magnetic fields are preferentially located at sinks. We find that 40 % of the pixels with longitudinal component of the magnetic field higher than 500 G are located in the close neighborhood of sinks. In contrast, the small-scale magnetic loops detected by Martínez González et al. at the same two observed areas do not show any preferential distribution at mesogranular scales. The study of individual examples reveal that sinks can play an important role in the evolution of quiet-Sun magnetic features.

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Type of contribution: Standard talk

Author(s): Catherine Fischer, Nazaret Bello González, Reza Rezaei

Title: Temporal evolution of an exploding granule and its surrounding magnetic elements

Abstract:
We will present the temporal evolution of an exploding granule and the surrounding magnetic elements using photospheric full Stokes polarimetric data in the Fe I 630 nm doublet as well as narrowband filter magnetograms in Na I D and broadband images in Ca II H from the Hinode satellite. Additional co-temporal and co-spatial data obtained with the IRIS satellite allow us to study the connection between the photospheric magnetic and velocity field dynamics and the chromospheric response. The event takes place within approximately 15 minutes with the IRIS slit fortunately situated at the location of one of the magnetic elements being squeezed by the horizontal granular motions. During this process we observe changes in the magnetic field vector and an oscillation pattern in the chromospheric diagnostics which we analysis using a wavelet analysis.

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Type of contribution: Standard talk

Author(s): A.Y. Gorobets, J.M. Borrero, S. Berdyugina

Title: Markov fluctuations of the magnetic concentrations in the quiet Sun.

Abstract:
The observed magnetic field on the solar surface is characterized by a very complex spatial and temporal behaviour. Although feature-tracking algorithms have allowed us to deepen our understanding of this behaviour, subjectivity plays an important role in the identification, tracking of such features.
In this talk we report on studies of the temporal stochasticity of the magnetic field on the solar surface without relying neither on the concept of magnetic feature nor on subjective assumptions about their identification and interaction. The analysis is applied to observations of the magnetic field of the quiet solar photosphere carried out with the Sunrise-IMaX, Hinode-SOT and SDO-HMI instruments. We show that the joint probability distribution functions of the longitudinal and transverse components of the magnetic field, verify the necessary and sufficient condition for the Markov chains. Therefore we establish that the magnetic field can be considered as a memoryless temporal fluctuating quantity at sufficiently high resolution.

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Type of contribution: Standard talk

Author(s): Guglielmino S.L., Martínez Pillet V., Ruiz Cobo B., Bellot Rubio L. R., del Toro Iniesta J. C., Solanki S. K. and Zuccarello F.

Title: On the magnetic nature of solar exploding granules

Abstract:
We report on spectropolarimetric observations acquired by the imaging magnetograph SUNRISE/IMaX at high spatial (0.3'') and temporal (31.5 s) resolution during the first science flight of this balloon-borne solar observatory. We describe the photospheric evolution of an exploding granule observed in the quiet Sun. This granule is cospatial with a magnetic flux emergence event occurring at mesogranular scale (up to ~12 Mm2 area). Using a modified version of the SIR code, we show that we can estimate the longitudinal field also in presence of a residual cross-talk in these IMaX longitudinal measurements. We determine the magnetic flux content of the structure (~3 x 1018 Mx), which appears to have a multipolar configuration, and discuss the origin of such flux emergence events.
This research work has received funding from the European Commissionís Seventh Framework Programme under the grant agreements no. 312495 (SOLARNET project). This research is also supported by the ITA MIUR-PRIN grant on 'The active sun and its effects on space and Earth climate' and by Space Weather Italian COmmunity (SWICO) Research Program.

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Type of contribution: Standard talk

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

Title: Comparison of the Scattering Polarization Observed by CLASP; Possible indication of the Hanle Effect

Abstract:
The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP) observed scattering polarization in the hydrogen Lya (121.57 nm) and Si III (120.56 nm) lines for the first time. The complicated properties of the scattering polarization (i.e., conspicuous spatial variations in Q/I and U/I at the spatial scales of 10" and the absence of the center-to-limb variation in the Lya center) motivate us to search for possible hints of the operation of Hanle effect by comparing these scattering polarizations. To that end, we pay careful attention to the Lya core signal, where the critical field strength (BH) for the onset of the Hanle effect is 53 G, the Lya wing, which is insensitive to the Hanle effect, and the Si III line whose BH = 290 G. We focus on bright regions, where U/I spatial distribution consists of negative and positive patches in the Lya wing, finding that such bright regions can be classified in three types: [1] positive and negative distributions in U/I are the same among the three spectral ranges, [2] the Lya wing and Si III line show positive and negative distributions, and [3] only the Lya wing shows positive and negative patches. Interestingly, the photospheric magnetic fields mapped by SDO/HMI, show stronger field strengths from [1] to [3] (i.e., region [3] shows the strongest photospheric magnetic concentration). These observational results suggest that the Hanle effect might be operating due to the presence of ~50 G magnetic fields in the upper solar chromosphere.

