IAUS300, Nature of prominences and their role in Space Weather

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Session III Stellar Ejecta and Impact on Exoplanets

Fine structures and dynamics of prominences and filaments

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We review recent observations of prominence and filament fine structure and dynamics made with the Hinode/Solar Optical Telescope (SOT), the Solar Dynamics Observatory/Atmospheric Imaging Assembly (AIA), and ground-based telescopes. The 2006 launch of the Hinode/SOT revitalized the study of prominence dynamics by showing that even the most quiescent prominences are in constant motion with filamentary downflows, large-scale vortex motions, fine-scale oscillations, and occasional Rayleigh-Taylor buoyancy instabilities triggering turbulent upflows. The (re)discovery of the prominence Rayleigh-Taylor instabiltiy in particular has led to vigorous debate on the nature of flows in prominences, the role of the magnetic field in structuring those flows, and the origin of the buoyancy in the generating "bubbles". We focus on the nature of these prominence bubbles, using AIA observations to explore the hypothesis that they are due to emerging magnetic flux that undergoes rapid heating to create a "magneto-thermal" buoyancy instabilty (Berger et al. 2011 Nature). Together with the observations of apparent runaway radiative cooling leading to prominence condensation from the corona (Liu et al. 2012, Berger et al. 2012 ApJL) and new theoretical developments on spontaneous current sheet formation leading to prominence downflows (Low et al. 2012a,b ApJ), these observations imply the possibility of a novel form of convection that transports hot plasma and magnetic flux upwards into the corona while the cool prominence plasma downflows represent the return flow of the system.

Theoretical Models of the Origin of Prominence Mass

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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 ? cool knots and threads suspended in the hot corona, alignment along inversion lines in the photospheric magnetic field within highly sheared filament channels, and a tendency to disappear through eruption ? 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?In this talk I will address the second question, although significant insight into the magnetic structure can also be gained from the plasma distribution and dynamics.

Despite centuries of increasingly detailed observations, the process responsible for prominence mass has been difficult to establish, although we have long known that the chromosphere is the only plausible source. A combination of observations, theory, and numerical modeling must be used to determine whether any of the competing theories accurately represents the physics of prominence mass formation and evolution. I will discuss the criteria for a successful prominence model, compare the leading models, and present in detail one promising, comprehensive scenario for prominence mass formation and evolution: the thermal nonequilibrium model.

Prominence Seismology

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Prominence Seismology

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Magnetohydrodynamic (MHD) wave activity is ubiquitous in the solar atmosphere. MHD seismology aims to determine difficult to measure physical parameters in solar magnetic and plasma structures combining observed and theoretical properties of MHD waves and oscillations. Here, we will present an overview of recent results obtained by applying this technique to large and small amplitude oscillations observed in prominences. Furthermore, we will consider how the study of MHD instabilities in prominences could also help to determine its physical properties.

Formation and evolution of an active region filament

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Several scenarios explaining how filaments are formed can be found in the literature. In our study, we studied an active region filament and critically evaluated the observed properties in the context of current filament formation models. This study is based on multi-height spectropolarimetric observations. The inferred vector magnetic field has been extrapolated starting from the photosphere and the chromosphere. The line-of-sight motions of the filament, which was located near disk center, have been analyzed inferring the Doppler velocities. We conclude that part of the magnetic structure emerges from below the photosphere.

The Evolution of Barbs of a Polar Crown Filament Observed by SDO

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From 16 to 21 August 2010, a northern (?N60) polar crown filament was observed bySolar Dynamics Observatory(SDO). Employing the six-day SDO/AIA data, we identify 69 barbs, and select 58 of them, which appeared away from the western solar limb (?W60), as our sample. We systematically investigate the evolution of filament barbs. Three different types of apparent formation of barbs are detected, including i) the convergence of surrounding moving plasma condensations, comprised 55.2 % of our sample, ii) the flows of plasma condensations from the filament, comprised 37.9 %, and iii) the plasma injections from the neighboring brightening regions, comprised 6.9 %. We also find three different ways that barb disappear, involving: i) bilateral movements (44.8 %), and ii) outflowing of barb plasma (27.6 %) results in the disappearance of a barb, as well as iii) disappearance of a barb is associated with a neighboring brightening (27.6 %). The evolution of the magnetic fields,e.g.emergence and cancellation of magnetic flux, may cause the formation or disappearance of the barb magnetic structures. Barbs exchange plasma condensations with the surrounding atmosphere, filament, and nearby brightenings, leading to the increase or drainage of barb material. Furthermore, we find that all the barbs undergo oscillations. The average oscillation period, amplitude, and velocity are 30 min, 2.4 Mm, and 5.7 km s?1, respectively. Besides the oscillations, 21 (36 %) barbs manifested sideward motions having an average speed of 0.45 km s?1. Small-scale wave-like propagating disturbances caused by small-scale brightenings are detected, and the barb oscillations associated with these disturbances are also found. We propose that the kinematics of barbs are influenced or even caused by the evolution of the neighboring photospheric magnetic fields.

The damping of transverse oscillations of prominence threads: a comparative study

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Transverse oscillations of thin threads in solar prominences are frequently reported in high-resolution observations. The typical periods of the oscillations are in the range of 3 - 5 minutes. A peculiar feature of the oscillations is that they are damped in time, with short damping times on the order of few periods of the oscillation. Theoretically, the oscillations are interpreted as kink magnetohydrodynamic waves. However, the mechanism responsible for the damping is not well known and several causes have been suggested. Here we perform a comparative study between different physical mechanisms that may damp kink waves in prominence threads. The considered processes are thermal conduction, cooling by radiation, resonant absorption, and ion-neutral collisions. Our results indicate that thermal conduction and cooling are very inefficient for the damping of kink waves and, therefore, these mechanisms can be discarded. Ion-neutral collisions are important for short-period waves but their effect is minor for waves with periods usually observed. Resonant absorption is the only process that produces an efficient damping. The damping times theoretically predicted by resonant absorption are compatible with those reported in the observations. Based on this conclusion and in the context of prominence seismology, we show that it is possible to apply the existing seismological schemes for resonantly damped kink waves to the case of prominence thread transverse oscillations.

Non-LTE Modeling and Observations of Oscillating Prominences

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We model H-alpha and H-beta spectral lines in the presence of prominence oscillations. Since MHD waves cause oscillatory fluctuations of the plasma parameters (velocity, temperature, pressure, density), which are different at different depths, the resulting line profiles consist of particular contributions from a range of optical depths. We analyze temporal behavior of the line profiles, namely the Doppler shift, maximum intensity, and FWHM. Our simulations were performed for the fundamental and first harmonic slow and fast modes. The synthetic spectra can be compared with the observed ones collected during the joint Polish-Czech observational campaign devoted to a simultaneous detection of prominence oscillations from two distant sites.

Quiescent prominence fine structure modelling

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Unprecedented amount of detailed, high-resolution observations of the prominence fine structures provided by present space-borne and ground-based observatories represents a significant challenge for the prominence modelling. Today's models have to cope with the increasingly finer dimensions and ever better resolved dynamics of the observed fine structures. However, the increasing complexity of the prominence fine structure models opens new opportunities for the deepening of our understanding of these spectacular solar features.
Currently, prominence fine structure modelling stands on three main pillars: simulations of prominence magnetic field configurations, modelling of radiative transfer in the prominence plasma, and modelling of prominence fine structure dynamics. We will review the state-of-the-art and achievements of the present models and we will try to illuminate the future directions in which these efforts will need to go in order to provide better answers to many questions posed by observations.

On the nature of the prominence corona transition region

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The Prominence-Corona-Transition-Region (PCTR) interfaces the cool and dense prominence with the hot and less dense corona. The PCTR, as observed for a prominence at the limb, is bright in the UV band and shows a fine scale dynamics. Having this interface role it contributes to the stability of the whole structure.
In this talk I will review the main observational properties of the PCTR. I will highlight the new advances as derived from recent data and point out the observational limitations still to be overcome.

Plasma properties in eruptive prominences

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Prominence eruptions are one of the most spectacular manifestations of our Sun's activity. Yet there is still some mystery around their relevant physical conditions. What are their plasma parameters? How different are they from those of quiescent prominences? How do they relate to those within coronal mass ejections?
I will briefly review some recent results which contribute to our knowledge of the plasma properties in eruptive prominences, with a slight emphasis towards advances in modelling. In particular I will discuss how non-LTE radiative transfer modelling, combined with observational data analysis, can help us achieving this goal. Open issues will be discussed.

Determination of Temperature in Solar Prominences/ Filaments Using FISS Observations

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Determining the distribution and variation of temperature inside a prominence is fundamental to understanding its thermal structure and the revevant heating/cooling processes. The spectral analysis of the H alpha line and the Ca II 854.2 nm line that sense the same volume of the prominence may lead to the determination of Doppler widths which in turn results in the separate determination of temperature and non-thermal speed of the volume. Using the Fast Imaging Solar Spectrograph of the New Solar Telescope at Big Bear, we simultaneously recorded the two lines at prominences observed outside the solar limb and filaments on the disk. We applied the Becker's cloud model fit to the data, with zero background intensity profile in prominences and with carefully constructed background intensity profile in filaments. These observations with different perspectives and different analyses produce consistent results: temperature inside prominences/ filaments ranges from 4500 to 14500 K (2 sigma range) with a mean of 9500 K. In addtion, we find that the varation of temperature occur spatially and temporarily in each prominence. We expect that this kind of observationa and analysis with higher spatial resolution and higher temporal resolution will provide us with a good chance for the detailed study of plasma processes in prominences.

