Major Challenges in Solar Physics

Sami Solanki

MPS, Goettingen, Germany

Abstract: The Sun is a complex object, with many different size and time-scales. These lead to a fragmentation of solar research due to the need for different instruments and theoretical tools to study different solar layers. This is in contrast to the nature of the Sun itself, which is a strongly coupled system, with different coupling agents, of which the magnetic field plays the leading role in the solar atmosphere. The key to the formation of the magnetic field in turn lies in the solar interior. In addition, many of the physical processes in the solar atmosphere occur at scales that cannot be directly accessed by current instruments. Consequently, it is not surprising that in spite of considerable efforts over the last decades, many of the Sun's secrets have not been uncovered. In this talk some of the important open questions in solar physics will be presented and how it is planned to address these by present and future solar facilities and space missions.

Session I -- Generation of Magnetic Field

Dynamo Models: where do we stand?

Kandaswamy Subramanian

IUCAA, Pune, India

Abstract: Understanding large scale turbulent dynamos which work at high Magnetic Reynolds numbers, like the solar dynamo, requires several issues to be resolved. The first is that of magnetic helicity of conservation and its consequences. Unless the Sun rids itself of small scale magnetic helicity, its dynamo could be catastrophically quenched. Further, at the kinematic stage the magnetic power at large Rm is necessarily peaked at resistive scales, and non linear evolution has to be such that it moves power to at least the turbulent scales, and then larger scales. Third, the calculation of turbulent transport co-efficients at high Rm, so useful in mean field models, requires a closure even for the kinematic stage. This could result in new effects which have not yet been taken into account in solar dynamo models. The talk will discuss all three issues in the context of the solar dynamo.

Solar Cycle Forecasting : The Underlying Physics

Dibyendu Nandi

IISER-Kolkata, India

Abstract: Predicting the strength of future solar cycles is important for mitigating the adverse impacts of space weather on our technologies based in space and on Earth. However, reliable solar cycle forecasting is still not possible due to a number of uncertainties regarding the theoretical basis of the solar cycle itself. For the ongoing solar cycle 24, no early consensus was achieved by the NOAA-NASA International Solar Cycle Prediction Panel and official forecasts were revised multiple times. In this talk, I will review our current understanding of the solar cycle and critically discuss the reasons behind diverging dynamo-based solar cycle forecasts. I will also present recent advances in understanding the underlying physics that may lead to more accurate solar cycle predictions.

Magnetohydrodynamic simulations of stellar differential rotation and meridional circulation

Bidya Binay Karak, Matthias Rheinhardt, Axel Brandenburg, Petri J. Kapyla & Maarit J. Mantere

NORDITA, Sweden

Abstract: We have studied some aspects of solar-like and anti-solar differential rotations using global compressible MHD simulations in spherical geometry. By taking different radiative conductivities, the convective velocities and hence the rotational influence is varied in a set of simulations. When we decrease the Coriolis number, differential rotation changes from solar-like to antisolar. We find that the magnetic field helps to produce solar-like differential rotation. In our simulations

we do not find any evidence of the bistable states of differential rotation which has been previously observed in hydrodynamic simulations. In the anti-solar differential rotation cases we get coherent single cell meridional circulations, whereas in solarlike rotation we get multi-cellular circulations. In all cases, the poleward propagating speed near the surface is close to the observed value. The large-scale flows show significant temporal variations which are also in observational ranges.

Is a Deep One-cell Meridional Circulation Essential for the Flux Transport Solar Dynamo?

Gopal Hazra, Bidya binay karak , Arnab Rai Choudhuri

Indian Institute of Science, Bangalore, India

Abstract: The most extensively studied theoretical model for solar activity cycle is the flux transport dynamo model, which usually assumes a single cell meridional circulation with equatorward return flow at the bottom of the convection zone. In view of the recent claims that the return flow occurs at a much shallower depth, we explore whether a meridional circulation with such a shallow return flow can still retain the attractive features of the flux transport dynamo. We find that we can retain most of the attractive features of the flux transport dynamo model if there is an equatorward flow in low latitudes at the bottom of the convection zone, even with a complicated multi-cell structure.

Session II -- Sub-surface Structure of

Large Scale Flows

Laurent Gizon

MPS, Goettingen, Germany and Institute of Astrophysics, Goettingen University, Germany

Abstract: In this lecture I will introduce helioseismology and discuss how it can be used to probe large scale motions in the solar interior. The variations of the angular velocity Ω with radius and latitude were revealed in the nineties by the SOHO/MDI and GONG mode frequency splittings. While SDO/HMI confirms the general picture, it leads to more accurate inferences of rotation at higher solar latitudes. In particular, a recent analysis by Barekat et al. shows that $d \ln \Omega / d\ln r \simeq -1$ in the near-surface shear layer at all latitudes up to 60 deg (no switch of sign at 55 deg as previously suggested). In parallel, work is under way to infer the meridional flow in the solar interior using local helioseismology --- a very challenging task given our lack of understanding of systematic errors. Finally, I will present new results by Langfellner et al. and Fournier et al. who used local helioseismology and granulation tracking to observe the effects of rotation on turbulent convection (anisotropic velocity correlations), which are thought to be responsible for the maintenance of the large-scale flows.

Imaging convection in the solar interior

Shravan Hanasoge

Tata Institute of Fundamental Research, Mumbai, India

Abstract: Seismic analyses of observations taken by the Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory (satellite) reveal convective velocities that are almost two orders in magnitude smaller than current theoretical and computational predictions. The associated Reynolds stresses would be too small to explain the observed large-scale flow systems of meridional circulation and differential rotation in the convection envelope of the Sun, throwing into question models of dynamo action. In this talk I will describe the analysis and discuss difficulties associated with rigorously inverting for flows.

Photospheric and Sub-photospheric Large Scale Flows in Active Regions

Kiran Jain, S. C. Tripathy, B. Ravindra, R.W. Komm, S. Gosain and F. Hill

National Solar Observatory, USA

Abstract: Determination of plasma flows in photospheric and sub-photospheric layers is important to understand the dynamics and structure of these layers. These flows also provide connections between solar interior and photosphere. In this paper, we present properties and dynamics of horizontal flows in the regions of strong magnetic field. We use full-disk high-resolution Doppler and magnetic

observations from both space-borne Helioseismic Magnetic Imager (HMI) and ground-based Global Oscillation Network Group(GONG). The photospheric flows are calculated using local correlation tracking (LCT) and differential affine velocity estimator for vector magnetograms (DAVE4VM) methods while ring-diagram technique is used to infer flows in the sub-photospheric layers. A detailed comparison between flows in sub-photospheric shear layer and photospheric layer will also be made in order to study similarities and discrepancies in these results.

Dynamics of small-scale granular cells

Birgit Lemmerer, Hanslmeier, A., Utz, D., Veronig, A., Grimm-Strele, H., Piantschitsch, I.

University of Graz, Austria

Abstract: High resolution solar simulations and observations indicate the existence of a subpopulation of granular cells that are smaller than 600 km. How they form and dissipate is unclear. Simulations suggest that small granules may not result from fragmentation of larger granular cells but instead evolve and dissolve in regions of intergranular lanes, rarely merging with other granules. In this study we investigate the formation and dynamics of these granular cells in two and three dimensions. We present newly developed algorithms that identify and track their evolution from the point of appearance to their dissolution. The algorithms are applied to data from observations and 3D numeric simulations. We investigate the structural variation of granules in 2D and their interaction with the surrounding convective cells, vortex motion and magnetic flux tubes, and study their 3D evolution and topology in the convection zone.