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Type of contribution: Standard talk

Author(s): F. Kahil, T. L. Riethm¸ller, S. K. Solanki

Title: Brightness of solar magnetic elements as a function of magnetic flux at high spatial resolution

Abstract:
We investigate the relationship between the photospheric magnetic field of small-scale magnetic elements in the internetwork region of the quiet Sun at disc center, and the brightness in the UV spectral ranges down to 214 nm, and in the visible at 525.02 nm (line core) and 525.40 (continuum), by analysing spectropolarimetric and imaging time series acquired simultaneously by the Imaging Magnetograph eXperiment (IMaX), and the SUnrise Filter Imager (SuFI), on-board the balloon-borne observatory SUNRISE during its first science flight in June 2009, with high spatial and temporal resolution. We find a tight dependence between the line of sight component of the magnetic field B_LOS, and the emission from the lower chromosphere (sampled by Ca II H-line at 397 nm), revealing the role of these elements in chromospheric heating. We also find a dependence between the contrast in the UV and B_LOS, that is best described by a logarithmic function. This, along with the high contrast reached at these wavelengths, reveals the contribution of small-scale elements in the QS to the irradiance changes for wavelengths below 388 nm, which was never studied before at such high resolution. We also show by plotting the continuum contrast at 525.40 nm against B_LOS, that strong magnetic field elements in the internetwork were resolved by IMaX, resulting in constant contrasts for large magnetic fields in our I-B scatterplot, unlike the turnover obtained in previous observational studies.

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Type of contribution: Standard talk

Author(s): Anjali Kaithakkal,Tino Riethmueller, Sami Solanki, Andreas Lagg

Title: Moving Magnetic Features around a Pore

Abstract:
Moving magnetic features (MMFs) are small-scale magnetic elements observed to move radially outward from sunspots. Some studies have reported the presence of MMFs around pores as well. We analyzed data from SunriseII/IMaX observations obtained on 12 June 2013 between 23:39:10 and 23:55:37 UT. IMaX scanned the Fe I 5250.225 ≈ spectral line at eight wavelength positions and recorded the full Stokes vector at each of these positions. The field of view covered a large pore (μ = 0.93) with pixel scale of 0".055. MMFs of opposite (positive)- and same (negative) polarity as the pore were observed to stream from the pore boundary. We carried out a statistical analysis of the physical properties of MMFs and the main results are: 1) The number of opposite polarity MMFs within 1.5 Mm from the pore border, when they were first identified, is twice that of the same polarity MMFs. 2) Only 11% of the chosen MMFs appear to be monopolar and they all have the same polarity as the pore. 3) Majority of MMFs of both polarity move away from the pore border with an average speed of 1.5 km/s. But they do not always follow a smooth radial track and some of them even move in tangential direction to the pore. 4) MMFs of opposite polarity show a preferential up-flow whereas those of the samepolarity do not show any preference. 5) MMFs of both polarity are characterized by inclined fields.

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Type of contribution: Standard talk

Author(s): R.Kano, J.Trujillo Bueno, A.Winebarger, F.Auchere, N.Narukage, R.Ishikawa, K.Kobayashi & CLASP team

Title: Lyman-alpha scattering polarization observed with the Chromospheric Lyman-Alpha Spectro-Polarimeter

Abstract:
The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP) is a NASA sounding-rocket experiment led by an international team from Japan, United States and Europe. Its scientific motivation has been to achieve the first measurement of the linear polarization produced by scattering processes in the Lyman-alpha line (121.567nm), so as to have observables sensitive to the magnetic and geometrical structure of the upper chromosphere and transition region. On September 3, 2015, the CLASP instrument was successfully launched at White Sands in United States, and perfectly performed the spectro-polarimetric observation not only in the planned Lyman-alpha line but also in a nearby Si III line.
CLASP has revealed that in quiet Sun near the limb the Lyman-alpha polarization is a few percent in the line wings and of the order of 0.1% in the line core, in agreement with the theoretical predictions based on radiative transfer calculations. In the wings of the Lyman-alpha Q/I, we find a clear center-to-limb variation (CLV) with negative (radial polarization) amplitudes increasing toward the limb. However, in the line core we do not find any clear CLV, in contrast with the results of spectral synthesis in the available models of the solar atmosphere. Both in the wings and core of the Lyman-alpha line, the linear polarization signals show local variations with a scale of ~10 arcsec, which confirms that the Lyman-alpha polarization is also sensitive to the 3D structure of the solar atmosphere.

