48th SPD Meeting
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Meeting Abstracts

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100 – Flares: Observations

100.01 – Magnetic vector rotation in response to the energetic electron beam during a flare

As one of the most violent forms of eruption on the Sun, flares are believed to be powered by magnetic reconnection, by which stored magnetic energy is released. The fundamental physical processes involving the release, transfer and deposition of energy in multiple layers of the solar atmosphere have been studied extensively with significant progress. Taking advantage of recent developments in observing facilities, new phenomena are continually revealed, bringing new understanding of solar flares. Here we report the discovery of a transient rotation of vector magnetic fields associated with a flare observed by the 1.6-m New Solar Telescope at Big Bear Solar Observatory. After ruling out the possibility that the rotation is caused by line profile changes due to flare heating, our observation shows that the transverse field rotateded by about 12-20 degrees counterclockwise, and returned quickly to previous values after the flare ribbons swept through. More importantly, as a consequence of the rotation, the flare loops untwisted and became more potential. The vector magnetograms were obtained in the near infrared at 1560 nm, which is minimally affected by flare emission and no intensity profile change was detected. Therefore, we believe that these transient changes are real, and conclude the high energy electron beams play an crucial role in the field changes. A straightforward and instructive explanation is that the induced magnetic field of the electron beam superimposed on the pre-flare field leads to a transient rotation of the overall field.

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100.02 – Temporal Evolution and Spatial Distribution of White-light Flare Kernels in a Solar Flare

On 2011 September 6, we observed an X2.1-class flare in continuum and Hα with a frame rate of about 30 Hz. After processing images of the event by using a speckle-masking image reconstruction, we identified white-light (WL) flare ribbons on opposite sides of the magnetic neutral line. We derive the light curve decay times of the WL flare kernels at each resolution element by assuming that the kernels consist of one or two components that decay exponentially,

starting from the peak time. As a result, 42% of the pixels have two decay-time components with average decay times of 15.6 and 587 s, whereas the average decay time is 254 s for WL kernels with only one decay-time component. The peak intensities of the shorter decay-time component exhibit good spatial correlation with the WL intensity, whereas the peak intensities of the long decay-time components tend to be larger in the early phase of the flare at the inner part of the flare ribbons, close to the magnetic neutral line. The average intensity of the longer decay-time components is 1.78 times higher than that of the shorter decay-time components. If the shorter decay time is determined by either the chromospheric cooling time or the nonthermal ionization timescale and the longer decay time is attributed to the coronal cooling time, this result suggests that WL sources from both regions appear in 42% of the WL kernels and that WL emission of the coronal origin is sometimes stronger than that of chromospheric origin.
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100.03 – A Study of Compound Solar Eruption in NOAA AR11429

We analyze and report a compound eruption process associated with an M8.4 flare occurred on March 10, 2012 in NOAA AR 11429. In the main phase of the flare, there were two major peaks in GOES X-ray at ~17:20 UT and ~ 17:40 UT respectively. We found that the two flare peaks, separated by about 20 minutes, corresponded to two individual erupting magnetic flux bundles from the same active region and along the same magnetic polarity inversion line. The erupting features were seen as a hot channel-like structure of a temperature of ~ 10 MK in coronal images obtained from SDO AIA 131 A passband. We believe that each erupting feature is originated from an individual magnetic flux bundle. Prior to the onset of the eruption, the magnetic structure of the source region likely contains a double decker configuration, i.e., a coherent flux bundle lies above another coherent flux bundle. The upper bundle became unstable and started to erupt. Shortly after, the lower bundle started to accelerate and merged with the upper bundle, forming a single CME as seen in coronagraph images. This study demonstrates that complex magnetic configuration could form in the corona and result in a compound solar eruption that involves energy release in different magnetic structures. We will discuss the physical processes that inter-connect multiple magnetic structure in an active region.
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100.04 – Observation of a Lyman-alpha flare with PROBA2/LYRA

Lyman-alpha (121.6 nm) is an optical thick line mostly formed in the chromosphere. Although one of the strongest lines of the solar spectrum, there are very few reports of solar flare signatures in Lyman-alpha and the few observations available differ significantly in shape, time duration and amplitude. Consequently, the fraction of non-thermal energy deposited during solar flares in this wavelength is still subject to discussion. The LYRA experiment is a radiometer on board the PROBA2 spacecraft launched in 2009. LYRA is composed of three identical units (one nominal, two backups), which each includes four distinct broadband channels, among which one covering Lyman-alpha. Despite the fact that the LYRA Lyman-alpha signal has degraded quickly at the beginning of the mission in the nominal channel, it observed about ten flares. Additionally, one more flare was observed in one of the backup channels. In this talk, we will analyse this particular flare profile and compare it to other instruments including Goes-15, EVE/MEGS-P, LYRA Zirconium channel.
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101 – Photosphere

101.01 – High-resolution Observations of Photospheric Structural Evolution Associated with a Flare

The structural evolution of the photosphere not only play an important role in contributing to the accumulation of free energy in the corona that powers solar flares, but also may response to the restructuring of coronal field as a result of flare energy release. A better understanding of these issues may be achieved by high-resolution observations of the photospheric structure covering the entire flaring period, which are, however, still rare. Here we present photospheric vector magnetograms and TiO images (at 0.2" and 0.09" resolution, respectively) from before to after a major flare, taken by the 1.6 m New Solar Telescope at Big Bear Solar Observatory. In the pre-flare state, a small-scale magnetic structure of opposite-polarity configuration is seen near the footpoints of sheared magnetic loops; its magnetic fluxes and currents enhance till the flare start time and decline afterwards. During the main phase, as one flare ribbon sweeps across a sunspot, its different portions accelerate at different times corresponding to peaks of flare hard X-ray emission. We suggest that the small-scale flux emergence between the two sheared flux systems triggers the flare reconnection, and that the sunspot rotation is driven by the surface Lorentz-force change due to the coronal back reaction.
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101.02 – Evolution of Photospheric Flow and Magnetic Fields Associated with the 2015 June 22 M6.5 Flare

The evolution of photospheric flow and magnetic fields before and after flares can provide important information regarding the flare triggering and back reaction processes. However, such studies on the flow field are rare due to the paucity of high-resolution observations covering the entire flaring period. Here we study the structural evolution of penumbra and shear flows associated with the 2015 June 22 M6.5 flare in NOAA AR 12371, using high-resolution imaging observation in the TiO band taken by the 1.6 m New Solar Telescope at Big Bear Solar Observatory, with the aid of the differential affine velocity estimator(DAVE) method for flow tracking. The accompanied photospheric vector magnetic field changes are also analyzed using data from the Helioseismic and Magnetic Imager. As a result, we found, for a penumbral segment in the negative field adjacent to the magnetic polarity inversion line (PIL), an enhancement of penumbral flows (up to ~2 km s^{-1}) and extension of penumbral fibrils after the first peak of the flare hard X-ray (HXR) emission. We also found a shear flow region at the PIL, which is co-spatial with a precursor brightening kernel and exhibits a gradual increase of shear flow velocity (up to ~0.9 km s^{-1}) after the flare. The enhancing penumbral and shear flow regions are also accompanied by an increase of horizontal field and decrease of magnetic inclination angle. These results are discussed in the context of the theory of back reaction of coronal restructuring on the photosphere as a result of flare energy release.

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101.03 – High-resolution Observation of Moving Magnetic Features in Active Regions

Moving magnetic features (MMFs) are small photospheric magnetic elements that emerge and move outward toward the boundary of moat regions mostly during a sunspot decaying phase, in a serpent wave-like magnetic topology. Studies of MMFs and their classification (e.g., unipolar or bipolar types) strongly rely on the high spatiotemporal-resolution observation of photospheric magnetic field. In this work, we present a detailed observation of a sunspot evolution in NOAA active region (AR) 12565, using exceptionally high resolution Halpha images from the 1.6 New Solar telescope (NST) at Big Bear Solar Observatory (BBSO) and the UV images from the Interface Region Imaging Spectrograph (IRIS). The spectropolarimetric measurements of photospheric magnetic field are obtained from the NST Near InfraRed Imaging Spectropolarimeter (NIRIS) at Fe I 1.56 um line. We investigate the horizontal motion of the classified MMFs and discuss the clustering patterns of the geometry and motion of the MMFs. We estimate the rate of flux generation by appearance of MMFs and the role MMFs play in sunspot decaying phase. We also study the interaction between the MMFs and the existing magnetic field features and its response to Ellerman bombs and IRIS bombs respectively at higher layers.

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101.04 – Sub-Pixel Magnetic Field and Plasma Dynamics Derived from Photospheric Spectral Data

Current high-resolution observations of the photosphere show small dynamic features at the resolving limit during emerging flux events. However, line-of-sight (LOS) magnetogram pixels only contain the net uncanceled magnetic flux, which is expected to increase for fixed regions as resolution limits improve. Using a new method with spectrographic images, we quantify distortions in photospheric absorption (or emission) lines caused by sub-pixel magnetic field and plasma dynamics in the vicinity of active regions and emerging flux events. Absorption lines—quantified by their displacement, width, asymmetry, and peakedness—have previously been used with Stokes I images from SOLIS/VSM to relate line distortions with sub-pixel plasma dynamics driven by solar flares or small-scale flux ropes. The method is extended to include the full Stokes parameters and relate inferred sub-pixel dynamics with small-scale magnetic fields. Our analysis is performed on several sets of spectrographic images taken by SOLIS/VSM while observing eruptive and non-eruptive active regions. We discuss the results of this application and their relevance for understanding magnetic fields signatures and coupled plasma properties on sub-pixel scales.

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101.05 – Observations of Magnetic Evolution and Network Flares Driven by Photospheric Flows in the Quiet Sun

The quiet Sun may be the biggest laboratory to study physical elementary processes of fundamental importance to space plasma. The advantage is the continuous availability of small-scale events, carrying the hidden microphysics that is responsible for larger-scale phenomena. By small-scale events, we mean spatial dimensions of a few Mm at most, and durations of less than an hour. I present here an attempt to describe and understand the coupling between the photospheric flows, the photospheric magnetic flux, and small-scale energetic transient events. By adapting and improving the highly efficient Balltracking technique for Hinode/SOT data, we relate the fine structures of the

supergranular flow fields with the magnetic flux evolution. For studying the dynamics of the latter, and more precisely, the magnetic flux cancellation at sites of energy releases, we applied a new feature tracking algorithm called "Magnetic Balltracking" -- which tracks photospheric magnetic elements -- to high-resolution magnetograms from Hinode/SOT.
Using observations of the low corona in soft X-rays with Hinode/XRT, we analyse the triggering mechanism of small-scale network flares. By tracking both the flow fields on the one hand, and the magnetic motions on the other hand, we relate the flows with cancelling magnetic flux. We identify two patterns of horizontal flows that act as catalysts for efficient magnetic reconnection: (i) Funnel-shaped streamlines in which the magnetic flux is carried, and (ii) large-scale vortices (~10 Mm and above) at the network intersections, in which distant magnetic features of opposite polarities seem to be sucked in and ultimately vanish. The excess energy stored in the stressed magnetic field of the vortices is sufficient to power network flares.
Prospects for determining the magnetic energy budget in the quiet sun are discussed.

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101.06 – The Role of Small-Scale Processes in Solar Active Region Decay

Active regions are locations of intense magnetic activity on the Sun, whose evolution can result in highly energetic eruptive phenomena such as solar flares and coronal mass ejections (CMEs). Therefore, fast and accurate simulation of their evolution and decay is essential in the prediction of Space Weather events. In this talk we present initial results from our new model for the photospheric evolution of active region magnetic fields. Observations show that small-scale processes appear to play a role in the dispersal and decay of solar active regions, for example through cancellation at the boundary of sunspot outflows and erosion of flux by surrounding convective cells. Our active region model is coupled to our existing model for the evolution of small-scale photospheric magnetic features. Focusing first on the active region decay phase, we consider the evolution of its magnetic field due to both large-scale (e.g. differential rotation) and small-scale processes, such as its interaction with surrounding small-scale magnetic features and convective flows.
This project is funded by The Carnegie Trust for the Universities of Scotland, through their Research Incentives Grant scheme.

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102 – Flares: Particles

102.02 – A New Paradigm for Flare Particle Acceleration

The mechanism that accelerates particles to the energies required to produce the observed high-energy impulsive emission and its spectra in solar flares is not well understood. Here, we propose a first-principle-based model of particle acceleration that produces energy spectra that closely resemble those derived from hard X-ray observations. Our mechanism uses contracting magnetic islands formed during fast reconnection in solar flares to accelerate electrons, as first proposed by Drake et al. (2006) for kinetic-scale plasmoids. We apply these ideas to MHD-scale islands formed during fast reconnection in a simulated eruptive flare. A simple analytic model based on the particles' adiabatic invariants is used to calculate the energy gain of particles orbiting field lines in our ultrahigh-resolution, 2.5D, MHD numerical simulation of a solar eruption (flare + coronal mass ejection). Then, we analytically model electrons visiting multiple contracting islands to account for the observed high-energy flare emission. Our acceleration mechanism inherently produces sporadic emission because island formation is intermittent. Moreover, a large number of particles could be accelerated in each macroscopic island, which may explain the inferred rates of energetic-electron production in flares. We conclude that island contraction in the flare current sheet is a promising candidate for electron acceleration in solar eruptions. This work was supported in part by the NASA LWS and H-SR programs.
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102.03 – Diffusive transport of energetic electrons in the solar corona: X-ray and radio diagnostics

Solar flares are associated with efficient particle acceleration. In particular, energetic electrons are diagnosed through X-ray and radio emissions produced as they interact with the solar atmosphere. Particle transport from the acceleration region to the emission sites remains one of the challenging topics in the field of high energy solar physics and has a crucial impact on the interpretation of particles emissions in the context of acceleration models.

In order to address the transport of flare associated energetic electrons in the low corona, we used the imaging spectroscopy capabilities of the RHESSI spacecraft to analyze the X-ray emission during the 2004 May 21 solar flare. We show that non-thermal X-ray emitting energetic electrons are trapped in the coronal part of the flaring loop. In the hypothesis of turbulent pitch-angle scattering of energetic electrons (Kontar et al. 2014), diffusive transport can lead to a confinement of energetic electrons in the coronal part of the loop. We show that this model can explain the X-ray observations with a scattering mean free path of the order of 10^8 cm, much smaller than the length of the loop itself.

Such results are compared with the study by Kuznetsov and Kontar (2015) of the gyrosynchrotron emission of the same flare. The diffusive transport model can explain the radio observations with a scattering mean free path of the order of 10^7 cm. This combination of X-ray and radio observations during a flare leads to the first estimate of the energy dependence of the scattering mean free path of energetic electrons in the low corona. This result is comparable with studies of the energy dependence of the scattering mean free path of electrons in the interplanetary medium.

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102.04 – Quantitative modeling of multiwavelength observations of the behind the limb solar flares observed by Fermi and other instruments

During the current solar cycle of the Sun the Fermi Large Area Telescope (LAT) has detected more than 40 flares up to GeV energies, some lasting many hours contemporaneous with Solar Energetic Particles (SEPs) and three that originate from active regions (AR) located behind the limb (BTL) as viewed from the Earth and detected by STEREO observations. Almost all are associated with fast Coronal Mass Ejections (CMEs). I will give a brief overview of the observations with focus on two of the three BTL flares that show RHESSI hard X-ray and SDO EUV emission coming from the top of a relatively large flare loop peeking over the limb. Radio emission with similar light curves is also attributed to this looptop source, while the centroids of the LAT gamma-rays are some distances away. This multiwavelength coverage of the well isolated looptop (presumably near the coronal acceleration site) combined with Fermi observations provides a unique opportunity to investigate possible mechanisms and sites of acceleration of particles (corona and/or CME shock), their transport and radiative signatures (leptonic or hadronic). I will present some quantitative result on accelerated particle spectra, magnetic field values at the looptop and its structure connecting the AR to the CME and back to the LAT source.

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102.05 – The Problematic High-Energy Flares of 2012 March 7

Two X-class flares occurred on 2012 March 7, an X5.3 and an X1.1. The earlier X5 flare gathered much attention, initiating a powerful and fast CME from the eastern hemisphere. The “forgotten” X1 flare exhibited much smaller CME from the same active region one hour later. However, extended high-energy gamma emission was present for almost the entire day of 2012 March 7. We have resolved the gamma emission into two separate, but overlapping extended occurrences, being from the two sequential X-class flares. We find that the later X1 event was slightly more prolific in gamma emission, mostly due to its duration, despite being much weaker in soft x rays and dynamic coronal activity. We attribute the entirety of the gamma emission from particle precipitation from the footpoints two separate quasi-static large-scale (of order 1 solar radius) coronal loops and not from the associated CMEs. Using constraints from ancillary data, we estimate the bounds in parameter space of the loop sizes and embedded turbulence necessary to accelerate protons and ions to high energies producing the gamma emission.

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103 – Flares: Modeling I

103.01 – Solar Flare Termination Shock and the Synthetic Fe XXI 1354.08 Å line

Solar flares are one of the most energetic phenomena occurred in the solar system. In the standard solar flare model, a fast mode shock, which is often referred to as the flare termination shock (TS), can exist above the loop-top source of hard X-ray emissions. The existence of the termination shock has been recently related to spectral hardening of flare hard X-ray spectrum at energies > 300 keV. Observations of the Fe XXI 1354.08 Å line during solar flares by the IRIS spacecraft have found significant redshift with >100 km/s, which is consistent with a reconnection downflow. The ability to identify such a redshift by IRIS is made possible by IRIS's high time resolution, high spatial resolution, high sensitivity and cadence spectral observations. The ability to identify such a redshift by IRIS suggests that one may be able to use IRIS observations to identify flare termination shocks. Using an MHD simulation to model magnetic reconnection of a solar flare and assuming the existence of a TS in the downflow of the reconnection plasma, we model the synthetic emission of the Fe XXI 1354.08 Å line in this work. We show that the existence of the TS in the solar flare may manifest itself from the Fe XXI 1354.08 Å line.

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103.02 – A weak thermal response on a strong electron acceleration in a 'cold' flare

Solar flares are sudden explosive processes in the solar atmosphere, which demonstrate remarkable variety of the partitions between various energy components. Understanding the flare acceleration site requires knowledge of exactly how flare energization works and what is the partition between nonthermal, thermal and kinetic energies. These partitions are known to vary broadly resulting in both 'entirely thermal' and primarily nonthermal, so-called 'cold' flares. These 'cold flares' are characterized by domination of nonthermal component, but very weak thermal emission and almost no soft X-ray enhancement; thus GOES often does not recognize such events as flares. Here we attempt to quantify the thermal and nonthermal energies and their evolving relationship in a 2013-Nov-05 cold flare. For nonthermal diagnostics we use the RHESSI data, while the AIA data are employed for the thermal diagnostics. We applied RHESSI spectral fits, with both 'cold' and 'warm' target to bracketing the low-energy cutoff, to quantify the rate of the nonthermal energy deposition in this flare as well to characterize a (tiny) hot component. We then computed evolving differential emission measure maps using the regularized inversion method and derived from them the emission measure and temperature maps. These inputs allowed us to accurately calculate the evolving thermal energy in the flare. This thermal energy was compared with the mentioned above rate of the nonthermal energy deposition. This comparison suggests that the observed plasma heating is entirely supplied by the loss of the nonthermal energy released in the impulsive phase of the flare. Using vector magnetic data from SDO/HMI we created a nonlinear force-free field reconstruction of the region of interest, and, using the available X-ray and EUV data set as a constraint, we developed a 3D model of the flare capable of correctly reproducing the data set. To validate the model, we used microwave data from Nobeyama and BBMS/SSRT instruments. Finally, this validated model has been used to quantify the nonthermal and thermal energies directly from the model 3D volume. We discuss physical implications of the obtained results.

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103.03D – Modelling of the hydrogen Lyman lines during solar flares

The hydrogen Lyman series and continuum are both observed with high cadence and spectral resolution by the EVE instrument on NASA's solar dynamics observatory. The Lyman lines, some of which will also be observed by the SPICE spectrometer on Solar Orbiter, can provide useful information about the dynamics of the solar chromosphere during a flare, where most of the event's energy is deposited. In Brown et al (2016), we measured line shifts in the Lyman lines using the EVE instrument and calculated corresponding plasma flow speeds of around 30 kilometres per second. However, the observed signs of these shifts varied. We have also modelled Lyman line profiles output from the radiative hydrodynamic code RADYN (Carlsson & Stein 1997, Allred et al 2015) and the radiative transfer code RH (Uitenbroek 2001) and present our initial findings. We show that the dynamics of the plasma are reflected in complex features in the true line profile, but that the detection of a line shift in a particular direction from EVE observations may not be indicative of the true plasma flow, particularly when these model profiles are passed through the EVE instrumental response. We present several cases of atmospheric responses for differing amounts of energy input, and outline interesting features in the Lyman line profiles which are thought to be linked to the response of the dynamic atmosphere.

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103.04D – Modelling The Effects of Density Gradients and Fluctuations on the Apparent Sizes and Positions of Low Frequency Solar Radio Sources

Recent high spatial and temporal resolution imaging of <250 MHz solar radio emission has enabled us to observe rapid variations in Type-III solar radio burst characteristics, revealing fast growth of the Type-III source and movement of the source centroid. In this work, we use a Monte-Carlo ray tracing simulation to model the passage of low frequency (5-240 MHz) radio waves through the solar corona from a point source, considering both isotropic and dipole emission. We model the effects of random density fluctuations and an isotropic density gradient on the transport of the rays, varying the strength of the scattering to observe the effects on images of the source from an observer at 1 AU. Absorption of photons is included, and the effects on the reproduced images and flux curves are observed. The apparent source size and centroid position are tracked through the simulation, and we find a general increase in source size with time, and a variation of centroid position in both directions throughout the simulation. We find that the size of the variation is strongly dependant upon frequency, with lower frequency sources appearing to move further on the disk than higher frequency sources. We also observe the strength of the effects at different viewing angles, finding that the greatest variation occurs closer to the solar limb. Further observational work is required to limit the scattering parameters, in order to allow for comparison with current radio images.

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103.05 – Effects of the canopy and anchoring on evaporation flow from a solar flare

Spectroscopic observations of flare ribbons typically show chromospheric evaporation flows which are subsonic for their high temperatures. This contrasts with many numerical simulation where evaporation is typically supersonic. These simulations typically assume flow along a flux tube with uniform cross-sectional area. A simple model of the chromospheric canopy, however, includes many regions of low magnetic field strength, where flux tubes achieve local maxima in area: effectively chambers in the flux tubes. We find that one third of all field lines in a model have some form of chamber through which evaporation flow must pass. Using a one dimensional isothermal hydrodynamic code we simulated supersonic flow through an assortment of chambers. We find that there is a subset of solutions that allow for a stationary standing shock in the chamber. These solutions result in a slower and denser upflow into the corona. We also constructed simple synthetic lines and found that shocked solutions showed brighter and slower emission. When taken as an ensemble over a cell of the model canopy, the lines appear slower, even subsonic, than expected due to the outsized contribution from shocked solutions.

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104 – Chromosphere

104.01 – A Model of the Solar Chromosphere: Structure and Internal Circulation

A model of the solar chromosphere is proposed that consists of two fundamentally different regions: a lower region and an upper region. The lower region is covered mostly by weak locally-closed magnetic field with small network areas of extremely strong locally-open field. The field in the upper region is relatively uniform and locally-open connecting to the corona. The chromosphere is heated by strong collisional damping of Alfvén waves, which are driven by turbulent motions below the photosphere. The heating rate depends on the field strength, wave power from the photosphere, and altitude in the chromosphere. Waves in the inter-network area are mostly damped in the lower region supporting radiation in the lower chromosphere. The waves in the network area, carrying more Poynting flux, are only weakly damped in the lower region. They propagate into the upper region. As the thermal pressure decreases with height, the network field expands to form the magnetic canopy where damping of the waves from the network area supports radiation in the whole upper region. Because of the vertical stratification and horizontally nonuniform distribution of the magnetic field and heating, two vertically located circulation cells are formed on each side of the strong field. The two circulation cells distort the magnetic field and reinforce the funnel-canopy-shaped magnetic geometry. The model is based on classical processes and semi-quantitative. The estimates are constrained according to observational knowledge. No anomalous process is invoked or needed. Overall, the heating mechanism is able to damp 50% of the total wave energy.

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104.02 – Magnetic Reconnection in the Solar Chromosphere

We report on the most recent efforts to accurately and self-consistently model magnetic reconnection processes in the context of the solar chromosphere. The solar chromosphere is a notoriously complex and highly dynamic boundary layer of the solar atmosphere where local variations in the plasma parameters can be of the order of the mean values. At the same time, the interdependence of the physical processes such as magnetic field evolution, local and global energy transfer between internal and electromagnetic plasma energy, radiation transport, plasma reactivity, and dissipation mechanisms make it a particularly difficult system to self-consistently model and understand. Several recent studies have focused on the micro-physics of multi-fluid magnetic reconnection at magnetic nulls in the weakly ionized plasma environment of the lower chromosphere[1-3]. Here, we extend the previous work by considering a range of spatial scales and magnetic field strengths in a configuration with component magnetic reconnection, i.e., for magnetic reconnection with a guide field. We show that in all cases the non-equilibrium reactivity of the plasma and the dynamic interaction among the plasma processes play important roles in determining the structure of the reconnection region. We also speculate as to the possible observables of chromospheric magnetic reconnection and the likely plasma conditions required for generation of Ellerman and IRIS bombs.

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[3] Murphy and Lukin, "Asymmetric magnetic reconnection in weakly ionized chromospheric plasmas," ApJ **805** (2015).

[*Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.]

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104.03 – Impact of Type II Spicules into the Corona

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

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104.04 – Chromospheric heating due to internetwork magnetic flux cancellations

The heating of the solar chromosphere is one of the most intriguing unanswered problems in solar physics. It is believed that this phenomenon may significantly be supported by small-scale internetwork (IN) magnetic fields. Indeed, cancellations of IN magnetic flux patches might be an efficient way to transport flux and energy from the photosphere to the chromosphere. Because of this, it is essential to determine where they occur, the rates at which they proceed, and understand their influence on the chromosphere. Here we study the spatial and temporal evolution of IN cancelling patches using high resolution, multiwavelength, coordinated observations obtained with the Interface Region Imaging Spectrograph (IRIS) and the Swedish 1-m Solar Telescope (SST). Employing multi-line inversions of the Mg II h&k lines we show that cancelling events, while occurring ubiquitously over IN regions, produce clear signatures of heating in the upper atmospheric layers. Using the RADYN code we determine the energy released due to cancellations of IN elements and discuss about their impact on the dynamics and energetics of the solar chromosphere.

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104.05 – Extending Counter-Streaming Motion from an Active Region Filament to Sunspot Light Bridge

In this study, we analyze the high-resolution observations from the 1.6 m New Solar Telescope at Big Bear Solar Observatory that cover an entire active region filament. The southern end of the filament is well defined by a narrow lane situated in the negative magnetic polarity, while the northern end lies in the positive polarity, extending to a much larger area. Counter-streaming motions are clearly seen in the filament. The northern end of the counter-streaming motions extends to a light bridge, forming a spectacular circulation pattern around a sunspot, with clockwise motion in the blue wing and counterclockwise motion in the red wing as observed in H-alpha off-band. The apparent speed of the flow is around 10 km/s. We show that the southern end of the filament is consistent with that of a flux rope in a NLFFF extrapolation model, but the northern ends of the modeled flux rope and observed H-alpha footpoints have a significant spatial mismatch. The most intriguing results are the magnetic structure and the counter-streaming motions in the light bridge. Similar to those in the filament, magnetic fields show a dominant transverse component in the light bridge. However, the filament is located between opposite magnetic polarities, while the light bridge is between strong fields of the same polarity. We studied the correlation coefficients of image sequences of constructed Dopplergrams, and found that the filament and the section of light bridge next to it do not show oscillation motions, while a small section of light bridge shows a prominent oscillation pattern. Therefore, we conclude that the observed circulating counter-streaming motions are largely collections of physical mass flows in the transverse direction from the filament extending to a large section of the light bridge, rather than a form of periodic oscillatory mass motions in line-of-sight direction generated by perturbations omnipresent in the chromosphere.

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104.06 – Shocks and currents in stratified atmospheres with a magnetic null point

We use the resistive MHD code LARE (Arber et al 2001) to inject a compressive MHD wavepacket into a stratified atmosphere that has a single magnetic null point, as recently described in Tarr et al 2017. The 2.5D simulation represents a slice through a small ephemeral region or area of plage. The strong gradients in field strength and connectivity related to the presence of the null produce substantially different dynamics compared to the more slowly varying fields typically used in simple sunspot models. The wave-null interaction produces a fast mode shock that collapses the null into a current sheet and generates a set of outward propagating (from the null) slow mode shocks confined to field lines near each separatrix. A combination of oscillatory reconnection and shock dissipation ultimately raise the plasma's internal energy at the null and along each separatrix by 25-50% above the background. The resulting pressure gradients must be balanced by Lorentz forces, so that the final state has contact discontinuities along each separatrix and a persistent current at the null. The simulation demonstrates that fast and slow mode waves localize currents to the topologically important locations of the field, just as their Alfvenic counterparts do, and also illustrates the necessity of treating waves and reconnection as coupled phenomena.

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105 – Chromosphere Poster Session

105.03 – High-resolution Observations of Sympathetic Filament Eruptions by NVST

We investigate two sympathetic filament eruptions observed by the New Vacuum Solar Telescope (NVST) on 2015 October 15. The full picture of the eruptions is obtained from the corresponding SDO/AIA observations. The two filaments start from the east border of active region NOAA 12434 in the north and end in one large quiescent filament channel in the south. The left filament erupts firstly, followed by the right filament eruption about 10 minutes later. Clear twist structure and rotating motion are observed in both filaments during the eruption. Both eruptions are failed, since the filaments firstly rise up, then flow towards the south and merge into the southern large quiescent filament. We also observe repeating activations of mini filaments below the right filament after its eruption. Using magnetic field models constructed based on SDO/HMI magnetograms by flux rope insertion method, we find that the left filament eruption is likely to be triggered by kink instability, while weakening of overlying magnetic fields due to magnetic reconnection at an X-point between the two filament systems might play an important role in the onset of the right filament eruption.