Session III -- Magneto-Convection and Transport

Magneto-Convection, the Small-scale and the Large-scale Dynamo

Matthias Rempel

High Altitude Observatory, USA

Abstract: Small-scale magnetic field is ubiquitous in the solar photosphere and in its properties mostly independent from the solar cycle, i.e. the large-scale field component. While likely both, the large- and small-scale dynamos contribute to the observed magnetic field, recent research points toward a dominant contribution from a small-scale dynamo. In this talk I review progress made in numerical simulations of small-scale dynamo action in the solar photosphere and bulk of the solar convection zone. It is found that an efficient small-scale dynamo operating just in the uppermost layers of the convection zone is not sufficient. The observationally inferred level of quiet Sun magnetic field implies small-scale dynamo action throughout the solar convection zone across all scales. Under these circumstances there is no clear separation between small- and large-scale dynamo action and vertical transport of mixed polarity magnetic field into the photosphere through convective upflows significantly influences the saturation field strength of the photosphere. Compared to the latter, a net flux imbalance (i.e. magnetic flux from active regions) is found to have only a weak influence on the amount of mixed-polarity field in the photosphere. While the observed quiet Sun magnetic field is generally regarded as rather weak, models that are consistent with observations imply a convection zone that is magnetized close to equipartition. I will conclude my talk with a discussion of potential dynamical consequences from a magnetic field that reaches equipartition strength throughout most of the convection zone. Recent research points toward a significant influence of magnetic stresses on angular momentum and energy transport in the bulk of the convection zone.

Transport of magnetic fields from the convection zone to the corona

Fernando Moreno-Insertis

Instituto de Astrofisica de Canarias, Spain

Abstract: Many of the traditional barriers between different subfields within theoretical solar physics (like: solar interior, photosphere, chromosphere and corona; magnetofluid dynamics and radiation transfer; high- and low-beta plasmas) have to be lifted when dealing with the emergence of magnetized plasma from the subphotospheric layers into the low atmosphere and the corona. This leads to a substantial complication of this field when trying to understand the underlying basic physical phenomena. Progress is being achieved in large part thanks to the use of numerical modeling with the large multidimensional radiation-MHD numerical codes that have been developed over the past years and decades. In this lecture, I will describe a few attempts at understanding physical processes related with the emergence of magnetized plasma which are of particular current interest: first, magnetic flux emergence in a quiet-Sun region, in which flux appears in moderate amounts, less than \$10^{18}\$ Mx, and typically within individual granules, leading first to bipolar structures and then to flux sheets at intergranular lanes. In some cases, the magnetic flux further rises into the chromosphere and low corona where it interacts with the ambient coronal field. In the second part, attempts at understanding the physics of coronal jets as observed on larger scales in the EUV

and X-Rays will be presented.

Formation of intense bipolar regions in spherical dynamo simulations with stratification

Sarah Jabbari, Axel Brandenburg, Dhrubaditya Mitra

NORDITA, Sweden

Abstract: We study a system of a highly stratified turbulent plasma. In such a system, when the magnetic Reynolds number is large enough and there is a background field of suitable strength, a new effect will play role in concentrating magnetic fields such that it leads to the formation of magnetic spots and bipolar regions. This effect is due to the fact that the turbulent pressure is suppressed by the large-scale magnetic field, which adds a negative term to the total mean- field (effective) pressure. This leads to an instability, which is known as the negative effective magnetic pressure instability (NEMPI). Direct numerical simulations (DNS) of isothermally forced turbulence have shown that NEMPI leads to the formation of spots in the presence of an imposed field. Our main aim now is to use NEMPI to explain the formation of active regions and sunspots. To achieve this goal, we need to move progressively to more realistic models. Here we extend our model by allowing the magnetic field to be generated by a dynamo. A dynamo plays an important role in solar activity. Therefore, it is of interest to investigate NEMPI in the presence of dynamo-generated magnetic fields. Mean-field simulations (MFS) of such systems in spherical geometry have shown how these two instabilities work in concert. In fact NEMPI will be activated as long as the strength of the magnetic field generated by the dynamo is in a proper range (for more detail see Jabbari et al. 2013). In our new study, we use DNS to investigate a similar system. The turbulence is forced in the entire spherical shell, but the forcing is made helical in the lower 30% of the shell, similar to the model of Mitra et al. (2014). We perform simulations using the Pencil Code for different density contrasts and other input parameters. We applied vertical field boundary conditions in the r direction. The results show that, when the stratification is high enough, intense bipolar regions form and as time passes, they expand, merge and create giant structures. At the same time, the new structures appear at different latitudes. By extending in the Ï† direction, the size of the bipolar regions decreases. When the helical zone is thinner, the structures appear at a later time.

The importance of a coronal envelope for modeling the global turbulent dynamo of the Sun.

Joern Warnecke, P.J. Kapyla, M.J. Mantere, A. Brandenburg

MPG, Goettingen, Germany

Abstract: Global simulations of turbulent convective dynamos are now able to reproduce many features observed on the Sun. The magnetic field shows an equatorward migration and the differential rotation has a conical spoke- like structure. In this work we report on results obtained by spherical wedge simulations with and without a coronal envelope. This coronal envelope resambles a "free" boundary for the magnetic field, the temperature fluctuations and the flow. A coronal envelope results in a different magnetic field pattern but prefers a

spoke- like differential rotation with multi-cellular meridional circulation. Numerical simulations of turbulent dynamos show that the amplification of magnetic fields can be catastrophically quenched at magnetic Reynolds numbers typical of the interior of the Sun. A strong flux of magnetic helicity leaving the dynamo domain can alleviate this quenching. As the matter of fact, simplified spherical forced turbulent simulations produce CME-like ejections of current helicity and indicate that the dynamo action benefits substantially from the presence of a corona.

Session IV – Photospheric Magnetic Field

Photospheric Magnetic Field: what are the remaining open questions?

Robert Cameron

MPS, Goettinge, Germany

Abstract: The photosphere is the most observed layer of the Solar atmosphere. The observations are rich in information, and the plasma conditions in various types of photospheric magnetic structures have been investigated in exquisite detail. It is also the simplest layer of the solar atmosphere to model because both the fluid and LTE assumptions are appropriate for at least most of its dynamics. For these two reasons substantial progress has been made in understanding the physics relevant to many different types of photospheric feature. Much however remains to be done, and this talk will outline some of the outstanding problems and why they remain open.

Sunspots

Juan Manuel Borrero

KIS, Freiburg, Germany

Abstract: Recent developments in our observing capabilities (spatial and spectral resolution), in our inference tools (inversion codes for the radiative transfer equation) as well as theoretical modelling (numerical simulations) have resulted in a myriad of new and exciting results about sunspot fine structure and dynamics. In this contribution I will review some of the the most recent fidings on the penumbra, umbral dots, light bridges and moat flow. I will also summarize some of most imporant open questions and attempt to foresee our future observational and theoretical challenges.