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Type of contribution: Standard talk

Author(s): Sami K. Solanki

Title: First results from the second science flight of Sunrise

Abstract:
The balloon-borne solar observatory Sunrise flew for a second time in June 2013 and provided seeing-free spectropolarimetric data at close to the diffraction limit of the 1m telescope. The data analysis has so far concentrated on a time series of the heart of an active region recorded in the Stokes vector of the Fe I 525.02 nm line and a time series of UV images of the same region. First results suggest the presence of very strong fields in pores, a low-lying canopy of slender fibrils and waves propagating along these fibrils. Furthermore, properties of the complex emergence of magnetic flux, of moving magnetic features around a pore and of a siphon flow along a low-lying slender magnetic loop are determined. A novel technique for inversions of Stokes profiles including constraints to make the results more physically consistent has also been developed and for the first time applied to Sunrise II data. These and more results will be briefly presented.

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Type of contribution: Standard talk

Authors: J. Stepan, J. Trujillo Bueno, L. Belluzzi, A. Asensio Ramos, R. Manso Sainz, and the CLASP team

Title: CLASP: Lyman-alpha spectropolarimetric observations versus radiative transfer modeling

Abstract:
The Chromospheric Lyman-Alpha Spectro-Polarimeter (CLASP) was launched on September 3, 2015. The sub-orbital NASA sounding rocket carried the vacuum ultraviolet telescope and the spectropolarimeter that performed the first successful measurement of the hydrogen Ly-alpha intensity and linear polarization profiles of the upper solar chromosphere and transition region. The experiment aimed at reaching two main scientific goals motivated by previous theoretical studies: (1) to measure scattering polarization signals on quiet regions of the solar disk, and (2) to infer information on magnetic fields in the chromosphere-corona transition region. The Ly-alpha line polarization is produced by scattering of anisotropic radiation and modified by the action of magnetic fields via the Hanle effect. Here we report on comparisons between the CLASP observations at various distances from the solar limb and radiative transfer calculations in 1D and 3D models of the solar atmosphere.
Although the theoretical results are largely consistent with the observations, we find that the peculiar center-to-limb variation of the line-center Q/I signals observed by CLASP can only be explained by assuming that the magnetization and/or the geometrical complexity of the chromosphere-corona transition region is significantly larger than previously thought.

Session 4-II

Space-borne polarization measurements: observations, analysis and interpretation

Posters

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Type of contribution: Poster

Author(s): Di Serego Alighieri, Sperello

Title: The conventions for the polarization angle

Abstract:
Since more than a century astronomers measure the position angle of the major axis of the polarization ellipse starting from the North direction and incresing counter-clockwise, when looking at the source. This convention has been enforced by the IAU with a Resolution in 1974. Much later unfortunately the WMAP satellite, which has observed the CMB polarization, decided to adopt the opposite convention: the polarization position angle is measured starting from the South and increasing clockwise looking at the source. This opposite convention is causing obvious problems and misunderstandings. The attempts and prospects towards a solution will be described.

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Type of contribution: Poster

Author(s): N. Narukage, R. Kano, R. Ishikawa, A. Winebarger, K. Kobayashi, J. Trujillo Bueno, and CLASP team

Title: Temporal variation in the Ly-alpha linear polarization observed with the CLASP sounding rocket

Abstract:
Our international team developed the Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP). CLASP aimed at measuring for the first time scattering polarization in the hydrogen Ly-alpha line (121.6 nm) and at probing the magnetization of the upper chromosphere and transition region via the Hanle effect. This experiment requires precise spectropolarimetric observations with a 3 sigma polarimetric sensitivity of ~ 0.1 % and a wavelength resolution of 0.01 nm. On 3rd September 2015, CLASP was launched from White Sands Missile Range (New Mexico, USA) using a NASA sounding rocket. During five minutes, CLASP successfully observed the Stokes I, Q, U profiles of the hydrogen Ly-alpha line with a polarization accuracy of 0.1 %. Using the CLASP data, we can track the temporal variation in the Ly-alpha linear polarization, with a 2 sigma polarization accuracy of ~ 0.1 %, a spatial resolution of ~ 6 arcsec (sufficient to see chromospheric structures), and a spectral resolution of 0.02 nm. The CLASP data shows that the linear polarization signals of the Ly-alpha line vary within a range of a few 0.1 % during about 200 sec. We show that the tracked temporal variations can be classified into several types, which we discuss carefully.