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105.04 – 3-D velocities of a whole filament channel obtained by imaging and spectroscopic observations of IRIS

The dynamics of a filament channel are of great importance to understand its formation and evolution.
In this work, we try to make the best use of IRIS's imaging and spectroscopic observations at the same time. With IRIS's high spatial resolutions, we can clearly see that material in the filament channel moves in two opposite directions in the form of streams. It implies that counter-streamings may also be caused by siphon flows, as well as the common ways of thread longitudinal oscillations.
Furthermore, the 3-D velocities of the whole filament channel are able to provide its exact information of magnetic configurations, which are mainly relied on magnetic extrapolation before.

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105.05 – The NST observation of a small loop eruption in He I D3 line on 2016 May 30

Since the He I D3 line has a unique response to a flare impact on the low solar atmosphere, it can be a powerful diagnostic tool for energy transport processes. In order to obtain comprehensive data sets for studying solar flare activities in D3 spectral line, we performed observations for several days using the 1.6m New Solar Telescope of Big Bear Solar Observatory (BBSO) in 2015 and 2016, equipped with the He I D3 filter, the photospheric broadband filter, and Near IR imaging spectrograph (NIRIS). On 2016 May 30, we observed a small loop eruption in He I D3 images associated with a B class brightening, which is occurred around 17:10 UT in a small active region, and dynamic variations of photospheric features in G-band images. Accordingly, the cause of the loop eruption can be magnetic reconnection driven by photospheric plasma motions. In this presentation, we will give the observation results and the interpretation.

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105.06 – Evidence from IRIS that Sunspot Large Penumbral Jets Spin

Recent observations from {\it Hinode} (SOT/FG) revealed the presence of large penumbral jets (widths $\ge$500 km, larger than normal penumbral microjets, which have widths $<$ 400 km) repeatedly occurring at the same locations in a sunspot penumbra, at the tail of a filament or where the tails of several penumbral filaments apparently converge (Tiwari et al. 2016, ApJ). These locations were observed to have mixed-polarity flux in Stokes-V images from

SOT/FG. Large penumbral jets displayed direct signatures in AIA 1600, 304, 171, and 193 channels; thus they were heated to at least transition region temperatures. Because large jets could not be detected in AIA 94 \AA, whether they had any coronal-temperature plasma remains unclear. In the present work, for another sunspot, we use IRIS Mg II k 2796 Å slit jaw images and spectra and magnetograms from Hinode SOT/FG and SOT/SP to examine: whether penumbral jets spin, similar to spicules and coronal jets in the quiet Sun and coronal holes; whether they stem from mixed-polarity flux; and whether they produce discernible coronal emission, especially in AIA 94 \AA\ images. The few large penumbral jets for which we have IRIS spectra show evidence of spin. If these have mixed-polarity at their base, then they might be driven the same way as coronal jets and CMEs.

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105.07 – The Sunrise balloon-borne observatory: Results from the second flight and outlook on the third flight

The balloon-borne solar observatory Sunrise flew for a second time in June 2013 and provided seeing-free UV images and spectropolarimetric data at close to the diffraction limit of the 1m telescope. The data analysis has so far concentrated on a time series of the heart of an active region recorded in the Stokes vector of the Fe I 525.02 nm line and a time series of UV images of the same region. First results were published in a special issue of the ApJ Supplement, vol. 229, in April 2017. The data suggest the presence of very strong fields in pores, a low-lying canopy of slender fibrils and different types of waves propagating along these fibrils. Furthermore, properties of the complex emergence of magnetic flux, of moving magnetic features around a pore and of a siphon flow along a low-lying slender magnetic loop are determined. A novel technique for inversions of Stokes profiles including constraints to make the results more physically consistent has also been developed and for the first time applied to Sunrise II data. In addition, the presence of small-scale mixed polarities and chromospheric jets was detected at the footpoints of particularly bright coronal loops. These and more results will be briefly presented.

Preparations for the next flight of Sunrise have started. Many new features are being designed for this flight, which will allow it to reach considerably extended science goals. Thus it will feature two new spectropolarimeters, one exploring the near UV (from MPS), the other concentrating on chromospheric fields and their connection to the photosphere (led by NAOJ). The IMaX vector-magnetograph (provided by a Spanish consortium) will also be updated to be able to sample multiple spectral lines. Finally, Sunrise will have a new gondola (coming from APL) and an improved image stabilization system (from KIS).

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106 – Corona Poster Session

106.01 – Sunspots, Starspots, and Elemental Abundances

The composition of plasma in solar and stellar atmospheres is not fixed, but varies from feature to feature. These variations are organized by the First Ionization Potential (FIP) of the element. Solar measurements often indicate that low FIP elements (< 10eV, such as Fe, Si, Mg) are enriched by factors of 3–4 in the corona relative to high FIP elements (>10 eV, such as C, N, O, Ar, He) compared to abundances in the photosphere. Stellar observations have also shown similar enrichments. An inverse FIP effect, where the low FIP elements are depleted, has been observed in stellar coronae of stars believed to have large starspots in their photospheres. The abundances are important for determining radiative loss rates in models, tracing the origin of the slow solar wind, and for understanding wave propagation in the chromosphere and corona. Recently, inverse FIP effects have been discovered in the Sun (Doschek, Warren, & Feldman 2015, ApJ, 808, L7) from spectra obtained by the Extreme-ultraviolet Imaging Spectrometer (EIS) on the Hinode spacecraft. The inverse FIP regions seem always to be near sunspots and cover only a very small area (characteristic length = a few arcseconds). However, in pursuing the search for inverse FIP regions, we have found that in some sunspot groups the coronal abundance at a temperature of 3-4 MK can be near photospheric over much larger areas of the sun near the sunspots (e.g., 6,000 arcsec^2). Also, sometimes the abundances at 3-4 MK are in between coronal and photospheric values. This can occur in small areas of an active region. It is predicted (Laming 2015, Sol. Phys., 12, 2) that the FIP effect should be highly variable in the corona. Several examples of coronal abundance variations are presented. Our work indicates that a comprehensive re-investigation of solar abundances is highly desirable. This work is supported by a NASA Hinode grant.

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106.02 – Feel the Burn, Part II: Quantifying and mapping spectral, spatial, and temporal structures of the transition region under hot and cold coronal regions

The coronal volume is filled with magnetic field, yet only part of that volume has sufficient volume to exhibit hot X-ray loops. Using XRT and AIA images, we identify footpoints of hot coronal loops. We then use IRIS rasters to compare the spatial, temporal, and spectral structure of these relatively "heated" and "unheated" regions. We seek a signature of upward-propagating energy that could be associated with hot active region loops.

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106.04 – A New Method for Coronal Magnetic Field Reconstruction

A precise way of coronal magnetic field reconstruction (extrapolation) is an indispensable tool for understanding of various solar activities. A variety of reconstruction codes have been developed so far and are available to researchers nowadays, but they more or less bear this and that shortcoming. In this paper, a new efficient method for coronal magnetic field reconstruction is presented. The method imposes only the normal components of magnetic field and current density at the bottom boundary to avoid the overspecification of the reconstruction problem, and employs vector potentials to guarantee the divergence-freeness. In our method, the normal component of current density is imposed, not by adjusting the tangential components of $\boldsymbol{A}$, but by adjusting its normal component. This allows us to avoid a possible numerical instability that on and off arises in codes using $\boldsymbol{A}$. In real reconstruction problems, the information for the lateral and top boundaries is absent. The arbitrariness of the boundary conditions imposed there as well as various preprocessing brings about the diversity of resulting solutions. We impose the source surface condition at the top boundary to accommodate flux imbalance, which always shows up in magnetograms. To enhance the convergence rate, we equip our code with a gradient-method type accelerator. Our code is tested on two analytical force-free solutions. When the solution is given only at the bottom boundary, our result surpasses competitors in most figures of merits devised by Schrijver et al. (2006). We have also applied our code to a real active region NOAA 11974, in which two M-class flares and a halo CME took place. The EUV observation shows a sudden appearance of an erupting loop before the first flare. Our numerical solutions show that two entwining flux tubes exist before the flare and their shackling is released after the CME with one of them opened up. We suggest that the erupting loop is created by magnetic reconnection between two entwining flux tubes and later appears in the coronagraph as the major constituent of the observed CME.

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106.05 – Quantifying the Density Structure of the Solar Corona

Images show that the solar corona is highly structured, with density variations transverse to the magnetic field on scales down to the resolution limit of the instruments. This suggests unresolved structure at yet smaller length scales as well. Understanding this density structure is important for modeling coronal heating and predicting solar wind properties. We present a new method for quantifying the density structure using EUV line intensities to derive a density irregularity parameter that measures the relative amount of structure along the line of sight. We interpret the irregularity using a simple model in order to relate our results to physical quantities such as filling factor and density contrast. For quiet Sun regions and interplume regions of coronal holes, we find density contrasts of at least a factor of three to ten with filling factors of about 10-20%.

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106.06 – The study of Equatorial coronal hole during maximum phase of Solar Cycle 21, 22, 23 and 24

The 11-year Solar Cycle (SC) is characterized by the periodic change in the solar activity like sunspot numbers, coronal holes, active regions, eruptions such as flares and coronal mass ejections. We study the relationship between equatorial coronal holes (ECH) and the active regions (AR) as coronal whole positions and sizes change with the solar cycle. We made a detailed study of equatorial coronal hole for four solar maximum: Solar Cycle 21 (1979,1980,1981 and 1982), Solar Cycle 22 (1989, 1990, 1991 and 1992), Solar Cycle 23 (1999, 2000, 2001 and 2002) and Solar Cycle 24 (2012, 2013, 2014 and 2015). We used publically available NOAA solar coronal hole data for cycle 21 and 22. We measured the ECH region using the EIT and AIA synoptic map for cycle 23 and 24. We noted that in two complete 22-year cycle of solar activity, the equatorial coronal hole numbers in SC 22 is greater than SC 21 and similarly, SC 24 equatorial coronal hole numbers are greater than SC 23. Moreover, we also compared the position of AR and ECH during SC 23 and 24. We used daily Solar Region Summary (SRS) data from SWPC/NOAA website. Our goal is to examine the correlation between equatorial holes, active regions, and flares.

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106.07 – Using Coronal Hole Maps to Constrain MHD Models

In this presentation, we explore the use of coronal hole maps (CHMs) as a constraint for thermodynamic MHD models of the solar corona. Using our EUV2CHM software suite (*predsci.com/chd*), we construct CHMs from

SDO/AIA 193Å and STEREO-A/EUVI 195Å images for multiple Carrington rotations leading up to the August 21st, 2017 total solar eclipse. We then contruct synoptic CHMs from synthetic EUV images generated from global thermodynamic MHD simulations of the corona for each rotation. Comparisons of apparent coronal hole boundaries and estimates of the net open flux are used to benchmark and constrain our MHD model leading up to the eclipse. Specifically, the comparisons are used to find optimal parameterizations of our wave turbulence dissipation (WTD) coronal heating model.

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106.08 – Constraints on Nonuniform Expansion in Coronal Loops

We use measurements of coronal loop properties to constrain the hypothesis that coronal loops expand differently in different directions. A long standing problem in understanding coronal loops is that although the magnetic field is expected to expand with altitude and does indeed seem to do so on scales of active regions, individual loops seem to have fairly uniform diameters along the length of the loop. Malanushenko & Schrijver (2013) have suggested that loops may be expanding, but with a non-circular cross section. In this scenario a loop might have a constant width in the plane of the sky, but expand along the line of sight. Furthermore, such loops might be easier to see from the point of view that does not show expansion. We use Hinode/EIS and SDO/AIA data to measure loop intensities, electron densities, temperatures and dimensions in order to determine the extent to which loops may be expanding along the line of sight.

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106.10 – Measuring Plasma Flows in Transition Region Loops Using the MOSES Instrument

While traditional slit spectrographs have been extremely valuable for observing coronal loops, the narrow slit of these instruments does not allow the properties and dynamic evolution of coronal loops to be measured simultaneously across their entire structure. The Multi-Order Solar EUV Spectrograph (MOSES) is a rocket-borne slitless spectrograph capable of measuring doppler shifts simultaneously over a wide field of view. On August 27, 2015, we observed AR 12403 in Ne VII (46.5 nm) at T ~ 500,000 K. We present time dependent measurements of downflow velocities for loop footpoints, with physical interpretation based on 1D modeling.

Author(s): Roy Smart[1], Charles C Kankelborg[1], Nick Bonham[1], Hans Courrier[1]
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106.11 – In What Magnetic Environment Are Coronal Loop Plasmas Located?

As for coronal loops, there is a conventional wisdom that the plasma is confined inside magnetic flux tubes. However, a plasma pressure profile, which decreases from the center of a flux rope to its periphery, can be ideal MHD interchange unstable if field line ends are freely movable. In the solar corona, the strong line-tying condition impedes the interchange of the positions of elementary flux tubes, but ubiquitous magnetic reconnection processes can change plasma distribution in such a way that the system moves to a more stable state with a lower energy. In this study, we investigate the plasma redistribution in the merging process of many small flux ropes possibly representing loop strands, by an MHD simulation. We have found that the redistributed plasma is more concentrated between flux ropes rather than near the center of individual flux ropes. When flux ropes initially have different amounts of twists, the plasma tends to accumulate in less twisted regions. As larger and larger flux ropes are formed by successive merging processes, the ratio of poloidal flux to toroidal flux in a merged flux rope becomes smaller and smaller, i.e., field lines are less and less twisted. Our study may explain why the observed coronal loops appear very little twisted and quite well ordered in spite of continuous entangling motions in the photosphere and below.

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106.12 – Ponderomotive Acceleration in Coronal Loops

Ponderomotive acceleration has been asserted to be a cause of the First Ionization Potential (FIP) effect, the by now well known enhancement in abundance by a factor of 3-4 over photospheric values of elements in the solar corona with FIP less than about 10 eV. It is shown here by means of numerical simulations that ponderomotive acceleration occurs in solar coronal loops, with the appropriate magnitude and direction, as a ``byproduct'' of coronal heating. The numerical simulations are performed with the HYPERION code, which solves the fully compressible three-dimensional magnetohydrodynamic equations including nonlinear thermal conduction and optically thin radiation. Numerical simulations of a coronal loops with an axial magnetic field from 0.005 Teslas to 0.02 Teslas and lengths from 25000 km to 75000 km are presented. In the simulations the footpoints of the axial loop magnetic field are convected by random, large-scale motions. There is a continuous formation and dissipation of field-aligned current sheets which act to heat the loop. As a consequence of coronal magnetic reconnection, small scale, high speed jets form. The familiar vortex quadrupoles form at reconnection sites. Between the magnetic footpoints and the corona the reconnection flow merges with the boundary flow. It is in this region that the ponderomotive acceleration occurs. Mirroring the character of the coronal reconnection, the ponderomotive acceleration is also found to be intermittent.

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106.13 – Comparison of the Scaling Properties of EUV Intensity Fluctuations in Coronal Holes to those in Regions of Quiet Sun

We investigate the scaling properties of EUV intensity fluctuations seen in low-latitude coronal holes (CH) and in regions of Quiet Sun (QS), in signals obtained with the SDO/AIA instrument in the 193 Å waveband. Contemporaneous time series in the 171 and 211 Å wavebands are used for comparison among emissions at different heights in the transition region and low corona. Potential-field extrapolations of contemporaneous SDO/HMI line-of-sight magnetic fields provide a context in the physical environment. Detrended fluctuation analysis (DFA) shows that the variance of the fluctuations obeys a power-law as a function of temporal scales with periods in the range ~15-60 min. This scaling is characterized by a generalized Hurst exponent α. In QS regions, and in regions within CHs that include magnetic bipoles, the scaling exponent lies in the range $1.0 < \alpha < 1.5$, and it thus corresponds to anti-correlated, turbulent-like, dynamical processes. Regions inside the coronal holes primarily associated with magnetic field of a dominant single polarity, have a generalized exponent ($0.5 < \alpha < 1$) corresponding to positively correlated ("persistent") processes. The results indicate the influence of the magnetic fields on the dynamics of the emission.

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106.14 – Hard X-Ray Constraints on Small-Scale Coronal Heating Events

A large body of evidence suggests that the solar corona is heated impulsively. Small-scale heating events known as nanoflares may be ubiquitous in quiet and active regions of the Sun. Hard X-ray (HXR) observations with unprecedented sensitivity >3 keV have recently been enabled through the use of focusing optics. We analyze active region spectra from the FOXSI-2 sounding rocket and the NuSTAR satellite to constrain the physical properties of nanoflares simulated with the EBTEL field-line-averaged hydrodynamics code. We model a wide range of X-ray spectra by varying the nanoflare heating amplitude, duration, delay time, and filling factor. Additional constraints on the nanoflare parameter space are determined from energy constraints and EUV/SXR data.

Author(s): Andrew Marsh[3], David M. Smith[3], Lindsay Glesener[6], James A. Klimchuk[1], Stephen Bradshaw[2], Iain Hannah[5], Juliana Vievering[6], Shin-Nosuke Ishikawa[4], Sam Krucker[4], Steven Christe[1]
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106.15 – Detection of Heating Processes in Coronal Loops by Soft X-ray Spectroscopy

Imaging and Spectroscopic observations in the soft X-ray band will open a new window of the heating/acceleration/transport processes in the solar corona. The soft X-ray spectrum between 0.5 and 10 keV consists of the electron thermal free-free continuum and hot coronal lines such as O VIII, Fe XVII, Mg XI, Si XVII. Intensity of free-free continuum emission is not affected by the population of ions, whereas line intensities especially from highly ionized species have a sensitivity of the timescale of ionization/recombination processes. Thus, spectroscopic observations of both continuum and line intensities have a capability of diagnostics of heating/cooling timescales.

We perform a 1D hydrodynamic simulation coupled with the time-dependent ionization, and calculate continuum and line intensities under different heat input conditions in a coronal loop. We also examine the differential emission measure of the coronal loop from the time-integrated soft x-ray spectra. As a result, line intensity shows a departure from the ionization equilibrium and shows different responses depending on the frequency of the heat input.

Solar soft X-ray spectroscopic imager will be mounted in the sounding rocket experiment of the Focusing Optics X-ray Solar Imager (FOXSI). This observation will deepen our understanding of heating processes to solve the "coronal heating problem".

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106.16 – The Onset of Magnetic Reconnection: Tearing Instability in Current Sheets with a Guide Field

Magnetic reconnection is fundamental to many solar phenomena, ranging from coronal heating, to jets, to flares and CMEs. A poorly understood yet crucial aspect of reconnection is that it does not occur until magnetic stresses have built to sufficiently high levels for significant energy release. If reconnection were to happen too soon, coronal heating would be weak and flares would be small. As part of our program to study the onset conditions for magnetic reconnection, we have investigated the instability of current sheets to tearing. Surprisingly little work has been done on this problem for sheets that include a guide field, i.e., for which the field rotates by less than 180 degrees. This is the most common situation on the Sun. We present numerical 3D resistive MHD simulations of several sheets and show how the behavior depends on the shear angle (rotation). We compare our results to the predictions of linear theory and discuss the nonlinear evolution in terms of plasmoid formation and the interaction of different oblique tearing modes. The relevance to the Sun is explained.

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106.17 – Hemispheric Preference and Cyclic Variation of Solar Filament Chirality

Although the hemispheric preference of magnetic topological features in the solar atmosphere is a well-established fact, strength and cyclic variation of the hemispheric rule is a debatable issue. In this work, we study the chirality of 3480 solar filaments from 2000 to 2016. We determine the chirality of filaments manually and compare with the results obtained from the Advanced Automated Filament Detection and Characterization Code (AAFDCC). We find that 83% of our manually determined filaments follow the hemispheric chirality rule, while 58% of automatically determined filaments
follow the same. We also compare our result with an other manually compiled list by Pevtsov et al. (2003). We find that our list matches Pevtsovs manually compiled list with 90% accuracy. We also find that the hemispheric chirality rule does not vary from cycle to cycle. However, the strength of the hemispheric preference decreases at the end and beginning phase of the solar cycle.

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106.18 – Filament Channel Formation, Eruption, and Jet Generation

The mechanism behind filament-channel formation is a longstanding mystery, while that underlying the initiation of coronal mass ejections and jets has been studied intensively but is not yet firmly established. In previous work, we and collaborators have investigated separately the consequences of magnetic-helicity condensation (Antiochos 2013) for forming filament channels (Zhao et al. 2015; Knizhnik et al. 2015, 2017a,b) and of the embedded-bipole model (Antiochos 1996) for generating reconnection-driven jets (Pariat et al. 2009, 2010, 2015, 2016; Wyper et al. 2016, 2017). Now we have taken a first step toward synthesizing these two lines of investigation. Our recent study (Karpen et al. 2017) of coronal-hole jets with gravity and wind employed an ad hoc, large-scale shear flow at the surface to introduce magnetic free energy and form the filament channel. In this effort, we replace the shear flow with an ensemble of local rotation cells, to emulate the Sun's ever-changing granules and supergranules. As in our previous studies, we find that reconnection between twisted flux tubes within the closed-field region concentrates magnetic shear and free energy near the polarity inversion line, forming the filament channel. Onset of reconnection between this field and the external, unsheared, open field releases stored energy to drive the impulsive jet. We discuss the results of our new simulations with implications for understanding solar activity and space weather.

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Institution(s): *1. NASA GSFC*

106.19 – Does the magnetic expansion factor (f_s) play a role in solar wind acceleration?

For the past 25 years, magnetic expansion factor (f_s) has been a key parameter used in the calculation of terminal solar wind speed (v_{sw}) in both the Wang-Sheeley-Arge (WSA) model and its predecessor the Wang-Sheeley (WS) model. Since the discovery of an inverse relationship between f_s and v_{sw}, the physical role that magnetic expansion factor plays in the acceleration of the solar wind has been explored and debated. In this study, we investigate whether magnetic expansion factor plays a causal role in determining the terminal speed of the solar wind or merely serves as proxy. To do so, we explore how f_s, as determined by WSA, relates to v_{sw} for two different scenarios: 1) extended periods where the fast solar wind emerges from the centers of large coronal holes, and 2) periods where the solar wind emerges from pseudostreamers. For these same scenarios, we will also consider an alternative empirical relationship between solar wind speed and the minimum angular distance at the photosphere of a solar wind source to the nearest coronal hole boundary (i.e., DCHB, θ_b). We then compare these two different prediction techniques directly with heliospheric observations (i.e., ACE, STEREO-A & B, Ulysses) of solar wind speed to determine whether one clearly out performs the other.

Author(s): Samantha Wallace[2], Charles N Arge[1], Ylva Pihlstrom[2]
Institution(s): *1. NASA GSFC, 2. University of New Mexico*

106.20 – Understanding Solar Coronal Heating through Atomic and Plasma Physics Experiments

Recent solar observations suggest that the Sun's corona is heated by Alfven waves that dissipate at unexpectedly low heights in the corona. These observations raise a number of questions. Among them are the problems of accurately quantifying the energy flux of the waves and that of describing the physical mechanism that leads to the wave damping. We are performing laboratory experiments to address both of these issues.

The energy flux depends on the electron density, which can be measured spectroscopically. However, spectroscopic density diagnostics have large uncertainties, because they depend sensitively on atomic collisional excitation, de-excitation, and radiative transition rates for multiple atomic levels. Essentially all of these data come from theory and have not been experimentally validated. We are conducting laboratory experiments using the electron beam ion trap (EBIT) at Lawrence Livermore National Laboratory that will provide accurate empirical calibrations for spectroscopic density diagnostics and which will also help to guide theoretical calculations.

The observed rapid wave dissipation is likely due to inhomogeneities in the plasma that drive flows and currents at small length scales where energy can be more efficiently dissipated. This may take place through gradients in the Alfvén speed along the magnetic field, which causes wave reflection and generates turbulence. Alternatively, gradients in the Alfvén speed across the field can lead to dissipation through phase-mixing. Using the Large Plasma Device (LAPD) at the University of California Los Angeles, we are studying both of these dissipation mechanisms in the laboratory in order to understand their potential roles in coronal heating.

Author(s): Daniel Wolf Savin[1], Thusitha Arthanayaka[1], Sayak Bose[1], Michael Hahn[1], Peter Beiersdorfer[2], Gregory V. Brown[2], Walter Gekelman[3], Steve Vincena[3]
Institution(s): *1. Columbia Astrophysics Lab., 2. Lawrence Livermore National Laboratory, 3. University of California at Los Angeles*

106.21 – Data-driven MHD simulation of a solar eruption observed in NOAA Active Region 12158

We present a data-driven magnetohydrodynamic (MHD) simulation of a solar eruption where the dynamics of a background solar wind is incorporated. The background solar wind exists in the real solar atmosphere, which continuously transports magnetized plasma toward the interplanetary space. This suggests that it may play a role in producing a solar eruption. We perform a simulation for NOAA AR 12158 accompanied with X1.6-class flare and CME on 2014 September 10. We construct a magnetohydrostatic state used as the initial state of data-driven simulation, which is composed of a nonlinear force-free field (NLFFF) derived from observation data of photospheric vector magnetic field and a hydrostatic atmosphere with prescribed distributions of temperature and gravity. We then reduce the gas pressure well above the solar surface to drive a solar wind. As a result, a magnetic field gradually evolves during an early phase, and eventually eruption is observed. To figure out what causes the transition from gradual evolution to eruption, we analyze the temporal development of force distribution and geometrical shape of magnetic field lines. The result suggests that the curvature and the scale height of a coronal magnetic field play an important role in determining its dynamic state.

Author(s): Hwanhee Lee[1], Tetsuya Magara[1], Jihye Kang[1]
Institution(s): *1. Kyung Hee Univeristy*

106.22 – Non-Linear Force-Free Field Modelling of Solar Coronal Jets in Theoretical Configurations

Coronal jets occur frequently on the Sun, and may contribute significantly to the solar wind. With the suite of instruments avilable now, e.g. on IRIS, Hinode and SDO, we can observe these phenomena in greater detail than ever before. Modeling and simulations can assist further in understanding the dynamic processes involved, but previous studies tend to consider only one mechanism (e.g. emergence or rotation) for the origin of the jet. In this study we model a series of idealised archetypal
jet configurations and follow the evolution of the coronal magnetic field. This is a step towards understanding these idealised situations before considering their observational counterparts. Several simple situations are set up for the evolution of the photospheric magnetic field: a single parasitic polarity rotating or moving in a circular path; as well as opposite polarity pairs involved in flyby (shearing), cancellation or emergence; all in the presence of a uniform, open background magnetic
field. The coronal magnetic field is evolved in time using a magnetofrictional relaxation method. While magnetofriction cannot accurately reproduce the dynamics of an eruptive phase, the structure of the coronal magnetic field, as well as the build up of electric currents and free magnetic energy are instructive. Certain configurations and motions produce a flux rope and allow the significant build up of free energy, reminiscent of the progenitors of so-called blowout jets, whereas other, simpler configurations are more comparable to the standard jet model. The next stage is a comparison with observed coronal jet structures and their corresponding photospheric evolution.

Author(s): Antonia Savcheva[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

106.23 – Introduction of the ASGARD code (Automated Selection and Grouping of events in AIA Regional Data)

We have developed the ASGARD code to automatically detect and group brightenings ("events") in AIA data. The event selection and grouping can be optimized to the respective dataset with a multitude of control parameters. The code was initially written for IRIS data, but has since been optimized for AIA. However, the underlying algorithm is not limited to either and could be used for other data as well.

Results from datasets in various AIA channels show that brightenings are reliably detected and that coherent coronal structures can be isolated by using the obtained information about the start, peak, and end times of events. We are presently working on a follow-up algorithm to automatically determine the heating and cooling timescales of coronal structures. This will be done by correlating the information from different AIA channels with different temperature responses. We will present the code and preliminary results.

Author(s): Christian Bethge[3], Amy Winebarger[1], Sanjiv K. Tiwari[1], Brian Fayock[2]
Institution(s): *1. NASA Marshall Space Flight Center, 2. Raytheon, 3. Universities Space Research Association*

106.24 – An innovative browser-based data exploration tool with simultaneous scrolling in time and wavelength domains

We present Cruiser, a new web tool for the precision interactive blending of image series across time and wavelength domains. Scrolling in two dimensions enables discovery and investigation of similarities and differences in structure and evolution across multiple wavelengths. Cruiser works in the latest versions of standards compliant browsers on both desktop and IOS platforms. Co-aligned data cubes have been generated for AIA, IRIS, and Hinode SOT FG, and image data from additional instruments, both space-based and ground-based, can be data sources. The tool has several movie playing and image adjustment controls which will be described in the poster and demonstrated on a MacOS notebook and iPad.

Author(s): Gregory L. Slater[1], David Schiff[1], Bart De Pontieu[1], Theodore D. Tarbell[1], Samuel L Freeland[1]
Institution(s): *1. Lockheed Martin*

106.25 – Determination of CME 3D parameters based on a new full ice-cream cone model

In space weather forecast, it is important to determine three-dimensional properties of CMEs. Using 29 limb CMEs, we examine which cone type is close to a CME three-dimensional structure. We find that most CMEs have near full ice-cream cone structure which is a symmetrical circular cone combined with a hemisphere. We develop a full ice-cream cone model based on a new methodology that the full ice-cream cone consists of many flat cones with different heights and angular widths. By applying this model to 12 SOHO/LASCO halo CMEs, we find that 3D parameters from our method are similar to those from other stereoscopic methods (i.e., a triangulation method and a Graduated Cylindrical Shell model). In addition, we derive CME mean density ($\rho_{mean}=M_{total}/V_{cone}$) based on the full ice-cream cone structure. For several limb events, we determine CME mass by applying the Solarsoft procedure (e.g., cme_mass.pro) to SOHO/LASCO C3 images. CME volumes are estimated from the full ice-cream cone structure. From the power-law relationship between CME mean density and its height, we estimate CME mean densities at 20 solar radii (R_s). We will compare the CME densities at 20 R_s with their corresponding ICME densities.