Quiet Sun Magnetic Fields

Sanja Danilovic

MPS, Goettingen, Germany

Abstract: Determination of magnetic field properties in the solar photosphere is challenged. Due to the weak field strength and very small scales on which relevant dynamical processes take place, the high spatial resolution of the instrumentation, combined with high sensitivity, is required. The greatest breakthroughs in recent years came from the combination of high-resolution observations with the state-of-the-art magnetohydrodynamical simulations, which enabled us to see beyond the capabilities of observations and estimate the errors of our diagnostics. Here

we summarize our current views on the quiet Sun photospheric field. We start with the dynamics on the sub-granular and granular scale, expand on the global properties of the field and end with studies of the field organization on supergranular scales.

Statistical evolution of quiet-Sun small scale magnetic features using Sunrise observations

Anusha Bhasari, Johan Hirzberger, Alex Feller, Sami, K. Solanki

MPS, Goettingen, Germany

Abstract: Recent studies of evolution of small-scale magnetic features in the quiet regions of the Sun reveal that only a small fraction of the magnetic flux in the quiet Sun is observed to emerge as bipolar structures and a relatively smaller fraction of flux are removed through cancellation of opposite polarity fields. Such unexpected results demand a detailed analysis using an independent algorithm and the best data currently available. We present results obtained with a newly developed code applied to high resolution time series of magnetograms obtained in the quiet Sun with the Imaging Magnetograph eXperiment (IMaX) on the Sunrise balloon borne telescope. We identify the small-scale magnetic features in a 20 minutes time-series data set. We develop a suitable algorithm that carefully classifies the features that participate in events such as simple appearance and disappearance, splitting, merging, bi-polar emergence and cancellation. The algorithm tracks the magnetic features by assigning a unique birth, unique death and a well defined lifetime to each of the detected magnetic feature. We then carry out an analysis of the statistical properties of these features, such as distributions of area, magnetic field, magnetic fluxes, lifetimes and their relationships. We also present a detailed study of the birth and death of magnetic features due to different events discussed above and their contribution to the total flux contained in them.

Session V – PCC II – Chromospheric Field

Chromospheric Magnetic Field and Dynamics Deduced from MHD Simulations

Mats Carlsson

Institute for theoretical astrophysics, University of Oslo, Norway

Abstract: The enigmatic chromosphere is the transition between the solar surface and the eruptive outer solar atmosphere. The chromosphere harbours and constrains the mass and energy loading processes that define the heating of the corona, the acceleration and the composition of the solar wind, and the energetics and triggering of solar outbursts (filament eruptions, flares, coronal mass ejections). The chromosphere is arguably the most difficult and least understood domain of solar physics. All at once it represents the transition from optically thick to thin radiation escape, from gas-pressure domination to magnetic-pressure domination, from neutral to ionised state, from MHD to plasma physics, and from near-equilibrium ("LTE") to non-equilibrium conditions. To diagnose the chromosphere it is therefore necessary to combine observations with numerical simulations that include a realistic description of the complicated physics of the chromosphere. In this talk, we will present such realistic simulations, spanning the solar atmosphere from the convection zone to the corona, and synthetic observations calculated from the simulations. These synthetic observations are compared with observations from the Swedish 1-m Solar Telescope (SST) and the Interface Region Imaging Spectrograph (IRIS) and chromospheric properties are deduced with special emphasis on the heating, dynamics and magnetic field properties.

The Chromospheric Field Probed by the He I 10830 line

Andreas Lagg

MPS, Goettinge, Germany

Abstract: Among the various spectral lines suitable for chromospheric magnetic field diagnostics the He I 10830 takes an extraordinary position: The special formation mechanism, requiring coronal ultra-violet (UV) radiation to populate the ground-state of ortho-Helium, makes this line almost free of any photospheric contamination. The optical thickness of the chromosphere to this UV radiation limits the presence of ortho-Helium to a thin slab located in the upper chromosphere, avoiding the necessity of complex radiative transfer computations. Atomic polarization and its modification caused by the Hanle effect extends the range for magnetic field measurements from the typical Zeeman-dominated hecto-Gauss regime down to several Gauss.

Recent developments in ground based solar instrumentation allow to exploit the potential of the He I triplet with unprecedented detail. The largest solar telescopes available (GREGOR, NST) are equipped with powerful spectrographs to measure the He I 10830 absorption and emission profiles at spatial scales down to 200 km. In this talk I present a review of important discoveries made using this line, as well as a selection of very recent, spectacular observations in He I 10380.

Formation of Delta type sunspots and its effects on the solar atmosphere

Sreejith Padinhatteeri, Eamon Scullion, Paul A. Higgins, D. Shaun Bloomfield, Peter T. Gallagher

Trinity College, Dublin, Ireland

Abstract: Sunspot groups that contain opposite-polarity umbrae surrounded by a common penumbra are known as delta-spots in the modified Mount Wilson classification scheme. These magnetically complex sunspot groups are associated with many major solar flares, so the formation of a delta-spot can be a precursor of an active regions potential for major flaring. We have observed four cases of delta-spot development and evolution, in high resolution using SST and more than 20 cases using SDO/HMI. In this presentation we present the changes in different physical properties in the photosphere, including plasma flow velocity and magnetic flux as the delta-spots form and evolve. We will also be discussing physical changes occurring in the chromosphere and corona as they evolve.

Coronal Magnetic Field from Radio Observations and First Results from MWA

Divya Oberoi and the MWA Collaboration

NCRA-TIFR, Pune, India

Abstract: Solar radio studies have now been carried out for many decades. However due to a combination of the intrinsically highly dynamic nature of solar radio emission, and technological challenges associated with the Fourier radio imaging technique, high fidelity and time resolution spectroscopic wide-band solar radio imaging has remained a challenge. The steady and impressive march of technology has now lead to a new generation of radio observatories which rise to this challenge. The Murchison Widefield Array (MWA), located in Western Australia, is one such instrument which is especially well suited for solar observations.

At the low radio frequencies where MWA operates, the active emission is dominated by coherent plasma processes. The coherent nature of these emission mechanisms makes them a sensitive probe of the coronal regions which is reflected in the fact that many of the emissions seen at these frequencies do not seem to have counterparts at other wavebands. Additionally, for many of the emissions seen the frequency of active emission usually corresponds to the funamental or harmonic of the local plasma frequency. Consequently by observing across a large frequency range, one can investigate a range of coronal heights. These observations usually probe coronal heights higher than the regions where the bulk of the activity at higher frequencies is observed.

The radio observations thus provide access to novel information about solar dynamics inaccesible at other wavebands, and the data from the capable new generation of instruments now allow us to follow the solar dynamics simultaneously along the time, frequency and morphology axes. Here we present some early observations from the MWA to showcase its abilities and give a taste of the science returns from these observations.

From Emergence to Eruption: Data-Driven Modeling Of Solar Active Regions

Mark Cheung

Lockheed Martin Solar and Astrophysics Lab, California, USA

Abstract: Advances in theory and numerical modeling have yielded important insights regarding the key physical processes responsible for the evolution of active regions (ARs) and their associated eruptions. Though many studies are based on idealized scenarios, they have been helpful in providing qualitative guidance for interpreting observations. At the same time, our observational capability has been greatly enhanced by new instruments on space-borne and ground-based telescopes. In particular, high cadence, full-disk observations of the solar corona and the underlying photosphere by NASA's Solar Dynamics Observatory presents us an unprecedented opportunity to bring numerical models

closer to observations. In this talk, we will discuss the challenges in data-driven modeling of AR evolution and survey some recent progress in this active field of research.