Rayleigh?Taylor instability in prominences from numerical simulations including partial ionization effects

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Solar prominences consist in cool, dense, and partially ionized chromospheric plasma remaining stable for days in the solar corona. They should be a subject to Rayleigh?Taylor instability (RTI), when a cooler material forms turbulent drops, mixing with a hotter underlying material. High-resolution observations indeed reveal turbulent up- and down-flows from the visible base of prominences. We study the physics of Rayleigh?Taylor instability by means of 2.5D numerical simulations in a single-fluid MHD approach including a generalized Ohm's law. Our aim is to understand the influence of a large fraction of neutral atoms into the the stability of prominences and the development of RTI. The initial configuration includes a homogeneous magnetic field forming an angle with the direction in which the plasma is perturbed. We study the instability onset time, the growth rate, and the velocity of the downflowing turbulent drop as a function of the orientation of the magnetic field and the fraction of neutrals in the prominence material. We compare the numerical results with the analytical linear calculations in the initial stage of the instability.

Determination of Prominence Plasma ? from the Dynamics of Rising Plumes

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The launch of Hinode satellite gave high resolution observations of rising plumes, dark in chromospheric lines, in quiescent prominences that propagate from large bubbles that form at the base the prominences. These plumes present a very interesting opportunity to study Magnetohydrodynamic (MHD) phenomenon in quiescent prominences, but obstacles still remain. One of the biggest issues is that of the magnetic field strength, which is not easily observable in prominences.
In this paper we present a method that may be used to determine the plasma ? (ratio of gas pressure to magnetic pressure) when rising plumes are observed. Using the classic fluid dynamic solution for flow around a circular cylinder, the compression of the prominence material can be estimated. This has been successfully confirmed through simulations, and application to a prominence gave an estimate of the plasma ? as ?=0.47 - 1.13 for a ratio of specific heats of 1.4 - 1.7.
Using this method it may be possible to estimate the magnetic field of observed prominences, therefore helping our understanding of a prominence's dynamics in terms of MHD phenomenon.

Inference of the Magnetic Field Vector in Prominences

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Prominences owe their existence to the presence of magnetic fields in the solar corona. The magnetic field determines their geometry and are crucial to their stability, energetics, and dynamics. This review summarizes techniques for measurement of the magnetic field vector in prominences. New techniques for inversions of full Stokes spectro-polarimetry, incorporating the the Zeeman and Hanle mechanisms for generation and modification of polarization, are now at the forefront of field measurements in prominences. Instrumental requirements for effective measurement of prominences are also reviewed, as are measurements of the magnetic fields in the photosphere below prominences, and how they may be used to infer the field geometry in and surrounding the prominence itself.

On the magnetic topology of quiescent prominence bubbles

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Dudik, J., Aulanier, G., Schmieder, B., Zapior, M., Heinzel, P.
We report on observations and modeling of cusp-shaped polar-crown prominence with a large bubble observed by the SDO/AIA imager and H alpha MSDP spectrograph (Bialkow). Intensity cuts in the SDO/AIA coronal images show that the emission of the bubble viewed face-on is equivalent or less than the typical coronal emission away from the prominence. We built linear force-free models of the observed prominences. These models contain a flux rope perturbed by inclusion of one or two parasitic bipoles. Shearing these bipole lead to formation of cusp-shaped with bubbles similar to the observed ones. Projection effects create illusion of vertical structures, which are in fact composed of magnetic dips viewed nearly along the magnetic field. While the prominence body contains magnetic dips, the field geometry in the bubble is that of an arcade. These different flux systems are separated by fan surfaces of two magnetic null-points. The fan surfaces intersect at a separator located at the boundary between the bubble and the prominence body. We conjecture that the formation of plumes involves reconnection at the separator.

A first look into the magnetic field configuration of prominence threads and bubbles using spectropolarimetric data

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We show first results of an ongoing investigation aimed at determining the configuration of the magnetic field vector in the threads of a quiescent hedgerow solar prominence using high-spatial resolution spectropolarimetric observations taken in the He I 1083.0 nm multiplet. The data consist of a two-dimensional map of a quiescent prominence and a slit time series showing the evolution of prominence threads. The time series samples the rise of a prominence bubble. The observations were obtained with the Tenerife Infrared Polarimeter (TIP) attached to the German Vacuum Tower Telescope at the Observatorio del Teide (Spain). We also use data from the Solar Dynamic Observatory and the STEREO satellites to put the TIP observations in context. The He I 1083.0 nm Stokes signals are interpreted with the HAZEL inversion code, which takes into account the key physical processes that generate and/or modify circular and linear polarization signals in the He I 1083.0nm triplet: the Zeeman effect, anisotropic radiation pumping, and the Hanle effect. We investigate the polarization signals and show maps of the strength and orientation of the magnetic field vector in the prominence threads and in areas surrounding of the prominence bubble. We also investigate the variations of the magnetic field vector during the rising of the prominence bubble.

Observation of the magnetic field in solar tornadoes

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We present high sensitivity (10^-4) spectropolarimetric observations, with high spatial resolution (~0.6"), and temporal evolution (up to four hours) of the recently discovered "solar tornadoes". The spectropolarimetry was performed at the He I line at 108.3 nm with the TIP instrument attached at the VTT (Observatorio del Teide). Simultaneously, at the same telescope, we recorded high cadence (~ 2sec) movies at the core of the Halpha line and the Ca II K line, which have been treated with blind deconvolution techniques to reach the diffraction limit of the telescope. Context EUV images from the SDO satellite have also been included in our analysis.
From inversion of the spectropolarimetric data and the simultaneous multiwavelength observations we recover the full magnetic field topology and strength, evolving in time. This is the first empirical reconstruction of the magnetic field in a solar tornado, which have been associated with the barbs of filaments. Finally, I will also discuss important issues on the observations and data analysis, as well as on the weaknesses of previous inversion approaches, and how to overcome them.

Chromospheric magnetic field of an active region filament using the He I triplet and the primary observation of filaments (prominences) using New Vacuum Solar Tower of China

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There are two parts in my presentation. In the first part I present the magnetic field measurement of an active region filament using the full Stokes profiles of He I 10830 and Si I 10827 band when the filament in its stable phase. This observation was fulfilled using German Vacuum Tower Telescope (VTT). The vector magnetic field and Doppler velocity map both in the photosphere and chromosphere were observed and analyzed co-temporally and co-spatially. The observation findings reveal that we were observing the emergence of a flux rope with a subsequent formation of a filament.
In the second part, I would like to exhibit another ground-based observation facility, 1m New Vacuum Solar Telescope (NVST) located in Fu-Xian Lake Solar Observatory of China. After the basic introduction including the location and instrumentations, I give some high lights including granulation, faculae, micro-flares, jets, and filaments or prominence since the first running in 2010, showing our potential ability to do high-resolution solar observation from the ground. Observation proposals from the international solar community are well appreciated in future.

3D PROMINENCE-HOSTING MAGNETIC CONFIGURATIONS: CREATING A HELICAL MAGNETIC FLUX ROPE

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The magnetic configuration hosting prominences and their surrounding coronal structure is a key research topic in solar physics. Recent theoretical and observational studies strongly suggest that a helical magnetic flux rope is a key ingredient to fulfill most of the theoretical and observational requirements for hosting prominences. The formation of a flux rope has to date been studied by models based on force-free extrapolations or zero-beta magnetohydrodynamic simulations. The key process, involving magnetic reconnection of sheared magnetic arcades at polarity inversion lines, has not fully been demonstrated. To understand flux rope formation details and obtain magnetic configurations suitable for future prominence formation studies, we here report on three-dimensional isothermal magnetohydrodynamic simulations including finite gas pressure and gravity. Starting from a magnetohydrostatic corona with a linear force-free bipolar magnetic field, we follow its evolution when introducing vortex flows around the main polarities and converging flows towards the polarity inversion near the bottom of the corona. The converging flows bring feet of different loops together above the polarity inversion line and magnetic reconnection happens. Outflow signatures of the reconnection process are identified, and the thereby newly formed helical loops wind around pre-existing ones so that a complete flux rope grows and ascends. When a macroscopic flux rope is formed, we switch off the driving flows and find that the system relaxes to a stable state containing a helical magnetic flux rope embedded in an overlying arcade structure. This is the first numerical demonstration of large-scale stable helical flux rope formation which includes plasma and gravitational stratification effects. This paves the way to true ab-initio simulations for prominence-hosting magnetic configurations.

Structure and topology of magnetic fields in solar prominences and their local environments

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Magnetic fields are believed to play an important role in the support of filament/prominence plasmas against gravity. I review recent observations of prominence fine structure and dynamics, as well as measurements of prominence magnetic fields using the Hanle effect. Observations indicate that on large scales (~ 100 Mm) prominences are located in coronal magnetic flux ropes or sheared arcades that lie horizontally above polarity inversion lines in the photosphere. For active region filaments the field is highy sheared but weakly twisted; for quiescent filaments the degree of twist in the flux ropes is still unknown. The plasma may be supported by dips in the field lines. The long lifetime of prominences implies that the flux ropes or sheared arcades are in magnetostatic balance with their surroundings, i.e., they are held down by less-sheared overlying arcades. Models for the 3D magnetic fields in and around prominences, based on photospheric magnetograms, have been developed using various techniques. These models allow detailed investigation of the magnetic topology and the role of the magnetic field in solar eruptions. On smaller spatial scales (A related question is how mass is injected into the these vertical threads. Different models for prominence formation and support are discussed.