Author(s): Hyeonock Na[1], Yong-Jae Moon[1]
Institution(s): *1. School of Space Research, Kyung Hee University*

106.26 – MHD Forces in Quasi-Static Evolution, Catastrophe, and ``Failed'' Eruption of Solar Flux Ropes

This paper presents the first unified theoretical model of flux rope dynamics---a single set of flux-rope equations in ideal MHD---to describe as one dynamical process the quasi-static evolution, catastrophic transition to eruption, cessation (``failure'') of eruption, and the post-eruption quasi-equilibria. The model is defined by the major radial {\it and} minor radial equations of motion including pressure. The initial equilibrium is a flux rope in a background plasma with pressure $p_c(Z)$ and an overlying magnetic field $B_c(Z)$. The flux rope is initially force-free, but theevolution is not required to be force- free. A single quasi-static control parameter, the rate of increase in poloidal flux, is used for the entire process. As this parameter is slowly increased, the flux rope rises, following a sequence of quasi-static equilibria. As the apex of the flux rope rises past a critical height Z_{crt}, it expands on a dynamical (Alfv\'enic) timescale. The eruption rapidly ceases, as the stored magnetic energy of eruption is exhausted, and a new equilibrium is established at height $Z_1 > Z_{crt}$. The calculated velocity profile resembles the observed velocity profiles in ``failed'' eruptions including a damped oscillation. In the post-eruption equilibria, the outward hoop force is balanced by the tension of the toroidal self magnetic field and pressure gradient force. Thus, the flux rope does not evolve in a force-free manner. The flux rope may also expand without reaching a new equilibrium, provided a sufficient amount of poloidal flux is injected on the timescale of eruption. This scenario results in a full CME eruption. It is shown that the minor radial expansion critically couples the evolution of the toroidal self-field and pressure gradient force. No parameter regime is found in which the commonly used simplifications---near-equilibrium minor radial expansion, force-free expansion, and constant aspect ratio R/a (e.g., the torus instability equation)---are valid.

Work supported by the Naval Research Laboratory Base Research Program
Author(s): James Chen[1]
Institution(s): *1. NRL*

106.27 – X-ray bright points above emerging flux regions

There are many bright soft X-ray (SXR) loops above active regions on the Sun. We don't fully understand the heating mechanisms of the loops yet.

In order to obtain the information of the initial heat-up of the coronal loops, we study X-ray bright points (XBPs) above emerging flux regions (EFRs) in early phase.

First we identify appearances of XBPs in Hinode/XRT data; then search for EFRs under the XBPs by using magnetograms from SDO/HMI. Multiple wavelength images from SDO/AIA were also used to find signs of heating in corona.

In the previous study where we compared XRT and SoHO/MDI data, we reported that the onset of the SXR brightenings delayed longer than one hour after the appearances of the EFRs in magnetogram data (Yoshimura 2009). We found similar time lag in the EUV, including 304Å, images this time. We will also discuss the evolution of the XBPs with differential emission measure (DEM) analysis.

Author(s): Keiji Yoshimura[1]
Institution(s): *1. Montana State University*

106.28 – Magneto-sonic Waves as a Trigger of Coronal Condnsations

Thermal non-equilibrium is believed to be a critical process in the formation of coronal condensations that become coronal rain. Preliminary simulations using a 2.5D MHD code of a helmet streamer in the presence of solar wind, suggest that magneto-sonic waves, generated by the disconnection of slow wind blobs at the streamer base, may be an effective initial density perturbation triggering the non-equilibrium condensation process. In this presentation we take a dipolar flux tube from the streamer base and model the gasdynamics within the flux tube using a high order Godunov algorithm, with adaptive mesh refinement(AMR). We adjust the flux tube cross-section in a time dependent manner to simulate the temporary compressive influence of an imposed magneto-sonic wave train. The 1D code with AMR offers the ability to model the field aligned energy balance with much greater resolution and accuracy than is possible in the 2.5D MHD code, and so is a necessary step in validating the coronal rain results observed in the 2.5D MHD solution.

Author(s): Peter MacNeice[1]
Institution(s): *1. NASA/GSFC*

106.30 – Association of solar coronal loops to photospheric magnetic field

Magnetic connectivity and its evolution from the solar photosphere to the corona will play a crucial role in the energetics of the solar atmosphere. To explore this connectivity, we use high spatial resolution magnetic field observations of an active region from the balloon-borne SUNRISE telescope, in combination with the observations of coronal loops imaged in extreme ultraviolet by SDO/AIA. We show that photospheric magnetic field at the base of coronal loops is rapidly evolving through small-scale flux emergence and cancellation events with rates on the order of 10^15 Mx/s. When observed at high spatial resolution better than 0.5 arcsec, we find that basically all coronal loops considered so far are rooted in the photosphere above small-scale opposite polarity magnetic field patches. In the photosphere, the magnetic field threading coronal loops is interacting with opposite polarity parasitic magnetic concentrations leading to dynamic signatures in the upper atmosphere. Chromospheric small-scale jets aligned to coronal loops are observed at these locations. We will present preliminary results from 3D MHD simulations of coronal loops driven by realistic magneto-convection and discuss what role the magnetic interactions at coronal loop footpoints could play in the evolution of coronal loops and their heating.

Author(s): Lakshmi Pradeep Chitta[1], Hardi Peter[1], Sami Solanki[1]
Institution(s): *1. Max Planck Institute for Solar System Research*

106.31 – Forecast of Solar Energetic Particles Depending on Magnetic Connectivity and Coronal Mass Ejection Properties Using Multi-Spacecraft Observations

For the forecast of solar energetic particles (SEPs), we study the relationships between the peak fluxes of 18 SEP events and associated coronal mass ejection (CME) 3D parameters (speed, angular width and separation angle) obtained from SOHO, STEREO-A and/or B for the period from 2010 August to 2013 June. We apply the STEREO CME Analysis Tool (StereoCAT) to the SEP-associated CMEs to obtain 3D speeds and 3D angular widths. The separation angles are determined as the longitudinal angle between flaring regions and magnetic footpoints of the spacecraft, which are calculated by the assumption of Parker spiral field. The main results are as follows. 1) We find the dependence of the SEP peak fluxes on CME 3D speed and 3D angular width from multi-spacecraft. 2) There is a noticeable anti-correlation (r=-0.62) between SEP peak flux and separation angle. 3) We predict the SEP peak fluxes using a multiple regression method considering longitudinal separation angle, CME 3D speed and 3D angular width. It shows that the separation angle is the most important parameter, and the CME 3D speed is secondary on SEP peak flux.

Author(s): Jinhye Park[2], Yong-Jae Moon[2], Harim Lee[2], Stephen W. Kahler[1]
Institution(s): *1. Air Force Research Laboratory, 2. Kyung Hee University*

106.32 – DEM analysis of FOXSI-2 microflare using AIA observations

The second flight of Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket experiment was successfully completed on 11 December 2014. FOXSI makes direct imaging and spectral observation of the Sun in hard X-rays using grazing incidence optics modules which focus X-rays onto seven focal plane detectors kept at a 2m distance, in the energy range 4 to 20 keV, to study particle acceleration and coronal heating. Significant HXR emissions were observed by FOXSI during microflare events with A0.5 and A2.5 class, as classified by GOES, that occurred during FOXSI-2 flight.

Spectral analysis of FOXSI data for these events indicate presence of plasma at higher temperatures (>10MK). We attempt to study the plasma content in the corona at different temperatures, characterized by the differential emission measure (DEM), over the FOXSI-2 observed flare regions using the Atmospheric Imaging Assembly (SDO/AIA) data. We utilize AIA observations in different EUV filters that are sensitive to ionized iron lines, to determine the DEM by using a regularized inversion method. This poster will show the properties of hot plasma as derived from FOXSI-2 HXR spectra with supporting DEM analysis using AIA observations.

Author(s): Subramania Athiray Panchapakesan[4], Lindsay Glesener[4], Juliana Vievering[4], Juan Camilo Buitrago-Casas[3], Steven Christe[1], Andrew Inglis[2], Sam Krucker[3],Sophie Musset[4]
Institution(s): *1. NASA Goddard Space Flight Center, 2. The Catholic University of America, 3. University of California at Berkeley, 4. University of Minnesota*

106.33 – Application of sensitivity-analysis techniques to the calculation of topological quantities

Magnetic reconnection in the corona occurs preferentially at sites where the magnetic connectivity is either discontinuous or has a large spatial gradient. Hence there is a general interest in computing quantities (like the squashing factor) that characterize the gradient in the field-line mapping function. Here we present an algorithm for calculating certain (quasi)topological quantities using mathematical techniques from the field of ``sensitivity-analysis''. The method is based on the calculation of a three dimensional field-line mapping Jacobian from which all the present topological quantities of interest can be derived. We will present the algorithm and the details of a publicly available set of libraries that implement the algorithm.

Author(s): Stuart Gilchrist[1]
Institution(s): *1. NorthWest Research Associates*

106.34 – Kinematic classification of coronal mass ejections and its dependence on speed

In this study we investigate the classification of the kinematics of coronal mass ejections (CMEs) using about 4,000 SOHO/LASCO CMEs from 1996 to 2015. For this we use their SOHO/LASCO C3 data and exclude all poor events. Using the constant acceleration model, we classify these CMEs into three groups: Acceleration group, Constant Velocity group, and Deceleration group. For classification we adopt four different methods: Acceleration method, Velocity Variation method, Height Contribution method, and Visual Inspection method. Our major results are as follows. First, the fractions of three groups depend on the method used. Second, the results of the Height Contribution method are most consistent with those of the Visual Inspection method, which is thought to be most promising. Third, the fractions of different kinematic groups for the Height contribution method are: Acceleration (35%), Constant speed (47%), and Deceleration (18%). Fourth, the fraction strongly depend on CME speed; the fraction of Acceleration decreases from 0.6 to 0.05 with CME speed; the fraction of Constant increases from 0.3 to 0.7; the fraction of Deceleration increases from 0.1 to 0.3. Finally we present dozens of CMEs with non-constant accelerations and discuss their physical origins.

Author(s): SeongGyeong Jeon[1], Yong-Jae Moon[1], Kangwoo Yi[1]
Institution(s): *1. Kyung-hee university*

106.35 – Comparison of coronal electron density distributions from MLSO/MK4, STEREO/SECCHI-COR1, SOHO/LASCO-C2, and SOHO/UVCS

The coronal electron density is a fundamental and important physical quantity in solar physics. In this study, we compare coronal electron density distributions (CEDDs) derived from polarized brightness (pB) observations (MLSO/MK4 coronameter, STEREO/SECCHI-COR1 and SOHO/LASCO-C2 Coronagraphs) and one spectroscopic observation (SOHO/UVCS). For this, we consider data from January to August 2007 with the following conditions: the separation angle between the either of the STEREO spacecraft and Earth is less than 10 degrees and the observation time differences from one another are less than 1 minutes. In the pB observations, the CEDDs can be estimated by using inversion methods (Van de Hulst inversion for MK4 and LASCO-C2 pB data, and spherically symmetric polynomial approximation inversion for COR1 pB data). In the spectroscopic observation, we use the ratio of radiative and collisional components of the O vi doublet (O vi 1032 Å and 1037.6 Å) to estimate the CEDDs. We will show you some results about the estimated CEDDs and their dependence on different coronal regions such as backgournd corona and streamers.

Author(s): Jae-Ok Lee[3], Kyung-Suk Cho[3], Jin-Yi Lee[1], Kyoung-Sun Lee[2], Soojeong Jang[3], Roksoon Kim[3], Yong-Jae Moon[4]
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107 – Eclipse Experiments/Science Poster Session

107.02 – Fluxon Global Predictions for the 2017 Eclipse

We present predicted coronal morphologies for the 2017 total solar eclipse, produced using quasi-stationary MHD simulation on a semi-Lagrangian grid with the FLUX code. FLUX uses the "fluxon" approach to ideal MHD: the magnetic field is modeled as a finite-element skeleton of field lines, which experience the familiar magnetic energy density ("pressure") and curvature ("tension") forces. Ongoing and recent work with FLUX enables simulation of solar wind flow and coronal density in the low-beta regime, and permits global 3-D solutions without the use of a supercomputer.

Using magnetograms acquired up to one solar rotation before the eclipse, we expect to publish fluxon-derived models 2-3 weeks before the eclipse, and will present those models side-by-side with actual eclipse images to compare the model and actual coronae.

Author(s): Craig DeForest[1], Derek Lamb[1]
Institution(s): *1. Southwest Research Inst.*

108 – Flares Poster Session

108.02 – Microflare Heating of an Active Region Observed with *NuSTAR*, *Hinode*/XRT, and *SDO*/AIA

We present the first joint observation of a *GOES* equivalent A0.2 microflare that occurred on the 29 Apr 2015 with *Hinode*/XRT and *NuSTAR*. During the three hours of combined observation we observe distinctive loop heating in the soft X-rays from *Hinode*/XRT, and the hottest channels from *SDO*/AIA. Crucially the impulsive phase of this microflare was also observed by *NuSTAR*, a highly sensitive hard X-ray (2.5-80 keV; Harrison et al. 2013) focussing optics imaging spectrometer. The *NuSTAR* spectrum before and after the microflare is well-fitted by a single thermal model of about 3.3 - 3.5 MK, but at the impulsive phase shows additional material up to 10 MK. This higher temperature emission is confirmed when we produce the DEM using a combination of *SDO*/AIA, *Hinode*/XRT, and *NuSTAR* data. During the impulsive phase of the microflare we determine the heating rate to be about 3×10^{25} erg s^{-1}. Although non-thermal emission is not detected we find upper-limits that are consistent with the required heating rate.

Author(s): Paul James Wright[6], Iain Hannah[6], Brian Grefenstette[2], Lindsay Glesener[7], Sam Krucker[3], Hugh S. Hudson[6], David M. Smith[4], Andrew Marsh[4], Stephen M. White[1], Matej Kuhar[5]
Institution(s): *1. Air Force Research Laboratory, 2. Caltech, 3. UC Berkeley, 4. UC Santa Cruz, 5. University of Applied Sciences and Arts Northwestern Switzerland, 6. University of Glasgow, 7. University of Minnesota*

108.03 – Results from NuSTAR: Dynamics and time evolution in a sub-A class hard X-ray flare

We report a NuSTAR observation of a solar microflare, SOL2015-09-01T04. Although it was too faint to be observed by the GOES X-ray Sensor, we estimate the flare to be an A0.2 class flare in brightness. This flare, with only ~5 counts s−1 detector−1 observed by RHESSI, is fainter than any hard X-ray (HXR) flare in the existing literature. The flare occurred during a solar pointing by the highly sensitive NuSTAR astrophysical observatory, which used its direct focusing optics to produce detailed HXR flare spectra and images. The flare exhibits HXR properties commonly observed in larger flares, including a fast rise and more gradual decay, earlier peaking time with higher energy, similar spatial dimensions to the RHESSI microflares, and a high-energy excess beyond an isothermal spectral component during the impulsive phase. The flare is small in emission measure, temperature, and energy, though not in physical size; observations are consistent with its arising via the interaction of at least two magnetic loops. We estimate the increase in thermal energy at the time of the flare to be 1.8×1027 ergs. The observation suggests that flares do indeed scale down to extremely small energies and retain what we customarily think of as “flarelike” properties.

Author(s): Lindsay Glesener[7], Sam Krucker[3], Iain Hannah[6], Hugh S. Hudson[4], Brian Grefenstette[2], Stephen M. White[1], David M. Smith[5], Andrew Marsh[5]
Institution(s): *1. Air Force Research Laboratory, 2. Caltech, 3. FHNW, 4. UC Berkeley, 5. UC Santa Cruz, 6. University of Glasgow, 7. University of Minnesota*

108.06 – Multi-Wavelength Spectroscopic Observations of a White Light Flare Produced Directly by Non-thermal Electrons

An X1.6 flare on 2014 October 22 was observed by multiple spectrometers in UV, EUV and X-ray (Hinode/EIS, IRIS, and RHESSI), and multi-wavelength imaging observations (SDO/AIA and HMI). We analyze a bright kernel that produces a white light (WL) flare with continuum enhancement and a hard X-ray (HXR) peak. Taking advantage of the spectroscopic observations of IRIS and Hinode/EIS, we measure the temporal variation of the plasma properties in the bright kernel in the chromosphere and corona. We find that explosive evaporation was observed when the WL emission occurred. The temporal correlation of the WL emission, HXR peak, and evaporation flows indicates that the WL emission was produced by accelerated electrons. We calculated the energy flux deposited by non-thermal electrons (observed by RHESSI) and compared it to the dissipated energy estimated from a chromospheric line (Mg II triplet) observed by IRIS. The deposited energy flux from the non-thermal electrons is about $(3–7.7)\times10^{10}$ erg cm^{-2} s^{-1} for a given low-energy cutoff of 30–40 keV, assuming the thick-target model. The energy flux estimated from the changes in temperature in the chromosphere measured using the Mg II subordinate line is about $(4.6–6.7)\times10^{9}$ erg cm^{-2} s^{-1}: ~6%–22% of the deposited energy. This comparison of estimated energy fluxes implies that the continuum enhancement was directly produced by the non-thermal electrons.

Author(s): Kyoung-Sun Lee[4], Shinsuke Imada[3], Kyoko Watanabe[5], Yumi Bamba[2], David Brooks[1]
Institution(s): *1. George Mason University, 2. Institute of Space and Astronautical Science, 3. Nagoya University, 4. National Astronomical Observatory of Japan, 5. National Defense Academy*

108.09 – Energy Transport by Propagating Alfvén Waves in Solar Flares

Magnetic reconnection generates Alfvénic waves, which carry a significant fraction of energy in a solar flare. In previous work, we showed that the dissipation of these waves due to ion-neutral collisions effectively deliver that energy to the upper chromosphere, and are capable of heating the atmosphere strongly enough to drive explosive evaporation. However, that work disregarded travel times of these waves, which is an assumption that we now correct. Using a ray tracing method, we have implemented heating by propagating Alfvénic waves into a hydrodynamics code. We validate the method against an MHD code. We examine the effects of travel times, and find that the waves are extremely efficient at heating the chromosphere, that the ionization level plays a critical role in determining the depths and rate of wave dissipation, that the first waves effectively bore a hole into the chromosphere so that any successive waves travel even deeper into the chromosphere so that the heating falls to greater depths with time, which is opposite to the behavior of an electron beam.

Author(s): Jeffrey Reep[1]
Institution(s): *1. National Research Council Post-doc at the US Naval Research Laboratory*

108.10 – A one-dimensional loop model invoking reconnection-driven turbulence for electron acceleration

We have recently developed a one-dimensional flare loop model in which magnetic energy release occurs via loop retraction following reconnection. The plasma in our retracting flux tube evolves several propagating shock including a kind of slow magnetosonic shock at which the plasma is heated to flare temperatures. The model has proven able to reproduce several features observed in flares. Our model, like that original proposed by Petschek, is framed in terms of fluid equations (MHD), and therefore lacks the population of non-thermal electrons. While missing from fluid models, non-thermal electrons are one of the most important characteristics observed in flares. A separate line of flare modeling has focused on the generation of non-thermal electrons by, for example, MHD turbulence. These model have not generally included the reconnection process believed to drive that turbulence. Here we describe a model in which flux retracting from reconnection generates turbulence, which then generates a non-thermal electron population. While not entirely self-consistent, this model combines into a single chain those elements by which magnetic energy is converted into different forms observed in flares.

Author(s): Dana Longcope[1]
Institution(s): *1. Montana State Univ.*

108.12 – 3D Simulation Study of the Spreading/Elongation of Ribbons in Two-Ribbon Flares

Two-ribbon solar flares are characterized by the appearance in pairs of bright ribbons on the surface of the Sun. The ribbons separate from each other in time, which has been cited as one of many pieces of evidence that magnetic reconnection participates in the release of magnetic energy in solar flares. In addition to moving apart from each other, observations have revealed that ribbons also elongate (or spread) in time along the polarity inversion line. This is likely related to the spreading of the magnetic reconnection process in the corona. Recent observations have shown ribbons can elongate either unidirectionally or bidirectionally. We investigate the physics of reconnection spreading and its potential relation to two-ribbon flares via a parametric study using 3D numerical simulations with the two-fluid (MHD + Hall effect + electron inertia) model. We study how anti-parallel reconnection spreads in current sheets with a non-uniform thickness in the out-of-plane direction. Previous numerical work on spreading in current sheets of uniform thickness revealed that anti-parallel reconnection spreads at a speed given by the current carriers, but it is not obvious how the spreading occurs in a current sheet with non-uniform thickness. We compare spreading in this system with spreading in current sheets of uniform thickness that are thicker than the dissipation scale. The results may be useful not just for solar flares, but also for Earth's magnetotail, laboratory reconnection experiments, and reconnection in the solar wind.

Author(s): Milton Arencibia[2], Paul Cassak[2], Jiong Qiu[1], Dana Longscope[1], Eric R. Priest[1]
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108.14 – Predicting Solar Flares Using SDO/HMI Vector Magnetic Data Product and Random Forest Algorithm

Adverse space weather effects can often be traced to solar flares, prediction of which has drawn significant research interests. Many previous forecasting studies used physical parameters derived from photospheric line-of-sight field or ground-based vector field observations. The Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory produces full-disk vector magnetograms with continuous high-cadence, while flare prediction efforts utilizing this unprecedented data source are still limited. Here we report results of flare prediction using physical parameters provided by the Space-weather HMI Active Region Patches (SHARP) and related data products. We survey X-ray flares occurred from 2010 May to 2016 December, and categorize their source regions into four classes (B, C, M, and X) according to the maximum GOES magnitude of flares they generated. We then retrieve SHARP related parameters for each selected region at the beginning of its flare date to build a database. Finally, we train a machine-learning algorithm, called random forest (RF), to predict the occurrence of a certain class of flares in a given active region within 24 hours, evaluate the classifier performance using the 10-fold cross validation scheme, and characterize the results using standard performace metrics. Compared to previous works, our experiments indicate that using the HMI parameters and RF is a valid method for flare forecasting with fairly reasonable prediction performance. We also find that the total unsigned quantities of vertical current, current helicity, and flux near polarity inversion line are among the most important parameters for classifying flaring regions into different classes.

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108.17 – Analysis of Chromospheric Evaporation in Solar Flares

Chromospheric evaporation is one of the key processes of solar flares. Properties of chromospheric evaporation are thought to be closely connected to the energy release rates and energy transport mechanisms. Previous investigations revealed that in addition to electron-beam heating the chromospheric evaporation can be driven by heat fluxes and, probably, by other mechanisms. In this work, we present a study of flare events simultaneously observed by IRIS, SDO and RHESSI, focusing on spatio-temporal characteristics of the flare dynamics and its relation to the magnetic field topology. Event selection is performed using the Interactive Multi-Instrument Database of Solar Flares (IMIDSF) recently developed by the Center for Computational Heliophysics (CCH) at NJIT. The selection of IRIS observations was restricted to the fast-scanning regimes (coarse-raster or sparse-raster modes with ≥ 4 slit positions, ≥ 6`` spatial coverage, and ≤ 60 sec loop time). We have chosen 14 events, and estimated the spatially-resolved intensities and Doppler shifts of the chromospheric (Mg II), transition region (C II) and hot coronal (Fe XXI) lines reflecting the dynamics of the chromospheric evaporation. The correlations among the derived line profile properties, flare morphology, magnetic topology and hard X-ray characteristics will be presented, and compared with the RADYN flare models and other scenarios of chromospheric evaporations.

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108.18 – Application of a deep-learning method to the forecast of daily solar flare occurrence using Convolution Neural Network

As the application of deep-learning methods has been succeeded in various fields, they have a high potential to be applied to space weather forecasting. Convolutional neural network, one of deep learning methods, is specialized in image recognition. In this study, we apply the AlexNet architecture, which is a winner of Imagenet Large Scale Virtual Recognition Challenge (ILSVRC) 2012, to the forecast of daily solar flare occurrence using the MatConvNet software of MATLAB. Our input images are SOHO/MDI, EIT 195Å, and 304Å from January 1996 to December 2010, and output ones are yes or no of flare occurrence. We select training dataset from Jan 1996 to Dec 2000 and from Jan 2003 to Dec 2008. Testing dataset is chosen from Jan 2001 to Dec 2002 and from Jan 2009 to Dec 2010 in order to consider the solar cycle effect. In training dataset, we randomly select one fifth of training data for validation dataset to avoid the overfitting problem. Our model successfully forecasts the flare occurrence with about 0.90 probability of detection (POD) for common flares (C-, M-, and X-class). While POD of major flares (M- and X-class) forecasting is 0.96, false alarm rate (FAR) also scores relatively high(0.60). We also present several statistical parameters such as critical success index (CSI) and true skill statistics (TSS). Our model can immediately be applied to automatic forecasting service when image data are available.

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108.19 – Relationship between the Occurrence of a Flare and the Small-Scale Variation of Photospheric Magnetic Field in Active Region 12371

We investigate the flare productivity of a magnetic structure by focusing on the spatial and temporal changes of photospheric magnetic field. The physical process to develop a flare-producing magnetic structure in the corona in response to these photospheric changes is one of the hot topics. We analyzed small-scale photospheric changes of observation data to see how they are related to the occurrence of a flare. It is found that difference of transverse components between potential field and observed photospheric vector field is noticeable in a small-scale emerging region near the main polarity inversion line in AR12371 when it produced an M-class flare. We also investigate a flare-producing coronal magnetic configuration of this active region by using a nonlinear force-free field model.

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108.20 – Analysis of Condensation Downflows in Post-Flare Loops Using Solar Synoptic Chart

Post-flare loops (PFLs) are significant feature of eruptive flares during their gradual phases. The condensation downflows in PFLs have been found for decades; however they do not receive enough attention, especially in EUV wavelengths. The solar synoptic chart (SSC) is designed to cover the key objects of solar activities, including active regions, coronal holes, filaments/prominences, flares, and coronal mass ejections. The main aim of the SSC is presenting a timely, comprehensive, and concise chart for space weather forecast; therefore it can provide a complete image of solar activities before, during, and after a flare process. Furthermore, because the composite image of SSC made by high-quality images in multiple EUV wavelengths from the Atmospheric Imaging Assembly instrument onboard the Solar Dynamics Observatory, it can reveal fine structures of condensation downflows in PFLs in different temperatures. Using the SSC, we analyze the condensation downflows in PFLs of X-class flares. The results show that the overall situation of solar activities shown by SSC is helpful for studying the flare process, and SSC effectively presents fine and multi-temperature structure of the condensation downflows in PFLs. Therefore, the SSC is a useful tool not only for space weather forecast but also for the research of solar activities.

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108.21 – The thermal infrared continuum in solar flares

Observations of the Sun with the Atacama Large Millimeter Array have now started, and the thermal infrared will regularly be accessible from the NSF's Daniel K. Inouye Solar Telescope. Motivated by the prospect of these new observations, and by recent flare detections in the mid infrared, we set out here to model and understand the source of the infrared continuum in flares, and to explore its diagnostic capability for the physical conditions in the flare atmosphere. We use the 1D radiation hydrodynamics code RADYN to calculate mid-infrared continuum emission from model atmospheres undergoing sudden deposition of energy by non-thermal electrons. We identify and characterise the main continuum thermal emission processes relevant to flare intensity enhancement in the mid- to far-infrared (2–200 micron) spectral range as free-free emission on neutrals and ions. We find that the infrared intensity evolution tracks the energy input to within a second, albeit with a lingering intensity enhancement, and provides a very direct indication of the evolution of the atmospheric ionization. The prediction of highly impulsive emission means that, on these timescales, the atmospheric hydrodynamics need not be considered in analysing the mid-IR signatures.

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108.22 – Multi-wavelength Observation of M-class Flare associated with Filament eruption

We have investigated a M-class flare associated with filament eruption which developed into a Halo CME. The M-class flare occurred in 2011 August 4. For this study, we used the Nobryama Radioheliograph (NoRH) 17 and 34 GHz, RHESSI Hard X-ray satellite, and Atmo- spheric Imaging Assembly (AIA) and the Heliospheric Magentic Imager(HMI) onboard the Solar Dynamic Observatory (SDO). During the pre-eruption phase, clear nonthermal emission was detected in microwaves of NoRH and hard-X-ray of RHESSI. At the moment that the nonthermal emission start, the nonthermal sources appeared at the one edge of the filament structure on a polarity inversion line, and the slowing rising filament structure in AIA 94A underwent a sudden acceleration on its ascendance. Magnetograms showed converging motion of magnetic elements at the source position of HXR and MW. Based on the results, we conjecture that the plausible trigger of the filament eruption is magnetic reconnections at the HXR source position by converging motion of magnetic elements. In addition, we will discuss on the magnetic flux variation before and after the eruption based on the result of Nonlinear force-free field model.

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108.23 – Multi-wavelength Observation of Recurrent Circular-Ribbon Flares

Circular ribbon flare suggests the existence of a particular fan-spine magnetic topology in the solar corona. Here we present a multi-wavelength study of recurrent circular-ribbon flares in AR 12242 during 7 days when it passes across the solar disk. As the central parasitic polarities continuously emerge through the solar surface, the circular ribbons grow correspondingly. The evolution of the overall 3D magnetic configurations is studied with potential-field extrapolations. Following the expansion of the fan surface, the heights of the null point tend to increase and then decrease, while the length of the spine tends to shrink. We discuss the evolution of the fan-spine structure and its implications for varying flare emissions in different wavelengths.

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108.24 – A Database of Flare Ribbon Properties From Solar Dynamics Observatory: Reconnection Flux

We present a database of 3137 solar flare ribbon events corresponding to every flare of GOES class C1.0 and greater within 45 degrees from the disk center, from April 2010 until April 2016, observed by the Solar Dynamics Observatory. For every event in the database, we compare the GOES peak X-ray flux with corresponding active-region and flare-ribbon properties. We find that while the peak X-ray flux is not correlated with the AR unsigned magnetic flux, it is strongly correlated with the flare ribbon reconnection flux, flare ribbon area, and the fraction of active region flux that undergoes reconnection. We find the relationship between the peak X-ray flux and the flare ribbon reconnection flux to be I_{X,peak} ~ \Phi_{ribbon}^{1.3} for flares >M1 and I_{X,peak} ~ \Phi_{ribbon}^{1.5} over the entire flare set (>C1). This scaling law is consistent with earlier hydrodynamic simulations of impulsively heated flare loops. Using the flare reconnection flux as a proxy for the total released flare energy E, we find that the occurrence frequency of flare energies follows a power-law dependence: dN/dE ~ E^{-1.6} for E within 10^{31} to 10^{33} erg, consistent with earlier studies of solar and stellar flares. This database is available online and can be used for future quantitative studies of flares.