Recent progress in coronal magnetic field modeling

Julia K. Thalmann

University of Graz, Austria

Abstract: For the most part, the structure of the solar corona is controlled by the time evolution of the magnetic field because, in typical coronal conditions, the magnetic energy density is greater than the kinetic, gravitational and thermal energy density. Additionally, the time scale on which the coronal magnetic field evolves is much larger than that of the plasma motions in the nearsurface layers of the Sun, where these fields are anchored. This results in the coronal magnetic field evolving through a continuous sequence of equilibrium states, driven by the near-surface dynamics and only interrupted locally during dynamical events like flares and coronal mass ejections. Fortunately, the magnetic field at the photosphere is routinely measured, providing a lower boundary condition for the derivation of the three dimensional magnetic field structure in the atmosphere above, which is not accessible to direct measurements. To date, the most widely used methods include steady-state magnetohydrodynamic models (aiming to describe the magnetic field and related plasma properties in a self-consistent way) and quasi-static force-free approaches (aiming to picture the magnetic field alone). I will discuss the strengths and weaknesses of the methods used, in relation to recent advances in our understanding of the activeregion and global scale coronal magnetic field structure and its temporal evolution.

Nonlinear Force-free Modeling of the Solar Magnetic Carpet – Results and Remarks

Lakshmi Pradeep Chitta, R. Kariyappa, A. A. van Ballegooijen, E. E. DeLuca, and S. K. Solanki

Indian Institute of Astrophysics, Bengalore, India

Abstract: The mixed polarity fields in the solar photosphere form a magnetic carpet. The carpet is continually recycled and evolved with newly emerging flux replacing the pre- existing flux. Magnetic elements split, Contributed merge, and cancel due to granular action. Observations of these magnetic elements show evidence for swirl events, and significant horizontal motions that can reach supersonic speeds. All these dynamical aspects of the magnetic carpet make the overlying field non-potential source of magnetic energy to heat the solar atmosphere. In this talk we present the results from a nonlinear force- free modeling of the solar magnetic carpet. Time sequence of the observed line-of-sight magnetograms are used as the lower boundary conditions in our simulations. These results and implications will be discussed in relation to the coronal heating.

Session VII -- Coupling of the Solar Atmosphere I

Structure and Evolution of Features in Chromosphere, Transition Region and Corona

Hardi Peter

MPS, Goettingen, Germany

Abstract: The atmospheric layers of the Sun show a continuous magnetic coupling from the surface all the way into the corona. The different regimes are characterised by quite different conditions. In most parts of the regions to be discussed here the magnetic field is dominating, but different mechanisms govern the thermal structure of the plasma. Still, the magnetic connection requires a holistic treatment, in particular the heat input might follow the same process(es) and the intimate connection does not allow to treat the regimes separately. Models covering the whole upper atmosphere, including the driver in the photosphere, can provide a more or less realistic description of many observables and this allow insight into the mechanisms governing the spatial structuring and dynamics found in observed features. These include coronal loops covering a wide range of temperatures and sizes, jet-like features feeding mass to the corona, or small-scale energy release processes. The utilisation of 3D numerical experiments is a key to interpret and hopefully understand the enormous zoo of observational features, both on a case-to-case basis as well as in a statistical sense. Is there hope to find unifying explanations for the broad range of features or will we get completely lost in the increasing amount of detail provided by advanced modelling and observations?

Connections Between Chromosphere,Transition Region and Corona: IRIS perspective

Hui Tian

Harvard-Smithsonian Center for Astrophysics, Cambridge, USA

Abstract: The recently launched Interface Region Imaging Spectrograph (IRIS) mission is now providing high-cadence, high-resolution, and continuous observations of the solar transition region and chromosphere. Combined observations of IRIS and SDO/AIA provide an excellent opportunity to investigate the coupling between the chromosphere, transition region and corona. In this talk, i will present an overview of IRIS observations mainly in coronal holes and sunspots. IRIS has revealed the presence of prevalent highspeed jets from the chromospheric network. I will talk about the chromospheric and transition region signatures of these network jets, and explain how they connect to possible coronal signatures observed with SDO/AIA. I will also present IRIS obervations of oscillations and transient events in sunspots, show the different behaviors of these dynamics in different passbands and spectral lines, and explain these different behaviors in a unified scenario.

Ellerman bombs

Rob Rutten

Lingezicht Astrophysics, The Neatherlands

Abstract: Ellerman bombs (EBs) are small shortlived brightenings of the Halpha wings that result from photospheric reconnection in active regions with much flux emergence. Many reported Ebs were not such but simply magnetic bright points; I will demonstrate with SDO/AIA movies how to discriminate real EBs from such pseudo Ebs. The EB visibility in Halpha, the CaII lines and MgII h&k and their invisibility in MgIb, NaID, FeI and the continuum has not been explained, but I will show how to do this. Their visibility in the UV continua sampled by AIA makes EBs eligible to large-volume study of their occurrence patterns as indicator of photospheric reconnection.

Multi-wavelength study of Recurrent Solar Jets on 11December, 2010

Ramesh Chandra, G. R. Gupta, S. Mulay, Durgesh Tripathi

Kumaun University, Nainital, India

Abstract: We present and discuss here a multiwavelength study of five homologous recurrent solar jets occurred in active region NOAA 11133 on December 11, 2010. These jets were well observed by Solar Dynamic observatory (SDO) with high spatial and temporal resolution. The kinematics, morphological properties along with association of these EUV jets with type III radio burst have been studied. In order to understand the trigger mechanism for these jets, we have studied the magnetic field evolution of the active region. We find the emergence of magnetic field at jet site just before the appearance of first jet. Thereafter magnetic flux was continuously emerging. We also tracked sunspot oscillations from the sunspot interior to foot-points of jets and found ~3 min propagating waves in several AIA passbands. We also found increase in oscillatory power in AIA 211 passband just before the triggering of the first jet. We believe that these propagating waves emanating from sunspot may play an important role in the triggering of observed jets.

Session VIII -- Coupling of the Solar Atmosphere II

Waves in the Solar Atmosphere

Tom Van Doorsselaere

K U Leuven, Bengium

Abstract: In this presentation, I will give an observational and theoretical overview of magnetic waves in the solar photosphere, chromosphere and corona. I will study the propagation of energy by these waves throughout the different atmospheric layers, and show recent observational studies that estimate the energy transport of these waves. Moreover, I will stress that the waves can be used for MHD seismology, and thus reveal the solar atmospheric structure and the coupling between the layers.

Waves in coronal holes

Dipankar Banerjee

Indian Institute of Astrophysics, Bengalore, India

Abstract: Coronal holes are associated with rapidly expanding open magnetic fields and acceleration of the fast solar wind. Slow waves are ubiquitously observed in coronal holes and active region fan loops. These waves cause periodic disturbances in intensity and are mostly identified from the alternate slanted ridges in the space-time maps. They are observed to have a range of periodicities from 3 to 30 minutes and are found to be rapidly damped. I will focus on their characteristic properties including damping. These characteristics allows us to perform coronal seismology. I will also discuss on the possibility of other wave modes and their role in coronal seismology. In the context of the current space missions like IRIS, the wave identification in terms of spectral signature will be also discussed.

Are some coronal loop oscillations interference fringes?