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Type of contribution: Poster

Author(s): Hanna Strecker, Nazaret Bello González

Title: Sunspot decay: Transition from moat flow to supergranular flow cell

Abstract:
Fully-fledge sunspots are known to be surrounded by a radial outflow - the moat flow. Here, we investigate the evolution of the horizontal flow field around sunspots during sunspot decay by means of SDO/HMI Dopplermaps. The main aspects which are analysed are the velocity and the extension of the flow field. All investigated, fully-developed sunspots are surrounded by an outflow whose horizontal velocity profile decreases continuously from 677-1051 m/s, at the sunspot boundary, down to 174-265 m/s at a mean distance of 10.63 Mm to the sunspot. These values are characteristic for the moat flow. For each sunspot, an individual behaviour for its decay and for the surrounding flow field can be observed. Yet, the flow field shows a common behaviour: After the penumbra is fully dissolved, the velocity profile of the flow field changes. The velocity increases with distance to the sunspot until a maximal value of 262-519 m/s is reached. Then, it decreases for larger distances. This flow field shows similar properties to horizontal flow profiles and velocities measured in supergranules when the same method is applied.
The different observed characteristics suggest that, as long as the penumbra is present, the sunspot with its moat cell is embedded in the network. The disappearance of the penumbra has a significant role in the evolution of the flow field: The moat cell transforms into a cell with characteristics similar to that of a supergranule including the remaining pore.

Session 5

Instrumentation for polarization studies

Review talks

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Type of contribution: Standard talk

Author(s): Wenda Cao

Title: The 1.6 Meter New Solar Telescope at Big Bear Solar Observatory

Abstract:
The 1.6-m New Solar Telescope (NST), at Big Bear Solar Observatory, is currently the worldís highest-resolution solar telescope, with long periods of excellent seeing due to its location at an excellent lake site in Big Bear, California, and equipped with high-order adaptive optics (AO) that, together with image processing techniques, provides diffraction-limited spatial resolution (~ 0.1”). Since 2013 after its commissioning, NST has regularly provided high resolution data covering the spectral range from 0.4 to 5.0 μm to photometrically, spectroscopically and polarimetrically probe the solar atmosphere from the deepest photosphere to the base of the corona, from the smallest scales to largest scales, and from the quietest to most active Sun. This presentation reports the up-to-date progress on the NST and its next generation instruments including the AO systems (GLAO & MCAO), the Near-InfraRed Imaging Spectro-polarimeter (NIRIS), the Visible Imaging Spectrometer (VIS), and the Cryogenic Infrared Spectrograph (CYRA).

Session 5

Instrumentation for polarization studies

Standard talks

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Type of contribution: Standard talk

Author(s): Kwangsu Ahn, Wenda Cao

Title: Calibration of the Instrumental Crosstalk for the Near-IR Imaging Spectropolarimeter at the NST

Abstract:
The Near-IR Imaging Spectropolarimeter (NIRIS) is a polarimeter that is installed at the New Solar Telescope at Big Bear Solar Observatory. This instrument takes advantages of the highest spatial resolution and flux. The primary mirror is an off-axis type, so it was our interest to evaluate its contribution to the crosstalk among the Stokes parameters since we could put our calibration optics before the mirror. We would like to present our efforts to compensate for the crosstalk among Stokes profiles caused by the relay optics from the telescope to the detector. The overall data processing pipeline is also introduced.

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Type of contribution: Standard talk

Author(s): Tom Baur, Michael Kraemer and Daniel Phipps

Title: New Optical tools for polarimetry and polarization control

Abstract:
Recent materials advances enable new optical components that are useful for solar polarimetry. These include a high speed modulator similar to common ferroelectric devices but achromatic in its performance. We will also discuss newer options for beamsplitting polarizers and retarder coatings that can be applied to optical elements and that can be patterned. Superachromatic retarder options will be discussed.

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Type of contribution: Standard talk

Author(s): R. Forte, F. Berrilli, S. Jefferies, N. Murphy, E. Pietropaolo, D. Del Moro, L. Giovannelli et al.