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108.25 – Predicting the Where and the How Big of Solar Flares

The approach to predicting solar flares generally characterizes global properties of a solar active region, for example the total magnetic flux or the total length of a sheared magnetic neutral line, and compares new data (from which to make a prediction) to similar observations of active regions and their associated propensity for flare production. We take here a different tack, examining solar active regions in the context of their energy storage capacity. Specifically, we characterize not the region as a whole, but summarize the energy-release prospects of different sub-regions within, using a sub-area analysis of the photospheric boundary, the CFIT non-linear force-free extrapolation code, and the Minimum Current Corona model. We present here early results from this approach whose objective is to understand the different pathways available for regions to release stored energy, thus eventually providing better estimates of the where (what sub-areas are storing how much energy) and the how big (how much energy is stored, and how much is available for release) of solar flares.

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109 – Helioseismology Poster Session

109.01 – The HMI Magnetic Activity Index for Local-Area Helioseismology

In order to provide context for the mapping of sub-surface flows and thermal structure by local helioseismic techniques and the study of their relation to local magnetic activity, a local Magnetic Activity Index (MAI) was introduced. The MAI provides an appropriate index value corresponding precisely to the extent in space and time of each region analyzed. It is intended to be a measure of the total magnetic flux in the region. Hemispheric averages of

the MAI are very well correlated with independent global measures of solar magnetic activity. Improvements in the determination of the MAI from Helioseismic and Magnetic Imager (HMI) measurements have revealed statistical anomalies affecting a small but significant number of high-cadence (45-sec) magnetograms. We describe modifications to the MAI being explored, the identification and treatment of anomalous magnetic field values, and explore likely causes.

Author(s): Richard S. Bogart[1], Charles Baldner[1]
Institution(s): *1. Stanford Univ.*

109.02 – The double-ridge structure of the high-frequency time-distance crosscorrelation function in local helioseismology

We model helioseismic high-frequency cross-correlation function and carry out comparison with observational data.We also discuss the source depth of the acoustic waves, one of the model parameters.
It has been reported that when time-distance analysis is applied to the high-frequency acoustic waves, with frequencies above the critical cutoff frequency, time-distance cross-correlation function exhibits double-ridge structure. It has been pointed out, however, that in such analyses subcritical components (frequency < 5.3 MHz) may not be completely filtered out, and a hypothesis is that the double ridges are generated as artificial interference patterns of the subcritical waves and the supercritical waves. We test this hypothesis using SDO/HMI data.
The data are put through a frequency filter before the cross-correlation function is computed. We vary the width and central frequency of the filter and examine when double ridges appear. When both the supercritical and the subcritical components are present in the filtered power spectrum, double ridges appear. When there is only one of the components, however, double ridges do not appear, confirming that interference between the two components is necessary for the double ridges.
Next, we construct a simple model of cross-correlation function by ray-tracing the waves generated at a certain depth. The model reproduces the double-ridge structure well, indeed by interference between the supercritical part and the subcritical part, each of which by itself exhibits only a single ridge. We find that the successful reproduction of the observations depends sharply on the source depth of the acoustic wave, one of the input parameters to the model. This indicates a possibility that we can measure the source depth of the acoustic waves precisely, using the double ridges.

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109.03 – Persistent retrograde flow structures at high latitudes - extent in depth and time

Medium resolution helioseismic studies of the near-surface layers of the Sun have revealed the existence of coherent retrograde flow structures that persist for multiple solar rotations (Bogart *et al.* 2015). Similar surface features have been detected and suggested to be related to giant cell convection (Hathaway *et al.* 2013). These structures seem to be confined to high latitudes (greater than 60°N/S) and are have magnitudes (relative to the mean solar flow) of less than 1 m s^{-1}. In this work we extend our earlier analysis of these flow structures by studying their extent and structure in depth and their evolution in time. In particular, we attempt to determine the depth at which the anomalous flow structures are most significant, and to determine their migration relative to the Carrington coordinate frame.

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109.04 – Acoustic Oscillation Properties of Active Region 12193

Solar flares are dynamic objects occurring randomly and yet unannounced in nature. In order to find an efficient detection method, we require a greater breadth of knowledge of the system. One path to such a method is to observe the solar atmosphere in a region around a flare in different wavelengths of light and acoustic frequency bands. This provides information from different altitudes in the solar atmosphere and allows us to study the temporal evolution of each altitude through the flaring event. A more complete understanding of the time evolution may lead to yet undiscovered precursors of the flare. In this project, we study Active Region 12192 using acoustic observations near an X3 flare occurring on October 24, 2014 at 21:41UT. Our wavelet analysis utilizes time series data to create Fourier power spectra of individual pixels spatially resolved around the flare region, to study the frequency bands. In order to study the power distribution in regions around the flare and to search for any correlation we apply several methods. One method we partition sub-regions in our main flaring region and take a survey of the oscillations for each frequency band within power maps. Another method we average the FFT to take measurements within the p-modes (2-4 mHz) and chromospheric (4-6 mHz) frequencies. The application of these methods should be able to get us closer to tracking waveforms within power maps.

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109.05 – Variation of acoustic mode parameters with distance from a nearby active region

In a previous paper (Rabello-Soares, Bogart & Scherrer 2016), we quantified the influence of magnetic fields on acoustic mode parameters and flows in and around active regions by comparing the differences in the parameters in magnetically quiet regions when there is an active region in their vicinity with those of quiet regions at the same disc locations for which there are no neighboring active regions. Here we detail further our analysis by estimating how these differences vary with distance from the active region. We use ring diagram analysis from almost five years of HMI observations.

In our first paper, we observed that the power reduction has a strong dependence on the wave direction but the amplitude enhacement (the `acoustic halo effect') has a very weak dependence on the wave propagation direction. We find that the effect on the amplitude decreases as the distance increases as expected. However, the dependence on the wave direction seems to reach a peak around 70 Mm from the active region. Very near the active region, the amplitude effects are independent of the direction of mode propagation.

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109.06 – Detection of g modes in the asymptotic frequency range: evidence for a rapidly rotating core

We present the identification of very low frequency g modes, in the asymptotic regime, and two important parameters: the core rotation rate and the asymptotic equidistant period spacing of these g modes. The GOLF instrument on the SOHO space observatory has provided two decades of full disk helioseismic data. The search for g modes in GOLF measurements has been extremely difficult, due to solar and instrumental noise. In the present study, the p modes of the GOLF signal are analyzed differently, searching for possible collective frequency modulations produced by periodic changes in the deep solar structure. Such modulations provide access to only very low frequency g modes, thus allowing statistical methods to take advantage of their asymptotic properties. For oscillatory periods in the range between 9 and nearly 48 hours, almost 100 g modes of spherical harmonic degree 1 and more than 100 g modes of degree 2 are predicted. They are not observed individually, but when combined, they unambiguously provide their asymptotic period equidistance and rotational splittings, in excellent agreement with the requirements of the asymptotic approximations. P0, the g-mode period equidistance parameter, is measured to be 34 min 01 s, with a 1 s uncertainty. The previously unknown g-mode splittings have now been measured from a non synodic reference with a very high accuracy, and they imply a mean weighted rotation of 1277 ± 10 nHz (9-day period) of their kernels, resulting in a rapid rotation frequency of 1644 ± 23 nHz (period of one week) of the solar core itself, which is a factor 3:8 ± 0:1 faster than the rotation of the radiative envelope.

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110 – Instrumentation Poster Session

110.02 – The Effect of Tropopause Seeing on Solar Telescope Site Testing

The site testing for and seeing correction planning of the 4-m solar telescopes has failed to take into account the significant amount of seeing at tropopause levels (10-20 km altitude).The worst aspect of that seeing layer is its small isoplanatic patch size which at low solar elevations can be significantly less than 1 arcsec.

The CLEAR/ATST/DKIST SDIMM seeing monitor is insensitive to this type of seeing. A correction for this missed seeing significantly decreases the measured seeing qualities for the sites tested especially in the early morning and late afternoon. It clearly shows the lake site to be superior with mid-day observations much to be preferred.

The small tropopause isoplanatic patch size values also complicate the implementation of the solar MCAO systems aimed at large field-of-view sun imaging. Currently planned systems only correct for lower-layer seeing for which the isoplanatic patch size is about one arc minute. To fully achieve the diffraction limit of the 4-meter class (0.025 arcsec at 500 nm), over a large enough field-of-view to be of scientific interest, complicated Multi-Conjugate Adaptive Optics systems will be needed.

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110.03 – Status update of the effort to correct the SDO/HMI systemmatic errors in Doppler velocity and derived data products

This poster provides an update of the status of the efforts to understand and correct the leakage of the SDO orbit velocity into most HMI data products. The following is extracted from the abstract for the similar topic presented at the 2016 SPD meeting: “The Helioseismic and Magnetic Imager (HMI) instrument on the Solar Dynamics Observatory (SDO) measures sets of filtergrams which are converted into velocity and magnetic field maps. In addition to solar photospheric motions the velocity measurements include a direct component from the line-of-sight component of the SDO orbit. Since the magnetic field is computed as the difference between the velocity measured in left and right circular polarization, the orbit velocity is canceled only if the velocity is properly calibrated. When the orbit velocity is subtracted the remaining "solar" velocity shows a residual signal which is equal to about 2% of the c. +- 3000 m/s orbit velocity in a nearly linear relationship. This implies an error in our knowledge of some of the details of as-built filter components. This systematic error is the source of 12- and 24-hour variations in most HMI data products. While the instrument as presently calibrated (Couvidat et al. 2012 and 2016) meets all of the “Level-1” mission requirements it fails to meet the stated goal of 10 m/s accuracy for velocity data products. For the velocity measurements this has not been a significant problem since the prime HMI goals of obtaining data for helioseismology are not affected by this systematic error. However the orbit signal leaking into the magnetograms and vector magnetograms degrades the ability to accomplish some of the mission science goals at the expected levels of accuracy. This poster presents the current state of understanding of the source of this systematic error and prospects for near term improvement in the accuracy of the filter profile model.”

Author(s): Philip H. Scherrer[1]
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110.04 – Solar Orbiter Status Report

With the delivery of the instruments to the spacecraft builder, the Solar Orbiter mission is in the midst of Integration & Testing phase at Airbus in Stevenage, U.K. This mission to “Explore the Sun-Heliosphere Connection” is the first medium-class mission of ESA’s Cosmic Vision 2015-2025 program and is being jointly implemented with NASA. The dedicated payload of 10 remote-sensing and in-situ instruments will orbit the Sun as close as 0.3 A.U. and will provide measurments from the photosphere into the solar wind. The three-axis stabilized spacecraft will use Venus gravity assists to increase the orbital inclination out of the ecliptic to solar latitudes as high as 34 degrees in the extended mission. The science team of Solar Orbiter has been working closely with the Solar Probe Plus scientists to coordinate observations between these two highly-complementary missions. This will be a status report on the mission development; the interested reader is referred to the recent summary by Müller et al., *Solar Physics* **285** (2013).

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Institution(s): *1. ESA, 2. NASA's Goddard Space Flight Center, 3. UCLA*

110.05 – The Radio & Plasmas Waves instrument on the Solar Orbiter mission : science objectives and capabilities

We will review the science objectives of the Radio & Plasmas Waves (RPW) instrument on the Solar Orbiter mission. Among those the study of the connectivity between the solar corona and the inner Heliosphere as close as from 0.3 AU and the kinetic behavior of the Solar Wind are of prime importance. We present then the RPW technical capabilities which will allow in-situ and remote sensing measurements of both electrostatic and electromagnetic fields and waves in a broad frequency range, typically from a fraction of Hertz to a few tens of MHz.

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110.06 – Mission Concepts for High-Resolution Solar Imaging with a Photon Sieve

The best EUV coronal imagers are unable to probe the expected energy dissipation scales of the solar corona (<100 km) because conventional optics cannot be figured to near diffraction-limited accuracy at these wavelengths. Davila (2011) has proposed that a photon sieve, a diffractive imaging element similar to a Fresnel zone plate, provides a technically feasible path to the required angular resolution. We have produced photon sieves as large as 80 mm clear aperture. We discuss laboratory measurements of these devices and the path to larger apertures. The focal length of a sieve with high EUV resolution is at least 10 m. Options for solar imaging with such a sieve include a sounding rocket, a single spacecraft with a deployed boom, and two spacecraft flying in precise formation.

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110.07 – The Ultraviolet Spectro-Coronagraph (UVSC) Pathfinder Experiment for the Remote Detection of Suprathermal Seed Particles: Instrument Status

The largest solar energetic particle (SEP) storms are produced by fast coronal mass ejection (CME) shocks. Efficient shock acceleration of ambient particles requires a near sun reservoir of suprathermal (proton) seed particles. However, the requisite seed particle reservoir has not been detected near the sun where CME shocks first appear. We are developing the Ultraviolet Spectro-Coronagraph (UVSC) Pathfinder space experiment to test for the presence or absence of the requisite suprathermal proton seed particle population within 3 solar radii of sun-center. In this poster, we present the instrument design concept, its development status, and the expected experimental results. The ultimate goal for the experiment is to demonstrate how such measurements can be used as a part of a future SEP space weather warning system.

UVSC Pathfinder is scheduled to be launched in 2019 by the DoD Space Test Program. It is supported by funds from the Chief of Naval Research (via the NRL basic research program) and from NASA (via NDPR NNG13WF951 and NNH16AC29I).

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110.08 – MUSE: the Multi-Slit Solar Explorer

The Multi-Slit Solar Explorer is a proposed Small Explorer mission for studying the dynamics of the corona and transition region using both conventional and novel spectral imaging techniques. The physical processes that heat the multi-million degree solar corona, accelerate the solar wind and drive solar activity (CMEs and flares) remain poorly known. A breakthrough in these areas can only come from radically innovative instrumentation and state-of-the-art numerical modeling and will lead to better understanding of space weather origins. MUSE's multi-slit coronal spectroscopy will use a 100x improvement in spectral raster cadence to fill a crucial gap in our knowledge of Sun-Earth connections; it will reveal temperatures, velocities and non-thermal processes over a wide temperature range to diagnose physical processes that remain invisible to current or planned instruments. MUSE will contain two instruments: an EUV spectrograph (SG) and EUV context imager (CI). Both have similar spatial resolution and leverage extensive heritage from previous high-resolution instruments such as IRIS and the HiC rocket payload. The MUSE investigation will build on the success of IRIS by combining numerical modeling with a uniquely capable observatory: MUSE will obtain EUV spectra and images with the highest resolution in space (1/3 arcsec) and time (1-4 s) ever achieved for the transition region and corona, along 35 slits and a large context FOV simultaneously. The MUSE consortium includes LMSAL, SAO, Stanford, ARC, HAO, GSFC, MSFC, MSU, ITA Oslo and other institutions.

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Institution(s): *1. Lockheed Martin Solar and Astrophysics Laboratory*

110.09 – Science with the Expanded Owens Valley Solar Array

The Expanded Owens Valley Solar Array (EOVSA) is a solar-dedicated radio array that makes images and spectra of the full Sun on a daily basis. Our main science goals are to understand the basic physics of solar activity, such as how the Sun releases stored magnetic energy on timescales of seconds, and how that solar activity, in the form of solar flares and coronal mass ejections, influences the Earth and near-Earth space environment, through disruptions of communication and navigation systems, and effects on satellites and systems on the ground. The array, which is composed out of thirteen 2.1 m dishes and two 27 m dishes (used only for calibration), has a footprint of 1.1 km EW x 1.2 km NS and it is capable of producing, every second, microwave images at two polarizations and 500 science channels spanning the 1-18 GHz frequency range. Such ability to make multi-frequency images of the Sun in this broad range of frequencies, with a frequency dependent resolution ranging from ~53" at 1 GHz to ~3"at 18 GHz, is unique in the world. Here we present an overview of the EOVSA instrument and a first set of science-quality active region and solar flare images produced from data taken during April 2017.
This research is supported by NSF grant AST-1615807 and NASA grant NNX14AK66G to New Jersey Institute of Technology.

Author(s): Gelu M. Nita[2], Dale E. Gary[2], Gregory D. Fleishman[2], Bin Chen[2], Stephen M. White[1], Gordon J. Hurford[3], James McTiernan[3], Jack Hickish[3], Sijie Yu[2], Kjell B. Nelin[2]
Institution(s): *1. Air Force Research Laboratory, 2. NJIT, 3. UC, Berkeley*

110.10 – CLASP2: The Chromospheric LAyer Spectro-Polarimeter

We present the instrument, science case, and timeline of the CLASP2 sounding rocket mission. The successful CLASP (Chromospheric Lyman-Alpha Spectro-Polarimeter) sounding rocket flight in 2015 resulted in the first-ever linear polarization measurements of solar hydrogen Lyman-alpha line, which is sensitive to the Hanle effect and can be used to constrain the magnetic field and geometric complexity of the upper chromosphere. Ly-alpha is one of several upper chromospheric lines that contain magnetic information. In the spring of 2019, we will re-fly the modified CLASP telescope to measure the full Stokes profile of Mg II h & k near 280 nm. This set of lines is sensitive to the upper chromospheric magnetic field via both the Hanle and the Zeeman effects.

Author(s): Laurel Rachmeler[8], David E McKenzie[8], Ryohko Ishikawa[7], Javier Trujillo Bueno[2], Frédéric Auchère [3], Ken Kobayashi[8], Amy Winebarger[8], Christian Bethge[11],Ryouhei Kano[7], Masahito Kubo[7], Donguk Song[7], Noriyuki Narukage[7], Shin-nosuke Ishikawa[5], Bart De Pontieu[6], Mats Carlsson[10], Masaki Yoshida[7], Luca Belluzzi[4], Jiri Stepan[1],Tanausú del Pino Alemná[9], Ernest Alsina Ballester[2], Andres Asensio Ramos[2]
Institution(s): *1. Astronomical Institute of the Czech Academy of Sciences, 2. IAC, 3. IAS, 4. IRSOL, 5. ISAS/JAXA, 6. LMSAL, 7. NAOJ, 8. NASA/MSFC, 9. NCAR/HAO, 10. Univ of Oslo, 11. USRA*

111 – Magnetic Fields Poster Session

111.02 – Mi Gauss es su Gauss: Lessons from Cross-Calibrating 40 years of Full Disk Magnetograms

Full-disk line-of-sight magnetograms from the Kitt Peak Vacuum Telescope (KPVT) are a highly valuable, but underutilized, source of data for understanding long-term solar variability. Here we present the results of a project for obtaining a cross-callibrated series of magnetograms spanning 40 years including KPVT (512 and SPMG), SOHO/MDI and SDO/HMI magnetographs. The biggest challenge we face is empirically identifying a calibration factor and estimate of uncertainty between instruments with little temporal overlap.

Here we propose a method that fragments magnetograms into spherical quadrangles bounded by latitudes and longitudes and calculates various information such as total area, mean flux density, and distance from disk center. Our main assumption is that the Sun does not change significantly over daily time periods.

First a magnetogram to be calibrated is differentially rotated to match a reference magnetogram in time. Then the smaller magnetogram is interpolated into the larger one to account for sub-pixel heliographic coordinates. We then produce equally spaced bands of latitude and longitude determined from a fragmentation parameter. These are used to map out regions on each magnetogram that are expected to relay the same information. Our efforts to cross-calibrate lead to results that vary with fragmentation parameters, the difference in time of selected magnetograms, and distance from disk center.

Given that this cross-callibrated series will be made publically available, we are looking for constructive criticism, suggestions, and feedback. Please join us in making these data as good as they can be.

Author(s): Zachary Werginz[1], Andres Munoz-Jaramillo[3], Petrus C. Martens[1], J. W. Harvey[2]
Institution(s): *1. Georgia State University, 2. National Solar Observatory, 3. SouthWest Research Institute*

111.03 – Babcock Redux: An Amendment of Babcock's Schematic of the Sun's Magnetic Cycle

We amend Babcock's original scenario for the global dynamo process that sustains the Sun's 22-year magnetic cycle. The amended scenario fits post-Babcock observed features of the magnetic activity cycle and convection zone, and is based on ideas of Spruit & Roberts (1983, Nature, 304, 401) about magnetic flux tubes in the convection zone. A sequence of four schematic cartoons lays out the proposed evolution of the global configuration of the magnetic field above, in, and at the bottom of the convection zone through sunspot Cycle 23 and into Cycle 24. Three key elements of the amended scenario are: (1) as the net following-polarity magnetic field from the sunspot-region Ω-loop fields of an ongoing sunspot cycle is swept poleward to cancel and replace the opposite-polarity polar-cap field from the previous sunspot cycle, it remains connected to the ongoing sunspot cycle's toroidal source-field band at the bottom of the convection zone; (2) topological pumping by the convection zone's free convection keeps the horizontal extent of the poleward-migrating following-polarity field pushed to the bottom, forcing it to gradually cancel and replace old horizontal field below it that connects the ongoing-cycle source-field band to the previous-cycle polar-cap field; (3) in each polar hemisphere, by continually shearing the poloidal component of the settling new horizontal field, the latitudinal differential rotation low in the convection zone generates the next-cycle source-field band poleward of the ongoing-cycle band. The amended scenario is a more-plausible version of Babcock's scenario, and its viability can be explored by appropriate kinematic flux-transport solar-dynamo simulations. A paper giving a full description of our dynamo scenario is posted on arXiv (http://arxiv.org/abs/1606.05371).

This work was funded by the Heliophysics Division of NASA's Science Mission Directorate through the Living With a Star Targeted Research and Technology Program and the Hinode Project.

Author(s): Ronald L. Moore[1], Jonathan W. Cirtain[1], Alphonse C. Sterling[1]
Institution(s): *1. NASA's MSFC*

111.04 – Solar Spectral Lines with Special Polarization Properties for the Calibration of Instrument Polarization

We investigate atomic transitions that have previously been identified as having zero polarization from the Zeeman effect. Our goal is to identify spectral lines that can be used for the calibration of instrumental polarization of large astronomical and solar telescopes, such as the Daniel K. Inouye Solar Telescope, which is currently under construction on Haleakala. We use a numerical model that takes into account the generation of scattering polarization and its modification by the presence of a magnetic field (Hanle effect, Zeeman effect, and incomplete Paschen-Back effect). We adopt values for the Land\'e factors from spectroscopic measurements or semi-empirical results, thus relaxing the common assumption of LS-coupling previously used in the literature. The mechanisms dominating the polarization of particular transitions are identified, and we summarize groups of various spectral lines useful for the polarization calibration of spectro-polarimetric instruments, classified according to their polarization properties.

Author(s): Wenxian Li[1], Roberto Casini[1], Phil Judge[1], Tanausú del Pino Alemná[1]
Institution(s): *1. High Altitude Observatory, NCAR*

111.05 – Global Evolving Models of Photospheric Flux as Driven by Electric Fields

We present a novel method for modeling the global radial magnetic field that is based on the incorporation of time series of photospheric electric fields. The determination of the electric fields is the result of a recently developed method that uses as input various data products from SDO/HMI, namely vector magnetic fields and line-of-sight Doppler images. For locations on the sphere where electric field data are unavailable, we instead use electric fields that are consistent with measurements of the mean differential rotation, meridional flow, and flux dispersal profiles. By combining these electric fields, a full-Sun model of the photospheric radial magnetic field can be advanced forward in time via Faraday's Law.

Author(s): Marc L. DeRosa[1], Mark Cheung[1], Maria D. Kazachenko[2], George H. Fisher[2]
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111.06 – Predicting Solar Cycle 25 using Surface Flux Transport Model

It is thought that the longer-term variations of the solar activity may affect the Earth's climate. Therefore, predicting the next solar cycle is crucial for the forecast of the "solar-terrestrial environment". To build prediction schemes for the next solar cycle is a key for the long-term space weather study. Recently, the relationship between polar magnetic field at the solar minimum and next solar activity is intensively discussed. Because we can determine the polar magnetic field at the solar minimum roughly 3 years before the next solar maximum, we may discuss the next solar cycle 3years before. Further, the longer term (~5 years) prediction might be achieved by estimating the polar magnetic field with the Surface Flux Transport (SFT) model. Now, we are developing a prediction scheme by SFT model as a part of the PSTEP (Project for Solar-Terrestrial Environment Prediction) and adapting to the Cycle 25 prediction. The predicted polar field strength of Cycle 24/25 minimum is several tens of percent smaller than Cycle 23/24 minimum. The result suggests that the amplitude of Cycle 25 is weaker than the current cycle. We also try to obtain the meridional flow, differential rotation, and turbulent diffusivity from recent modern observations (*Hinode* and *Solar Dynamics Observatory*). These parameters will be used in the SFT models to predict the polar magnetic fields strength at the solar minimum. In this presentation, we will explain the outline of our strategy to predict the next solar cycle and discuss the initial results for Cycle 25 prediction.

Author(s): Shinsuke Imada[2], Haruhisa Iijima[2], Hideyuki Hotta[1], Daiko Shiota[2], Kanya Kusano[2]
Institution(s): *1. Chiba university, 2. Nagoya University*

111.07 – A new method to quantify and reduce projection error in whole-solar-active-region parameters measured from vector magnetograms

Projection error limits the use of vector magnetograms of active regions (ARs) far from disk center. For ARs observed up to 60^{o} from disk center, we demonstrate a method of measuring and reducing the projection error in the magnitude of any whole-AR parameter derived from a vector magnetogram that has been deprojected to disk center. The method assumes that the center-to-limb curve of the average of the parameter's absolute values measured from the disk passage of a large number of ARs and normalized to each AR's absolute value of the parameter at central meridian, gives the average fractional projection error at each radial distance from disk center. To demonstrate the method, we use a large set of large-flux ARs and apply the method to a whole-AR parameter that is among the simplest to measure: whole-AR magnetic flux. We measure 30,845 SDO/HMI vector magnetograms covering the disk passage of 272 large-flux ARs, each having whole-AR flux $>10^{22}$ Mx. We obtain the center-to-limb radial-distance run of the average projection error in measured whole-AR flux from a Chebyshev fit to the radial-distance plot of the 30,845 normalized measured values. The average projection error in the measured whole-AR flux of an AR at a given radial distance is removed by multiplying the measured flux by the correction factor given by the fit. The correction is important for both the study of evolution of ARs and for improving the accuracy of forecasting an AR's major flare/CME productivity. We will also show corrections for other whole-AR parameters, especially AR free-energy proxies.

Author(s): David Falconer[1], Sanjiv K Tiwari[1], Ronald L. Moore[1], Igor Khazanov[1]
Institution(s): *1. UAH*

111.08 – Studying the Formation and Evolution of Eruptive Magnetic Flux Ropes

Solar magnetic eruptions are dramatic sources of solar activity, and dangerous sources of space weather hazards. Many of these eruptions take the form of magnetic flux ropes, i.e., magnetic fieldlines wrapping around a core magnetic flux tube. Investigating the processes which form these flux ropes both prior to and during eruption, and investigating their evolution after eruption, can give us a critical window into understanding the sources of and processes involved in these eruptions. This presentation will discuss modeling and observational investigations into these various phases of flux rope formation, eruption, and evolution, and will discuss how these different explorations can be used to develop a more complete picture of erupting flux rope dynamics.

Author(s): Mark Linton[1]
Institution(s): *1. NRL*

112 – Photosphere Poster Session

112.01 – Lewis M. Rutherfurd and the First Photograph of Solar Granulation

A major astronomical controversy of the mid-19th century was discordant descriptions of the small scale structure of the solar surface. Visual observers contradicted each other by describing the surface as consisting of "corrugations", "willow leaves", "rice grains", "cumuli", "thatch", "granules", etc. Early photographs of the solar surface were not good enough to settle the controversy. The French astronomer Jules Janssen is credited with the first 1876 photographs that clearly showed what we now call solar granulation (1876, CRAS 82, 1363). Upon seeing these images, New Yorker Lewis M. Rutherfurd (1878, MNRAS 38, 410) praised the high quality of Janssen's images but asserted that he had also photographed granulation as early as 1871 using collodion wet plates. He sent copies of his best photograph to the Royal Astronomical Society to support his assertion. Curious about his claim, Briggs and Harvey set up Rutherfurd's 13-inch achromatic refractor on Kitt Peak and found that it easily showed well-resolved solar granulation, so his claim might well have been justified. But without his plates we could not confirm the claim. For 140 years the copies of Rutherfurd's best solar photograph remained in the archives of the Royal Astronomical Society and were recently discovered by Prosser (RAS Photographs A3/001B and A3/002). By coincidence a few days later, Briggs found the original August 11, 1871 plate. Despite poor condition these photographs show solar granulation. There are at least two other possible early claimants (Reade; Vogel) but their plates are almost certainly lost. Rutherfurd was a master of astronomical instrumentation and photography. He was reticent about his work, letting results speak for themselves, so it is satisfying to find that he was justified in making his claim of priority.

Author(s): J. W. Harvey[2], John W. Briggs[1], Sian Prosser[3]
Institution(s): *1. Astronomical Lyceum, 2. National Solar Obs., 3. Royal Astronomical Society*

112.02 – Update on a Solar Magnetic Catalog Spanning Four Solar Cycles

Bipolar magnetic regions (BMRs) are the cornerstone of solar cycle propagation, the building blocks that give structure to the solar atmosphere, and the origin of the majority of space weather events. However, in spite of their importance, there is no homogeneous BMR catalog spanning the era of systematic solar magnetic field measurements. Here we present the results of an ongoing project to address this deficiency applying the Bipolar Active Region Detection (BARD) code to magnetograms from the 512 Channel of the Kitt Peak Vaccum Telescope, SOHO/MDI, and SDO/HMI.