Rekha Jain

University of Sheffield, UK

Abstract: Transverse, standing kink mode of oscillations have been observationally detected in many solar coronal loops. Recently, some observations also report small amplitude, decayless oscillations with or without impulsive oscillations. We present a theoretical model to investigate the flareinduced waves and decay less oscillations. We attribute both these oscillations as MHD fast waves, a result of superposition of waves generated by strong localised sources of short impulsive nature and continuous stochastic sources. The oscillatory signal arising from a localised, short-duration source is interpreted as a pattern of interference fringes produced by waves that have travelled different routes of different pathlengths through the waveguide. The resulting amplitude of the fringes slowly decays in time with an inverse square root dependence. We discuss the details of the interference pattern with a view to understand the excitation mechanisms of the oscillations and the seismological implications of such oscillations.

Title: Doppler velocities in kink MHD waves in solar flux tubes

Marcel Goossens, R. Soler, J. Terradas, T. Van Doorsselaere, G. Verth

K U Leuven, Bengium

Abstract: The standard interpretation of the transverse MHD waves observed in the solar atmosphere is that they are non-axisymmetric kink (m=1) waves on magnetic flux tubes. This interpretation is based on the fact that axisymmetric (m=0) and non-axisymmetric fluting $(m \geq 2)$ waves do not displace the axis of the loop and the loop as a whole while kink waves indeed do so. A uniform transverse motion produces a Doppler velocity that is constant across the magnetic flux tube. A recent development is the observation of Doppler velocities that vary across the loop. The aim of the present contribution is to show that spatial variations of the Doppler velocities across the loop can be caused by kink waves. The motion associated with a kink wave is purely transverse only when the flux tube is uniform and sufficiently thin. When the flux tube is non-uniform and has a non-zero radius the conditions for the generation of a purely transverse motion are not any longer met. In that case the motion in a kink wave is the sum of a transverse motion and a nonaxisymmetric rotational motion that depends on the azimuthal angle. It can produce complicated variations of the Doppler velocities across the loop. I shall discuss the various cases of possible variations of Doppler velocities that can occur depending on the relative sizes of the amplitudes of the radial and azimuthal components of the displacement in the kink wave and on the orientation of the line of sight.

Session IX – Magnetic Structures in Solar Atmosphere I

Formation and Dynamics of Solar Prominences

Judy Karpen

NASA Goddard Space Flight Centre, USA

Abstract: Prominences are spectacular manifestations of both quiescent and eruptive solar activity. The largest examples can be seen with the naked eye during eclipses, making prominences among the first solar features to be described and catalogued. Steady improvements in temporal and spatial resolution from both ground- and space-based instruments have led us to recognize how complex and dynamic these majestic structures really are. Their distinguishing characteristics â€“ cool knots and threads suspended in the hot corona, alignment along polarity inversion lines in the photospheric magnetic field within highly sheared filament channels, and a tendency to disappear through eruption â€“ offer vital clues as to their origin and dynamic evolution. Interpreting these clues has proven to be contentious, however, leading to fundamentally different models that address the basic questions: What is the magnetic structure supporting prominences, and how does so much cool, dense plasma appear in the corona? A combination of observations, theory, and numerical modeling must be used to answer these fundamental questions. I will discuss the necessary conditions that must be met by any successful prominence model, and present in detail one promising, comprehensive scenario for quiescent prominence structure and mass formation.

Waves and Oscillations in Prominences

Joten Okamoto

ISAS/JAXA, Japan

Abstract: Coronal heating and the acceleration of the solar wind are unsolved problems in solar physics. The propagation of Alfvenic waves along magnetic field lines is one of the candidate mechanisms to carry energy to large distances from

the surface and heat the coronal plasma.

Such waves can be observed in fine structures of prominences. In particular, Hinode observations have directly resolved small- scale transverse oscillations of field lines as a result of Alfvenic waves. These waves had a period of 2-5 minutes (low frequency) and the velocity amplitudes are up to 20 km/s. If we assume these are propagating waves, the waves have enough power to heat the corona.

More recently, IRIS provides spectral information of fine strucutures to investigate the detailed property of these waves. With collaborative observations of IRIS and Hinode, we found the following interesting features associated with waves and possible heating: (1) The velocity amplitude of the oscillations tends to be larger at higher altitudes. (2) The horizontal threads have smaller length and shorter lifetime at higher altitudes. (3) As the moving threads in the Ca II line (10 kK) fade away, co-spatial threads appear in the hotter Si IV line (60 kK) with similar horizontal speeds. (4) Characteristic phase differences around 180 degrees between transverse motions in the plane of the sky and line-of-sight velocities of the oscillating threads were detected, and this phenomenon supports a scenario in which resonant absorption takes place on the surface of oscillating prominence flux tubes in the corona.

In this talk, I will show these observational results and discuss propagation and dissipation of waves.

Three-dimensional simulation of the plasmoid instability and comparison with micro-jets observed by

Lijia Guo, D. E. Innes, Y.-M. Huang, A. Bhattacharjee

MPS, Goettingen, Germany

Abstract: Small-scale transient events are ubiquitous on the solar disk. Some of these events are thought to be related to magnetic reconnection and proposed to be candidates for coronal heating. The high spatial- resolution and time-cadence data sets from IRIS have provided us with unprecedented details about jets in the solar corona. The reconnection rates of jets observed by IRIS and measured in units of the Alfven speed are estimated to fall in the range of 0.01 ~ 0.05. Since the classical Sweet-Parker reconnection fails to account for these observed timescales, a fast reconnection mechanism is called for. Recently, the fragmentation of a current sheet in the high- Lundquist-number regime caused by the plasmoid instability has been proposed as a possible mechanism for fast reconnection. The plasmoid instability (2D or 3D) yields a fast reconnection rate in the sense that the reconnection rate becomes very weakly dependent on the Lundquist number (unlike the Sweet-Parker model).

The line profiles of jets observed by IRIS suggests existence of Alfvenic bi-directional flows along the out-of-plane direction in addition to in-plane reconnection outflows along current sheets. This result implies a three-dimensional evolution of the jet current sheet. To test the idea of three- dimensional plasmoid instability accounting for IRIS observations of micro-jets, we set up a high-Lundquist-number MHD model to study the three-dimensional evolution of jet current sheet. The simulation results show that the 3D plasmoid instability

introduces out-of-plane Alfvenic flows that appear to coincide with the location of 3D plasmoids. Furthermore, the simulation results are used for constructing synthetic spectra that are compared with IRIS observations. The synthesized line profiles appear to agree well with IRIS observations.

Spectroscopic Signature and Modelling of Plasma Flows, Jets, and MHD Waves in the Solar Corona

Abhishek Kumar Srivastava, P. Jelinek, K. Murawski, B.N. Dwivedi, P. Konkol, P. Kayshap, A. Mohan

IIT-BHU, Varanasi, India

Abstract: The large-scale plasma flows, jets, and MHD waves are ubiquitous in the solar corona. They contribute significantly to the energy transport and mass supply (nascent wind) in the solar atmosphere. In the present paper, we describe spectroscopic observations from the Hinode/EIS and a numerical model which collectively reveal the formation of plasma outflows in weakly curved and expanding coronal funnels by the magnetic reconnection generated heating pulse. We find the signature of such flows which substantially transport the heated plasma up to the inner coronal heights. This then contributes to the formation of nascent solar wind. Apart from such large-scale plasma flows, the coronal jets (guided plasma flows) and associated MHD waves may also be the potential candidates to contribute to the plasma dynamics and energy transport in the loalized corona. We show the formation of a coronal jet in the open magnetic field lines of the polar corona. The presence of impulsive Alfven wave is found along the jet using Hinode/EIS spectroscopic observations. The 2.5 D numerical model shows that the reconnection in the vertical current sheet is capable of generating such waves along the jet, while associated vertical flows create the jet plasma moving into the corona at higher heights. In conclusion, we underline the crucial role of MHD activity as the cause of plasma and wave dynamics in the solar atmosphere, and the nature of drivers in light of realistic atmosphere affecting their evolution.