Title: The calibration pipeline for the MOTH II – Magneto Optical filters at Two Heights

Abstract:
We present the calibration procedures used by the automatic reduction pipeline running at the solar telescope Magneto Optical filters at Two Heights (MOTH II). The MOTH II, located at the Mees Observatory (Maui, USA) and operated by IfA - University of Hawaii, consists in a dual-channel optics mounting magneto-optical filters (MOF) at 589 nm (Na D2-line) and 770 nm (K I-line).
The MOTH II reduction pipeline is applied to level 0 MOTH II images (red and blue spectral points and two circular polarization states) before the data are passed to users: level 1 and 2 FITS. The MOTH II reduction pipeline includes: bias and dark subtraction, atmospheric transparency correction, bad pixels mask, flat-fielding, leakage correction, image registration (translation, rotation and scale parameters). The instrument is able to perform multi-line, high-cadence synoptic observations of the Sun and solar activity to investigate the dynamics of line-of-sight magnetic field and velocity at two heights of the solar atmosphere. These data will allow to study and evaluate new flare forecasting methods for Space Weather prediction.

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Type of contribution: Standard talk

Author(s): Demidov M.L., Wang X.F., Hou J.F., Wang D.G., Kiselev A.V.

Title: On the cross-calibration of the HSOS SMAT full disk longitudinal magnetograms with data sets from some other instruments

Abstract:
The reliable information about distribution of magnetic fields across the whole solar surface is important for many solar and space weather issues. There are some ground-based and space telescopes which provide such observations with different spatial resolution and in different spectral lines. The problem is that measurements from different instruments could differ quite significantly, what among other things cause the difference of results in extrapolations (e.g. position and size of coronal holes). So the cross-calibration of different data sets and searching of possible reasons for their systematic differences are extremely reasonable.

The aim of this study is in first time comprehensive analysis of the Huairou Solar Observation Station's (HSOS) Solar Magnetic Activity Telescope (SMAT) of full disk longitudinal magnetograms (spectral line FeI 532.4 nm). Some instrumental and methodical peculiarities of Lyot IPF-based SMAT telescope are presented. The regression and correlation comparison of SMAT magnetograms with ones obtained at STOP telescopes (Irkutsk, Russia) (line FeI 525.0 nm) and SDO/HMI (line FeI 617.3 nm) have shown the existence of essential differences of SMAT measurements from other ones for some periods of time. The possible reasons for that are considered and the ways to re-calibrate such observations are suggested. Simultaneous observations in both spectral lines (525.0 nm and 532.4 nm) made at STOP were very useful for that purpose. It is pointed out that observations at SMAT in combination with other data could be used for diagnostics of solar magnetic fields. The results obtained in this study partly due to support from a cooperative project under NSF of China and RFBR of Russia (grant 15-52-53125 GFEN_a).

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Type of contribution: Standard talk

Author(s): David Harrington, Stacey Sueoka

Title: DKIST Polarization Modeling and Performance Predictions

Abstract:
The Daniel K Inouye Solar Telescope (DKIST) polarimetric instrumentation requires very high accuracy calibration of a complex coude path with an off-axis f/2 primary mirror, time dependent optical configurations and substantial field of view. Polarization predictions have been created in Zemax across a diversity of optical configurations, tracking scenarios, slit geometries and optical coating formulations. Recent daytime sky based polarization calibrations of the 4m AEOS telescope and HiVIS spectropolarimeter on Haleakala have provided system Mueller matrices over full telescope articulation for a 15-reflection coude system which matches the behavior predicted in Zemax. These new modeling tools and polarization predictions have substantial impact for the design, fabrication and calibration process in the presence of manufacturing issues, science use-case requirements and ultimate system calibration limitations in the complex DKIST optical train.

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Type of contribution: Standard talk

Author(s): Junfeng Hou

Title: Spectral-modulation-based polarization calibration method for AIMS telescope

Abstract:
We describe a novel method for the polarization calibration of AIMS (Accurate Infrared Magnetic field Measurements of the Sun) telescope. A pair of thick multi-order retarders is incorporated into the polarization calibration unit (PCU), so the detected channeled spectrum intensity by telescope is composed of three quasi-cosinusoidal components of wave number carrying the information about polarization response parameters of telescope that is being measured. Fourier inversion of the channeled spectrum intensity determines the polarization response parameters of telescope. No mechanically movable or modulated components for PCU are used, and all the polarization response parameters can be determined at once from only the single spectrum. We discuss the effectiveness and limit of this method for the mid-infrared telescope AIMS.