The BARD code automatically identifies BMRs and tracks them as they are rotated by differential rotation. The output of the automatic detection is supervised by a human observer to correct possible mistakes made by the automatic algorithm (like incorrect pairings and tracking mislabels). Extra passes are made to integrate fragmented regions as well as to balance the flux between BMR polarities. At the moment, our BMR database includes nearly 10,000 unique objects (detected and tracked) belonging to four separate solar cycles (21-24).

Author(s): Juan Pablo Vargas-Acosta[5], Andres Munoz-Jaramillo[6], Santiago Vargas Dominguez[5], Zachary Werginz[7], Michael D DeLuca[8], Dana Longcope[3], J. W. Harvey[4],John Windmueller[3], Jie Zhang[1], Petrus C. Martens[2]
Institution(s): *1. George Mason University, 2. Georgia State University, 3. Montana State University, 4. National Solar Obs., 5. National University of Colombia, 6. Southwest Research Institute, 7. St. Norbert College, 8. University of Colorado*

112.06 – Studying the transfer of magnetic helicity in solar active regions

Analyzing the transfer of magnetic helicity in active regions is a key component for understanding the nature of its coronal storage and release and for identifying its role in the coronal dynamics of active regions. We recently developed a method for studying the photospheric flux of magnetic helicity in both 2D and 3D. The method takes into account the 3D nature of magnetic helicity by explicitly using knowledge of the magnetic field connectivity. Since the coronal magnetic field in active regions is not measured, we rely on the non-unique 3D solution obtained from force-free coronal magnetic field extrapolations to derive the magnetic field connectivity. In this poster, we apply the method to the complex and highly-flaring active region NOAA 11158 using the magnetic field connectivity derived from different force-free extrapolation models and implementations. We show that the calculations of photospheric flux of magnetic helicity are robust to different extrapolation methods and assumptions, in particular with regards to identifying regions of opposite magnetic helicity flux. Finally, we discuss the implications of our results for tracking the transfer of magnetic helicity in active regions and relate it to their flaring activity.

Author(s): Kevin Dalmasse[2], Gherardo Valori[4], Ju Jing[3], Etienne Pariat[1], Pascal Demoulin[1]
Institution(s): *1. LESIA - Paris Observatory, 2. NCAR, 3. New Jersey Institute of Technology, 4. University College London*

112.07 – The Great Solar Active Region NOAA 12192: Helicity Transport, Filament Formation, and Impact on the Polar Field

The solar active region (AR), NOAA 12192, appeared in 2014 October as the largest AR in 24 years. Here we examine the counterintuitive nature of two diffusion-driven processes in the region: the role of helicity buildup in the formation of a major filament, and the relationship between the effects of supergranular diffusion and meridional flow on the AR and on the polar field. Quantitatively, calculations of current helicity and magnetic twist from Helioseismic and Magnetic Imager (HMI) vector magnetograms indicate that, though AR 12192 emerged with negative helicity, positive helicity from subsequent flux emergence, consistent with the hemispheric sign-preference of helicity, increased over time within large-scale, weak-field regions such as those near the polarity inversion line (PIL). Morphologically, Atmospheric Imaging Assembly observations of filament barbs, sigmoidal patterns, and bases of Fe xii stalks initially exhibited signatures of negative helicity, and the long filament that subsequently formed had a strong positive helicity consistent with the helicity buildup along the PIL. We find from full-disk HMI magnetograms that AR 12192's leading positive flux was initially closer to the equator but, owing either to the region's magnetic surroundings or to its asymmetric flux density distribution, was transported poleward more quickly on average than its trailing negative flux, contrary to the canonical pattern of bipole flux transport. This behavior caused the AR to have a smaller effect on the polar fields than expected and enabled the formation of the very long neutral line where the filament formed.

Author(s): Gordon Petrie[2], Tyler C McMaken[1]
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113 – Solar Interior Poster Session

113.01 – Initial Results from Fitting Resolved Modes using HMI Intensity Observations

The HMI project recently started processing the continuum intensity images following global helioseismology procedures similar to those used to process the velocity images. The spatial decomposition of these images has produced time series of spherical harmonic coefficients for degrees up to l=300, using a different apodization than the one used for velocity observations. The first 360 days of observations were processed and made available. I present initial results from fitting these time series using my state of the art fitting methodology and compare the derived mode characteristics to those estimated using co-eval velocity observations.

Author(s): Sylvain G. Korzennik[1]
Institution(s): *1. Harvard-Smithsonian, CfA*

113.02 – Detailed Image Comparison using MDI, HMI and GONG Co-Eval Observations

I present preliminary results from detailed image comparison using MDI, HMI and GONG co-eval observations taken in 2014, when all three instruments were operational. This comparison allows me to estimate both the instrumental image distortion and the instrument PSF, with respect to HMI. Both intensity and velocity images are compared when available. The precise observing perspective of each instrument had to be accounted since it affects the projected image on the instrument detector at the required level of precision (i.e., a fraction of an HMI pixel). In the process, it was discovered that the meta data generated by the respective projects were not accurate enough. While the inclusion of the image distortion and the instrument PSF in the spatial decomposition will improve the determination of high degree modes, it may also benefit other local helioseismic analysis.

Author(s): Sylvain G. Korzennik[1]
Institution(s): *1. Harvard-Smithsonian, CfA*

113.03 – Progress Towards a Time-Dependent Theory of Solar Meridional Flows

Large-scale meridional motions of solar materials play an important role in flux transport dynamo models. Meridional flows transport surface magnetic flux to polar regions of the Sun, where it may later be subducted and conveyed back towards the equatorial region by a deep return flow in the convection zone. The transported flux may thereafter lead to the generation of new toroidal fields, thereby completing the dynamo cycle. More than two decades of observations have revealed that meridional flow speeds vary substantially with time. Further, a complex morphological variability of meridional flow cells is now recognized, with multiple cell structures detected both in latitude and in depth. 'Countercells' with reversed flow directions have been detected at various times. Flow speeds are apparently influenced by the proximity of flows to active regions. This complexity represents a considerable challenge to dynamo modeling efforts. Flows morphology and speed changes may be arbitrarily prescribed in models, but physical realism of model outputs may be questionable, and elusive: The models are 'trying to hit a moving target.' Considerations such as these led Belucz et al. (2013; Ap. J. 806:169) to call for "time-dependent theories that can tell us theoretically how this circulation may change its amplitude and form in each hemisphere." Such a theory now exists for planetary atmospheres (Shirley, 2017; Plan. Sp. Sci. 141, 1-16). Proof of concept for the non-tidal orbit-spin coupling hypothesis of Shirley (2017) was obtained through numerical modeling of the atmospheric circulation of Mars (Mischna & Shirley, 2017; Plan. Sp. Sci. 141, 45-72). Much-improved correspondence of numerical modeling outcomes with observations was demonstrated. In this presentation we will briefly review the physical hypothesis and some prior evidence of its possible role in solar dynamo excitation. We show a strong correlation between observed meridional flow speeds of magnetic features in Cycle 23 with the putative dynamical forcing function. We will also briefly discuss the potential for incorporating orbit-spin coupling accelerations within existing numerical solar dynamo models.

Author(s): James H. Shirley[1]
Institution(s): *1. JPL*

113.04 – Helioseismic Constraints on the Depth Dependence of Large-Scale Solar Convection

A recent helioseismic statistical waveform analysis of subsurface flow based on a 720-day time series of SOHO/MDI Medium-l spherical-harmonic coefficients has been extended to cover a greater range of subphotospheric depths. The latest analysis provides estimates of flow-dependent oscillation-mode coupling-strength coefficients b(s,t;n,l) over the range l = 30 to 150 of mode degree (angular wavenumber) for solar p-modes in the approximate frequency range 2 to 4 mHz. The range of penetration depths of this mode set covers most of the solar convection zone. The most recent analysis measures spherical harmonic (s,t) components of the flow velocity for odd s in the angular wavenumber range 1 to 19 for t not much smaller than s at a given s. The odd-s b(s,t;n,l) coefficients are interpreted as averages over depth of the depth-dependent amplitude of one spherical-harmonic (s,t) component of the toroidal part of the flow velocity field. The depth-dependent weighting function defining the average velocity is the fractional kinetic energy density in radius of modes of the (n,l) multiplet. The b coefficients have been converted to estimates of root velocity power as a function of l0 = nu0*l/nu(n,l), which is a measure of mode penetration depth. (nu(n,l) is mode frequency and nu0 is a reference frequency equal to 3 mHz.) A comparison of the observational results with simple convection models will be presented.

Author(s): Martin F. Woodard[1]
Institution(s): *1. NorthWest Research Associates*

113.05 – A Gravitational, Mathematical Model for the Energy, Emitted Power and Longevity of the Sun and Stars that does not use E=mc^2

A gravitational mathematical model for the energy, radiated power and lifetime of the sun and stars is derived that does not use E=mc^2. The speed of solar flares, 200 to 1000km/sec is used to derive the surface temperature of the sun as 1.4(10^6)degrees K. Optical radiation results as gamma rays leave the sun's surface and traverse and lose energy to the ~10^6km of the sun's corona. The corona is a result of solar flares with a speed component of 424km/sec parallel to the sun's surface placing their atoms into gravitational orbit about the sun. The temperature, density, and pressure of the sun are derived as a function of r, i.e. the distance from the center of the sun. The complete article is chapter 11 of my text that can be found on my website www.jmkingsleyiii.info

Author(s): James Morse Kingsley[1]
Institution(s): *1. University of Californai, Berkeley*

114 – Solarterrestrial and Heliosphere Poster Session

114.01 – Triggering Scenario of Geo-effective Solar Eruption on 15 March 2015

The largest magnetic storm so far, called St Patricks's Day event, in the solar cycle 24 occurred on 17 March 2015. It was caused by fast coronal mass ejection (CME) on 15 March 2015 from solar active region (AR) NOAA 12297. Surprisingly, the CME is suggested to be related to a C9.1 flare while the large CME is usually corresponding to a large flare. The purpose of this study is to understand the onset mechanism of the huge solar eruption which caused big impact on a magnetic environment of the geospace. The magnetic field structure in the AR was complicated: There were several filaments including the one which erupted and caused the CME. We hence carefully investigated the photospheric magnetic field, brightenings observed in the region from the chromosphere to the corona, and the three-dimensional coronal magnetic field calculated through our nonlinear force-free field (NLFFF) model using photospheric vector magnetic field data from the Hinode SOT and the Solar Dynamics Observatory (SDO). We focused on the C2.4 flare occurred prior to the C9.1 flare and filament eruption. Through our provisional analysis covering long time span, we noticed the C2.4 flare prior to the C9.1 flare is important to understanding the dynamics of this AR system and the CME event. (1) There was a compact but noticeably highly twisted magnetic field structure. During the C2.4 flare, flux cancellation was seen on the photospheric magnetic field data. (2) The erupting filament is

sustained by the coronal magnetic field prior to the flare, and C2.4 flaring site locates in the vicinity of one footpoint of them. (3) The top of the coronal loops sustaining the filament touch to a region where the torus instability would be expected.Therefore, we consider that the magnetic reconnection at the C2.4 flaring site changed the magnetic environment of the filament, destabilized the highly twisted magnetic field structure, and finally allowed the twisted magnetic field to erupt.
Author(s): Yumi Bamba[2], Satoshi Inoue[1], Keiji Hayashi[1]
Institution(s): *1. Institute for Space-Earth Environmental Research (ISEE), Nagoya University, 2. Japan Aerospace Exploration Agency*

114.03 – Identification of Solar Events Responsible for ICMEs at 1AU - Estimation of Chirality and Helicity

We start with the table of identified interplanetary magnetic clouds provided by the WIND/SWI project at https://wind.gsfc.nasa.gov/mfi/mag_cloud_S1.html .

Our procedure uses the following steps:
1) We take candidates observed during the HMI era from the above catalogue.
2) We average cloud start and end times.
3) We subtract an estimated travel time to get an origin time.
4) We find a halo or partial halo CME near the origin time using the CDAW catalogue.
5) We estimate a quadrant for the solar event from the CME shape.
6) We use the jHelioviewer on AIA 173 differences with a 5 minute cadence to find an ejected loop near the origin time.
7) We place the foot points near the locations of maxima and minima of Br (i.e. the strongest fields of opposite sign).
8) We find the field gradients such as (curl B)r at these points.

The above steps have been applied to the 37 clouds listed in the MFI table for the period 2011 to 2012 with the result that only 7 clouds could be identified and clearly associated with solar surface origination points. The MFI table includes an estimation of the cloud chirality. Transverse magnetic fields on the solar surface can be determined from the observations of the HMI instrument on the SDO spacecraft in two different ways: the standard HMI pipeline or the Ulrich - Boyden method. The Ulrich - Boyden method gives the correct chirality for all 7 cases while the standard pipeline gives the correct chirality for 6 of the 7 clouds.

The clouds are below
AR Solar Source Helicity
MFI Number Source Day/Hr Coord Pred Obs
129 11158 11/02/15:02:24 S22W09-S18W18 L L
133 11226 11/06/01:18:36 S21E19-S19E15 R R
134 11226-11227 11/06/02:07:41 S20E26-S21E16 R R
138 11289-11293 11/09/13:23:12 N23W13-N17W23 L L
148 11504 12/06/14:14:12 S16E11-S16E03 R R
154 11560-11561 12/09/02:04:00 N01W04-N05W11 L L
161 11610 12/11/10:05:12 S24E11-S20E07 R R

This research has been supported by NASA through award NNX15AF39G to Predictive Science, Inc. and subaward to UCLA
Author(s): Roger K. Ulrich[2], Tham tran[2], Pete Riley[1]
Institution(s): *1. Preditive Science Incorporated, 2. Univ. of California, Los Angeles*

114.05 – Comparing Recent Solar Wind Structures at 1 AU (STEREO A and OMNI)

One may use the longitudinal coverage of different spacecraft assets, or the same asset over sequential Carrington Rotations, to study the solar wind behavior from long-lived structures, or occasionally observe the extent of transient structures (Farrugia et al., 2011). This is of interest as the evolution of the extent and persistence of interplanetary coronal mass ejections (ICMEs) and of stream interaction regions (SIRs) have implications for space weather forecasting. One challenge is that one must be aware of the temporal evolution of the structure on the Sun and the affect of ‘sampling’ different solar sources due to different solar latitudes of the in-situ spacecraft observations. Here we look at recent time intervals where solar wind from long-lived coronal-hole structures are observed at STEREO A and near-Earth assets (OMNI2), at similar solar longitudes but with several days lapsing between observations.
Author(s): Antoinette B. Galvin[1], Charlie Farrugia[1]
Institution(s): *1. Univ. of New Hampshire*

114.06 – Space Weathering of the Lunar Surface by Solar Wind Particles

The lunar regolith is space-weathered to a different degree in response to the different fluxes of incident solar wind particles and micrometeoroids. Crater walls, among other slating surfaces, are good tracers of the space-weathering process because they mature differently depending on the varying incident angles of weathering agents. We divide a crater wall into four quadrants (north, south, east, and west) and analyze the distribution of 950-nm/750-nm reflectance-ratio and 750-nm reflectance values in each wall quadrant, using the topography-corrected images by Multispectral Imager (MI) onboard SELENE (Kaguya). For thousands of impact craters across the Moon, we interpret the spectral distributions in the four wall quadrants in terms of the space weathering by solar wind particles and micrometeoroids and of gardening by meteroids. We take into account the solar-wind shielding by the Earth's magnetotail to correctly assess the different spectral behaviors between east- and west-facing walls of the craters in the near-side of the Moon.

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Institution(s): *1. Kyung Hee University*

114.07 – Stealthy but Geoeffective Coronal Mass Ejections

We have long known about the existence of "problem" geomagnetic storms whose origins are elusive. In more general terms, not all the 1 AU disturbances can be clearly attributed to coronal mass ejections (CMEs), high speed streams (HSSs) or corotation interaction regions (CIRs.) When interplanetary CME (ICME) signatures are found in in situ data, there is not always a flare or filament eruption on the Sun or even an obvious CME observed close to the Sun that correlates with the ICME within a reasonable time range. These ICMEs sometimes result in intense storms. Furthermore, there is a possibility that some of the more severe storms could be partly contributed by such ICMEs of unclear origin. Therefore space weather prediction will remain incomplete without properly understanding these ICMEs. Even if the ICME is paired with a CME, it is sometimes difficult to find where the latter comes from. This is often called the "stealth CME" that apparently lacks low coronal signatures (LCSs). STEREO's second and third view points have tremendously helped us determine its front-side origin and find when and where it forms and accelerates, which is important for isolating possible LCSs. Although SDO/AIA has been continuously taking full-disk EUV images in a wide temperature range since 2010, there are still a number of stealthy CMEs whose LCSs are unclear or ambiguous. It is assumed that they start at high altitudes, leaving weak or negligible LCSs. Some of them seem to involve multiple magnetic domains, and weak or open field regions. We present AIA observations of several stealthy CMEs, including recent ones, that were responsible for geomagnetic storms, emphasizing the need to compare images with long time differences and to find the periods at which the CME forms and accelerates. We also discuss uncertainties in interpreting in situ data as to whether a CME is present when data are dominated by other solar wind features, such as HSS and CIR.

Author(s): Nariaki Nitta[1], Tamitha Mulligan[2]
Institution(s): *1. Lockheed Martin, ATC, 2. The Aerospace Corporation*

114.08 – Solar Orbiter Science Operations: Not A Typical Heliophysics Mission

ESA's *Solar Orbiter* is scheduled for launch in February 2019, and will approach the Sun to a distance of 0.28 AU, in an orbit progressively more inclined to the Ecliptic plane. *Solar Orbiter* will provide landmark new views of a star, up-close, often observing its poles, while measuring the coupling of the solar phenomena and features to the relatively pristine solar wind that it measure *in situ*. The unique orbit of the spacecraft and the arrangement and composition of its scientific payload impose unique constraints on how scientific operations can be conducted. These operations involve long- to very short-term planning in carefully arranged steps, which have much in common with planetary-encounter missions than preceding heliophysics missions. In this presentation, we explain the details of how science observations will be arranged and conducted, often very far from Earth, and how data from the mission will be returned and distributed.

Author(s): David R Williams[1], Anik De Groof[1], Andrew Walsh[1]
Institution(s): *1. European Space Agency*

115 – Data Poster Session

115.01 – The Virtual Solar Observatory: Progress and Diversions

The Virtual Solar Observatory (VSO) is a known and useful method for identifying and accessing solar physics data online. We review current "behind the scenes" work on the VSO, including the addition of new data providers and the return of access to data sets to which service was temporarily interrupted. We also report on the effect on software development efforts when government IT "security" initiatives impinge on finite resoruces. As always, we invite SPD members to identify data sets, services, and interfaces they would like to see implemented in the VSO.

Author(s): Joseph B. Gurman[1], R. S Bogart[5], A. Amezcua[5], Frank Hill[4], Niles Oien[4], Alisdair R. Davey[4], Joseph Hourcle[2], E. Mansky[2], Jennifer L Spencer[3]
Institution(s): *1. NASA GSFC, 2. NASA GSFC and ADNET, 3. NASA GSFC and Telophase, 4. NSO, 5. Stanford U.*

115.03 – Adding EUNIS and VAULT rocket data to the VSO with Modern Perl frameworks

A new Perl code is described, that uses the modern Object-oriented Moose framework, to add EUNIS and VAULT rocket data to the Virtual Solar Observatory website. The code permits the easy fixing of FITS header fields in the case where some FITS fields that are required are missing from the original data files. The code makes novel use of the Moose extensions “before” and “after” to build in dependencies so that database creation of tables occurs before the loading of data, and that the validation of file-dependent tables occurs after the loading is completed. Also described is the computation and loading of the deferred FITS field CHECKSUM into the database following the loading and validation of the file-dependent tables. The loading of the EUNIS 2006 and 2007 flight data, and the VAULT 2.0 flight data is described in detail as illustrative examples.

Author(s): Edmund Mansky[1]
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115.04 – Data processing pipeline of the Near-Infrared Imaging Spectropolarimeter at the NST

The Near-Infrared Imaging Spectropolarimeter (NIRIS) is made for imaging magnetic field structures on the Sun. The data acquired undergoes extensive post-processing to ensure high resolution, high signal to noise ratio, and high accuracy. We would like to introduce how the data are processed by demonstrating data processing pipeline. In this manner, the capabilities and the limits in data analysis would be evaluated. The NIRIS is dedicated to Fe I 15648 band observation for now, while it has potential for expanding their choice of bands as well as improving data quality. Such upgrade plans should be discussed and prioritized.

Author(s): Kwangsu Ahn[1], Wenda Cao[1]
Institution(s): *1. Big Bear Solar Observatory*

115.05 – Development of KASI Geomagnetic Storm Forecast System using Coronagraph Data

We present Korea Astronomy and Space Science Institute (KASI) Geomagnetic Storm Forecast System. The aim of the system is to calculate the CME arrival time and predict the geoeffectiveness of the CME. To implement the system, we use the Large Angle and Spectrometric Coronagraph (LASCO) C2 and C3 data, the HMI magnetogram data of Solar Dynamics Observatory(SDO), and CACTUS CME list. The system consists of servers, which are to download, process, and publish data, data handling programs and web service. We apply an image differencing technique on LASCO data to determine speed and earthward direction parameters of CMEs. KASI Geomagnetic Storm Forecast Model has installed and being tested at Community Coordinated Modeling Center (CCMC) of NASA/GSFC. We expect that users can predict CME arrival time and geoeffectiveness of the CME easily and fast using the system. In order to improve the forecast performance of the system, we plan to incorporate advanced coronagraph data which will be developed and installed on ISS by KASI and NASA in collaboration.

Author(s): Ji-Hye Baek[1], SeongHwan Choi[1], Jongyeob Park[1], Roksoon Kim[1], Sujin Kim[1], Jihun Kim[1]
Institution(s): *1. Korea Astronomy and Space Science Institute*

115.06 – SunPy 0.8 - Python for Solar Physics

SunPy is a community-developed open-source software library for solar physics. It is written in Python, a free, cross-platform, general-purpose, high-level programming language which is being increasingly adopted throughout the scientific community. Python is one of the top ten most often used programming languages, as such it provides a wide array of software packages, such as numerical computation (NumPy, SciPy), machine learning (scikit-learn), signal processing (scikit-image, statsmodels) to visualization and plotting (matplotlib, mayavi). SunPy aims to provide the software for obtaining and analyzing solar and heliospheric data. This poster introduces a new major release of SunPy (0.8). This release includes two major new functionalities, as well as a number of bug fixes. It is based on 1120 contributions from 34 unique contributors. Fido is the new primary interface to download data. It provides a consistent and powerful search interface to all major data sources provides including VSO, JSOC, as well as individual data sources such as GOES XRS time series and and is fully pluggable to add new data sources, i.e. DKIST. In anticipation of Solar Orbiter and the Parker Solar Probe, SunPy now provides a powerful way of representing coordinates, allowing conversion between coordinate systems and viewpoints of different instruments, including preliminary reprojection capabilities. Other new features including new timeseries capabilities with better support for concatenation and metadata, updated documentation and example gallery. SunPy is distributed through pip and conda and all of its code is publicly available (sunpy.org).

Author(s): Andrew Inglis[7], Monica Bobra[6], Steven Christe[3], Russell Hewett[1], Jack Ireland[3], Stuart Mumford[11], Juan Carlos Martinez Oliveros[9], David Perez-Suarez[2], Kevin P. Reardon[5], Sabrina Savage[4], Albert Y. Shih[3], Daniel Ryan[3], Brigitta Sipocz[10], Nabil Freij[8]
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115.07 – Statistical Study of Eruptive Filaments using Automated Detection and Tracking Technique

Solar filaments are dense and cool material suspended in the low solar corona. They are found to be on the Sun for periods up to a few weeks, and they end their lifetime either as a gradual disappearance or an eruption. We have developed an automated detection and tracking technique to study such filament eruptions using full-disc Hα images. Various processing steps are used before subjecting an image to segmentation, that would extract only the filaments. Further steps track the filaments between successive images, label them uniquely, and generate output that can be used for a comparative study. In this poster, we would use this technique to carry out a statistical study of several erupting filaments through which the common underlying properties of such eruptions can be derived. Details of the technique will also be discussed in brief. Filament eruptions are found to be closely associated with coronal mass ejections (CMEs) wherein a large mass from corona is ejected into the interplanetary space. If such a CME hits the Earth with a favourable orientation of magnetic field a geomagnetic storm can result adversely affecting electronic infrastructure in space as well as ground. The properties of filament eruptions derived can be used in future to predict an eruption in an almost real-time basis, thereby giving a warning of imminent storm.

Author(s): Anand D Joshi[1], Yoichiro Hanaoka[1]
Institution(s): *1. NAOJ*

115.08 – IRISpy: Analyzing IRIS Data in Python

IRISpy is a new community-developed open-source software library for analysing IRIS level 2 data. It is written in Python, a free, cross-platform, general-purpose, high-level programming language. A wide array of scientific computing software packages have already been developed in Python, from numerical computation (NumPy, SciPy, etc.), to visualization and plotting (matplotlib), to solar-physics-specific data analysis (SunPy). IRISpy is currently under development as a SunPy-affiliated package which means it depends on the SunPy library, follows similar standards and conventions, and is developed with the support of of the SunPy development team. IRISpy's has two primary data objects, one for analyzing slit-jaw imager data and another for analyzing spectrograph data. Both objects contain basic slicing, indexing, plotting, and animating functionality to allow users to easily inspect, reduce and analyze the data. As part of this functionality the objects can output SunPy Maps, TimeSeries, Spectra, etc. of relevant data slices for easier inspection and analysis. Work is also ongoing to provide additional data analysis functionality including derivation of systematic measurement errors (e.g. readout noise), exposure time correction, residual wavelength calibration, radiometric calibration, and fine scale pointing corrections. IRISpy's code base is publicly available through github.com and can be contributed to by anyone. In this poster we demonstrate IRISpy's functionality and future goals of the project. We also encourage interested users to become involved in further developing IRISpy.

Author(s): Daniel Ryan[4], Steven Christe[4], Stuart Mumford[5], Ankit Baruah[1], Shelbe Timothy[3], Tiago Pereira[2], Bart De Pontieu[3]
Institution(s): *1. Indian Institute of Technology, 2. Institute of Theoretical Physics, University of Oslo, 3. Lockheed Martin Solar and Astrophysics Lab, 4. NASA Goddard Space Flight Center, 5. University of Sheffield*

P6.01 – Noise Gating Solar Images

I present and demonstrate a new, general purpose post-processing technique, "3D noise gating", that can reduce image noise by an order of magnitude or more without effective loss of spatial or temporal resolution in typical solar applications.

Nearly all scientific images are, ultimately, limited by noise. Noise can be direct Poisson "shot noise" from photon counting effects, or introduced by other means such as detector read noise. Noise is typically represented as a random variable (perhaps with location- or image-dependent characteristics) that is sampled once per pixel or once per resolution element of an image sequence. Noise limits many aspects of image analysis, including photometry, spatiotemporal resolution, feature identification, morphology extraction, and background modeling and separation.

Identifying and separating noise from image signal is difficult. The common practice of blurring in space and/or time works because most image "signal" is concentrated in the low Fourier components of an image, while noise is evenly distributed. Blurring in space and/or time attenuates the high spatial and temporal frequencies, reducing noise at the expense of also attenuating image detail. Noise-gating exploits the same property -- "coherence" -- that we use to identify features in images, to separate image features from noise.

Processing image sequences through 3-D noise gating results in spectacular (more than 10x) improvements in signal-to-noise ratio, while not blurring bright, resolved features in either space or time. This improves most types of image analysis, including feature identification, time sequence extraction, absolute and relative photometry (including differential emission measure analysis), feature tracking, computer vision, correlation tracking, background modeling, cross-scale analysis, visual display/presentation, and image compression.

I will introduce noise gating, describe the method, and show examples from several instruments (including SDO/AIA , SDO/HMI, STEREO/SECCHI, and GOES-R/SUVI) that explore the benefits and limits of the technique.

Author(s): Craig DeForest[3], Daniel B. Seaton[1], John A. Darnell[2]
Institution(s): *1. CU/CIRES, 2. NOAA/SWPC, 3. Southwest Research Inst.*

P1 – Tuesday E-Posters Screen 1

P1.01 – Interactive Multi-Instrument Database of Solar Flares (IMIDSF)

Solar flares represent a complicated physical phenomenon observed in a broad range of the electromagnetic spectrum, from radiowaves to gamma-rays. For a complete understanding of the flares it is necessary to perform a combined multi-wavelength analysis using observations from many satellites and ground-based observatories. For efficient data search, integration of different flare lists and representation of observational data, we have developed the Interactive Multi-Instrument Database of Solar Flares (https://solarflare.njit.edu/). The web database is fully functional and allows the user to search for uniquely-identified flare events based on their physical descriptors and availability of observations of a particular set of instruments. Currently, data from three primary flare lists (GOES, RHESSI and HEK) and a variety of other event catalogs (Hinode, Fermi GBM, Konus-Wind, OVSA flare catalogs, CACTus CME catalog, Filament eruption catalog) and observing logs (IRIS and Nobeyama coverage), are integrated. An additional set of physical descriptors (temperature and emission measure) along with observing summary, data links and multi-wavelength light curves is provided for each flare event since January 2002. Results of an initial statistical analysis will be presented.

Author(s): Viacheslav M Sadykov[1], Gelu M. Nita[1], Vincent Oria[1], Alexander G Kosovichev[1]
Institution(s): *1. New Jersey Institute of Technology*

P1.02 – Simulating the Mg II NUV Spectra & C II Resonance Lines During Solar Flares

The solar chromosphere is the origin of the bulk of the enhanced radiative output during solar flares, and so comprehensive understanding of this region is important if we wish to understand energy transport in solar flares. It is only relatively recently, however, with the launch of IRIS that we have routine spectroscopic flarea observations of the chromsphere and transition region. Since several of the spectral lines observed by IRIS are optically thick, it is necessary to use forward modelling to extract the useful information that these lines carry about the flaring chromosphere and transition region. We present the results of modelling the formation properties Mg II resonance lines & subordinate lines, and the C II resonance lines during solar flares. We focus on understanding their relation to the physical strucutre of the flaring atmosphere, exploiting formation height differences to determine if we can extract information about gradients in the atmosphere. We show the effect of degrading the profiles to the resolution of the IRIS, and that the usual observational techniques used to identify the line centroid do a poor job in the early stages of the flare (partly due to multiple optically thick line components). Finally, we will tentatively comment on the effects that 3D radiation transfer may have on these lines.