Session X – Magnetic Structures in Solar Atmosphere II

Lagomorphs, lollypops, and lift-off: magnetic flux rope signatures of coronal cavities

Sarah Gibson

High Altitude Observatory, USA

Abstract: It is widely accepted that magnetic flux ropes lie at the heart of coronal mass ejections (CMEs). However, the extent to which stable magnetic flux ropes exist prior to eruption, and the physical mechanisms that may form them, remain subjects of lively debate. Coronal cavities are dark elliptical regions surrounding solar prominences and present compelling evidence for flux ropes as sites of the gradual buildup of magnetic energy prior to eruption. I will present observed cavity properties, including morphology, polarimetry, substructure, and dynamics, and describe how these constrain magnetic and thermodynamic models. I will further consider how the observed evolution of cavities immediately prior to eruption may indicate topological changes and the onset of instability. I will conclude by discussing how future observation and models may be used to resolve open questions on the nature and significance of magnetic flux ropes in the solar corona.

Stable Compound Flux Rope Formation via Merging of Filament Channels

Navin Chandra Joshi, Tetsuya Magara, Satoshi Inoue

School of Space Research, Kyung Hee University, Korea

Abstract: In this paper, we present the observations of stable compound flux rope formation through merging of two nearby filament channels. We will also discuss the cool and hot plasma dynamics along the compound flux rope and its stability in the corona. The Global Oscillation Network Group (GONG), H-alpha, SDO/AIA, SDO/HMI, RHESSI, GOES, observations have been used to interpret the event in different wavelengths. The merging of southern/northern legs of northward/southward filaments started at around 01:21 UT and continue till the compound flux rope formed at around 01:33 UT. Near the merging region we also observed an C-class solar flare. We have observed the hot flows towards north and south from the point of merging along the newly formed flux rope with an average speed of around 265 km/s and 118 km/s. Some of the hot plasma showing returning motion along the compound flux rope channel after 02:00 UT. This observation is an interesting example of filament channels merging and the formation of compound flux rope and can be explained using tether cutting reconnection scenario. However, the compound flux rope shows its stability against the eruption in the solar corona at the later phase. To check the overlying magnetic field conditions we have calculated the decay index over the flux rope axis. We found that the whole flux rope and filaments lie in the region of stability (decay index <1.5) upto 86.4 Mm. That causes the stability of this flux rope in the solar corona ever after the strong perturbation due to merging dynamics.

Formation of magnetic discontinuities through contortion of magnetic flux surfaces

Sanjay Kumar, R. Bhattacharyya, P. K. Smolarkiewicz

Udaipur Solar Observatory, India

Abstract: According to the Parker magnetostatic theorem, tangential discontinuities in magnetic field, or current sheets (CSs), are generally unavoidable in an equilibrium magnetofluid with infinite electrical conductivity and complex magnetic topology. These CSs are due to a failure of a magnetic field in achieving force-balance everywhere and preserving its topology while remaining in a spatially continuous state. A recent work [Kumar, Bhattacharyya, and Smolarkiewicz, Phys. Plasmas 20, 112903 (2013)] demonstrated this CS formation utilizing numerical simulations in terms of the vector magnetic field. The magnetohydrodynamic simulations presented here complement the above work by demonstrating CS formation by employing a novel approach of describing the magnetofluid evolution in terms of magnetic flux surfaces instead of the vector magnetic field. The magnetic flux surfaces being the possible sites on which CSs develop, this approach provides a direct visualization of the CS formation, helpful in understanding the governing dynamics. The simulations confirm development of tangential discontinuities through a favorable contortion of magnetic flux surfaces, as the magnetofluid undergoes a topology-preserving viscous relaxation from an initial non-equilibrium state with twisted magnetic field. A crucial finding of this work is in its demonstration of CS formation at spatial locations away from the magnetic nulls.

Flow structure of transition region explosive events

Davina Innes

MPS, Goettingen, Germany

Abstract: Explosive event is the name given to transition region brightenings showing broad, non-Gaussian line profiles. They are thought to be a consequence

of reconnection in the transition region. Although they have been observed since the early 80s, it has only recently become possible, with the advent of simultaneous high cadence, slit-jaw images and stigmatic spectra from IRIS, to observe their structure. Here we present IRIS and SDO observations of small-scale transition region loops and jets, highlighting aspects that support and conflict with reconnection scenarios.

Energy transport and heating in the upper chromosphere, transition region, and lower solar corona

Viggo Hansteen

Institute of Theoretical Astrophysics, Norway

Abstract: Hinode and IRIS observations, especially when combined with high resolution ground based data, are giving unprecedented clues as to the transport of energy from the photosphere through the chromosphere and transition region into the lower solar corona. Real progress on finding the sources of outer atmosphere heating can be made when these observations are combined with state of the art numerical simulations. In this talk we will discuss several exciting developments relevant to the understanding of energy transport and heating in these regions of the atmosphere, including UFS-loops, RBEs/spicules type II, pervasive twist in small scale structures, evidence for Alfvenic waves, and flux emergence.

Magnetic Reconnection in Partially Ionized Plasmas and its effect in Heating of the Atmosphere

Hiroaki Isobe

Unit of Synergetic Studies for Space, Kyoto University, Japan

Abstract: The lower atmosphere of the Sun, namely the photosphere and the chromosphere, is fully collisional and partially ionized. Recent observations, in particular those from the Solar Optical Telescope on board Hinode spacecraft, have revealed that the solar chromosphere is full of dynamic activities, such as plasma jets and Ellerman bombs (transient heating of low-chromosphere). These dynamic phenomena are believed to be associated with magnetic reconnection in the chromosphere, but the nature of magnetic reconnection in such plasma environment has been much less studied compared with reconnection in fully ionized, collisionless plasmas. The solar lower atmosphere is therefore an unique laboratory for the physics of reconnection in partially ionized plasmas. In this paler we first present the observations of chromospheric reconnection events that show the ejection of multiple plasma blobs and bursty nature of reconnection. Then we present the result of 1-fluid MHD simulation with Cowling resistivity (also called Pederson resistivity or ambipolar resistivity) to investigate the effect of partial ionization on reconnection. We found that the nonuniformity of Cowling resistivity is an essential factor that determines the structure of reconnection region and hence the reconnection rate.

Hydraulic effects in a partially ionized radiative solar atmosphere

Pallavi Bhat, Axel Brandenburg

IUCAA, Pune, India

Abstract: We study here realistic solar atmospheres which includes radiation and partial ionisation, by using them in 2D simulations of a hydraulic model for forming

magnetic flux concentrations. In early models of Parker (1974), magnetic flux concentrations at the solar surface were thought to be the result of hydraulic downward motion along vertical magnetic field lines. To isolate the effects of partial ionization and radiation, we ignore turbulence and convection. Flows are driven by an imposed gradient force for a hydraulic action. Strong flux concentrations are formed as a result of converging return flows from the downward suction in the deeper parts. We use either a Kramers-like opacity or the Halpha opacity resulting in either convectively marginal stratification or stable stratification, in the deeper parts. Partial ionization results in a decreased ratio of specific heats near the surface, making the stratification always unstable near the surface. This strongly exaggerates flux concentration. However, owing to the absence of turbulence, the downflows reach transonic speeds unimpededly.