Hemispheric Patterns in Filament Chirality and Sigmoid Morphology over the Solar Cycle

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We have used two automated feature finding modules developed by the SDO Feature Finding Team (FFT), namely the "Sigmoid Sniffer" and the "Advanced Automated Solar Filament Detection and Characterization Code", to study the statistics and correlations of these two phenomena from AIA and ground-based H-alpha observations. We find some familiar, some new, and some startling results.
New, as far as we know, but expected, is the strong correlation between filament chirality and sigmoid handedness. Surprising is a double-humped distribution of the angle that filaments make with respect to the equator. Startling is that we have found no confirmation of the chirality hemispheric rule so far for the current cycle. Looking at the filament chirality data since 2000 we find earlier published results on the hemispheric chirality rule at the beginning of cycle 23 confirmed, and we also find that this rule sometimes applies while at other times there is no hemispheric rule. We will offer suggestions, but have no definitive answer as to why this happens.

Magnetism and the Invisible Man: The Mysteries of Coronal Cavities

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Magnetism defines the complex and dynamic solar corona. Twists and tangles in coronal magnetic fields build up energy and ultimately erupt, hurling plasma into interplanetary space. These coronal mass ejections (CMEs) are transient riders on the ever-outflowing solar wind, which itself possesses a three-dimensional morphology shaped by the global coronal magnetic field. Coronal magnetism is thus at the heart of any understanding of the origins of space weather at the Earth. However, we have historically been limited by the difficulty of directly measuring the magnetic fields of the corona, and have turned to observations of coronal plasma to trace out magnetic structure. This approach is complicated by the fact that plasma temperatures and densities vary among coronal magnetic structures, so that looking at any one wavelength of light only shows part of the picture. In fact, in some regimes it is the lack of plasma that is a significant indicator of the magnetic field. Such a case is the coronal cavity: a dark, elliptical region in which strong and twisted magnetism dwells. I will elucidate these enigmatic features by presenting observations of coronal cavities in multiple wavelengths and from a variety of observing vantages, including unprecedented coronal magnetic field measurements now being obtained by the Coronal Multichannel Polarimeter (CoMP). These observations demonstrate the presence of twisted magnetic fields within cavities, and also provide clues to how and why cavities ultimately erupt as CMEs.

Diagnosing the Prominence-Cavity Connection

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The leading paradigm to describe the formation of cavities suggests that cavities are rarified because they supply mass to the prominence through a condensing process. In this study, we use time-dependent EUV emission and a hydrodynamic model for catastrophic cooling to test this hypothesis. Observationally, the cavity and the prominence exhibit strongly correlated dynamic emission structures that we refer to as horns. We conduct a statistical study of the spatial, temporal, and spectral characteristics of horns in the SDO/AIA dataset. We find there is a strong correlation between the 304A and 171A data but a very weak correlation between the 171A and 193A data. This suggests that horns may be a signature of the cooling process. We extend this analysis by comparing the light curves observed in horns to synthetic light curves based on 1D simulations of the thermal non-equilibrium (TNE) model, which produces a prominence through heating. While the TNE model shows a correlation between 171A emission and the formation of a condensation, the model predicts that the coronal segment of a post-condensation loop will be density-enhanced relative to an identical non-condensed loop. Based on the TNE model, we suggest that the cavity cannot be the mass source of the prominence, as the cooling process would produce density-enhanced cavities as opposed to the rarified cavities we observe in the corona.

Observation of the Prominence Cavity Regions using slitless Eclipse Flash Spectra and Spaceborn filtergrams

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During the total solar eclipse of 11 July 2010, slitless flash spectra were obtained simultaneously with SWAP/Proba2 174 and AIA/SDO 171, 193, 304 and 131 images.
The optically thin neutral Helium at 4713 A and singly ionized Helium 4686 A Paschen alpha lines are identified on eclipse (15 frames/seconde cadence) spectra where regions of limb prominences are obtained with space-borne imagers.
We summed 80 individual spectra to perform a 2D mapping of the ratio I (He I 4713) / I (He II 4686) and demonstrate a rising of the average temperature at the edge of the prominence. We also evaluate for the first time the continuum modulations in spectra with photometric accuracy. Intensity deficits are observed near the prominence boundaries in both eclipse spectra and in EUV images, confirming that the prominence cavity regions are characterized by some relative depression of plasma density in the surrounding corona.
The enhanced heating occurring in these regions is also discussed.

Large-amplitude longitudinal oscillations in solar prominences

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Large amplitude longitudinal (LAL) prominence oscillations consist of periodic mass motions along a filament axis. The oscillations appear to be triggered by an energetic event, such as a microflare, subflare, or small C-class flare, close to one end of a filament. Observations reveal speeds of several tens to 100 km/s, periods of order 1 hr, damping times of a few periods, and displacements equal to a significant fraction of the prominence length. We have developed a theoretical model to explain the restoring force and the damping mechanism. Our analytic model for the LAL oscillations demonstrates that the main restoring force is the projected gravity in the flux tube dips where the threads oscillate. Although the period is independent of the tube length and the constantly growing mass, the motions are strongly damped by the steady accretion of mass onto the threads. We conclude that the LAL movements represent a collective oscillation of a large number of cool, dense threads moving along dipped flux tubes, triggered by a small, nearby energetic event. Our model yields a powerful seismological method for constraining the coronal magnetic field strength and radius of curvature at the thread locations.

Observations and simulations of longitudinal oscillations of an active region prominence

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Context. Filament longitudinal oscillations have been observed in H? observations of the solar disk.
Aims: We intend to find an example of the longitudinal oscillations of a prominence, where the magnetic dip can be seen directly, and examine the restoring force of this type of oscillations.
Methods: We carry out a multiwavelength data analysis of the active region prominence oscillations above the western limb on 2007 February 8. In addition, we perform a one-dimensional hydrodynamic simulation of the longitudinal oscillations.
Results: Our analysis of high-resolution observations performed by Hinode/SOT indicate that the prominence, seen as a concave-inward shape in lower-resolution extreme ultraviolet (EUV) images, consists of many concave-outward threads, which is indicative of magnetic dips. After being injected into the dip region, a bulk of prominence material started to oscillate for more than 3.5 h, with the period of 52 min. The oscillation decayed with time, on the decay timescale 133 min. Our hydrodynamic simulation can reproduce the oscillation period, but the damping timescale in the simulation is 1.5 times as long as the observations.
Conclusions: The results clearly show the prominence longitudinal oscillations around the dip of the prominence and our study suggests that the restoring force of the longitudinal oscillations might be the gravity. Radiation and heat conduction are insufficient to explain the decay of the oscillations. Other mechanisms, such as wave leakage and mass accretion, have to be considered. The possible relation between the longitudinal oscillations and the later eruption of a prominence thread, as well as a coronal mass ejection (CME), is also discussed.

Unusual migration of the prominence activities in recent solar cycles

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The solar activity in recent solar cycles shows some anomalies. One of the significant anomalies is that few sunspots appeared in this solar minimum. The number of the spotless days from the late phase of Cycle 23 to the early phase of Cycle 24 is largest in the past 100 years. The other significant anomaly is that the period of Cycle 23 was over 12 years. In order to understand the anomalies, it is essential to know the variation of magnetic field distribution at the solar surface. It is well known that a prominence always lies on the boundariy between the opposite magnetic polarities and a prominences becomes a good indicator of the global magnetic distribution. Hence we investigated the global magnetic variation of the Sun based on the prominence activities.
Nobeyama Radioheliograph (NoRH) is an interferometer dedicated for solar observations in microwave. NoRH started the observation in July 1992 and is continuing to take the microwave images of the Sun. We developed the semi-automatic detection system of prominence activities and applied it to over 20 years data of NoRH. As a result, 1059 prominence activities were detected. From the detected events, we made the butterfly diagram of the prominence activities, and investigated the migrations of the producing region of prominence activities. The plot shows that the magnetic variation in the southern hemisphere strayed from a usual solar-cycle variation after the solar maximum of Cycle 23, despite the fact that the magnetic variation in the northern hemisphere is usual. The hemispheric asymmetry may help to explain the anomalies of recent cycles.

Global magnetic field cycle evolution and prominence eruptions

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It has been shown that the evolution of the solar global magnetic field is characterized by relatively sudden rearrangements of the structure. It has also been found that the coronal magnetic field strength follows the global magnetic field structure evolution and undergoes abrupt changes, reflecting changes in activity within the large-scale magnetic patterns. The field strength decreases during the times of the reorganizations of the global magnetic field. The prominence eruptions can be the result of the removal of the restraining coronal magnetic field. When the coronal magnetic structure is destroyed and the field diminishes, the force, which prevent a filament from eruption, decreases and a prominence can erupt. This explains destabilization and eruption of prominences not associated with flares, and processes in active regions, or with a new magnetic flux emergence. Furthermore, during such a global magnetic field structure reorganization, the number of prominence associated coronal mass ejections increases. The properties of prominences and coronal mass ejections associated with the global magnetic field structure reorganization are analyzed and an eruption scenario is proposed.

Explaining the Hemispheric Pattern of Filament Chirality

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Solar filaments are known to exhibit a hemispheric pattern in their chirality where dextral/sinistral filaments dominate in the northern/southern hemisphere. This pattern which has only been quantified in detail for the rising phase of the solar cycle, illustrates a global pattern of magnetic helicity and free magnetic energy that is critical for filament eruptions and CMEs. We show that this pattern can be explained through data driven 3D global magnetic field simulations of the Sun's large-scale magnetic field (Yeates at al 2008). Through a detailed comparison with 109 filaments over a 6 month period, the model correctly reproduces the filament chirality and helicity with a 96% agreement for 109 filaments. Following the models success, the data driven simulation is extended to run over a full solar cycle (Yeates and Mackay 2012) where predictions are made for the spatial and temporal dependence of the hemispheric pattern in the declining phase of the solar cycle. This prediction may be tested through new observing programs designed for the declining phase of the present cycle.