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Type of contribution: Standard talk

Author(s): F. Landini, M. Pancrazzi, M. Focardi, C. Baccani, M. Romoli

Title: PENCIL: a wire grid polarimeter at 121.6 nm

Abstract:
The magnetic field (MF) in corona can be measured through the Hanle effect, which is the MF induced modification of the linear polarization signals produced by anisotropic scattering processes. The HI Lyman-alpha 121.6 nm is the most intense emission line of the EUV coronal spectrum. It is formed by resonant scattering of the underlying chromospheric emission, and is thus sensitive to the Hanle effect. Through the comparison between the measured and the expected polarization in the HI line it is possible to infer the component of the MF along the line of sight.
PENCIL (Polarimetry with Nanowires for Coronal Imaging of Ly-alpha) may constitute the ideal candidate to measure the linear polarization of the whole Lyman-alpha 121.6 nm corona. It is a transmitting polarimeter optimized for the Ly-alpha 121.6 nm line, thought as part of an internally occulted coronagraph to be flown aboard a future small solar mission or a sounding rocket. It is a light device, completely free of mechanical moving parts, made by a fixed MgF2 quarter wave retarder, a nano-wire grid polarizer (nano-WGP), a MgF2 variable retarder modulated through a calibrated piezo-clamp (PCVR), and the needed relay optics.
The nano-WGP and the PCVR are the two main components of PENCIL and represent a first-ever achievement in the history of technology development for VUV.
This talk will address the status of the project with particular emphasis on the design and manufacturing of the nano-WGP and the PCVR.

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Type of contribution: Standard talk

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Title: Progresses in Shaping Fiber Arrayed Solar Optic Telescope (FASOT)

Abstract:
Since proposed in 2009, Fiber Arrayed Solar Optic Telescope has been achieved to the second stage. The prototype FASOT has been finished and some results are obtained from solar eclipse spectro-imagng-polarimetry that shows complex profiles in solar corona. A reduced polarimetric optic switching procedure is presented to promote the temporal resolution while the polarimetric sensitivity can be achieved as same as that from the traditional polarimetric optic switching. Now we are on the way to construct a second generation of FASOT, aiming at the normal spectro-imaging-polarimetry of multiple lines with a couple of 64 by 64 Integral Field Unit(IFU).

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Type of contribution: Standard talk

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Title: Progress in modeling polarization optical components for the Daniel K. Inouye Solar Telescope

Abstract:
The Daniel K Inouye Solar Telescope (DKIST) will have a suite of first-light polarimetric instrumentation requiring calibration of a complex off-axis optical path. The DKIST polarization calibration process requires modeling and fitting for several optical, thermal and mechanical effects. Three dimensional polarization ray trace codes (PolarisM) allow modeling of polarization errors inherent in assuming a linear retardation as a function of angle of incidence for our calibration retarders at Gregorian focus. Stress induced retardation effects from substrate and coating absorption, mechanical mounting stresses, and inherent polishing uniformity tolerances introduce polarization effects at significant levels. These effects require careful characterization and modeling for mitigation during design, construction, calibration and science observations. Modeling efforts, amplitude estimates and mitigation efforts will be presented for the suite of DKIST calibration optics planned for first-light operations.

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Type of contribution: Standard talk

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Title: Polarization modeling for the main optics of Chinese Giant Solar Telescope

Abstract:
Chinese Giant Solar Telescope, which has an 8m diameter segmented primary mirror, is a plan for the next generation ground-based large solar telescope in China. A major scientific requirement for this telescope is the high accuracy polarimetry. In this paper, the instrumental polarization of the main optics is analyzed by polarization modeling, which is caused by off-axial field of view, spider asymmetry, nonuniform segment gap and segment coating. The result shows that the net polarization is sensitive to the asymmetrical spider leg widening and the uniformity of the segment optical property. For meeting the accuracy requirement, the extinction ratio and retardence error for each segment should be less than 0.3% and 0.8 degree, respectively. Generally, the ring segmented primary mirror have advantage in controlling the instrumental polarization for large main optics.