Calculation of the excitation and ionization state of the plasma for the electron kappadistribution

Elena Dzifcakova, J. Dudik

Astronomical Institute, Czech Republic

Abstract: The presence of non-Maxwellian electron distributions in the solar corona and transition region is supported by many theoretical calculations and several diagnostics. The kappa-distributions or distributions exhibiting high-energy tails can also be expected as a result of particle acceleration processes by a nanoflare heating in the solar corona. Generally, the non-Maxwellian distributions change individual ionization, recombination and collisional excitation rates. These changes lead to the modification of the line intensities and enable diagnostics of non- Maxwellian distributions from observed spectra. The synthetic line intensities for the kappa-distributions can be calculated directly from atomic cross sections, which are however not available. Therefore, we modified CHIANTI 7.1 software and extended its database for the calculation of the synthetic spectra for the kappadistributions. This modified version of CHIANTI contains data for calculation of the excitation rates together with the newest calculations of the ionization equilibrium. It allows us fast calculations of synthetic spectra and search for diagnostic opportunities of the kappa-distribution. This enables us to calculate e.g., the effect of the kappa-distributions on the filter responses, study the influence of the kappadistribution on the observed temperature distribution in emitting plasma represented by DEM, and so on.

Session XII – Chromospheric and Coronal Heating II

Key issues in coronal heating

James Klimchuk

NASA Goddard Space Flight Centre, USA

Abstract: The question of what heats the corona to multi-million degree temperatures remains one of the great unsolved problems in space science. Much progress has been made in recent years, both observationally and theoretically, but much work is left to be done. I will highlight what I consider to be some of the key issues that must be addressed before we can truly understand coronal heating.

Heating and Dynamics of Solar Active Regions(observations)

Helen Mason, G. Del Zanna, Durgesh Tripathi, S. Subramanian, G.R. Gupta

DAMTP, University of Cambridge, UK

Abstract: This paper will review the observational constraints on the heating of quiescent active region loops. Particular attention will be paid to constraints provided by recent imaging (SDO/AIA) and spectroscopic (Hinode/EIS) observations for the hot core emission. The slope of the Emission Measure (EM) between LogT=6 to LogT=6.5 provides one useful constraint. The higher temperature emission is more difficult to constrain. The physical parameters for individual cool (1MK) loops and the diffuse background emission have also been studied.

Explanation of Coronal bright point oscillation using a nanoflare heating model

Aveek Sarkar, K Chandrashekhar Reddy

CESSI, IISER Kolkata, India

Abstract: npreceded spatial and temporal resolution of the Solar Dynamic Observatory (SDO) has revealed that coronal bright points are actually smaller active regions. They consist of loop like magnetic field structures which go through continuous evolution. Using wavelet analysis of the intensity images of such structures, we observe an oscillation with period of around 20 minutes. Simultaneously using our multithermal hydrodynamic loop model we show that such oscillations can be generated if loops are heated by nanoflare like tiny heating events.

Asymmetries of Coronal Spectral Lines and their Emission Measure

Durgesh Tripathi and James Klimchuk
IUCAA, Pune, India

Abstract: Needs to be written

Solar Flares: what we have learnt from Hinode observations

Hirohisa Hara

National Astronomical Observatory, Japan

Abstract: Solar flares, explosive events on the Sun, release huge magnetic energy in a short time of minutes to hours. The magnetic fields in the flare site are converted to thermal and non-thermal energies via physical processes that occur in the solar atmosphere. I will review the achievement of solar flare studies from Hinode observations. The 3rd Japanese space solar observatory, Hinode, equips three major telescopes that cover the solar atmosphere from the photosphere to the corona. The magnetic-field configuration and coronal dynamics including magnetic reconnection are the central topics of this presentation with desired directions to be studied in the future.

Slipping magnetic reconnection in solar flares

Miho Janvier

University of Dundee, UK

Abstract: Solar flares are powerful events occurring in the solar atmosphere that lead to great energy releases. Their intrinsic mechanism is magnetic reconnection, a phenomenon that changes the connectivity of magnetic field lines while transforming the available magnetic energy into other energy sources. Magnetic reconnection itself occurs at small scales, rendering direct observations difficult, in regions of high current density where the ideal MHD breaks down. However, its consequences are visible within a large range of the electromagnetic spectrum. Among them, evidence of reconnection can be found as localised brightenings such as kernels, flare ribbons, and strongly emitting flare loops, as well as signatures of energetic particles. I will show how in 3D, narrow current layers form in regions where there is a drastic change of field-line connectivity. These regions are referred to as Quasi-Separatrix Layers (QSLs), which generalise the concept of separatrices commonly used in 2D. In QSLs, field lines continuously reconnect, leading to an apparent motion: magnetic field lines are referred to as slipping. I will then discuss how the knowledge of the topology of a flare, and therefore the location of the QSLs, allows us to predict its evolution and understand its observational features. We will see how 3D MHD simulations can be used to study in more detail the slipping reconnection process during different reconnection regimes. In particular, numerical simulations of an eruptive flare will be used to show how flare loops, flux ropes and flare ribbons are formed via slipping reconnection. We will also see how the slipping velocities are directly related to the geometry and the evolution of the QSLs during the flare. Finally, those results will be compared with EUV observations of the corona. I will show show the high-cadence of recent solar observation missions such as SDO can be used to verify the predictions given by 3D MHD simulations. These recent findings are very important in completing a generic 3D model for solar flares.

MHD Simulations of quasi- periodic pulsations from post flare loop top

Shinsuke Takasao, Kazunari Shibata

Kyoto University, Japan

Abstract: Quasi-periodic pulsations (QPP) are a common feature in the light curves of solar flares. The period ranges from seconds to several minutes. Recent observations have shown that QPPs are also commonly observed in the light curves of many stellar flares. In some events of the solar flares, QPPs with the period of > a few sec are detected in the microwave, white light, EUV and X-ray emission, implying that QPPs are likely to be associated with both non-thermal and MHD processes. For this reason, QPPs seem to provide many pieces of the information about the regions that cannot be directly observed at present, like the particle acceleration sites and flaring regions in the stellar atmosphere. Therefore theoretical understanding of QPPs are impoertant to interpret the observations better. Motivated by the observations, we performed 2.5D MHD simulations of a solar flare to understand the possible mechanisms of QPPs. Considering that strong non-thermal emissions are commonly observed at the apex of the post flare loop, we seek the quasi periodic features in the apex region in the simulations. We made the light curve of the thermal free-free emission of the apex region from the simulations. Then we found that the light curve exhibits a quasi-periodic behavior with the period of several tens seconds. In the simulations we analyzed, QPP is probably generated by the quasi-periodic Alfvenic motions in the apex region of the post flare loop. The magnetic field at the apex has a concave structure when the collimated reconnection outflow collides with it. The deformed field seems to show the Alfvenic motion when it relaxes to a lower energy state. The oscillations in the post flare loop are found to quasi-periodically modify the strength of the termination shock. If the non-thermal particles are efficiently created at the termination shock, then it is highly possible that QPPs are observed simultaneous and in phase in the thermal and non-thermal emissions. In this paper, we will discuss the physical process of QPP in detail on the basis of the numerical experiments.