Yeates, Mackay and van Ballegooijen, A, 2008, Solar Physics, 247, 103
Yeates and Mackay, 2012, ApJ, 753, L34

Dynamics of prominences from combined ground-based and space-borne observations

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Data from two ground-based instruments operating continuously in Argentina since 1999 are analyzed in combination with satellite images to shed some light into the kinematical properties of erupting prominences during their early stages. In particular, images from MICA (Mirror Coronagraph for Argentina) in the green line (530.3 nm) allow us to study the acceleration phase of the events exceptionally close to the solar limb (1.05 to 2.0 solar radii), with a high temporal cadence (1 min in average) and also a relatively high spatial resolution of ~3.6 arcsec/pixel. On the other hand, HASTA (H-alpha Solar Telescope for Argentina) provides daily full Sun disk images in the hydrogen H? emission line at 656.27 nm with an spatial resolution of ~2 arcsec/pixel and a cadence of 1.5 min when running in patrol mode. Thus, both telescopes make an excellent complement to existent space instrumentation. We make use of white-light data from the SOHO/LASCO C2 and C3 coronagraphs in order to track the evolution of the erupting prominences at larger distances from the Sun and analyze modern data from SDO/AIA telescope when available. We present some case studies from a selection of events occurring at different phases of the solar cycle.

Evidence for Flux Ropes

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Observation with the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Explorer (SDO) together with data from the Extreme Ultraviolet Imager (EUVI) on STEREO and and the Large Angle Spectrometric Coronagraph (LASCO) on Solar Heliospheric Observatory (SOHO) have provided evidence for flux ropes that lie immediately above filaments seen in Helium II 30.4 nm. The flux ropes become detectable when the the filaments begin to rise. The rope structures can be later recognized when they appear in LASCO C2 and C3. Movies of these events will be shown.

Key Physics of Prominence Eruption : Models and Observations

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Prominence eruption is a key physical process in eruptive flares (i.e., CME related flares), and thus important for space weather research. Since erupting prominence often has a helical structure, it can be said that the erupting prominence is a kind of plasmoid (or flux rope in 3D space). We will discuss the prominence eruption as a prototype of the plasmoid ejection in reconnection dynamics, and will argue basic physics of reconnection (i.e., flares): why and how rapid energy release become possible via reconnection associated with plasmoid ejection (i.e., prominence eruption). In this sense, the prominence eruption is important not only in solar flares, but also in magnetospheric substorms and magnetically confined fusion plasmas. In this talk, we will discuss physics of prominence formation, its stability, and triggering mechanism of prominence eruption, and review recent studies of prominence eruption from both theoretical and observational points of view.

Where do we stand in understanding prominence eruptions

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Prominence eruptions are due to a violent destabilization of previously energized force-free coronal magnetic fields. But the detailed mechanisms which can [i] bring the corona towards an eruptive stage, then [ii] trigger and [iii] drive the eruption, and finally [iv] make it explosive, are not fully understood. A large variety of storage-and-release models have been developped and opposed to each other since the last decades. For example, photospheric flux emergence vs. flux cancellation, localized coronal reconnection vs. large-scale ideal instabilities and loss of equilibria, tether-cutting vs. beakout reconnection, local vs. inter active region couplings, and so on. The competition between all these approaches has led to a tremendous drive in developping and testing all these concepts, by coupling state-of-the-art models and instruments. Thanks to these developments, it now becomes possible to take all these models together, so as to identify and quantify the processes that contribute to [i-iv] respectively. I will show where we stand, and discuss which questions are still open. The hope is to move on to the development of yet-inexistant data-driven and physically-sound models, to catch-up with new observational puzzles and space weather forecasting.

Magnetohydrodynamic study on the effect of the gravity stratification on flux rope ejections

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Coronal Mass Ejections (CMEs) are one of the most violent phenomena found on the Sun. One model to explain their occurrence is the flux rope ejection model. In this model, magnetic flux ropes form slowly over time periods of days to weeks. They then loose equilibrium and are subsequently ejected from the solar corona over a few hours. The contrasting time-scales of formation and ejection pose a serious problem for a consistent modelling of the whole life-span of a flux rope.
In order to investigate if magnetic flux ropes formed during a quasi-static evolution can erupt to produce a CME, we run simulations of the full life-span of magnetic flux ropes coupling two models. The Global Non-Linear Force-Free Field (GNLFFF) evolution model of Mackay and van Ballegooijen (2006) is used to follow the quasi-static formation of a flux rope; the MHD code ARMVAC is used to simulate the production of a CME through the loss of equilibrium and ejection of this flux rope in presence of solar gravity and density stratification.
Our realistic multi-beta simulations describe the CME following the flux rope ejection and highlight the decisive role played by the gravity stratification on the CME propagation speed.

Torus instability of a line-tied flux rope

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In this study we presupposed the existence of a line-tied flux rope in the corona and impose that 1. its footpoints remain fixed to the solar surface, and 2. that the vertical magnetic field at the photosphere remain constant during an eruption. We adopt the magnetic configuration of Titov & Démoulin 1999 to model the flux rope. To satisfy the line-tying condition, an image current loop is specified that mirrors the evolution of the flux rope, as was done by Isenberg & Forbes 2007. Three forces are identified in this configuration: 1. the repulsive current force attributed to the image current loop, 2. the outward Lorentz self-force due to the curvature, and 3. the restoring external Lorentz force of the ambient magnetic fields. In this work, for the first time, all three forces are analyzed together. We use an ellipse current loop to model the flux rope plus image loop system. This model has the property that it can smoothly reproduce the force of the infinite straight current channel model and the circular loop model. Our analysis finds that stability is most dependent on how the ambient fields decay, in agreement with the torus instability. Finally, our study reveals that the imposed line-tying condition gives stability to shallow flux ropes, which are stable for all decay index values. These results are in contradiction to the conclusions of Démoulin & Aulanier 2010 and not in agreement with the law of instability of low lying loops.

Initiation of Coronal Mass Ejections by Sunspot Rotation

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We study a filament eruption, two-ribbon flare, and coronal mass ejection (CME) that occurred in active region NOAA 10898 on 6 July 2006. The filament was located south of a strong sunspot that dominated the region. In the evolution leading up to the eruption, and for some time after it, a counter-clockwise rotation of the sunspot of about 30 degrees was observed. We suggest that the rotation triggered the eruption by progressively expanding the magnetic field overlying the filament and test this scenario with three-dimensional zero-beta MHD simulations. To this end, we study the effect of twisting the potential field overlying a pre-existing flux rope by imposing appropriate vortex flows at the bottom boundary of the simulation box. We first consider a relatively simple and symmetric system, and then study a more complex and asymmetric magnetic configuration, whose photospheric flux distribution and coronal structure is guided by the observations and a potential field extrapolation. In both cases, we find that the twisting leads to the expansion of the overlying field. As a consequence of the progressively reduced magnetic tension, the flux rope quasi-statically adapts to the changed environmental field, rising slowly. Once the tension is sufficiently reduced, a distinct second phase of evolution occurs where the flux rope enters an unstable regime characterized by a strong acceleration.

Flux rope formation prior to filament eruption

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This talk will review the current understanding of the magnetic configuration of filaments at the onset of their eruption as a coronal mass ejection, including both active region and quiet sun prominences. The evolution of the magnetic field will be discussed as inferred from multiwavelength observations that indicate the formation of a magnetic flux to be occurring in the days before the CME associated with active region filaments. In addition, spectroscopic data will be discussed in the context of learning more about the 3D magnetic structure that cannot be deduced from imagers alone.

Three-dimensional Reconstruction of Eruptive Prominences

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On 2009 September 26, a dramatic and large filament (LF) eruption and a small filament (SF) eruption were
observed in the He ii 304Å line by the two EUVI telescopes aboard the STEREO A and B spacecraft. The LF
heads out into space and becomes the bright core of a gradual coronal mass ejection (CME), while the eruption
of the SF is characterized by motions of the filament materials. Using stereoscopic analysis of EUVI data, we
reconstruct the three-dimensional shape and evolution of two eruptive filaments. For the first time, we investigate
the true velocities and accelerations of 12 points along the axis of the LF, and find that the velocity and acceleration
vary with the measured location. The highest points among the 12 points are the fastest in the first half hour, and
then the points at the low-latitude leg of the LF become the fastest. For the SF, it is an asymmetric whip-like
filament eruption, and the downward motions of the material lead to the disappearance of the former high-latitude
endpoint and the formation of a new low-latitude endpoint. Based on the temporal evolution of the two filaments,
we infer that the two filaments lie in the same filament channel. By combining the EUVI, COR1, and COR2 data
of STEREO A together, we find that there is no impulsive or fast acceleration in this event. It displays a weak
and persistent acceleration for more than 17 hr. The average velocity and acceleration of the LF are 101.8 km s?1
and 2.9 m s?2, respectively. The filament eruptions are associated with a slow CME with an average velocity of
177.4 km s?1. The velocity of the CME is nearly 1.6 times as large as that of the filament material. This event is
one example of a gradual filament eruption associated with a gradual CME. In addition, the moving direction of
the LF changes from a non-radial to a nearly radial direction with a variation of inclination angle of nearly 38.2 degree.