Author(s): Graham Stewart Kerr[1], Joel C. Allred[1], Jorrit Leenaarts[2], Elizabeth Butler[3], Adam Kowalski[3]
Institution(s): *1. NASA/Goddard Space Flight Center, 2. Stockholm University, 3. University of Colorado Boulder*

110.01 – VUV Spectroscopy of the Sun as a Star

We describe a new sounding rocket mission to obtain the first high resolution, high quality VUV (100-200 nm) spectrum of the Sun-as-a-star. Our immediate science goal is to understand better the processes of chromospheric and coronal heating. HST data exist for a dozen or so Sun-like stars of a quality already beyond our ability to construct a comparable sun-as-a-star UV spectrum. The solar spectrum we obtain will enable us to understand the nature of magnetic energy dissipation as a Sun-like star evolves, and the dependence of magnetic activity on stellar mass and metallicity. This poster presents the instrument design, scientific prospects, and broader impacts of the proposed mission.

Author(s): Charles Kankelborg[2], Judge Philip[1], Amy R. Winebarger[3], Ken Kobayashi[3], Roy Smart[2]
Institution(s): *1. High Altitude Observatory, 2. Montana State Univ., 3. NASA/MSFC*

P2 – Tuesday E-Posters Screen 2

P2.01 – Further Exploration of Post-Flare Giant Arches

Recent observations from the SWAP EUV imager on-board PROBA2 and SXI X-ray observations from the GOES satellite have shown that post-flare giant arches and regular post-flare loops are one and the same thing. However, it is still not clear how certain loop systems are able to sustain prolonged growth to heights of approximately 400000 km (>0.5 solar-radii). In this presentation we further explore the energy deposition rate above post-flare loop systems through high-energy RHESSI observations. We also explore the difference between the loop systems through a multi-wavelength epoch analysis.

Author(s): Matthew West[4], Daniel B. Seaton[1], Brian R. Dennis[2], Li feng[3]
Institution(s): *1. Cooperative Institute for Research in Environmental Sciences, 2. NASA GSFC, 3. Purple Mountain Observatory, 4. Royal Observatory Belgium*

P2.02 – Effects of transport coefficients on excitation of flare-induced standing slow-mode waves

The flare-excited longitudinal intensity oscillations in hot flaring loops have been recently detected by SDO/AIA, and interpreted as the slow-mode standing waves. By means of the seismology technique we have, for the first time, determined the transport coefficients in the hot (>9 MK) flare plasma, and found that thermal conductivity is suppressed by at least 3 times and viscosity coefficient is enhanced by a factor of 15 as the upper limit (Wang et al. 2015, ApJL, 811, L13). In this presentation, we first discuss possible causes for conduction suppression and viscosity enhancements. Then we use the nonlinear MHD simulations to validate the seismology method that is based on linear analytical analysis, and demonstrate the inversion scheme for determining transport coefficients using numerical parametric study. Finally, we show how the seismologically-determined transport coefficients are crucial for understanding the excitation of the observed standing slow-mode waves in coronal loops and the heating of the loop plasma by a footpoint flare.

Author(s): Tongjiang Wang[1], Leon Ofman[1], Joseph Davila[2]
Institution(s): *1. Catholic Univ of America / NASA GSFC, 2. NASA GSFC*

P2.03 – Relationship Between High-Energy X-ray Sources and Helioseismic Impact of X-Class Flare

The X-class solar flare of October 23, 2012, generated the strongest sunquake event of the current solar cycle. We study properties of the energy release with high temporal and spatial resolutions, using photospheric data from the Helioseismic Magnetic Imager (HMI) onboard Solar Dynamics Observatory (SDO), and hard X-ray observations made by the Ramaty High-Energy Solar Spectroscopic Imager (RHESSI). To investigate the photospheric impact with high temporal resolution we developed a special procedure for analysis of level-1 HMI data (filtergrams), obtained by scanning the Fe I line (6731 A) with the time cadence of 3.6 s and spatial resolution of 0.5 arcsec per pixel. The helioseismic holography technique was used to reconstruct the helioseismic impact. It is found that the photospheric disturbances caused by the flare spatially coincide with the region of hard X-ray emission, but are delayed by 4 seconds. This delay is consistent with predictions of the flare hydrodynamics RADYN models. However, the models fail to explain the magnitude of variations observed by the HMI. The data indicate that the photospheric impact and helioseismic wave might be caused by the electron energy flux substantially higher than that in the current flare radiative hydrodynamic models.

Author(s): Alexander G. Kosovichev[2], Ivan N. Sharykin[3], Viacheslav M Sadykov[2], Ivan V. Zimovets[3], Ivan I. Myshyakov[1]
Institution(s): *1. Institute of Solar-Terrestrial Research, 2. New Jersey Institute of Technology, 3. Space Research Institute*

P3 – Tuesday E-Posters Screen 3

P3.01 – Spectral Analysis Flare ribbons by NST and IRIS

As one of the most powerful phenomena of solar activities, flares have long been observed and studied extensively. Taking advantages of observing capabilities of modern solar telescopes and focal-plane instruments such as the Interface Region Imaging Spectrograph (IRIS) and the 1.6 m New Solar Telescope (NST) at Big Bear Solar observatory (BBSO), we are able to obtain high resolution imaging spectroscopic data in UV, visible and near-infrared (NIR) wavelengths. Here we present the spectral analysis of an M6.5 flare (SOL2015-06-22T18:23) which was well covered by the joint observation of IRIS and NST. In the visible wavelengths H-alpha and TiO, we can separate the flare ribbon into a very narrow leading front and faint trailing component, of which the former is characterized by the intense emission and significant Doppler signals. In the IRIS UV spectra, the ribbon front shows distinct properties, such as the line broadening, Doppler shifts and central reversal pattern, which are consistent with the visible observations. These characteristics suggest that the ribbon front to be the p

Author(s): Nengyi Huang[1], Yan Xu[1], Haimin Wang[1], Ju Jing[1]
Institution(s): *1. New Jersey Institute of Tech*

108.01 – After the Fall: The RHESSI Legacy Archive

Launched in 2002 the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) continues to observe the Sun with a nearly 50% duty cycle. During that time the instrument has recorded ~100,000 solar flares in energies from 4 keV to over 10 MeV.with durations of 10s to 1000s of seconds. However, for the reasons of the decline of the solar cycle, possible failure of the instrument, or the absence of funding, our operational phase will end someday. We describe here our plans to continue to serve this dataset in raw, processed, and analyzed forms to the worldwide solar community to continue our legacy of a stream of rich scientific results.

We have and are providing a stream of quicklook lightcurves, spectra, and images that we mainly serve through a web interface as well as the data in raw form to be fully analyzed within our own branch of Solar Software written in IDL. We are in the process of creating higher quality images for flares in multiple energy bands on relevant timescales for those whose needs can be met without further processing. For users with IDL licenses we expect this software to be available far into the unknowable future. Together with a database of AIA cutouts during all SDO-era flares, along with software to recover saturated images by using the AIA diffraction fringes, these will be a highly used resource.

We also are developing additional tools and databases that will increase the utility of RHESSI data to members of the community with and without either IDL licenses or full access to the RHESSI database. We will provide a database of RHESSI x-ray visibilities obtained during flares at a >4 second cadence over a broad range of detectable energies. With our IDL software those can be rendered as images for times and energies of nearly the analysts's choosing. And going beyond that we are converting our imaging procedures to the Python language to eliminate the need for an IDL license. We are also developing methods to allow the customization of these visibilities in time and energy by access from a non-local server which has full access to all of the IDL software and database files.

Author(s): Richard A. Schwartz[1], Dominic M. Zarro[1], Anne K. Tolbert[1]
Institution(s): *1. NASA's GSFC*

P3.03 – Data-driven Simulations of Magnetic Connectivity in Behind-the-Limb Gamma-ray Flares and Associated Coronal Mass Ejections

Recent Fermi detection of high-energy gamma-ray emission from the behind-the-limb (BTL) solar flares pose a puzzle on the particle acceleration and transport mechanisms in such events. Due to the large separation between the flare site and the location of gamma-ray emission, it is believed that the associated coronal mass ejections (CMEs) play an important role in accelerating and subsequently transporting particles back to the Sun to produce obseved gamma-rays. We explore this scenario by simulating the CME associated with a well-observed flare on 2014 September 1 about 40 degrees behind the east solar limb and by comparing the simulation and observational results. We utilize a data-driven global magnetohydrodynamics model (AWSoM: Alfven-wave Solar Model) to track the dynamical evolution of the global magnetic field during the event and investigate the magnetic connectivity between the CME/CME-driven shock and the Fermi emission region. Moreover, we derive the time-varying shock parameters (e.g., compression ratio, Alfven Mach number, and ThetaBN) over the area that is magnetically connected to the visible solar disk where Fermi gamma-ray emission originates. Our simulation shows that the visible solar disk develops connections both to the flare region and to the CME-driven shock during the eruption, which indicate that the CME's interaction with the global solar corona is critical for understanding such Fermi BTL events and gamma-ray flares in general. We discuss the causes and implications of Fermi BTL events, in the framework of a potential shift of paradigm on particle acceleration in solar flares/CMEs.

Author(s): Meng Jin[1], Vahe Petrosian[2], Wei Liu[1], Nicola Omodei[2]
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P4 – Tuesday E-Posters Screen 4

P4.01 – Fast-mode Coronal EUV Wave Trains Associated with Solar Flares and CMEs

As a new observational phenomenon, Quasi-periodic, Fast Propagating EUV wave trains (QFPs) are fast-mode magnetosonic waves closely related to quasi-periodic pulsations commonly detected in solar flares (traditionally with non-imaging observations). They can provide critical clues to flare energy release and serve as new tools for coronal seismology. We report recent advances in observing and modeling QFPs, including evidence of heating and cooling cycles revealed with differential emission measure (DEM) analysis that are consistent with alternating compression and rarefaction expected for magnetosonic waves. Through a statistical survey, we found a preferential association of QFPs with eruptive flares (with CMEs) rather than confined flares (without CMEs). We also identified some correlation with quasi-periodic radio bursts observed at JVLA and Ondrejov observatories. We will discuss the implications of these results and the potential roles of QFPs in coronal heating and energy transport.

Author(s): Wei Liu[2], Leon Ofman[3], Cooper Downs[5], Marian Karlicky[1], Bin Chen[4]
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105.02 – Realistic Modeling of Interaction of Quiet-Sun Magnetic Fields with the Chromosphere

High-resolution observations and 3D MHD simulations reveal intense interaction between the convection zone dynamics and the solar atmosphere on subarcsecond scales. To investigate processes of the dynamical coupling and energy exchange between the subsurface layers and the chromosphere we perform 3D radiative MHD modeling for a computational domain that includes the upper convection zone and the chromosphere, and investigate the structure and dynamics for different intensity of the photospheric magnetic flux. For comparison with observations, the simulation models have been used to calculate synthetic Stokes profiles of various spectral lines. The results show intense energy exchange through small-scale magnetized vortex tubes rooted below the photosphere, which provide extra heating of the chromosphere, initiate shock waves, and small-scale eruptions.

Author(s): Irina Kitiashvili[1], Alexander G Kosovichev[2], Nagi N Mansour[1], Alan A. Wray[1]
Institution(s): *1. NASA Ames Research Center, 2. New Jersey Institute of Technology*

105.01 – The Fate of Cool Material in the Hot Corona: Solar Prominences and Coronal Rain

As an important chain of the chromosphere-corona mass cycle, some of the million-degree hot coronal mass undergoes a radiative cooling instability and condenses into material at chromospheric or transition-region temperatures in two distinct forms - prominences and coronal rain (some of which eventually falls back to the chromosphere). A quiescent prominence usually consists of numerous long-lasting, filamentary downflow threads, while coronal rain consists of transient mass blobs falling at comparably higher speeds along well-defined paths. It remains puzzling why such material of similar temperatures exhibit contrasting morphologies and behaviors. We report recent SDO/AIA and IRIS observations that suggest different magnetic environments being responsible for such distinctions. Specifically, in a hybrid prominence-coronal rain complex structure, we found that the prominence material is formed and resides near magnetic null points that favor the radiative cooling process and provide possibly a high plasma-beta environment suitable for the existence of meandering prominence threads. As the cool material descends, it turns into coronal rain tied onto low-lying coronal loops in a likely low-beta environment. Such structures resemble to certain extent the so-called coronal spiders or cloud prominences, but the observations reported here provide critical new insights. We will discuss the broad physical implications of these observations for fundamental questions, such as coronal heating and beyond (e.g., in astrophysical and/or laboratory plasma environments).

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116 – Flares: Forecasting

116.01 – Characteristics of the Polarity Inversion Line and Solar Flare Forecasts

Studying connection between solar flares and properties of magnetic field in active regions is very important for understanding the flare physics and developing space weather forecasts. In this work, we analyze relationship between the flare X-ray peak flux from the GOES satellite, and characteristics of the line-of-sight (LOS) magnetograms obtained by the SDO/HMI instrument during the period of April, 2010 – June, 2016. We try to answer two questions: 1) What characteristics of the LOS magnetic field are most important for the flare initiation and magnitude? 2) Is it possible to construct a reliable forecast of ≥ M1.0 and ≥ X1.0 class flares based only on the LOS magnetic field characteristics? To answer these questions, we apply a Polarity Inversion Line (PIL) detection algorithm, and derive various properties of the PIL and the corresponding Active Regions (AR). The importance of these properties for flare forecasting is determined by their ability to separate flaring cases from non-flaring, and their Fisher ranking score. It is found that the PIL characteristics are of special importance for the forecasts of both ≥ M1.0 and ≥ X1.0 flares, while the global AR characteristics become comparably discriminative only for ≥ X1.0 flares. We use the Support Vector Machine (SVM) classifier and train it on the six characteristics of the most importance for each case. The obtained True Skill Statistics (TSS) values of 0.70 for ≥ M1.0 flares and 0.64 for ≥ X1.0 flares are better than the currently-known expert-based predictions. Therefore, the results confirm the importance of the LOS magnetic field data and, in particular, the PIL region characteristics for flare forecasts.

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116.02 – Forecast of a Major Flare Occurrence Rate within a Day Using SDO/HMI Data

We present the relationship between vector magnetic field parameters and solar major flare occurrence rate. Based on this we are developing the forecast of major flare (M and X-class) occurrence rate within a day using Space-weather HMI Active Region Patch (SHARP) vector magnetic field hourly data from May 2010 to December 2016. In order to reduce the projection effect, we use SHARP data whose longitudes are smaller than 60 degrees. We consider six SHARP magnetic parameters (the total unsigned current helicity, the total photospheric magnetic free energy density, the total unsigned vertical current, the absolute value of the net current helicity, the sum of the net current emanating from each polarity, the total unsigned magnetic flux) with high F-scores as useful predictors of flaring activity from Bobra *et al.* (2015). All magnetic parameters are divided into 100 groups to estimate the corresponding flare occurrence rates. The flare identification is determined by using LMSAL flare locations, giving more numbers of flares than the NGDC flare list. 70% of the data are used for setting up a flare model, and the other for test. Major results are as follows. First, flare occurrence rates (X-class and M & X-class) are well correlated with six magnetic parameters. Second, the occurrence rate ranges from 0.001 to 1 for M and X-class flares. Third, the logarithmic values of flaring rates are well approximated by two linear equations with different slopes: steeper one at lower values. Fourth, the sum of the net current emanating from each polarity gives the minimum RMS error between actual flare rate and predicted one.

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116.03 – Application of Convolution Neural Network to the forecasts of flare classification and occurrence using SOHO MDI data

A Convolutional Neural Network(CNN) is one of the well-known deep-learning methods in image processing and computer vision area. In this study, we apply CNN to two kinds of flare forecasting models: flare classification and occurrence. For this, we consider several pre-trained models (e.g., AlexNet, GoogLeNet, and ResNet) and customize them by changing several options such as the number of layers, activation function, and optimizer. Our inputs are the same number of SOHO)/MDI images for each flare class (None, C, M and X) at 00:00 UT from Jan 1996 to Dec 2010 (total 1600 images). Outputs are the results of daily flare forecasting for flare class and occurrence. We build, train, and test the models on TensorFlow, which is well-known machine learning software library developed by Google. Our major results from this study are as follows. First, most of the models have accuracies more than 0.7. Second, ResNet developed by Microsoft has the best accuracies : 0.86 for flare classification and 0.84 for flare occurrence. Third, the accuracies of these models vary greatly with changing parameters. We discuss several possibilities to improve the models.

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116.04 – Flare Occurrence Prediction based on Convolution Neural Network using SOHO MDI data

In this study we apply Convolution Neural Network(CNN) to solar flare occurrence prediction with various parameter options using the 00:00 UT MDI images from 1996 to 2010 (total 4962 images). We assume that only X, M and C class flares correspond to “flare occurrence” and the others to “non-flare”. We have attempted to look for the best options for the models with two CNN pre-trained models (AlexNet and GoogLeNet), by modifying training images and changing hyper parameters. Our major results from this study are as follows. First, the flare occurrence predictions are relatively good with about 80 % accuracies. Second, both flare prediction models based on AlexNet and GoogLeNet have similar results but AlexNet is faster than GoogLeNet. Third, modifying the training images to reduce the projection effect is not effective.

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117 – Instrumentation: Photosphere

117.01D – Point-Spread Functions for the Near Ultraviolet Channel of the *Interface Region Imaging Spectrograph (IRIS)*

We present point-spread functions (PSFs) for the near ultraviolet (NUV) spectrograph channel of the *Interface Region Imaging Spectrograph (IRIS)*. The hard edge terminus of the 2016 Mercury transit of the Sun is used to measure the PSFs near instrument center field of view using an iterative semi-blind deconvolution method. The resulting PSFs exhibit an asymmetrical core with broader wings when compared to the theoretical diffraction limited PSFs. Deconvolution of our PSFs from the original Level 2 images produces images with improved stray light characteristics and increased contrast.

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117.02 – The Cryogenic Near Infrared Spectropolarimeter for the Daniel K. Inouye Solar Telescope

The Cryogenic Near Infrared Spectropolarimeter is one of the first light instruments for the Daniel K. Inouye Solar Telescope. This dual-beam instrument, which is currently characterized at the University of Hawaii’s Institute for Astronomy, is designed to sensitively measure the solar spectrum at wavelengths from 1 to 5 µm. The high dynamic range of the spectrograph and its context imager will provide sensitive data of the solar disk in the CO bands; unique observations of the low corona and unprecedented measurements of the coronal magnetic field. Observations near the limb and in the corona will greatly benefit from DKIST’s limb occulting system. The initial suite of filters includes selecting filters for the spectrograph at He I / Fe XIII 1080 nm, Si X 1430 nm, Si IX 3934 nm and CO 4651 nm as well as narrow band filters for the context imager at Fe XIII 1074.7 nm, He I 1083.0, Si X 1430.0 nm and J band 1250 nm. In this paper we will present an update on the ongoing instrument characterization and CryoNIRSP’s capabilities.

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117.03 – Critical Infrared Science with the Daniel K. Inouye Solar Telescope

Critical science planning for early operations of the Daniel K. Inouye Solar Telescope is underway. With its large aperture, all-reflective telescope design, and advanced instrumentation, DKIST provides unprecedented access to the important infrared (IR) solar spectrum between 1 and 5 microns. Breakthrough IR capabilities in coronal polarimetry will sense the coronal magnetic field routinely for the first time. The increased Zeeman resolution near the photospheric opacity minimum will provide our deepest and most sensitive measurement of quiet sun and active region magnetic fields to date. High-sensitivity He I triplet polarimetry will dynamically probe the chromospheric magnetic field in fibrils, spicules, and filaments, while observations of molecular CO transitions will characterize the coolest regions of the solar atmosphere. When combined with the longer timescales of good atmospheric seeing compared with the visible, DKIST infrared diagnostics are expected to be mainstays of solar physics in the DKIST era. This paper will summarize the critical science areas addressed by DKIST infrared instrumentation and invite the community to further contribute to critical infrared science planning.

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117.04 – An Update on the Diffraction-Limited Near Infrared Spectropolarimeter for the Daniel K. Inouye Solar Telescope

DL-NIRSP is an integral field imaging spectropolarimeter for photospheric, chromospheric, and coronal magnetic field studies which is currently under development by the University of Hawaii's Institute for Astronomy as part of the first light instrument suite for DKIST. DL-NIRSP pairs a multi-slit fiber-optic image slicer with narrow bandpass isolation filters and large format detectors to achieve very high cadence observations in three simultaneous wavelength channels in the Visible-IR. Planned diagnostics at first light include Fe XI 789.2 nm, Ca II 854.2 nm, Fe XIII 1074.7 nm, Si I/He I 1083.0 nm, Si X 1430.0 nm, and Fe I 1565.0 nm. More spectral lines will be added in the future. As the last stop in the DKIST light distribution system, DL-NIRSP will receive an AO corrected beam and will be able to operate simultaneously with the other visible light instruments. We provide an update on the current challenges and rewards yet to come with DL-NIRSP.

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200 – Flares: Statistics

200.01 – Magnetic Properties of Solar Active Regions that Govern Large Solar Flares and Eruptions

Strong flares and CMEs are often produced from active regions (ARs). In order to better understand the magnetic properties and evolutions of such ARs, we conducted statistical investigations on the SDO/HMI and AIA data of all flare events with GOES levels >M5.0 within 45 deg from the disk center for 6 years from May 2010 (from the beginning to the declining phase of solar cycle 24). Out of the total of 51 flares from 29 ARs, more than 80% have delta-sunspots and about 15% violate Hale's polarity rule. We obtained several key findings including (1) the flare duration is linearly proportional to the separation of the flare ribbons (i.e., scale of reconnecting magnetic fields) and (2) CME-eruptive events have smaller sunspot areas. Depending on the magnetic properties, flaring ARs can be categorized into several groups, such as spot-spot, in which a highly-sheared polarity inversion line is formed between two large sunspots, and spot-satellite, where a newly-emerging flux next to a mature sunspot triggers a compact flare event. These results point to the possibility that magnetic structures of the ARs determine the characteristics of flares and CMEs. In the presentation, we will also show new results from the systematic flux emergence simulations of delta-sunspot formation and discuss the evolution processes of flaring ARs.

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200.02 – Global Energetics in Solar Flares and Coronal Mass Ejections

We present a statistical study of the energetics of coronal mass ejections (CME) and compare it with the magnetic, thermal, and nonthermal energy dissipated in flares. The physical parameters of CME speeds, mass, and kinetic energies are determined with two different independent methods, i.e., the traditional white-light scattering method using LASCO/SOHO data, and the EUV dimming method using AIA/SDO data. We analyze all 860 GOES M- and X-class flare events observed during the first 7 years (2010-2016) of the SDO mission. The new ingredients of our CME modeling includes: (1) CME geometry in terms of a self-similar adiabatic expansion, (2) DEM analysis of CME mass over entire coronal temperature range, (3) deceleration of CME due to gravity force which controls the kinetic and potentail CME energy as a function of time, (4) the critical speed that controls eruptive and confined CMEs, (5) the relationship between the center-of-mass motion during EUV dimming and the leading edge motion observed in white-light coronagraphs. Novel results are: (1) Physical parameters obtained from both the EUV dimming and white-light method can be reconciled; (2) the equi-partition of CME kinetic and thermal flare energy; (3) the Rosner-Tucker-Vaiana scaling law. We find that the two methods in EUV and white-light wavelengths are highly complementary and yield more complete models than each method alone.

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200.03 – The Dependence of Solar Flare Limb Darkening on Emission Peak Formation Temperature

Solar limb effects are local brightening or darkening of an emission that depend on where in the Sun's atmosphere it forms. Near the solar limb, optically thick (thin) emissions will darken (brighten) as the column of absorbers (emitters) along the line-of-sight increases. Note that in limb brightening, emission sources are re-arranged whereas in limb darkening they are obscured. Thus, only limb darkening is expected to occur in disk integrated observations. Limb darkening also results in center-to-limb variations of disk-integrated solar flare spectra, with important consequences for how planetary atmospheres are affected by flares. Flares are typically characterized by their flux in the optically thin 0.1-0.8 nm band measured by the X-ray Sensor (XRS) on board the Geostationary Operational Environmental Satellite (GOES). On the other hand, Extreme Ultraviolet (EUV) line emissions can limb darken because they are sensitive to resonant scattering, resulting in a flare's location on the solar disk controlling the amount of ionizing radiation that reaches a planet. For example, an X-class flare originating from disk center may significantly heat a planet's thermosphere, whereas the same flare originating near the limb may have no effect because much of the effective emissions are scattered in the solar corona.
To advance the relatively poor understanding of flare limb darkening, we use over 300 M-class or larger flares observed by the EUV Variability Experiment (EVE) onboard the Solar Dynamics Observatory (SDO) to characterize limb darkening as a function of emission peak formation temperature, T_f. For hot coronal emissions (T_f>2 MK), these results show a linear relationship between the degree of limb darkening and T_f; where lines with T_f=2 MK darken approximately 7 times more than lines with T_f=16 MK. Because the extent of limb darkening is dependent on the height of the source plasma, we use simple Beer-Lambert radiative transfer analysis to interpret these results and characterize the average thermal structure of the flares considered. As such, these results can be used to constrain both empirical flare irradiance models and more sophisticated flare loop hydrodynamic models.

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200.04 – Investigation of Energy Release from X-ray Flares on Young Stellar Objects with *NuSTAR*

Young stellar objects (YSOs), which tend to flare more frequently and at higher temperatures than what is typically observed on Sun-like stars, are excellent targets for studying the nature of energy release and transport in large flaring events. Multiple star-forming regions have been observed in the past by soft x-ray missions such as *Chandra* and *XMM-Newton*, but the energy ranges of these missions fall off prior to the hard x-ray regime, where it would be possible to search for a crossover from thermal to nonthermal emission. To investigate this hard x-ray emission, three 50ks observations of the star-forming region rho Ophiuchi have been taken with the *Nuclear Spectroscopic Telescope Array* (*NuSTAR*), which is optimized over the energy range of 3-79 keV. Multiple stellar flares have been identified in the observations; here we present the current spectral and timing analyses of the brightest of the these events, exploring the way energy is released as well as the effects of these large flares on the surrounding environment. We compare these results to what is typically observed for solar flares.

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200.05 – Large Scale Coordination of Small Scale Structures

Transient brightenings are ubiquitous features of the solar atmosphere across many length and energy scales, the most energetic of which manifest as large-class solar flares. Often, transient brightenings originate in regions of strong magnetic activity and create strong observable enhancements across wavelengths from X-ray to radio, with notable dynamics on timescales of seconds to hours.

The coronal aspects of these brightenings have often been studied by way of EUV and X-ray imaging and spectra. These events are likely driven by photospheric activity (such as flux emergence) with the coronal brightenings originating largely from chromospheric ablation (evaporation). Until recently, chromospheric and transition region observations of these events have been limited. However, new observational capabilities have become available which significantly enhance our ability to understand the bi-directional flow of energy through the chromosphere between the photosphere and the corona.

We have recently obtained a unique data set with which to study this flow of energy through the chromosphere via the Interface Region Imaging Spectrograph (IRIS), Hinode EUV Imaging Spectrometer (EIS), Hinode X-Ray Telescope (XRT), Hinode Solar Optical Telescope (SOT), Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA), SDO Helioseismic and Magnetic Imager (HMI), Nuclear Spectroscopic Telescope Array (NuStar), Atacama Large Millimeter Array (ALMA), and Interferometric BIdimensional Spectropolarimeter (IBIS) at the Dunn Solar

Telescope (DST). This data set targets a small active area near disk center which was tracked simultaneously for approximately four hours. Within this region, many transient brightenings detected through multiple layers of the solar atmosphere. In this study, we combine the imaging data and use the spectra from EIS and IRIS to track flows from the photosphere (HMI, SOT) through the chromosphere and transition region (AIA, IBIS, IRIS, ALMA) into the corona (EIS, XRT, AIA).

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200.06 – Onset of the Magnetic Explosion in Solar Polar Coronal X-Ray Jets

We examine the onset of the driving magnetic explosion in 15 random polar coronal X-ray jets. Each eruption is observed in a coronal X-ray movie from *Hinode* and in a coronal EUV movie from *Solar Dynamics Observatory*. Contrary to the Sterling et al (2015, Nature, 523, 437) scenario for minifilament eruptions that drive polar coronal jets, these observations indicate: (1) in most polar coronal jets (a) the runaway internal tether-cutting reconnection under the erupting minifilament flux rope starts after the spire-producing breakout reconnection starts, not before it, and (b) aleady at eruption onset, there is a current sheet between the explosive closed magnetic field and ambient open field; and (2) the minifilament-eruption magnetic explosion often starts with the breakout reconnection of the outside of the magnetic arcade that carries the minifilament in its core. On the other hand, the diversity of the observed sequences of occurrence of events in the jet eruptions gives further credence to the Sterlling et al (2015, Nature, 523, 437) idea that the magnetic explosions that make a polar X-ray jet work the same way as the much larger magnetic explosions that make and flare and CME. We point out that this idea, and recent observations indicating that magnetic flux cancelation is the fundamental process that builds the field in and around pre-jet minifilaments and triggers the jet-driving magnetic explosion, together imply that usually flux cancelation inside the arcade that explodes in a flare/CME eruption is the fundamental process that builds the explosive field and triggers the explosion.