Session 5

Instrumentation for polarization studies

Posters

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Type of contribution: Poster

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Title: Developments of a spectro-polarimeter observing multi-wavelength windows simultaneously at Hida observatory

Abstract:
To observe full Stokes spectra in multi-wavelength windows simultaneously, we developed a new spectro-polarimeter on the Domeless Solar Telescope at Hida Observatory. The new polarimeter consists of a 60 cm aperture vacuum telescope, an adaptive optic system, an image rotator, a high dispersion spectrograph, polarization modulator and analyzer composed of a continuously rotating wave plate whose retardation is nearly constant in 450 - 1100 nm and a polarimetric beam splitter located closely behind the focus of the telescope, fast and large format CMOS cameras and an infrared camera. The slit spectrograph allows us to obtain spectra in as many wavelength windows as the number of cameras. We developed the polarization modulator and the analyzer, and calibrated instrumental polarizations of the image rotator and the adaptive optic system.

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Type of contribution: Poster

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Title: First results from the Chromosphere and Prominence Magnetometer ChroMag

Abstract:
The Chromosphere and Prominence Magnetometer (ChroMag) is an instrument with the goal of quantifying the intertwined dynamics and magnetism of the solar chromosphere and in prominences through imaging spectro-polarimetry of the full solar disk in a synoptic fashion. The picture of chromospheric magnetism and dynamics is rapidly developing, and a pressing need exists for breakthrough observations of chromospheric vector magnetic field measurements that can be considered to be a lower boundary of the heliospheric system. ChroMag will provide measurements that will enable scientists to study and better understand the energetics of the solar atmosphere, how prominences are formed, how energy is stored in the magnetic field structure of the atmosphere and how it is released during space weather events like flares and coronal mass ejections.
A prototype ChroMag instrument is currently deployed in Boulder, CO, USA. We will present an overview of instrument capabilities, a progress update on the ChroMag development, and show initial results.

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Type of contribution: Poster

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Title: Application of New Birefringent Tunable Filters at Hida Observatory

Abstract:
New birefringent tunable filters were developed by utilizing liquid crystal variable retarders as tuning elements at Hida observatory. One of them (UTF-32) is a universal one that is applicable for the wavelength range of 500 - 1100nm. Using this filter we realized a dual camera observing system on the Domelass Solar Telescope at Hida observatory. The system enable us to take images in Ha+/-0.5A simultaneously for obtaining high precision Dopplergrams to study the chromospheic dynamics. The other one (TF-40) is dedicated for Ha and it is used for a synoptic solar observation for taking large dynamic range Dopplergrams. The system, Solar Dynamics Doppler Imager, aims to capture the velocity of high speed eruptions in 3D space and to contribute the space whether prediction. Overview of the new observing systems will be presented together with the performance of the tunable filters.

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Type of contribution: Poster

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Title: Polarization-holographic imaging Stokes polarimeter for observational study of the Sun

Abstract:
We present an innovative polarization-holographic imaging Stokes polarimeter based on an integral polarization-holographic diffraction element, which enables the complete real time analysis of the polarization state of an incoming light. An element, recorded in a laboratory by a special holographic schema using circularly and linearly polarized beams, decomposes an incoming light into diffraction orders the intensities of which vary depending on the polarization state of a light source.
After the CCD intensity measurements of the corresponding points or areas in the diffraction orders and further data reduction through the calibration parameters we get the real-time Stokes images of a light source which allows to determine full polarization state of a point or extended space object in narrow or wide spectral range.
The operating spectral range of the polarimeter is 500-1600 nm with diffraction efficiency equal to 20% at 532 nm, 16% at 635 nm and 2% at 1550 nm.
The theoretical model of relations between measured intensities in different diffraction orders and Stokes parameters, developed by the authors (Kilosanidze B., Kakauridze G. SPIE Proceedings, vol. 8082-126, 2011), were used to calibrate the polarimeter. The laboratory tests show that the resulting errors are near of 1% or better. First polarimetric test images were obtained for stars and the Sun.
The polarimeter is compact, light weight and could be installed both on ground-based or airborne telescopes.

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Type of contribution: Poster

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Title: Tomographic Mission from Space to Disentangle the 3D Magnetic and Thermodynamic Structures of the Solar Corona

Abstract
Decades after the discovery of energetic solar eruptions, the physics governing these phenomena are still not well understood. While generations of space observatories had yielded invaluable information, the critical information about the structure and evolution of the magnetic fields in the solar corona, and their interaction with the highly ionized plasma remain missing. Therefor the development of the capability to determine the 3D magnetic and thermodynamic structures of the solar corona with sufficient spatial and temporal resolution that also cover a large volume during energetic solar eruptions is now one of the most urgent task for the advancement of coronal research. However, we have witnessed important advancements in instrumentation for coronal magnetometry, and in tomographic inversion techniques using coronal intensity and polarized spectra to derive the 3D magnetic fields, temperature, and density structures of the corona. This paper describes a new mission concept consists of a constellation of spacecraft in circumsolar orbits to obtain simultaneous coronal intensity and polarization data from multiple sight lines. Each spacecraft consists of a small coronagraph equipped with a massively multiplexed spectropolarimeter capable of measuring the polarized spectra of multiple coronal emission lines simultaneously. This mission will allow us to observationally determine the 3D structures of the coronal magnetic field, temperature, and density, and to follow the evolution of energetic solar eruptions.