Hinode/EIS - SDO/AIA study of a filament eruption

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On 5 January 2012 Hinode/EIS observed in scanning mode during a filament eruption which took place close to disk center. The filament was located along the NE external boundary of AR 11389, where it interfaced with a coronal hole. We combine the EIS observations with high temporal resolution observations from SDO/AIA to show details of the filament eruption. We present a detailed spectroscopic study (Doppler velocity, including its non-thermal component, temperature, density, FIP bias) from pre- to post-eruption evolution of the active region-filament-coronal hole complex, including that of a small anemone active region in the coronal hole as a potential trigger of the filament eruption. Hinode/EIS rasters capture the highly dynamic nature of the evolution including multiple jets, coronal hole boundary shift and depletion of high FIP bias plasma from the source region of the filament eruption.

Filaments Evolution and Flare in NOAA AR 11589

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Here, we present the dynamics of the filaments in NOAA AR 11589 and of the flare on 16 October, 2012. For this study, we used the multi-wavelength high resolution data from the Solar Dynamic Observatory (SDO) as well as THEMIS and ARIES, Nainital, India ground based observations. In the active region (AR), we follow the evolution of two filaments and observe the northern footpoint of both filaments coming closer to each other as time progresses but without merging. We derive the chirality of the filaments and find that both filaments have opposite chirality which, in this configuration, may have prevented them from merging. On 16 October 2012, we also observe a C3.3 class flare in the AR. At the flare location we notice the motion and cancellation of magnetic polarities. The flare occurred without eruption of the filaments present in the AR. According to the standard solar flare model, after the reconnection, the post flare loops form below the filaments. However, in our observations, we see the formation of post flare loops above the filaments, which is not consistent with the standard flare model. We perform linear force-free extrapolation and compute the quasi-separatrix layers (QSLs). The results show that the photospheric QSLs footprints matches the flare ribbons locations. We discuss how slipping or slip-running reconnection at the QSLs may explain the observed dynamics.

Transient Brightenings Associated with Flux Cancellation Along a Filament Channel

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Filament channels coincide with large-scale polarity inversion lines of the photospheric magnetic field, where flux cancellation continually takes place. High-cadence Solar Dynamics Observatory (SDO) images recorded in He II 30.4 nm and Fe IX 17.1 nm in August 2010 reveal numerous transient brightenings occurring along the edge of a filament channel within a decaying active region, where SDO line-of-sight magnetograms show strong opposite-polarity flux in close contact. The brightenings are elongated along the direction of the filament channel, with linear extents of several arcseconds, and typically last a few minutes; they sometimes have the form of multiple two-sided ejections with speeds on the order of 100 km/s. Remarkably, some of the brightenings rapidly develop into larger scale events, forming sheetlike structures that are eventually torn apart by the diverging flows in the filament channel and ejected in opposite directions. We interpret the brightenings as resulting from reconnections among filament-channel field lines having one footpoint located in the region of canceling flux. In some cases, the flow patterns that develop in the channel may bring successive horizontal loops together and cause a cascade to larger scales.

Fractal Reconnection and Stochastic Particle Acceleration induced by a Prominence Eruption

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Prominence eruptions in Solar flares are observed in association with intermittent high energy particle generation which is observed as footpoint hard X-ray brightening and super energetic particle (SEP) events in the interplanetary space. High energy particle generation is thought to be by acceleration inside or at around the reconnection current sheet below the flux rope and by shock acceleration near the propagation front of a prominence eruption or a coronal mass ejection (CME). These are strongly related to prominence eruption dynamics.
Here we performed 2D/3D MHD simulations and test particle simulation and revealed the following aspects. First, a current sheet is formed just below the flux rope and becomes thinner and thinner during the eruption. The current sheet with guide filed forms small multiple plasmoids inside and becomes turbulent. Locally enhanced electric field and trapping of particles inside the turbulent magnetic field are favorable for the stochastic particle acceleration. Second, a prominence eruption forms a current sheet at the propagation front to reconnect with the surrounding coronal fields. This connects a closed flare arcade and coronal open field lines, enabling accelerated particles to escape into the interplanetary space. Furthermore, multiple shocks are intermittently generated at around the reconnection point, propagating through the flux rope to the interplanetary space. At that time, escaping particles pass through the multiple shocks and accelerated intermittently. In this presentation, we will show our simulation results and compare them with recent observations such as SDO and Hinode.

Low polarised emission from the core of coronal mass ejections

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In white-light coronagraph images, the core of coronal mass ejections (CMEs) is sometimes identified with the cool prominence material. If, as generally assumed, this emission is caused by Thomson-scattered light from the solar surface, it should be strongly polarised tangentially to the solar limb. However, the observations of a CME made with the SECCHI/STEREO coronagraphs on 31 August 2007 show that the emission from the CME core is exceptionally low polarised.
We demonstrated for the first time that the bright core material is located close to the centre of the CME cloud. We show that the major part of the CME core emission, more than 85% in our case, is H alpha radiation and only a small fraction is Thomson-scattered light.

The 3-D NLFFF reconstruction of Active Region NOAA 11158

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A 3-D coronal magnetic fleld is reconstructed in NOAA 11158 on 2011 February 14 by a GPU-accelerated direct boundary integral equation method (GPU-DBIE), which is about 1000 times faster than the original DBIE for solar nonlinear force-free fleld modelling, with the SDO/HMI vector magnetogram as the bottom boundary condition. The reconstructed magnetic fleld lines are compared with the projected EUV loop structures as observed by SDO/AIA at line-of-sight and the STEREO A/B spacecraft at side views. They show very good agreement three-dimensionally so that the topology congurations of the magnetic fleld can be analyzed, and the role in the flare/CME process of the active region can be better understood. It is found that the observed coronal loop structures can be grouped into a number closed and open fleld structures with some central bright loop features across the polarity inversion line which may have played a key role. A group of electric current lines co-aligned with the central bright loops along the polarity inversion line has been obtained, which conrms its important role in the flare/CME process.

Sympathetic Partial and Full Filament Eruptions Observed in One Solar Breakout Event

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We report two sympathetic solar eruptions including a partial and a full flux rope eruption in a quadrupolar magnetic region where a large and a small filament resided above the middle and the east neutral lines, respectively. The large filament first rose slowly at a speed of 8 km s?1 for 23 minutes; it then accelerated to 102 km s?1 . Finally, this filament erupted successfully and caused a coronal mass ejection. During the slow rising phase, various evidence for breakout-like external reconnection has been identified at high and low temperature lines. The eruption of the small filament started around the end of the large filament's slow rising. This filament erupted partially, and no associated coronal mass ejection could be detected. Based on a potential field extrapolation, we find that the topology of the three-dimensional coronal field above the source region is composed of three low-lying lobes and a large overlying flux system, and a null point located between the middle lobe and the overlying antiparallel flux system.We propose a possible mechanism within the framework of the magnetic breakout model to interpret the sympathetic filament eruptions, in which the magnetic implosion mechanism is thought to be a possible link between the sympathetic eruptions, and the external reconnection at the null point transfers field lines from the middle lobe to the lateral lobes and thereby leads to the full (partial) eruption of the observed large (small) filament. Other possible mechanisms are also discussed briefly. We conclude that the structural properties of coronal fields are important for producing sympathetic eruptions.

A solar tornado caused by flares

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An enormous solar tornado was observed by SDO/AIA on 25 September 2011. It was associated with a quiescent prominence with an overlying coronal cavity. The tornado appeared near to the active region NOAA 11303 on the south west limb of the Sun. We investigate the triggering mechanism of the solar tornado by using the data from two instruments: SDO/AIA and STEREO-A/EUVI, observing the Sun from two directions. There were three flares from the active region which directly influenced the nearby prominence-cavity system. We propose that the release of free magnetic energy from the active region during the flares resulted in a lower pressure in the active region corona and a contraction of the active region field. The neighboring cavity then expanded to fill the vacated space in the corona which triggered the tornado at the top of the prominence due to the expansion of the prominence-cavity system.

Dynamo driven coronal ejections

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Observations show that the Sun sheds mass through twisted magnetic flux configurations, like Coronal Mass Ejections (CMEs). Conventionally, CMEs are modeled by adopting a given distribution of magnetic flux at the solar surface and letting it evolve by shearing and twisting the magnetic field at its footpoints at the surface. Of course, ultimately such velocity and magnetic field

patterns must come from a realistic simulation of the Sun's convection zone, where the field is generated by dynamo action. Therefore a unified treatment of convection zone and CMEs is needed. We combine a convectively driven dynamo with a polytropic layer that extends to 1.6 solar radii. The temperature increases in this region to about 8 times the value at the surface, corresponding to about 1.2 times the value at the bottom of the spherical shell. We associate this region with the solar corona. Magnetic fields are found to emerge at the surface and are ejected to the coronal part of the domain. These ejections occur in irregular intervals and are weaker than in earlier work. We tentatively associate these events with coronal mass ejections on the Sun. We find a solar-like differential rotation with radial contours of constant rotation rate, together with a solar-like meridional circulation and a near-surface shear layer. This spoke-like rotation profile is caused by a non-zero latitudinal entropy gradient which violates the Taylor-Proudman balance via the baroclinic term. The lower density stratification compared with the Sun leads to an equatorward return flow above the surface. The mean magnetic field is in most of the cases oscillatory with equatorward migration in one case. In other cases the equatorward migration is overlaid by stationary or even poleward migrating mean fields.