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201 – Corona: Flares, CMEs, Prominences

201.01 – NuSTAR's X-ray observations of a microflaring active region

We present observations of a weakly microflaring active region observed in X-rays with NuSTAR, UV with IRIS and EUV with SDO/AIA. NuSTAR was pointed at this unnamed active region near the East limb between 23:27UT and 23:37UT 26-July-2016, finding mostly quiescent emission except for a small microflare about 23:35UT. The NuSTAR spectrum for the pre-microflare time (23:27UT to 23:34UT) is well fitted by a single thermal of about 3MK and combined with SDO/AIA we can determine the differential emission measure (DEM), finding it, as expected, drops very sharply to higher temperatures. During the subsequent microflare, the increase in NuSTAR counts matches a little brightening loop observed with IRIS SJI 1400Å and SDO/AIA 94Å/Fe XVIII. Fortuitously the IRIS slit was on this microflaring loop and we find that the IRIS spectrum shows increased emission in Si IV 1394Å, O IV 1402Å and Si IV 1403Å but only average line widths and velocities. The NuSTAR microflare spectrum shows heating to higher temperatures and also allows us to investigate the energetics of this event.

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201.02 – Three-dimensional characteristics of solar coronal shocks determined from observations; Geometry, Kinematics, and Compression ratio

We investigate the three-dimensional (3D) characteristics of coronal shocks associated with Coronal Mass Ejections (CMEs), in terms of geometry, kinematics, and density compression ratio, employing a new method we have developed. The method uses multi-viewpoint observations from the *STEREO-A, -B* and *SOHO* coronagraphs. The 3D structure and kinematics of coronal shock waves and the driving CMEs are derived separately using a forward modeling method. We analyze two CMEs that are observed as halos by the three spacecraft, and the peak speeds are over 2000 km s^{-1}. From the 3D modeling, we find (1) the coronal shock waves are spherical apparently enclosing the Sun, in which the angular widths are much wider than those of CMEs (92° and 252° versus 58° and 91°), indicating shock waves are propagating away from the CMEs in the azimuthal directions, and (2) the speeds of the shock waves around the CME noses are comparable to those of the CME noses, but the speeds at the lateral flanks seem to be limited to the local fast magnetosonic speed. Applying our new method, we determine electron densities in the shock sheaths, the downstream-upstream density ratios, and the Mach numbers. We find (1) the sheath electron densities decrease with height in general but have the maximum near the CME noses, (2) the density ratios and Mach numbers also seem to depend on the position angle from the CME nose to the far-flank but are more or less constant in time, while the sheath electron densities and speeds decrease with time, because of the reduced local Alfven speed with height, and (3) the shocks could be supercritical in a wider spatial range, and it lasts longer, than those of what have been reported in the past. We conclude that the shock wave associated with an energetic CME is a phenomenon that is becoming a non-driven (blast-type), nearly freely propagating wave at the flank from a driven (bow- and/or piston-type) wave near the CME nose.

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201.03 – Prominence Bubble Shear Flows and the Coupled Kelvin-Helmholtz — Rayleigh-Taylor Instability

Prominence bubbles are large arched structures that rise from below into quiescent prominences, often growing to heights on the order of 10 Mm before going unstable and generating plume upflows. While there is general agreement that emerging flux below pre-existing prominences causes the structures, there is lack of agreement on the nature of the bubbles and the cause of the instability flows. One hypothesis is that the bubbles contain coronal temperature plasma and rise into the prominence above due to both magnetic and thermal buoyancy, eventually breaking down via a magnetic Rayleigh-Taylor (RT) instability to release hot plasma and magnetic flux and helicity into the overlying coronal flux rope. Another posits that the bubbles are actually just “arcades” in the prominence indicating a magnetic separator line between the bipole and the prominence fields with the observed upflows and downflows caused by reconnection along the separator. We analyze Hinode/SOT, SDO/AIA, and IRIS observations of prominence bubbles, focusing on characteristics of the bubble boundary layers that may discriminate between the two hypotheses. We find speeds on the order of 10 km/s in prominence plasma downflows and lateral shear flows along the bubble boundary. Inflows to the boundary gradually increase the thickness and brightness of the layer until plasma drains from there, apparently around the dome-like bubble domain. In one case, shear flow across the bubble boundary develops Kelvin-Helmholtz (KH) vortices that we use to infer flow speeds in the low-density bubble on the order of 100 km/sec. IRIS spectra indicate that plasma flows on the bubble boundary at transition region temperatures achieve Doppler speeds on the order of 50 km/s, consistent with this inference. Combined magnetic KH–RT instability analysis leads to flux density estimates of 10 G with a field angle of 30° to the prominence, consistent with vector magnetic field measurements. In contrast, we find no evidence of the impulsive brightening or bi-directional jets that are expected from reconnection driven flows at bubble boundaries. We conclude that observations to date are consistent with the hot bubble/Rayleigh-Taylor instability hypothesis.

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201.04 – Prominence and tornado dynamics observed with IRIS and THEMIS

Several prominences were observed during campaigns in September 2013 and July 2014 with the IRIS spectrometer and the vector magnetograph THEMIS (Tenerife). SDO/AIA and IRIS provided images and spectra of prominences and tornadoes corresponding to different physical conditions of the transition region between the cool plasma and the corona. The vector magnetic field was derived from THEMIS observations by using the He D3 depolarisation due to the magnetic field. The inversion code (PCA) takes into account the Hanle and Zeeman effects and allows us to compute the strength and the inclination of the magnetic field which is shown to be mostly horizontal in prominences as well as in tornadoes. Movies from SDO/AIA in 304 A and Hinode/SOT in Ca II show the highly dynamic nature of the fine structures. From spectra in Mg II and Si IV lines provided by IRIS and H-alpha observed by the Multi-channel Subtractive Double Pass (MSDP) spectrograph in the Meudon Solar Tower we derived the Doppler shifts of the fine structures and reconstructed the 3D structure of tornadoes. We conclude that the apparent rotation of AIA tornadoes is due to large-scale quasi-periodic oscillations of the plasma along more or less horizontal magnetic structures.

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202 – 2017 SPD George Ellery Hale Prize Talk: The Solar Magnetic Field: From Complexity to Simplicity (and back), Manfred Schüssler

202.01 – The solar magnetic field: from complexity to simplicity (and back)

Observations reveal a stunning complexity of the magnetic field due to its interaction with turbulent convection. Numerical simulations and observations strongly suggest that most of the small-scale field is generated by small-scale dynamo action. The fundamental nature of this process makes it potentially relevant in a broad variety of astrophysical settings.

On the other hand, the global nature of the 11-year cycle reveals a surprising simplicity. This suggests a description of

the global dynamo process in terms of relatively simple concepts. During the last decades, studies of magnetic flux transport at the solar surface provided crucial information about the workings of the dynamo process. They confirm the visionary approach proposed Babcock and Leighton. A recent update of their model permits a full study of the space spanned by the few remaining parameters in order to identify the regions with solar-like solutions. Observations of other cool stars suggest that the relatively slow rotation of the Sun puts it near to the threshold for which global dynamo action ceases. This suggests a further simplification of the dynamo model in terms of a generic normal form for a weakly nonlinear system. Including the inherent randomness brought about by the flux emergence process leads to a stochastic model whose parameters are fixed by observations. The model results explain the variability of the solar cycle amplitudes from decadal to millennial time scales.
However, the true complexity of the processes cannot be ignored. Simulations indicate that the connection between the toroidal field in the convection zone and the magnetic flux emerging at the surface is highly complex and non-trivial. This is an important "loose end" of Babcock-Leighton-type dynamo models. Furthermore, internal differential rotation, convective flows, meridional flows, and tilt angles are largely unknown in stars other the Sun and presently cannot be reliably inferred from theoretical models or simulations. Consequently, models for the solar dynamo cannot be easily extended to stars with different rotation rate, structure, or evolutionary state.

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203 – Corona: Eruptions

203.01 – MHD simulations of the eruption of prominence hosting coronal flux ropes

We present MHD simulations of the eruption of a prominence hosting coronal flux rope under a coronal streamer, with the thermodynamic treatment including a simple empirical coronal heating, optically thin radiative cooling and the field aligned thermal conduction. We first initialize a quasi-steady solar wind solution with a coronal helmet streamer, using an initial normal flux distribution of a simple bipolar arcade field on the lower boundary. Then into this coronal streamer with an ambient solar wind we impose at the lower boundary the slow emergence of a twisted magnetic torus. As a result a quasi-equilibrium flux rope is built up under the streamer magnetic field. With varying sizes of the streamer and the different length and total twist of the emerged flux rope, we found different scenarios for the evolution from quasi-equilibrium to loss of confinement and eruption. In the case with a broad streamer with slow decline of the overlying field, the flux rope remains well confined until there is sufficient twist such that it first develops the kink instability and evolves through a sequence of kinked, confined states with its apex rises slowly. It eventually develops a “hernia-like” eruption when the kinked apex reaches a certain height and can no-longer be confined. We find that for the long, significantly twisted flux ropes, prominence condensations form in the dips of the twisted field lines due to run-away radiative cooling. Once formed, the prominence carrying field becomes significantly non force-free due to the prominence weight despite being low plasma β. As the flux rope erupts, we also obtain the eruption of the prominence, which shows substantial draining along the legs of the erupting flux rope during the eruption. The prominence may not show a kinked morphology even the flux rope becomes kinked. On the other hand in the case with a narrower streamer, the flux rope with less than 1 wind of twist can erupt via the onset of the torus instability.

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203.02 – A Universal Model for Solar Eruptions

We present a universal model for solar eruptions that encompasses coronal mass ejections (CMEs) at one end of the scale, to coronal jets at the other. The model is a natural extension of the Magnetic Breakout model for large-scale fast CMEs. Using high-resolution adaptive mesh MHD simulations conducted with the ARMS code, we show that so-called blowout or mini-filament coronal jets can be explained as one realisation of the breakout process. We also demonstrate the robustness of this “breakout-jet” model by studying three realisations in simulations with different ambient field inclinations. We conclude that magnetic breakout supports both large-scale fast CMEs and small-scale coronal jets, and by inference eruptions at scales in between. Thus, magnetic breakout provides a unified model for solar eruptions. P.F.W was supported in this work by an award of a RAS Fellowship and an appointment to the NASA Postdoctoral Program. C.R.D and S.K.A were supported by NASA’s LWS TR&T and H-SR programs.

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203.03 – Evidence for the Magnetic Breakout Model in an Equatorial Coronal-Hole Jet

We have analyzed an equatorial coronal-hole jet observed by SDO/AIA on 09 January 2014. The source-region magnetic field structure is consistent with the embedded-bipole topology that we identified and modeled previously as a source of coronal jets (Pariat et al. 2009, 2010, 2015, 2016; Karpen et al. 2017; Wyper et al. 2016). Initial brightenings were observed below a small but distinct “mini-filament” about 25 min before jet onset. A bright circular structure, interpreted as magnetic flux rope (MFR), surrounded the mini-filament. The MFR and filament rose together slowly at first, with a speed of ~15 km s^{-1}. When bright footpoints and loops appeared below, analogous to flare ribbons and arcade, the MFR/mini-filament rose rapidly (~126 km s^{-1}), and a bright elongated feature interpreted as a current sheet appeared between the MFR and the growing arcade. Multiple plasmoids propagating upward (~135 km s^{-1}) and downward (~55 km s^{-1}) were detected in this sheet. The jet was triggered when the rising MFR interacted with the overlying magnetic structure, most likely at a stressed magnetic null distorted into a current sheet. This event thus exhibits clear evidence of "flare" reconnection below the MFR as well as breakout reconnection above it, consistent with the breakout model for a wide range of solar eruptions (Antiochos et al. 1999; Devore & Antiochos 2008; Karpen et al. 2012; Wyper et al. 2017). Breakout reconnection destroyed the MFR and enabled the entrained coronal plasma and mini-filament to escape onto open field lines, producing an untwisting jet. SDO/HMI magnetograms reveal small footpoint motions at the eruption site and its surroundings, but do not show significant flux emergence or cancellation during or 1-2 hours before the eruption. Therefore, the free energy powering this jet most likely originated in magnetic shear concentrated at the polarity inversion line within the embedded bipole – a mini-filament channel – possibly created by helicity condensation (Antiochos 2013; Knizhnik et al. 2015, 2017).

This work was supported in part by a grant from the NASA H-SR program and the NASA Postdoctoral Program.
Author(s): Judith T. Karpen[2], Pankaj Kumar[2], Spiro K. Antiochos[2], Peter Wyper[1], C. Richard DeVore[2]
Institution(s): *1. Durham University, 2. NASA Goddard Space Flight Center*

204 – Chromosphere: ALMA etc.

204.01 – UV and X-ray Evolution of AR12230 as Observed with IRIS and FOXSI-II

We present a multi-spectral and spatio-temporal analysis of AR12230 using both UV and X-ray spectroscopic imaging obtained as part of a coordinated observing campaign on 11 December 2014. The campaign involved IRIS (Interface Region Imaging Spectrometer) -- which provides both UV imaging and slit spectrograph observations of optically thick chromospheric and transition region emission -- and FOXSI-II (Focusing Optics X-ray Solar Imager) -- the second in a series of sounding rocket flights which combines grazing incidence direct focusing optics to produce solar X-ray spectroscopic imaging in the range 4-15keV. The active region exhibits a prolonged compact brightening in the IRIS 1330 A and 1400 A slit-jaw channels near the center of the active region throughout the duration of the observations. In the early phase of the observations FOXSI-II shows an X-ray source approximately 20x20 arcsec centered at the same location. The X-ray spectra show the presence of hot (~8 MK) thermal plasma and is suggestive of the presence of non-thermal electrons.. Later, two additional transient, spatially extended, simultaneous brightenings are observed, one of which was captured by the IRIS slit spectrograph. We combine these observations to explore the evolution and topology of the active region. Hydrodynamic modeling of the chromosphere is used to place a limit on the amount of non-thermal electrons required to produce the observed UV emission. This result is then compared to the limit inferred from the FOXSI-II X-ray spectra. Thus, we explore the role of non-thermal electrons and hydrodynamics in the energization and evolution of plasma in active regions.
Author(s): Daniel Ryan[1], Steven Christe[1], Lindsay Glesener[3], Julie Vievering[3], Sam Krucker[2], Shin-Nosuke Ishikawa[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. University of California, Berkeley, 3. University of Minnesota*

204.02 – Solar Commissioning Observations of the Sun with ALMA

PI-led science observations have commenced with the Atacama Large Millimeter-submillimeter Array (ALMA) following an extensive commissioning effort. This talk will summarize that effort and discuss some of the scientific results derived from the commissioning data. As the solar cycle declines, ALMA observations will mainly address chromospheric science topics. Examples of data obtained during commissioning, both from the interferometer and from single-dish observations, will be presented. The temperatures of the layers that ALMA is most sensitive to have been determined for the two frequency bands currently used for solar observations. Curious behavior in a sunspot umbra and an observations of a small chromospheric ejection will be discussed.
Author(s): Stephen M. White[1], Masumi Shimojo[7], Timothy S. Bastian[9], Kazumasa Iwai[6], Antonio Hales[2], Roman Brajsa[4], Ivica Skokic[3], Sujin Kim[5], Hugh S. Hudson[10], Maria Loukitcheva[8], Sven Wedemeyer[11]
Institution(s): *1. Air Force Research Laboratory, 2. ALMA JAO, 3. Czech Academy of Sciences, 4. Hvar Observatory, University of Zagreb, 5. KASI, 6. Nagoya University, 7. NAOJ, 8. NJIT, 9. NRAO, 10. SSL/UC Berkeley, 11. University of Oslo*

204.03 – A comparison of solar ALMA maps with solar images obtained at other wavelengths

We use recently released Commissioning and Science Verification data of the Sun from the observing campaigns perfomed with the ALMA radio telescope in December 2014 and in December 2015. The dataset consists of calibrated maps of the Sun recorded in ALMA observing band 3 (corresponding to a wavelength of 3 mm) and band 6 (1.2 mm) which show both bright and dark areas and a background of highly structured pattern. Solar ALMA maps are compared with images in EUV (SDO/AIA), H-alpha (NISP, Cerro Tololo) and He 1083 nm (NSO/SOLIS), as well as

with magnetograms (SDO/HMI) recorded at times closest to the ALMA observations. With a special software the images are overlapped and a correspondence of identified structures is checked in both ways. The visibility of active regions, sunspots, inversion lines of global magnetic field, prominences on the disc, coronal holes and coronal bright points is investigated in ALMA images at mm wavelengths. Single-dish ALMA images of the Sun reveal large-scale structures in the solar atmosphere, while high resolution interferometric images are used to analyse the fine-scale chromospheric structure. The intensities (the brightness temperatures) of identified structures were determined and compared with selected model-based predictions.
Author(s): Roman Brajsa[3], Davor Sudar[3], Ivica Skokic[2], Arnold Benz[4], Matej Kuhar[4], Stephen M. White[1]
Institution(s): *1. Air Force Research Laboratory, 2. Czech Academy of Sciences, 3. Faculty of Geodesy, University of Zagreb, 4. University of Applied Sciences and Arts Northwestern Switzerland*

206 – Corona: CMEs

206.02 – Coronal Mass Ejections and Dimmings: A Comparative Study using MHD Simulations and SDO Observations

Solar coronal dimmings have been observed extensively in the past two decades. Due to their close association with coronal mass ejections (CMEs), there is a critical need to improve our understanding of the physical processes that cause dimmings and determine their relationship with CMEs. In this study, we investigate coronal dimmings by combining simulation and observational efforts. By utilizing a data-driven global magnetohydrodynamics model (AWSoM: Alfven-wave Solar Model), we simulate coronal dimmings resulting from different CME energetics and flux rope configurations. We synthesize the emissions of different EUV spectral bands/lines and compare with SDO/AIA and EVE observations. A detailed analysis of simulation and observation data suggests that the “core” dimming is mainly caused by the mass loss from the CME, while the “remote” dimming could have a different origin (e.g., plasma heating). Moreover, the interaction between the erupting flux rope with different orientations and the global solar corona could significantly influence the coronal dimming patterns. Using metrics such as dimming depth, dimming slope, and recovery time, we investigate the relationship between dimmings and CME properties (e.g., CME mass, CME speed) in the simulation. Our result suggests that coronal dimmings encode important information about CMEs. We also discuss how our knowledge about solar coronal dimmings could be extended to the study of stellar CMEs.
Author(s): Meng Jin[1], Mark Cheung[1], Marc L. DeRosa[1], Nariaki Nitta[1], Karel Schrijver[1]
Institution(s): *1. Lockheed Martin Solar & Astrophysics Lab*

206.03 – Improving Our Understanding of the 3D Coronal Evolution of CME Propagation

An improved understanding of the kinematic properties of CMEs and CME-associated phenomena has several impacts: 1) a less ambiguous method of mapping propagating structures into their inner coronal manifestations, 2) a clearer view of the relationship between the “main” CME and CME-associated brightenings, and 3) an improved identification of the heliospheric sources of shocks, Type II bursts, and SEPs. We present the results of a mapping technique that facilitates the separation of CMEs and CME-associated brightenings (such as shocks) from background corona. The Time Convolution Mapping Method (TCMM) segments coronagraph data to identify the time history of coronal evolution, the advantage being that the spatiotemporal evolution profiles allow users to separate features with different propagation characteristics. For example, separating “main” CME mass from CME-associated brightenings or shocks is a well-known obstacle, which the TCMM aids in differentiating. A TCMM CME map is made by first recording the maximum value each individual pixel in the image reaches during the traversal of the CME. Then the maximum value is convolved with an index to indicate the time that the pixel reached that value. The TCMM user is then able to identify continuous “kinematic profiles,” indicating related kinematic behavior, and also identify breaks in the profiles that indicate a discontinuity in kinematic history (i.e. different structures or different propagation characteristics). The maps obtained from multiple spacecraft viewpoints (i.e., STEREO and SOHO) can then be fit with advanced structural models to obtain the 3D properties of the evolving phenomena.
Author(s): Shea A. Hess Webber[2], Barbara J. Thompson[3], Jack Ireland[1], Ryun Young Kwon[2]
Institution(s): *1. ADNET SYSTEMS INC, 2. GMU, 3. GSFC*

206.04 – Two distinct types of CME-flare relationships based on SOHO and STEREO observations

In this paper, we present two distinct types of CME-flare relationships according to their observing time differences using 107 events from 2010 to 2013. The observing time difference, ΔT, is defined as flare peak time minus CME first appearance time at STEREO COR1 field of view. There are 41 events for group A ($\Delta T<0$) and 66 events for group B ($\Delta T\geq0$). We compare CME 3D parameters (speed and kinetic energy) based on multi-spacecraft data (SOHO and STEREO A&B) and their associated flare properties (peak flux, fluence, and duration). Our main results are as follows. First, there are better relationships between CME and flare parameters for group B than that of group A. Especially, CME 3D kinetic energy for group B is well-correlated with flare fluence with the correlation coefficient of 0.67, which is much stronger than that (cc=0.31) of group A. Second, the events belonging to group A have short flare durations less than 1 hour (mean=21mins), while the events for group B have longer durations up to 4 hours (mean=81mins). Third, the mean value of height at peak speed for group B is 4.05 Rs, which is noticeably higher than that of group A (1.89 Rs). This is well correlated with CME acceleration duration (cc=0.75). A higher height at peak speed and a longer acceleration duration for group B could be explained by that magnetic reconnections for group B continuously occur for a longer time than those for group A.

Author(s): Soojeong Jang[2], Yong-Jae Moon[2], Roksoon Kim[1], Sujin Kim[1], Jae-Ok Lee[1]
Institution(s): *1. KASI, 2. Kyung Hee University*

206.05 – Imaging Spectroscopy of CME-Associated Solar Radio Bursts using OVRO-LWA

Energetic phenomenon on the Sun, such as solar flares and CMEs are a dynamic laboratory to study radio emission. We use Owens Valley Long Wavelength Array (OVRO-LWA) for the study. The new array with its 251 crossed broadband dipoles spread over a 200 m diameter core and 37 long baseline antennas extending to 1600 m baselines allows spatially resolving the Sun in the frequency range 24-82 MHz, with high spectral resolution.

We examine coherent Type III and Type IV burst emission associated with a CME from 2015 Sep 20, as well as quiet Sun images before and after the bursts. Images of 9 s cadence are used to study the event over a 100 minute period, out to a distance of about 2 solar radii, over the frequency range of 40-70 MHz available at that time. In order to understand better the behaviour and structural evolution of the bursts, we image the event at hundreds of frequencies and use the source centroids to obtain the velocity of outward motion. A coalignment with LASCO(C2) and SWAP data allows spatial and temporal comparison with observations of the CME in white light and EUV. We also place the bursts in context of AIA-EUV, Fermi hard X-ray and EOVSA Microwave emission associated with the event.

Author(s): Sherry Chhabra[2], Dale Gary[2], Bin Chen[2], Gregg Hallinan[1], Marin Anderson[1]
Institution(s): *1. California Institute of Technology , 2. New Jersey Institute of Technology*

206.06 – The Formation and Early Evolution of a CME and the Associated Shock on 2014 January 8

We study the formation and early evolution of a limb coronal mass ejection (CME) and its associated shock wave that occurred on 2014 January 8. The extreme ultraviolet (EUV) images provided by AIA on board \textit{Solar Dynamics Observatory} disclose that the CME first appears as a bubble-like structure. Subsequently, its expansion forms the CME and causes a quasi-circular EUV wave. Both the CME and the wave front are clearly visible at all of the AIA EUV passbands. Through a detailed kinematical analysis, it is found that the expansion of the CME undergoes two phases: a first phase with a strong but transient lateral over-expansion followed by a second phase with a self-similar expansion. The temporal evolution of the expansion velocity coincides very well with the variation of the 25--50 keV hard X-ray (HXR) flux of the associated flare, which indicates that magnetic reconnection most likely plays an important role in driving the expansion. Moreover, we find that, when the velocity of the CME reaches $\sim$600 km s^{-1}, the EUV wave starts to evolve into a shock wave, which is evidenced by the appearance of a type II radio burst. Interestingly, we also notice an unusual solar radio signal at $\sim$4 GHz that is similar to the pattern of a type II radio burst but drifts to higher frequencies at a rate of $\sim$0.3 MHz per second during about 7 minutes. Its derived density is $\sim$5$\times$10^{10} cm^{-3} and increases slowly with time. Joint imaging observations of HXR and EUV help to locate the loop-top region and calculate its thermal proprieties, including slowly increasing densities ($\sim$5$\times$10^{10} cm^{-3}) and temperatures ($\sim$14 MK). The similar results obtained from two different ways above imply the possibility of this scenario: plasma blobs that are ejected along the current sheet via magnetic reconnection collide with underlying flare loops that are undergoing chromospheric evaporation. Finally, we also study the thermal properties of the CME and the EUV wave. We find that the plasma in the CME leading front and the wave front has a temperature of $\sim$2 MK, while that in the CME core region and the flare region has a much higher temperature of $\ge$8 MK.

Author(s): Linfeng Wan[1], Xin Cheng[1], Tong Shi[1], Wei Su[1], Mingde Ding[1]
Institution(s): *1. Nanjing University*

206.07 – Flux Accretion and Coronal Mass Ejection Dynamics

Coronal mass ejections (CMEs) are the primary drivers of severe space weather disturbances in the heliosphere. The equations of ideal magnetohydrodynamics (MHD) have been used to model the onset and, in some cases, the subsequent acceleration of ejections. Both observations and numerical modeling, however, suggest that magnetic reconnection likely plays a major role in most, if not all, fast CMEs. Here, we theoretically investigate the dynamical effects of accretion of magnetic flux onto a rising ejection by reconnection involving the ejection's background field. This reconnection alters the magnetic structure of the ejection and its environment, thereby modifying forces acting during the eruption, generically leading to faster acceleration of the CME. Our ultimate aim is to characterize changes in CME acceleration in terms of observable properties of magnetic reconnection, such as the amount of reconnected flux, deduced from observations of flare ribbons and photospheric magnetic fields.

Author(s): Brian Welsch[1]
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207 – Photosphere & Image Processing

207.01D – Assessment of and a Solution to the Intensity Diffusion Error Intrinsic in Short-Characteristic Radiative Transfer

Short characteristic radiative transfer coupled with 3D MHD simulations are routinely used to compare simulations with observations of the solar atmosphere. While it has been known that the method of short characteristics radiative transfer results in intensity diffusion, it has been routinely employed to solve radiative transfer due to its computational expediency. In this talk, we discuss the effect of spatial smearing due to short characteristics radiative transfer under both linear and high-order interpolation. We then demonstrate that linear interpolation results in an effective spatial smearing related to the number of grid heights above the $\tau = 1$ surface and conserves intensity. Additionally, we show that the use of high-order strict monotonic interpolation reduces the amount of smearing, but at the expense of error in the integrated emergent intensity. Finally, we demonstrate that these issues can be easily avoided at no added computational expense by interpolating the atmosphere onto a ray-directed grid and computing the radiative transfer for vertical rays through the grid.

Author(s): Courtney Peck[2], Mark Rast[2], Serena Criscuoli[1]
Institution(s): *1. National Solar Observatory, 2. University of Colorado - Boulder*

207.02 – Addressing Systematic Errors in Correlation Tracking on HMI Magnetograms

Correlation tracking in solar magnetograms is an effective method to measure the differential rotation and meridional flow on the solar surface. However, since the tracking accuracy required to successfully measure meridional flow is very high, small systematic errors have a noticeable impact on measured meridional flow profiles. Additionally, the uncertainties of this kind of measurements have been historically underestimated, leading to controversy regarding flow profiles at high latitudes extracted from measurements which are unreliable near the solar limb.
Here we present a set of systematic errors we have identified (and potential solutions), including bias caused by physical pixel sizes, center-to-limb systematics, and discrepancies between measurements performed using different time intervals. We have developed numerical techniques to get rid of these systematic errors and in the process improve the accuracy of the measurements by an order of magnitude.
We also present a detailed analysis of uncertainties in these measurements using synthetic magnetograms and the quantification of an upper limit below which meridional flow measurements cannot be trusted as a function of latitude.

Author(s): Sushant S Mahajan[1], David H. Hathaway[2], Andres Munoz-Jaramillo[3], Petrus C. Martens[1]
Institution(s): *1. Georgia State University, 2. NASA Ames Research Center, 3. Southwest Research Institute*

207.03 – Photometric Properties of Network and faculae derived by HMI data compensated for scattered-light

We report on the photometric properties of faculae and network as observed in full-disk, scattered-light corrected images from the Helioseismic Magnetic Imager (HMI). We use a Lucy-Richardson deconvolution routine that corrects a full-disk intensity image in less than one second. Faculae are distinguished from network through proximity to active regions in addition to continuum intensity and magnetogram thresholds. This is the first report that full-disk image data, including center-to-limb variations, reproduce the photometric properties of faculae and network observed previously only in sub-arcsecond resolution, small field-of-view studies, i.e. that network exhibit in general higher photometric contrasts. More specifically, for magnetic flux values larger than approximately 300 G, the network is always brighter than faculae and the contrast differences increases toward the limb, where the network contrast is about twice the facular one. For lower magnetic flux values, pixels in network regions appear always darker than facular ones. Contrary to reports from previous full-disk observations, we also found that network exhibits a higher center-to-limb variation. Our results are in agreement with reports from simulations that indicate magnetic flux alone is a poor proxy of the photometric properties of magnetic features. We estimate that the facular and network contribution to irradiance variability of the current Cycle 24 is overestimated by at least 11% due to the photometric properties of network and faculae not being recognized as distinctly different.

Author(s): Serena Criscuoli[1], Aimee Ann Norton[2], Taylor Whitney[1]
Institution(s): *1. National Solar Observatory, 2. Stanford University*

207.04 – The Harm that Underestimation of Uncertainty Does to Our Community: A Case Study Using Sunspot Area Measurements

Data products in heliospheric physics are very often provided without clear estimates of uncertainty. From helioseismology in the solar interior, all the way to in situ solar wind measurements beyond 1AU, uncertainty estimates are typically hard for users to find (buried inside long documents that are separate from the data products), or simply non-existent.

There are two main reasons why uncertainty measurements are hard to find:
1. Understanding instrumental systematic errors is given a much higher priority inside instrumental teams.

2. The desire to perfectly understand all sources of uncertainty postpones indefinitely the actual quantification of uncertainty in our measurements.