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Type of contribution: Poster

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Title: CLASP2: The Chromospheric LAyer Spectro-Polarimeter

Abstract:
Recent observational advances by the Interface Region Imaging Spectrometer (IRIS) have revolutionized our view of the highly dynamic upper solar chromosphere and the critical role this interface region plays in energizing and structuring the outer solar atmosphere. A major remaining challenge for heliophysics is to decipher the magnetic structure of the chromosphere, important because of its role in energy transport into the corona and heliosphere. The hydrogen Lyman-alpha line at 121.6 nm and the Mg II k line at 279.5 nm are especially relevant since their line-center signals are formed in the chromosphere and transition region and also because their polarization signals have unique sensitivities to magnetic fields: both are sensitive to the magnetic field via the Hanle effect, while the Mg II h & k lines are sensitive to weaker fields, and importantly are also sensitive to the Zeeman effect.
We propose the Chromospheric LAyer Spectro-Polarimeter 2 (CLASP2), to build upon the success of the first CLASP flight, which measured the linear polarization in H Ly-a. The existing CLASP instrument will be refitted to measure all four Stokes parameters in the 280 nm range, including variations due to the anisotropic radiation pumping, the Hanle effect, and the Zeeman effect. CLASP2 is highly synergistic with IRIS, and serves as a pathfinder for missions to measure the magnetic field in the upper chromosphere and transition region.

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Type of contribution: Poster

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Title: Fine Magnetic Structure and Origin of Counter-streaming Mass Flows in a Quiescent Solar Prominence

Abstract:
We present observations of a quiescent solar prominence that consists of a vertical and a horizontal foot encircled by an overlying spine and has ubiquitous counter-streaming mass flows. While the horizontal foot and the spine were connected to the solar surface, the vertical foot was suspended above the solar surface and was supported by a semicircular bubble structure. The bubble first collapsed, then reformed at a similar height, and finally started to oscillate for a long time. We find that the collapse and oscillation of the bubble boundary were tightly associated with a flare-like feature located at the bottom of the bubble. Based on the observational results, we propose that the prominence should be composed of an overlying horizontal spine encircling a low-lying horizontal and vertical foot, in which the horizontal foot consists of shorter field lines running partially along the spine and has ends connected to the solar surface, while the vertical foot consists of piling-up dips due to the sagging of the spine fields and is supported by a bipolar magnetic system formed by parasitic polarities. The upflows in the vertical foot were possibly caused by the magnetic reconnection at the separator between the bubble and the overlying dips, which intruded into the persistent downflow field and formed the picture of counter-streaming mass flows. In addition, the counter-streaming flows in the horizontal foot were possibly caused by imbalanced pressure at the both ends.

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Type of contribution: Poster

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Title: Lyot Filter Based on Liquid Crystal Variable Retarder

Abstract:
Lyot filte based on Liquid Crystal Variable Retarder (LCVR) excluded motor, so as to greatly improves the performance of the equipment. This is a big advantage for space mission in reliability. Because of that, it avoid the oil-leaking between moving parts and interference to satellite pointing accuracy. It reduces electricity consumption and makes thermal control easy. Of course it is small and light compare to typical. This paper will introduce the development of this kind of Lyot filter in design and measurement.

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Type of contribution: Poster

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Title: Polarimetric Measurement System of Lijiang 2.4 meter telescope

Abstract:
We are constructing a linear polarimetric system to be mounted into Lijiang 2.4m general optical telescope (LJT) in order to make the telescope capable of imaging-polarimetry and spectro-polarimetry. This polarimetric instrument will be integrated onto the YFOSC (Yunnan Faint Object Spectrograph and Camera), and consists of accurate polarimeters control system on a narrow space of filter wheel. After the establishment, the capability of the telescope will be expanded to contain the polarimetry of bright objects, and thus the research fields can be extended further, especially to the fields of the Stellar physics, Gamma-Ray Bursts, Active Galactic Nuclei and Supernova explosions, etc.