An estimate of the contribution of blowout jets to the solar wind mass and energy

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Blowout jets constitute about 50% of the total number of X-ray jets observed in coronal holes. In these events, the base magnetic loop is supposed to blow open in what is a scaled-down representation of two-ribbon flares that accompany major coronal mass ejections (CMEs): indeed, miniature CMEs resulting from blowout jets have been observed. This raises the question of the possible contribution of this class of events to the solar wind mass and energy flux.
Here we make a first crude evaluation of the mass contributed to the wind and of the energy budget of the jet and related miniature CME, under the assumption that small-scale events behave as their large-scale analogs. This hypothesis allow us to adopt the same relationship between flare and CME parameters that have been shown to hold in regular events, thus inferring the values of the mass and kinetic energy of the miniature CMEs, currently not available from observations.
We conclude our work estimating the mass flux from the jets and miniature CMEs, as well as the energy budget of the blowout jet and CME, and giving a crude evaluation of the role possibly played by these events in supplying the mass and energy that feeds the solar wind.

Evolution of ICMEs and magnetic clouds in the heliosphere

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Significant quantities of magnetized plasma are transported from the Sun to the interstellar medium via interplanetary coronal mass ejections (ICMEs). Magnetic clouds are a particular subset of ICMEs, forming large-scale magnetic flux ropes. Their evolution in the solar wind is mainly determined by their own magnetic forces and the interaction with the surrounding solar wind. This interaction is complex since, for example, as their 3D magnetic structure expands in all directions while traveling away from the Sun, a sheath of plasma and magnetic field accumulates in front, which partially reconnects with the ICME magnetic field.
This talk will provide a summary of present knowledge and perspectives on the ICMEs propagation and interactions.

Coronal mass ejections from the upper corona to Earth's bow shock

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In the past six years, the two STEREO spacecraft have remotely observed hundreds of coronal mass ejections (CMEs), shedding light on their heliospheric evolution. Combined with global numerical simulations and multi-point in situ measurements, these observations can reveal intricate physical phenomena occurring during the propagation of CMEs between the Sun and the Earth. I will present recent simulations and observational results that give new insight on CME-CME interaction, but also raise new questions about CME heliospheric deflection and rotation as well as the nature of CMEs itself. I will also discuss some recent efforts in understanding the Sun-to-Earth evolution of complex series of eruptions as well as their geo-effectiveness and their effectiveness in accelerating particles, focusing on events from 2008 to 2011.

Characterization of global geometrical properties of magnetic clouds deduced from in-situ data

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Magnetic clouds (MCs) are sub-classes of interplanetary coronal mass ejections. One of their main characteristics is the strong rotation of the magnetic field that indicates the existence of a twisted magnetic flux tube, commonly called a flux rope. 1D in-situ data from probes crossing magnetic clouds only give local information on the magnetic field. Fitting these data with analytical models provide the magnetic field distribution within a cross section and can locally determine the flux rope axis orientation.
We first investigate the non-flat probability distribution of the impact parameter, as deduced from WIND data by Lepping & Wu (Annales Geophysicae, 2010). We compare this distribution with similar ones obtained with synthetic data simulating MCs crossing. We find that the probability distribution of detected MCs in WIND data can be understood as a natural consequence of flattened flux rope cross sections. Especially, we find that the velocity of the propagating MCs can lead to two categories of cross section shapes: circular for the faster ones, and elongated for the slower ones.
We further investigate the typical flux rope global shapes by studying the distribution of local axis orientation. We propose a new statistical method that allows deriving the mean global shape axis from a statistical study of the 107 MCs observed by WIND. This shape is also found in 3D structures deduced from heliospheric imagers of propagating MCs.
Such a work gives an important understanding on the global shape of flux ropes. These new methods can be applied to any other flux rope models fitted to the in situ data.

Reconstruction of Magnetic Clouds from In-Situ Spacecraft Measurements and Intercomparison with Their Solar Sources

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Coronal Mass Ejections (CMEs) are explosive events that originate, propagate away from the Sun, and carry along solar material with embedded solar magnetic field. Some are accompanied by prominence eruptions. The entire process can be observed by multiple instrumentations on-board several on-going spacecraft missions. The interplanetary counterparts of CMEs (ICMEs) are often detected in-situ by spacecraft ACE and Wind, which provide both magnetic field and plasma measurements sampled along the spacecraft path across the ICME structure. All these remote-sensing and in-situ measurements make it possible to perform the intercomparison between the (I)CMEs and their source regions at the Sun. In particular, a subset of ICMEs, so-called Magnetic Clouds (MCs) can be characterized by magnetic flux-rope structures. We will apply the Grad-Shafranov reconstruction technique to examine the configuration of MCs and to derive relevant physical quantities, such as magnetic flux content, the field-line twist, and relative magnetic helicity. We will select recent events during the rising phase of enhanced solar activity, and utilize additional observations from the most recent spacecraft missions, such as the STEREO and SDO spacecraft. Both observational analyses of solar source region characteristics including flaring and dimming, and the corresponding MC structures will be presented. We will perform both statistical and detailed case studies to examine the properties of different events with and without associated prominence eruptions. We will try to discern the role of prominence in the formation of flux ropes and its relations to MC properties derived from in-situ measurements.

Properties and processes that influence CME geo-effectiveness

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This presentation will provide a review of CMEs: (1) intrinsic properties set at the Sun (e.g., orientation, trajectory, acceleration, etc.), (2) processes that may occur during propagation (e.g., shocks, compressions, magnetic erosion, etc.), and (3) in the specific interaction with Earth's magnetosphere (e.g., preconditioning mechanisms) that can have a significant influence on their geo-effectiveness. Their relative importance will be discussed.

The geoeffectiveness of ICMEs

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It is well established that the origin of geomagnetic storms are related to interplanetary structures possessing southward interplanetary magnetic field component (Gonzalez et al., 1994). Coronal mass ejection counterparts observed in the interplanetary medium, called ICMEs, are found to be some of the most frequent sources of such southward fields. ICME internal fields and sheath fields associated with their interplanetary shocks are both the dominant origins of intense geomagnetic storms (Dst

Can a halo CME from the limb be geoeffective?

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The probability for a halo coronal mass ejection (CME) to be geoeffective is assumed to be higher the closer the CME launch site is located to the solar central meridian. However, events far from the central meridian may produce severe geomagnetic storms, like the case in April 2000. In this presentation, we show a study about the possible geoeffectiveness of full halo CMEs with the source region situated at solar limb. For this task, we select all limb full halo (LFH) CMEs that occurred during solar cycle 23, and we search for signatures of geoeffectiveness between 1 and 5 days after the first appearance of each CME in the LASCO C2 field of view. When signatures of geomagnetic activity are observed in the selected time window, interplanetary data are carefully analyzed in order to look for the cause of the geomagnetic disturbance. Finally, a possible association between geoeffective interplanetary signatures and every LFH CME in solar cycle 23 is checked in order to decide on the CME's geoeffectiveness. After a detailed analysis of solar, interplanetary, and geomagnetic data, we conclude that of the 25 investigated events, there are only four geoeffective LFH CMEs, all coming from the west limb. The geoeffectiveness of these events seems to be moderate, turning to intense in two of them as a result of cumulative effects from previous mass ejections. We conclude that ejections from solar locations close to the west limb should be considered in space weather, at least as sources of moderate disturbances.

Statistical analysis of magnetic cloud erosion by magnetic reconnection

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Magnetic clouds (MCs), described as large-scale toroidal magnetic structures, interact with the surrounding interplanetary medium during propagation. It has been suggested in particular that magnetic reconnection may peel off their outer magnetic structure. Recently, Ruffenach et al. (2012) confirmed the occurrence of MC erosion thanks to a multi-spacecraft study combining a set of key signatures expected from this process. The aim of the present study is to extend previous works on the topic to all MCs of solar cycle 23 in order to quantify this phenomenon. This statistical analysis, primarily carried out with WIND and complemented with recent STEREO data, focuses on three signatures. First, based on careful determination of the MCs main axes, we estimate the amount of magnetic flux eroded for each event by analysing the azimuthal flux imbalance during the spacecraft sampling of the flux rope. We also search for magnetic reconnection signatures at the front boundary of the MCs. Finally, we investigate the characteristics of suprathermal electrons in the back region of the MCs. Those electrons are considered to signal potential large-scale topological changes expected from the erosion process.

Coronal Mass Ejections and associated shocks: Build-up and propagation in a complex environment

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In recent years, new insight on the formation of CMEs and of their early expansion in the ambient magnetic field arisen from the high cadence observations obtained simultaneously with the SDO/AIA telescope and with the two-sided view of the STEREO spacecraft. We report on a series of CMEs events which occurred during two consecutive days in which EUV eruptive filament activity was quasi-continuously observed. The large set of imaging observations obtained in EUV, white light and radio joined to radio spectral data, provides an opportunity to trace in detail their evolution from the origin in the low corona to a few solar radii. We focus more particularly on i) the build-up of the erupting flux-rope and of the shock; ii) the interaction of the CME and of the associated driven shock with the complex environment which can strongly affect the physical parameters of the shock and the CME latitudinal migration.

The in-situ manifestation of solar prominence material

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Coronal mass ejections observed in the corona exhibit a «three-part structure», with a leading bright front indicating dense plasma, a low density cavity thought to be a signature of the embedded magnetic flux rope, and the high density core likely containing cold, prominence material When observed in-situ, as Interplanetary CMEs (or ICMEs), the presence of all three of these signatures remain elusive, with the prominence material rarely observed. We report on a comprehensive and long-term search for prominence material inside ICMEs as observed by the Solar Wind Ion Composition Spectrometer on the Advanced Composition Explorer. Using a novel data analysis process, we are able to identify traces of low charge state plasma created during prominence eruptions associated with ICMEs. We find that the likelihood of occurrence of cold material in the heliosphere is vastly lower than that observed in the corona but that conditions during the eruption do allow low charge ions to make it into the solar wind, preserving their expansion history. We discuss the implications of these findings.