Forward Modelling the Loop Top emission in Post Flare Loops using 1D Hydrodynamic Simulation

Rohit Sharma, Durgesh Tripathi, Hiroaki Isobe

NCRA-TIFR, Pune, India

Abstract: The observations of post flares loops in X-rays and EUV reveal strong localized brightenings at the loop top regions. The Hard X-ray imaging observations show that the brightening seen in Hard X-rays are at higher altitudes than the brightening observed in Soft X-rays and EUV. The origin of these brightenings is not explored extensively and therefore the reason for this is not known. The aim of this paper is to study the dynamics of post flare loops using 1D hydrodynamic modeling with the focus on the localized brightening and perform forward modeling of emission in various spectral lines observed by the Extreme-Ultraviolet Imaging Telescope aboard Hinode. Our findings suggest that these brightenings are the result of collisions between the counter-streaming chromospheric evaporation from both the foot points. The forward modeled intensities are well matched with the

observations recorded by EIS for the flare, which occurred in December 2006.

Session XIV – MHD Instability and Eruptions – CMEs

Coronal Mass ejections - how well do we understand their propagation dynamics?

Prasad Subramanian
IISER, Pune, Inndia

Abstract: Since coronal mass ejections from the Sun (Earth-directed ones, inparticular) are the primary drivers of significant space weather disturbances, it is important to have a robust understanding of their propagation dynamics. This is essential to building reliable models for CME arrival time and speed at the Earth. Owing to its obvious importance with regard to predicting space weather disturbances, this area has witnessed a great deal of activity in recent years. We have seen considerable progress in analysing Sun-Earth CME propagation data, semi-analytical modelling of the forces involved in CME propagation and sophisticated numerical simulations that attempt to reproduce the 3D evolution of CMEs. Nonetheless, it is well known that time-of-arrival and speed estimates for Earth-directed CMEs are far from satisfactory. I will argue that part of the reason for this is undoubtedly the complicated nature of the problem. However, a considerable part is also a lack of detailed microphysical knowledge about the basic forces responsible for CME propagation, such as the driving and drag forces. I will conclude with a sketch of some key unresolved problems in this regard.

EIT Waves: Observations and Modelings

Peng-Fei Chen

School of Astronomy & Space Science, Nanjing University, China

Abstract: Coronal ``EIT waves'' appear as bright fronts propagating across a significant part of the solar disk in EUV wavelengths. They were sometimes called solar tsunami. Upon the discovery in 1997 by the EIT telescope on board the SOHO satellite, the intriguing phenomenon provoked continuing debates on their nature and their relation with solar flares and coronal mass ejections (CMEs). The wavelike phenomenon was firstly and widely explained in terms of fast-mode magnetoaccoustic waves. However, such a model is contradictory with many observational features. To reconcile the discrepancy, several other models have been proposed. With the high spatiotemporal resolution observations from the newly-launched SDO satellite, a clearer and clearer pattern is emerging. In this talk, I will go through the history of the observational and theoretical researches on coronal ``EIT waves''. The implication of the ``EIT wave'' research to the understanding of CMEs and how ``EIT waves'' can be used to diagnose the coronal magnetic field will also be discussed.

Evolution and Consequences of Interacting CMEs using STEREO/SECCHI and In Situ Observations

Wageesh Mishra, Nandita Srivastava, D. Chakrabarty

Udaipur Solar Observatory, India

Abstract: Understanding of the kinematic evolution of Coronal Mass Ejections (CMEs) in the heliosphere is important to estimate their arrival time at the Earth. It is found that kinematics of CMEs can change when they interact or collide with each other as they propagate in the heliosphere. I will present the collision and postinteraction characteristics of two Earth-directed CMEs, using white light imaging observations from STEREO/SECCHI and in situ observations taken from WIND spacecraft. We also estimated the kinematics of the features of the CMEs and found a significant change in their dynamics after interaction. In in situ observations, we identified distinct structures associated with interacted CMEs. Our analysis shows an improvement in arrival time prediction of CMEs using their post-collision dynamics than using pre-collision dynamics. Estimating the true masses and speeds of these colliding CMEs, we investigated the nature of observed collision. Our investigation also places in perspective the geomagnetic consequences of the two CMEs and their interaction in terms of occurrence of geomagnetic storm and triggering of magnetospheric substorms.

The Trigger of a Spectacular Filament Eruption leading to CME and Flare

Ashok Ambastha

Udaipur Solar Observatory, India

Abstract: Coronal mass ejections (CMEs), prominence/filament eruptions, and flares are three different types of large scale eruptive phenomena closely related, different manifestations of a single physical process. Several CME models are developed to describe their pre-eruption structures (or progenitors), initiations, and eruptions based on the available observations. We present results of our study of a quiescent filament located in a weak magnetic field region, transiting on the solar disk during 20-29 September 2013. After several days of inactivity, the filament began restructuring and activation, eventually erupting catastrophically on 29 September 2013/21:22 UT. This eruption was seen in GONG H-alpha images as sudden disappearance of the filament or a disparition brusque event. The SDO-AIA 171 and 304\AA images, on the other hand, showed upward rise of filament and CME traveling at a speed of approximately 900 km/s. The signature of new emerging magnetic fluxes was found in the form of compact brightening in H-alpha images which developed near the filament central barb. SDO-HMI magnetogram movies confirmed the first sign of the emerging flux region (EFR) of both signs at the rate of 13.3(-74.1)Mx/hr on 29 September 2014/02:34 UT over an area of ~1.9x10^8 km^2, increasing both in rate and area with time. The difference images clearly showed detachment of the filament and its rise at the site of EFR, while it remained connected at its two extreme legs. Thus, the EFR was clearly responsible for triggering the eruption of the twisted flux rope structure of the filament, leading to a bodily transport of its flux system into the corona, and onwards into the interplanetary space as a CME. After a lapse of over 20 minutes of the filament eruption and CME launch, a classic long-duration, moderate Cclass two-ribbon flare started lasting over 3 hours. Host of post-flare loops formed during the decay phase of the flare, linking the two separating flare ribbons. This indicated a reconnection process taking place below the erupting filament/CME much after the filament eruption occurred, consistent

with the standard CME model.

Session XV – Current and Upcoming Facilites in India

India's National Large Solar Telescope project-an overview

K. E. Rangarajan and NLST Team

Indian Institute of Astrophysics, Bengalore, India

Abstract: The need for a fairly large modern solar telescope in India and the scientific objectives are discussed in this talk. The basic design of the telescope, the site survey undertaken, the proposed focal plane instruments and their design considerations are elaborated. The current status and the future prospects are explored.

Multi-Application Solar Telescope

Shibu Mathew

Udaipur Solar Observatory, India

Abstract: MAST is a 50 cm off-axis telescope installed on the Island site of Udaipur Solar Observatory (USO), India. The important science goal is to obtain near simultaneous high resolution chromospheric and photospheric observations, for magnetic and velocity field measurements in these layers. The telescope is being tested for the image quality and tracking accuracies. In this presentation I will discuss the salient features of this telescope. We have obtained a couple of test observations in g-band and H-alpha which will also be presented along with the details of the back-end instruments which we are testing for MAST telescope.

The Aditya-L1 Project

S. Seetha

Indian Space Research Organization, Bengalore, India

Abstract: Not provided