Interplanetary Disturbances Affecting Space Weather

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The Sun somehow accelerates the solar wind, an incessant stream of plasma originating in coronal holes and some, as yet unidentified, regions. Occasionally, coronal, and possibly sub-photospheric structures, conspire to energize a spectacular eruption from the Sun which we call a coronal mass ejection (CME). These can leave the Sun at very high speeds and travel through the interplanetary medium, resulting in a large-scale disturbance of the ambient background plasma. These interplanetary CMEs (ICMEs) can drive shocks which in turn accelerate particles, but also have a distinct intrinsic magnetic structure which is capable of disturbing the Earth's magnetic field and causing significant geomagnetic effects. They also affect other planets; in essence, they can and do contribute to space weather throughout the heliosphere.
This talk will present a review of these disturbances and attempt to discuss their global heliospheric effects.

Filament Eruptions, Jets, and Space Weather

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Previously, from chromospheric Ha and coronal X-ray movies of the Sun's polar coronal holes, it was found that nearly all coronal jets (>90%) are one or the other of two roughly equally common different kinds, different in how they erupt: standard jets and blowout jets (Yamauchi et al 2004, ApJ, 605, 511; Moore et al 2010, ApJ, 720, 757). Here, from inspection of SDO/AIA He II 304 Å movies of 54 polar X-ray jets observed in Hinode/XRT movies, we report, as Moore et al (2010) anticipated, that (1) most standard X-ray jets (>80%) show no ejected plasma that is cool enough (T ~ 105 K) to be seen in the He II 304 Å movies; (2) nearly all blowout X-ray jets (>90%) show obvious ejection of such cool plasma; (3) whereas when cool plasma is ejected in standard X-ray jets, it shows no lateral expansion, the cool plasma ejected in blowout X-ray jets shows strong lateral expansion; and (4) in many blowout X-ray jets, the cool-plasma ejection displays the erupting-magnetic-rope form of classic filament eruptions and is thereby seen to be a miniature filament eruption. The XRT movies also showed most blowout X-ray jets to be larger and brighter, and hence to apparently have more energy, than most standard X-ray jets.
These observations (1) confirm the dichotomy of coronal jets, (2) agree with the Shibata model for standard jets, and (3) support the conclusion of Moore et al (2010) that in blowout jets the magnetic-arch base of the jet erupts in the manner of the much larger magnetic arcades in which the core field, the field rooted along the arcade's polarity inversion line, is sheared and twisted (sigmoid), often carries a cool-plasma filament, and erupts to blowout the arcade, producing a CME. From Hinode/SOT Ca II movies of the polar limb, Sterling et al (2010, ApJ, 714, L1) found that chromospheric Type-II spicules show a dichotomy of eruption dynamics similar to that found here for the cool-plasma component of coronal X-ray jets. This favors the idea that Type-II spicules are miniature counterparts of coronal X-ray jets. In Moore et al (2011, ApJ, 731, L18), we pointed out that if Type-II spicules are magnetic eruptions that work like coronal X-ray jets, they carry an area-averaged mechanical energy flux of~7x105 erg cm-2 s-1 into the corona in the form of MHD waves and jet outflow, enough to power the heating of the global corona and solar wind. On this basis, from our observations of mini-filament eruptions in blowout X-ray jets, we infer that magnetic explosions of the type that have erupting filaments in them are the main engines of both (1) the steady solar wind and (2) the CMEs that produce the most severe space weather by blasting out through the corona and solar wind, making solar energetic particle storms, and bashing the Earth's magnetosphere. We conclude that in focusing on prominences and filament eruptions, Einar had his eye on the main bet for understanding what powers all space weather, both the extreme and the normal.
This work was funded by NASA's Science Mission Directorate through the Living With a Star Targeted Research and Technology Program and the Hinode Project, and by NSF through its Research Experience for Undergraduates Program.

Observations of coronae and prominences in active cool stars

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X-ray and EUV observations of young cool stars have shown that their coronae are extremely pressured environments with temperatures and densities that are up to two orders of magnitudes larger than those observed in the solar corona. At the same time rapidly transiting absorption features in optical and UV spectra reveal the presence of large cool, prominence-type complexes that can extend several stellar radii. I will give an overview of our current understanding of coronal structures in cool stars from multi-wavelength observations, detailing their properties and apparent dependence on spectral type. I will also outline future prospects in this field, particularly from observations of stellar coronal environments at radio and sub-mm wavelengths.

Coronal mass ejections and angular momentum loss in young stars

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In our own solar system, the necessity of understanding space weather is readily evident. Fortunately for Earth, our nearest stellar neighbor is relatively quiet, exhibiting activity levels several orders of magnitude lower than young, solar-type stars. In protoplanetary systems, stellar magnetic phenomena observed are analogous to the solar case, but dramatically enhanced on all physical scales: bigger, more energetic, more frequent. While coronal mass ejections (CMEs) could play a significant role in the evolution of protoplanets, they could also affect the evolution of the central star itself. To assess the consequences of prominence eruption/CMEs, we have invoked the solar-stellar connection to estimate, for young, solar-type stars, how frequently stellar CMEs may occur and their attendant mass and angular momentum loss rates. We will demonstrate the necessary conditions under which CMEs could slow stellar rotation. Finally, we will discuss the potential for observing stellar CMEs on stars of a variety of masses.

Magnetised stellar winds and their impact on exoplanets

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In this talk, I will review the latest progress made in data-driven modelling of magnetised stellar winds. The proper characterisation of the background wind is crucial to constrain interactions between exoplanets and their host-star's winds and also essential for the study of propagation of CMEs and space weather events on exoplanets. Although the great majority of exoplanets discovered so far are orbiting cool, low-mass stars with properties (mass, radius and effective temperatures) similar to solar, the stellar magnetism can be significantly different from the solar one, both in topology and intensity. In addition, due to the current technology used in exoplanetary searches, most of the currently known exoplanets are found orbiting at extremely close distances to their host stars (

Solar wind properties and coronal rotation during the activity cycle

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The properties of the solar wind flow are strongly affected by the time-varying strength and geometry of the global background magnetic field.
The wind velocity and mass flux depend directly on the size and position of the wind sources at the surface.
The angular momentum (torque) balance depends on how the differential surface rotation is transmitted upwards across the highly stratified chromospheric layers, and up to the corona along the magnetic field.
We address these problems by performing numerical simulations coupling a kinematic dynamo code (STELEM) evolve in a 2.5D axisymmetric coronal MHD code (DIP) covering an 11 yr activity cycle.
We defined and tested a simple approximation allowing the study of coronal phenomena while taking into account a parametrised effective chromospheric reflectivity (which accounts for the effects of the chromospheric stratification on rotation).
We found that the global Sun's mass loss rate, angular momentum flux and magnetic braking torque vary considerably throughout the cycle.
Also, a high (yet partial) effective reflectivity is required for sustaining the coronal rotation against the solar wind magnetic breaking torque, while still allowing for the necessary amount of footpoint leakage (coronal stress release).
Finally, we point out directions to assess the effects of more transient phenomena on the global properties of the wind.

Modeling magnetized star-planet interactions

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The diversity of discovered exoplanets in terms of mass, orbit and distance to their host stars promoted a renewed effort of the scientific community on better understanding star-planet interactions (SPI). Close- in planets provide a very interesting natural case of SPI in that their close orbit makes them more exposed to stellar ejecta. Also, they are in some cases likely to orbit inside the stellar wind Alfvèn radius and thus be able to impact their host star global properties (e.g., stellar rotational and/or magnetism evolution history). Among the numerous SPI models which have been developed over the past years, specific magnetohydrodynamic (MHD) simulations have been performed by a few different research groups in order to combine «state of the art» stellar wind numerical models with simplified models of planetary magnetospheres. Because those models are global, they are able to assess both the planetary evolution trends as well as the potential influence of close planets on their host stars self-consistently.
We present here a parametric study of global magnetic SPI using the PLUTO code. We distinguish the cases of magnetized and unmagnetized planets, which produce significantly different results, as expected. We characterize the potential influence of close-in planets on their host star properties, depending on their orbital position in the stellar wind. Thanks to the versatility of the PLUTO code, we put a particular emphasis on the influence of various numerical parameters (ideal vs diffusive MHD approaches, boundary conditions choices, numerical methods, magnetic toplogies) on the numerical simulations predictions. Finally, we discuss how to use such global models for studying short time-scale phenomena, such as coronal mass ejections (CME)-planet interactions and planetary magnetospheric response.

Stellar CME activity and its possible influence on exoplanets' environments

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CMEs are large-scale magnetized plasma structures carrying billions of tons of material that erupt from a star and propagate in the stellar heliosphere, interacting in multiple ways with the stellar wind. As one of the most important factors of the stellar activity, they are believed to be a critical element in the stellar dynamo which removes the dynamo-generated magnetic flux from the star and connects the internal stellar dynamo processes to the external stellar environment. Due to the high speed, intrinsic magnetic field and the increased plasma density compared to the stellar wind background, CMEs can produce strong effects on planetary environments when they collide with a planet. The main planetary impact factors of CMEs, are associated interplanetary shocks, energetic particles accelerated in the shock regions, and the magnetic field disturbances which create magnetic storms. All these factors should be considered during the study of the CMEs' role in creation of particular planetary conditions. Important parameters for characterization of the 'stellar CMEs - planetary atmosphere and surface interaction' are the density and velocity of the CMEs plasma. These may be highly variable with stellar age, as well as dependent on the stellar spectral type and the orbital distance of a planet. Because of relatively short range of propagation of majority of CMEs, they impact most strongly the magnetospheres and atmospheres of close orbit (0.1 AU) planets.
We have currently a good knowledge of CME parameters on the Sun, whereas the amount of corresponding data related to other stars is much more limited. On the Sun, CMEs are associated with flares and prominence eruptions and their sources are usually located in active regions and prominence sites. The likelihood of CME-events increases with the size and power of the related flare event. Therefore, the existing correlation between strong flares and CMEs on the Sun is often used, assuming a solar-stellar analogy, for judging about CME activity on active flaring stars. It is expected that the frequent and powerful flares on magnetically active flaring stars should be accompanied by an increased rate of CME production.
The plasma of stellar CMEs colliding with a planet, interacts with the planetary magnetosphere, and in the case of a weak magnetospheric protection (i.e., weak or no intrinsic planetary magnetic dipole), the magnetosphere is compressed down to the planetary surface, resulting in strong erosion of the planetary atmosphere. Sufficiently large magnetospheres are known to protect the underlying planetary environments, e.g. ionosphere, atmosphere, and surface against of stellar XUV/EUV and stellar wind factors. These usually require strong enough intrinsic planetary magnetic fields and/or extended magnetospheric current systems such as magnetodisks.
In the present talk we discuss the role of such factors like activity of a host star and intrinsic magnetic field of a planet and show how the account of these factors may influence the erosion of planetary upper atmospheres and their mass loss throughout the lifetime of a planet.

Space observations of evaporating exoplanets

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Soon after the first detection of an exoplanetary atmosphere in 2002, ultraviolet observations with Hubble revealed that the upper atmospheric layers of transiting hot Jupiters can be extremely extended, escaping the gravitational potential of the planets, and eventually forming hydrogen clouds occulting a large fraction of the star during planetary transits. Such atmospheric "evaporation" is surmised to impact the fate of low-mass exoplanet and to be triggered by the absorption of an intense stellar X and extreme UV irradiation in the upper atmospheres of planets. In September 2011, we started the first campaign of simultaneous UV and X space observations of transiting exoplanets, from giant planets down to super-Earths. I will present the first results of these combined observations, which hint at star-planet interaction and suggest that atmospheric evaporation is also possible for "warm" Jupiters, cooler than those previously studied, thus bridging the gap with our even cooler Solar System planets.

Prominences observations from space: advances and future challenges

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Despite important advances from recent space missions such as Hinode and SDO, questions concerning the formation and stability of prominences are still open. This is due in part to the limitations of the observations. The fine scale structure and dynamics are still poorly resolved in some temperature regimes, and magnetic field measurements remain very difficult. We will discuss what type of observations are needed to make progresses on these aspects. We will review the capabilities of the future planned space instrumentation and highlight what is missing.

The IRIS mission - prospects for prominence and filament science

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The Interface Regiion Imaging Spectrograph (IRIS) is a NASA Small explorer satellite to be launched May 18 2013. The satellite is taylored to study the solar chromosphere and transition region with high spatial (0.3"), spectral (28-55 mA) and temporal (10s) resolution in three wavelength bands (1332-1358, 1381-1407, 2783-2834 A). These bands include the Mg II h and k lines and C II lines formed in the chromosphere, Si IV and O IV lines formed in the transition region and hotter lines visible only in flares. In this talk focus will be on the instrument characteristics and the initial observing plan and the prospects for prominence and filament science.

Observation of the prominence eruptions and CME during the Interhelioprobe solar mission

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The Interhelioprobe (IHP) is a perspective space solar mission developed by the Russian Space Agency together with the Russian Academy of Sciences. The mission aims to provide long-term remote observations of the Sun and in-situ measurements of the heliospheric magnetic fields and plasma from the out-of-ecliptic heliocentric orbit with the perihelion of about 60 solar radii. The Interhelioprobe spacecraft is equipped with an ensemble of imaging instruments at least two of which are specially dedicated for observations of solar eruptive phenomena and CME. The first one is a white-field coronagraph named "Oka" which will observe the outer solar corona from the distance of 2? to 10? from the Sun's center. The second one is a white-field heliospheric imager "Heliosphera" with the field of view of 10? ? 30?. We describe in detail both these instruments and present our scientific program for observation of CME and eruptive phenomena during the IHP mission.

Introduction to the Chinese Giant Solar Telescope

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In order to detect the fine structures of solar magnetic field and dynamic field, an 8 meter solar telescope has been proposed by Chinese solar community. Due to the advantages of ring structure in polarization detection and thermal control, the current design of CGST (Chinese Giant Solar Telescope) is an 8 meter ring solar telescope. The spatial resolution of CGST is equivalent to an 8 meter diameter telescope, and the light-gathering power equivalent to a 5 meter full aperture telescope. The results of simulation and analysis showed that the current design could meet the demand of most science cases not only in infrared band but also in near infrared band and even in visible band. The observations of the prominence and the filament are also very important science cases of CGST. CGST was proposed by all solar observatories in Chinese Academy of Sciences and several overseas scientists. It is supported by CAS and NSFC (National Natural Science Foundation of China) as a long term astronomical project.

Scientific Programmes with India's National Large Solar Telescope and their contribution to Prominence Research

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India's National Large Solar Telescope (NLST) is a state-of-the-art 2-m class telescope for carrying out high-resolution studies of the solar atmosphere. Its geographical location in the Ladakh region of Jammu & Kashmir (India) will fill the longitudinal gap between Japan and Europe and is expected to be the largest solar telescope till ATST and EST come into operation. NLST is an on-axis alt-azimuth Gregorian multi-purpose open telescope with the provision of carrying out night time stellar observations using a spectrograph at the Nasmyth focus. The telescope utilizes an innovative design with low number of reflections to achieve a high throughput and low polarization. High order adaptive optics is integrated into the design that works with a modest Frieds parameter of 7-cm to give diffraction limited performance. The post-focus instruments include broad band and tunable Fabry-Perot narrow band imaging instruments, a high resolution spectropolarimeter and an echelle spectrograph for night time astronomy.
NLST will address a large number of scientific questions with a focus on high resolution observations. The direct measurements of magnetic fields in prominences have so far been obtained mainly in H-alpha, He I multiples at the visible and IR wavelength regions. However, they achieve a spatial resolution of few arc sec. With NLST, high spatial resolution observations of prominences are possible in these spectral lines using multi-line spectropolarimetry. Studies of filament eruptions as a whole, and the dynamics of filaments on fine scales using high resolution observations will be undertaken. An important issue is to examine he role of barbs that undergo appearance and disappearance in the activated phase of an eruptive filament.
NLST will carry out observations to examine the following aspects related to prominences:
(1) Morphology of different prominences and their association to the magentic field structure;
(2) Magnetic field structure of different barbs and how they are connected to the underlying photospheric magnetic field;
(3) Magnetic helicity in the solar prominences and filaments;
(4) Formation of prominence/filament plasma and how does it evolve along with its magnetic field configuration;
(5) Prominence/filament oscillation and its relation to the MHD waves and possible heating mechanisms;
(6) Magnetic structure of polar crown prominences.

ALMA Observations of Solar Prominences

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Atacama Large Millimeter/submillimeter Array (ALMA) is also intended to be used for solar research, with the European solar ALMA node located in Ondrejov. The great potential of ALMA lies
in rather straightforward temperature diagnostics of chromospheric-type plasmas, and in particular
of the coolest prominence structures. We briefly review the ALMA capabilities and then demonstrate
how a quiescent prominence would appear in different ALMA wavelength channels. We show that the prominence fine-structures are well detectable. Using an unprecedented spatial resolution of ALMA, together with a forward modeling techniques, we will be able to map the temperatures of cool prominence condensations and study their structure and dynamics.

Prominence science with the ATST first light instrumentation

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The 4m Advance Technology Solar Telescope (ATST) is under construction on Maui, HI. With its unprecedented resolution and photon collecting power ATST will be an ideal tool studying prominences and filaments and their role in producing Coronal Mass Ejections. The ATST facility will provide a set of first light instruments that enable imaging and spectroscopy of the dynamic filament and prominence structure at eight times the resolution of Hinode. Polarimeters allow high precision chromospheric and coronal magnetometry of prominence structure at visible and infrared (IR) wavelengths. The infrared is particularly attractive for coronal spectroscopy and magnetometry due to low sky and instrumental background and relatively bright mid-IR coronal emission lines. We will review the design and capabilities of the ATST first light instruments when operated individually or as a system. Current concepts for data products from the instruments and community access to data products will be discussed.

Instrument concepts for the observation of prominences with future ground-based telescopes

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Present trends in the observation of the Sun with ground-based solar telescopes converge into a desire of simultaneously measuring spatial, spectral and polarimetric information. Spectro-imagers with polarimetric capabilities of different kinds are seeing first light or being tested in most of the present ground-based solar telescopes. The observation of prominences is not strange to these trends. I will review present instrumentation in ground telescopes for prominences: from instruments measuring prominence magnetic fields (THEMIS, TIP and DST-Spinor) to those measuring the spatio-temporal evolution of the prominence plasma (like ROSA). The future instruments should maintain and combine the capabilities of present ones: what should those instruments look-like? This talk will try to answer this question in the advent of 4-m class solar telescopes as EST and ATST.

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