Using the cross calibration of 200 years of sunspot area measurements as a case study, in this presentation we will discuss the negative impact that inadequate measurements of uncertainty have on users, through the appearance of toxic and unnecessary controversies, and data providers, through the creation of unrealistic expectations regarding the information that can be extracted from their data. We will discuss how empirical estimates of uncertainty represent a very good alternative to not providing any estimates at all, and finalize by discussing the bare essentials that should become our standard practice for future instruments and surveys.

Author(s): Andres Munoz-Jaramillo[1]
Institution(s): *1. SouthWest Research Institute*

207.05 – Stray Light Correction of HMI Data

The point spread function (PSF) for HMI is an Airy function convolved with a Lorentzian. The parameters are bound by ground-based testing before launch, then post-launch off-limb light curves, lunar eclipse and Venus transit data. The PSF correction is programmed in C and runs within the HMI data processing pipeline environment. A single full-disk intensity image can be processed in less than one second. Deconvolution of the PSF on the Stokes profile data (a linear combination of original filtergrms) is less computationally expensive and is shown to be equivalent to deconvolution applied at the original filtergram level. Results include a decrease in umbral darkness of a few percent (~200 K cooler), a doubling of the granulation contrast in intensity from 3.6 to 7.2%, an increase in plage field strengths by a factor of 1.5, and a partial correction of the convective blueshift in Doppler velocities. Requests for data corrected for stray light are welcome and will be processed by the HMI team.

Author(s): Aimee Ann Norton[3], Thomas Duvall[2], Jesper Schou[2], Mark Cheung[1], Philip H. Scherrer[3]
Institution(s): *1. Lockheed Martin, 2. Max Planck, 3. Stanford University*

207.06 – Probing the Smallest Solar Scales Available in AIA

The solar imaging axiom, "the closer we look, the more we see," is as true now in the era of routine sub-arcsecond imaging as it has ever been. To make the most of these images and observe features at the instrumental limits of spatial and temporal resolution, we must first effectively assess and remove image noise. Noise is present in any measurement due to both instrumental and random effects. At the pixel scale, the noise component of the image can become significant and impede feature recognition and segmentation. A Poisson-Gaussian model of noise is well suited in the digital imaging environment due to the statistical distributions of photons and the characteristics of the CCD. We create a practical estimate of noise in the AIA images across the detector CCD using a variety of statistical techniques. We find that at the smallest scales, spatial and temporal signals are linked. This means that it is impossible to estimate and remove the noise at the smallest spatial scales without considering the temporal changes between images.

Author(s): Michael S. Kirk[2], Jack Ireland[1], C. Alex Young[3]
Institution(s): *1. Adnet Systems Inc., 2. Catholic University of America, 3. NASA Goddard Space Flight Center*

P5 – Wednesday E-Posters Screen 1

P5.01 – Polar Facular Observations by the Zurich Observatory: A Window to the Evolution of the Polar Fields during the Weakest Cycles of the Last 200 Years

The solar polar magnetic fields are believed to be a surface manifestation of the large-scale field that acts as the seed for each solar cycle. Because of this, they have received a lot of recent attention as the best proxy for solar cycle prediction.

Polar magnetic fields have been measured systematically since the 1970s and polar facular counts (which are directly correlated with polar field strength) have been used to infer the evolution of the polar fields going back to 1906. However, this period does not cover the solar minima of cycle 12 and 13 which preceded the weakest cycles of the last 200 years. These cycles are of great interest due to their similarity with solar cycle 24, which was preceded by the deepest minimum observed so far during the space age.

Here we present the results of a project to count polar faculae using recently digitized and released observations taken by the Zurich Observatory (1887 to 1937). These observations have the potential of extending our proxy for the polar fields further back into this period of great interest and help us test the validity of our understanding.

Author(s): Juan Pablo Vargas-Acosta[1], Andres Munoz-Jaramillo[2], Santiago Vargas Dominguez[1], Leif Svalgaard[3]
Institution(s): *1. National University of Colombia, 2. Southwest Research Institute Planetary Science Directorate, 3. Stanford University*

P5.02 – A simplfied MHD model of solar surface flows

Recent work on modeling solar photospheric flows has replaced those based on random-walks with kinematic models based upon observed convective properties. These models have successfully reproduced many aspects of the solar cycle. Here we present a dynamic model of surface flows based upon simplified MHD driven by supergranular-scale sources, along with global-scale differential rotation and meridonal flow. This approach can be used to investigate a variety of stellar and could supplant random walk methods in projecting solar fields outside the visible range of current magnetographs. The resulting self-consistent solutions are compared against observations and other models.

Author(s): Neal E. Hurlbert[1]
Institution(s): *1. Lockheed Martin Corp.*

P5.03 – Assessing the Impact of Small-Scale Magnetic Morphology on Solar Variability

Spectral solar irradiance (SSI), the radiant energy flux per wavelength of the Sun received at Earth, is an important driver of chemical reactions in the Earth's atmosphere. Accurate measurements of SSI are therefore necessary as an input for global climate models. While models and observations of the spectrally-integrated total solar irradiance (TSI) variations agree within ~ 95%, they can disagree on the sign and magnitude of the SSI variations. In this work, we examine the contribution of currently-unresolved small-scale magnetic structures to SSI variations in the photosphere. We examine the emergent spectra of two atmospheres with differing imposed-field conditions — one with a small-scale dynamo and the other with a predominantly vertical magnetic field — with similar mean field strengths at wavelengths spanning from visible to infrared. Comparing the radiative output at various viewing angles of pixels of equal vertical magnetic field strength between the two simulations, we find that the small-scale dynamo simulations produce higher radiative output than those in the predominantly vertical field simulation. This implies that the radiative output of a small magnetic structure depends on the magnetic morphology of the environment in which it is embedded, which is currently not included in SSI models. We deduce the effect on inferred irradiance by comparing the disk-integrated irradiance of these two atmospheres with standard 1D model atmospheres used in SSI modeling.

Author(s): Courtney Peck[2], Mark Rast[2], Serena Criscuoli[1]
Institution(s): *1. National Solar Observatory, 2. University of Colorado - Boulder*

P6 – Wednesday E-Posters Screen 2

107.01 – First results from the NASA WB-57 airborne observations of the Great American 2017 Total Solar Eclipse

Total solar eclipses present rare opportunities to study the complex solar corona, down to altitudes of just a few percent of a solar radius above the surface, using ground-based and airborne observatories that would otherwise be dominated by the intense solar disk and high sky brightness. Studying the corona is critical to gaining a better understanding of physical processes that occur on other stars and astrophysical objects, as well as understanding the dominant driver of space weather that affects human assets at Earth and elsewhere. For example, it is still poorly understood how the corona is heated to temperatures of 1-2 MK globally and up to 5-10 MK above active regions, while the underlying chromosphere is 100 times cooler; numerous theories abound, but are difficult to constrain due to the limited sensitivities and cadences of prior measurements. The origins and stability of coronal fans, and the extent of their reach to the middle and outer corona, are also not well known, limited in large part by sensitivities and fields of view of existing observations.

Airborne observations during the eclipse provide unique advantages; by flying in the stratosphere at altitudes of 50 kft or higher, they avoid all weather, the seeing quality is enormously improved, and additional wavelengths such as near-IR also become available due to significantly reduced water absorption. For an eclipse, an airborne observatory can also follow the shadow, increasing the total observing time by 50% or more.

We present the first results from airborne observations of the 2017 Great American Total Solar Eclipse using two of NASA's WB-57 research aircraft, each equipped with two 8.7" telescopes feeding high-sensitivity visible (green-line) and near-IR (3-5 µm) cameras operating at high cadence (30 Hz) with ~3 arcsec/pixel platescale and ±3 R_sun fields of view. The aircraft will fly along the eclipse path, separated by ~90 km, to observe a summed ~8 minutes of totality in both visible and NIR, enabling groundbreaking studies of high-speed wave motions and nanojets in the lower corona, the structure and extent of coronal fans, and constraints on a potential primordial dust ring around the Sun.

Author(s): Amir Caspi[5], Constantine Tsang[5], Craig DeForest[5], Daniel B. Seaton[1], Paul Bryans[2], Steven Tomczyk[2], Joan Burkepile[2], Phil Judge[2], Edward E. DeLuca[4], Leon Golub[4], Peter T Gallagher[6], Andrei Zhukov[3], Matthew West[3], Daniel D. Durda[5], Andrew J. Steffl[5]
Institution(s): *1. CU/CIRES, 2. NCAR/HAO, 3. Royal Observatory Belgium, 4. SAO, 5. Southwest Research Institute, Boulder, 6. Trinity College Dublin*

208 – Corona: Eclipse

208.01 – Prediction of the Solar Corona for the 2017 August 21 Total Solar Eclipse

It has become our tradition to predict the structure of the corona prior to eclipses, using a magnetohydrodynamic (MHD) model based on measurements of photospheric magnetic fields on the Sun. We plan to continue this tradition for the August 21, 2017 total solar eclipse that will sweep across the United States. We will predict the structure of the corona using SDO/HMI photospheric magnetic field data, including images of polarization brightness, magnetic field line traces, and images of simulated emission in EUV and X-rays. These images can be compared directly with observations of the total eclipse, as well as observations from SDO/AIA, Hinode/XRT, and STEREO/EUVI. This year we will attempt to energize the magnetic field within filament channels for a more realistic prediction, by constructing flux ropes at the locations where filament channels are observed. The handedness of the flux ropes will be deduced from a magnetofrictional model driven by the evolving photospheric field produced by the Advective Flux Transport model.

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Author(s): Zoran Mikic[2], Cooper Downs[2], Jon A. Linker[2], Ronald M Caplan[2], Roberto Lionello[2], Tibor Torok[2], Viacheslav Titov[2], Pete Riley[2], Duncan Mackay[3], Lisa Upton[1]
Institution(s): *1. High Altitude Observatory, 2. Predictive Science, Inc., 3. University of St. Andrews*

208.02 – New Techniques Used in Modeling the 2017 Total Solar Eclipse: Energizing and Heating the Large-Scale Corona

Over the past two decades, our group has used a magnetohydrodynamic (MHD) model of the corona to predict the appearance of total solar eclipses. In this presentation we detail recent innovations and new techniques applied to our prediction model for the August 21, 2017 total solar eclipse. First, we have developed a method for capturing the large-scale energized fields typical of the corona, namely the sheared/twisted fields built up through long-term processes of differential rotation and flux-emergence/cancellation. Using inferences of the location and chirality of filament channels (deduced from a magnetofrictional model driven by the evolving photospheric field produced by the Advective Flux Transport model), we tailor a customized boundary electric field profile that will emerge shear along the desired portions of polarity inversion lines (PILs) and cancel flux to create long twisted flux systems low in the corona. This method has the potential to improve the morphological shape of streamers in the low solar corona. Second, we apply, for the first time in our eclipse prediction simulations, a new wave-turbulence-dissipation (WTD) based model for coronal heating. This model has substantially fewer free parameters than previous empirical heating models, but is inherently sensitive to the 3D geometry and connectivity of the coronal field---a key property for modeling/predicting the thermal-magnetic structure of the solar corona. Overall, we will examine the effect of these considerations on white-light and EUV observables from the simulations, and present them in the context of our final 2017 eclipse prediction model.

Research supported by NASA's Heliophysics Supporting Research and Living With a Star Programs.
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208.03 – First Results from the August 21, 2017, Total Solar Eclipse

I report on the observations planned and, weather permitting, made from our site in Salem, Oregon, at the August 21, 2017, total solar eclipse. I also give a first report on collaborators' successes, including Megamovie and simultaneous space observations. We also describe our participation in PBS's NOVA on the eclipse that was to be aired on public television on eclipse night.
Our eclipse expedition is supported in large part by grants from the Solar Terrestrial Program of the Atmospheric Sciences Division of NSF and by the Committee for Research and Exploration of the National Geographic Society.
Author(s): Jay M. Pasachoff[1]
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208.04 – Spectropolarimetry of Solar Corona during Solar Eclipses

We present the results from spectropolarimetry of solar corona. These observations were conducted during solar eclipses in 2008 China, 2013 Gabon, and probably 2017 United States of America respectively. From the former two observations, it is shown that the patterns of linear polarization of radiation from the solar corona are very abundant, and the abundance may be related to the complexity of mass motions and magnetic configuration in the corona. And the spectropolarimetry during solar eclipses may open a new window to probe precisely the physical features of the local corona, especially its magnetic configuration.
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300 – Magnetic Fields

300.01 – Investigating the Magnetic Imprints of Major Solar Eruptions with SDO/HMI High-Cadence Vector Magnetograms

The solar active region photospheric magnetic field evolves rapidly during major eruptive events, suggesting appreciable feedback from the corona. Previous studies of these "magnetic imprints" are mostly based on line-of-sight only or lower-cadence vector observations; a temporally resolved depiction of the vector field evolution is hitherto lacking. Here, we introduce the high-cadence (90 s or 135 s) vector magnetogram data set from the Helioseismic and Magnetic Imager, which is well suited for investigating the phenomenon. These observations allow quantitative characterization of the permanent, step-like changes that are most pronounced in the horizontal field component (Bh). A highly structured pattern emerges from analysis of several events, including an archetypical example, SOL2011-02-15T01:56, where Bh near the main polarity inversion line increases significantly during the earlier phase of the associated flare with a timescale of several minutes, while Bh in the periphery decreases at later times with smaller magnitudes and a slightly longer timescale. The data set also allows effective identification of the "magnetic transient" artifact, where enhanced flare emission alters the Stokes profiles and the inferred magnetic field becomes unreliable. Our results provide insights on the momentum processes in solar eruptions. The data set may also be useful to the study of sunquakes and data-driven modeling of the corona.

Author(s): Xudong Sun[1], Jon Todd Hoeksema[1], Yang Liu[1], Maria D. Kazachenko[2], Ruizhu Chen[1]
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300.02 – Neutralization of Electric Current, Magnetic Shear, and Eruptive Activity in Solar Active Regions

There has been an ongoing debate on whether or not the electric currents in solar active regions (ARs) are neutralized. Current-neutralization means that the direct coronal currents that connect the AR polarity centers are surrounded by return currents of equal total strength and opposite direction, i.e. the net current is zero. Using data from SDO/HMI, we analyze the direct and return currents in four ARs; two eruptive ones and two non-eruptive ones. The eruptive ARs produced strong flares and CMEs (successful eruptions), while the non-eruptive ARs include one quiet AR that produced no strong eruptions and one that produced a series of failed eruptions. It is found that the eruptive ARs have strong net currents and large shear of the magnetic field near their polarity inversion lines (PILs). In contrast, the currents in the non-eruptive ARs are well neutralized, and the PIL-shear is rather small. This agrees with MHD simulations that demonstrate a relationship between the level of current neutralization and the amount of magnetic shear near the PIL. We discuss the implications of these results for the capability of ARs to produce strong eruptions.

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300.03 – 1.56 Micron Spectropolarimetry of Umbral Dots and Their Evolution Associated with a Major Flare

We present unprecedented high-resolution and high magnetic sensitivity spectropolarimetric characterization of umbral dots (UDs), the prevailing fine scale brightness structure manifesting magneto-convection inside sunspot umbrae where the magnetic fields are strongest and nearly vertical. This is made available by recent development of the Near InfraRed Imaging Spectropolarimeter (NIRIS) using the 1.56 micron FeI line at the 1.6 meter New Solar Telescope of Big Bear Solar Observatory. Vector magnetograms are obtained after Milne-Eddington Stokes inversions, 180-degree azimuthal ambiguity resolution, and correction of projection effects. A βγδ spot in NOAA AR 12371 was observed for six hours on June 22, 2015 with a cadence of 87 s, which covered an M6.6 flare. The overall umbra is separated into several smaller umbrae by light bridges. The umbrae are close to the flaring polarity inversion line and show an average inclination of about 17° and field strength of about 2100 Gauss. The UDs are resolvable in NIRIS vector magnetograms, especially for peripheral UDs. The measured field strength is about 3% lower in UDs comparing to umbral cores (UCs) where the continuum intensity is below the threshold of UDs. The field is more inclined in UDs by 5% ($\approx 1°$) than that in UCs. One of the umbrae showed rapid evolution associated with the flare. Its overall intensity and the number of UDs decrease by at least 7% within two hours after being swept by the flare ribbon. NIRIS vector magnetograms indicate that the average field strength of that umbra has a rapid stepwise increase for about 100 Gauss while the inclination almost has no change. The decreases of the umbral brightness and the number of UDs are thus attributed to the increase of the field strength. The results suggest that the field strength plays the most important role in constraining convective heat transport in umbra.

Author(s): Na Deng[2], Chang Liu[2], Yan Xu[2], Kwangsu Ahn[1], Ju Jing[2], Wenda Cao[2], Haimin Wang[2]
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300.04 – 3D Collision of Active Region-Sized Emerging Flux Tubes in the Solar Convection Zone and its Manifestation in the Photospheric Surface

We present observations obtained with the Solar Dynamics Observatory's Helioseismic Magnetic Imager (SDO/HMI) of target NOAA Active Regions (AR) 12017 and 12644, which initially were comprised of a simple bipole and later on became quadrupolar via parasitic bipole emergence right next to their leading polarities. Once these ARs became quadrupolar, they spewed multiple Coronal Mass Ejections (CMEs) and a multitude of highly energetic flares (a large number of M class flares). The proximity of the parasitic bipole to one of the two pre-existing sunspots forms a compact polarity inversion line (PIL). This type of quadrupolar ARs are known to be very flare- and CME-productive due to the continuous interaction of newly emerging non-potential flux with pre-existing flux in the photosphere. We show that well before the emergence of the parasitic bipole, the pre-existing polarity (typically a well-developed sunspot) undergoes interesting precursor dynamic evolution, namely (a) displacement of pre-existing sunspot's position, (b) progressive and significant oblateness of its initially nearly-circular shape, and (c) opposite polarity enhancement in the divergent moat flow around the sunspot. We employ high-resolution radiative-convective 3D MHD simulations of an emerging parasitic bipole to show that all these activity aspects seen in the photosphere are associated with the collision of a parasitic bipole with the nearby pre-existing polarity below the photospheric surface. Given the rich flare and CME productivity of this class of ARs and the precursor-like dynamic evolution of the pre-existing polarity, this work presents the potential for predicting inclement space weather.

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300.05 – The Emergence of Kinked Flux Tubes as the Source of Delta-Spots on the Photosphere

It has been observationally well established that the magnetic configurations most favorable to producing energetic flaring events reside in so called delta-spots. These delta-spots are a subclass of sunspots, and are classified as sunspots which have umbrae (dark regions in the interior of sunspots) with opposite magnetic polarities that share a common penumbra. They are characterized by strong rotation and an extremely compact magnetic configuration, and are observed to follow an inverse-Hale law. It has been shown that over 90% of X-class flares that occurred during solar cycles 22 and 23 originated in delta-spots (Guo, Lin & Deng, 2014). Understanding the origin of delta-spots, therefore, is a crucial step towards the ultimate goal of space weather forecasting. In this work, we argue that delta-spots arise during the emergence of kinked flux tubes into the corona, and that their unique properties are due to the emergence of knots present in the kink mode of twisted flux tubes. We present numerical simulations that study the emergence of both kink-stable and unstable flux tubes into the solar corona, and demonstrate quantitatively that their photospheric signatures are dramatically different, with the latter flux tubes demonstrating strong coherent rotation and a very tight flux distribution on the photosphere. We show that the coronal magnetic field resulting from the emergence of a kinked flux tube contains significantly more free energy than the unkinked case, potentially leading to more energetic flares. We discuss the implications of our simulations for observations.

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301 – Corona: Global/Model

301.01 – Study of the global corona evolution from the minimum to maximum of solar cycle 24 using 3D coronal electron density reconstructions with STEREO/COR1

This study aims at understanding the global corona evolution of the coronal activity during Solar Cycle 24 on both long-term and short-term time scales. By using a spherically symmetric polynomial approximation (SSPA) method described and validated in Wang and Davila (2014), the 3D coronal electron density in the height range of 1.5 to 3.7 Rsun is reconstructed based on STEREO/COR1-A and -B pB data. The reconstructions span a period from the Cycle 23/24 minimum to the Cycle 24 maximum, covering Carrington rotations (CRs) 2054-2153, for a total of 100 rotations. These 3D electron density distributions are validated by comparing with similar density models derived using other methods such as tomography and a MHD model as well as using data from SOHO/LASCO-C2. Uncertainties in the density reconstruction and estimated total coronal mass are analyzed. The cycle minimum-to-maximum modulation factors (MFs) of the coronal average electron density (or the total coronal mass) at different latitudinal ranges are quantified. Wavelet analysis of the cycle-long detrended density data reveals the existence of quasi-periodic short-term (7-8 months) variations during the rising and maximum activity phases. For the total mass of streamers the MFs depend on the changes in both their total area and average density, but the short-term oscillations are mainly caused by the streamer density fluctuations. A clear asymmetry is observed in the temporal evolution of the northern and southern hemispheres, with the former leading the latter by a lapse of 7-9 months, with a mild dependence on the latitude range.

Author(s): Tongjiang Wang[2], Nelson Leslie Reginald[2], Joseph Davila[3], Orville Chris St. Cyr[3], William T. Thompson[1]
Institution(s): *1. ADNET System, Inc. and NASA GSFC, 2. Catholic Univ of America / NASA GSFC, 3. NASA GSFC*

301.02 – Hybrid modeling of the lower corona using Faraday rotation observations and a MHD thermodynamic simulation

Study of coronal MHD wave energetics relies upon accurate representation of plasma particle number densities (n_e) and magnetic field strengths. In the lower corona, these parameters are obtained indirectly, and typically presented as empirical equations as a function of heliocentric radial distance (solar offset, SO). The development of coronal global models using synoptic solar surface magnetogram inputs has provided refined characterization of the coronal plasma organization and magnetic field. We present a cross-analysis between a MHD thermodynamic simulation and Faraday rotation (FR) observations over SO 1.63-1.89 solar radii (R_s) near solar minimum. MESSENGER spacecraft radio signals with a line of sight (LOS) passing through the lower corona were recorded in dual polarization using the Green Bank Telescope in November 2009. Polarization position angle changes were obtained from Stokes parameters. The magnetic field vector (**B**) and n_e along the LOS were obtained from a MHD thermodynamic simulation provided by the Community Coordinated Modeling Center. The modeled FR was computed as the integrated product of n_e and LOS-aligned **B** component. The observations over the given SO range yielded an FR change of 7 radians. The simulation reproduced this change when the modeled n_e was scaled up by 2.8x, close to values obtained using the Allen-Baumbach equation. No scaling of B from the model was necessary. A refined fit to the observations was obtained when the observationally based total electron content (TEC) curves were introduced. Changes in LOS TEC were determined from radio frequency shifts as the signal passed to successively lower electron concentrations during egress. A good fit to the observations was achieved with an offset of 7e21 m^{-2} added. Back-calculating n_e along the LOS from the TEC curves, we found that the equivalent n_e scaling compared to the model output was higher by a factor of 3. The combination of solar surface magnetogram-based MHD coronal simulations with transcoronal radio observations allows improved characterization of the lower corona. This hybrid approach potentially paves the way for more accurate use of Carrington rotation-specific coronal models.
Author(s): David B. Wexler[6], Joseph V. Hollweg[5], Elizabeth Jensen[3], Roberto Lionello[4], Peter J. Macneice[2], Anthea J. Coster[1]
Institution(s): *1. MIT Haystack Observatory, 2. NASA Goddard Space Flight Center, 3. Planetary Science Institute, 4. Predictive Science, 5. University of New Hampshire, 6. University of Southern Queensland*

301.03 – Where is the Open Flux?

The Sun’s magnetic field has been observed in the photosphere from ground- and space-based observatories for many years. Global maps of the solar magnetic field based on full disk magnetograms (either built up over a solar rotation, or evolved using flux transport models) are commonly used as boundary conditions for coronal and solar wind models. Maps from different observatories typically agree qualitatively but often disagree quantitatively. Estimation of the coronal/solar wind physics can range from potential field source surface (PFSS) models with empirical prescriptions to magnetohydrodynamic (MHD) models with realistic energy transport and sub-grid scale descriptions of heating and acceleration. Two primary observational constraints on the models are (1) The open field regions in the model should approximately correspond to coronal holes observed in emission, and (2) the magnitude of the open magnetic flux in the model should match that inferred from in situ spacecraft measurements. We have investigated the July 2010 time period, using PFSS and MHD models computed using several available magnetic maps, coronal hole boundaries detected from STEREO and SDO EUV observations, and estimates of the interplanetary magnetic flux from in situ ACE measurements. We show that for all the model/map combinations, models that agree for (1) underestimate the interplanetary magnetic flux, or, conversely, for models to match (2), the modeled open field regions are larger than observed coronal holes. Alternatively, we estimate the open magnetic flux entirely from solar observations by combining detected coronal hole boundaries with observatory synoptic magnetic maps, and show that this method also underestimates the interplanetary magnetic flux. We discuss possible resolutions.

Research supported by NASA, AFOSR, and NSF.
Author(s): Jon A. Linker[2], Cooper Downs[2], Ronald M Caplan[2], Roberto Lionello[2], Zoran Mikic[2], Pete Riley[2], Carl John Henney[2], Charles Arge[1], Matthew Owens[3]
Institution(s): *1. NASA/GSFC, 2. Predictive Science Inc, 3. University of Reading*

301.04 – WSA Coronal and Solar Wind Model Predictions Based ADAPT Model Input Using SDO/HMI Vector & Line-of-Site Magnetograms

As the primary input to nearly all coronal models, reliable estimates of the global solar photospheric magnetic field distribution are critical for accurate modeling and understanding of solar and heliospheric magnetic fields. The Air Force Data Assimilative Photospheric flux Transport (ADAPT) model generates synchronic (i.e., globally instantaneous) maps by evolving observed solar magnetic flux using relatively well understood transport processes when measurements are not available and then updating modeled flux with new observations (available from both the Earth and the far-side of the Sun) using data assimilation methods that rigorously take into account model and observational uncertainties. ADAPT is capable of assimilating line-of-sight and vector magnetic field data from all observatory sources including the expected photospheric vector magnetograms from the Polarimetric and Helioseismic Imager (PHI) on the Solar Orbiter, as well as those generated using helioseismic methods. This paper compares Wang-Sheeley-Arge (WSA) coronal and solar wind modeling results at Earth and STEREO A & B using ADAPT input model maps derived from both line-of-site and vector SDO/HMI magnetograms that include methods for incorporating observations of a large, newly emerged (July 2010) far-side active region (AR11087).

Author(s): Charles N Arge[3], Carl John Henney[1], Kathleen Shurkin[2], Samantha Wallace[4]
Institution(s): *1. AFRL, 2. Boston College, 3. NASA, 4. University of New Mexico*

301.05 – Q-Maps of the Solar Corona for Two Solar Cycles – 1996-2017

Maps of magnetic field structures called Q-maps characterize the changing geometry of the solar corona. The geometrical Q parameter describes the 'squashing factor' of elemental flux tubes. Q-maps are computed from models based on observations of the photospheric magnetic field and provide intuitive visualization of large-scale magnetic topological structures where reconnection preferably occurs. We have applied the method developed by Titov et al. (e.g. ApJ, 2008) to standard synoptic maps from SDO/HMI and SOHO/MDI and are computing daily-update synoptic frames to characterize coronal field evolution for more than twenty years, from 1996 - 2017. We are making available the vector magnetic field and value of signed log Q at ten or more heights from 1.001 to 2.5 Rs computed using the PFSS (Potential Field – Source Surface) model and for some rotations at greater height using other coronal field models. Maps showing foot points of computed open field regions are also provided.

Author(s): Jon Todd Hoeksema[2], Yang Liu[2], Xudong Sun[2], Viacheslav Titov[1], Zoran Mikic[1]
Institution(s): *1. Predictive Science Inc, 2. Stanford Univ.*

301.06D – Slow Solar Wind from S-Web Arcs

A long-standing mystery posed by in-situ heliospheric observations is the large angular extent of slow solar wind about the heliospheric current sheet (HCS). Measurements of plasma composition strongly imply that much of the slow wind consists of plasma from the closed corona that escapes onto open field lines, presumably by field-line opening or by interchange reconnection. Both of these processes are expected to release closed-field plasma into the solar wind within and immediately adjacent to the HCS. The recently proposed Separatrix-Web (S-Web) Theory postulates that the observations of slow wind far from the HCS can be explained by the dynamical interaction of open and closed flux in regions of complex coronal-hole topology. We present the first high-resolution, three-dimensional numerical simulations of the dynamic S-Web. These simulations suggest that photospheric motions at coronal-hole boundaries are responsible for the release of slow solar wind plasma from the magnetically closed solar corona, specifically through prolific interchange magnetic reconnection. The location of this plasma once it is released into the solar wind depends strongly on the geometry of the coronal-hole flux. We demonstrate how the dynamics at the boundaries of narrow corridors of open flux (coronal hole corridors) can create giant S-Web arcs of slow solar wind at high latitudes in the heliosphere, far from the HCS, accounting for the long-puzzling slow-wind observations.

Author(s): Aleida K. Higginson[3], Spiro K. Antiochos[1], C. Richard DeVore[1], Peter Wyper[2], Thomas H. Zurbuchen[3]
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302 – 2017 Karen Harvey Prize Talk: From Emergence to Eruption: The Physics and Diagnostics of Solar Active Regions, Mark Cheung

302.01 – From Emergence to Eruption: The Physics and Diagnostics of Solar Active Regions

The solar photosphere is continuously seeded by the emergence of magnetic fields from the solar interior. In turn, photospheric evolution shapes the magnetic terrain in the overlying corona. Magnetic fields in the corona store the energy needed to power coronal mass ejections (CMEs) and solar flares. In this talk, we recount a physics-based narrative of solar eruptive events from cradle to grave, from emergence to eruption, from evaporation to condensation. We review the physical processes which are understood to transport magnetic flux from the interior to the surface, inject free energy and twist into the corona, disentangle the coronal field to permit explosive energy release, and subsequently convert the released energy into observable signatures. Along the way, we review observational diagnostics used to constrain theories of active region evolution and eruption. Finally, we discuss the opportunities and challenges enabled by the large existing repository of solar observations. We argue that the synthesis of physics and diagnostics embodied in (1) data-driven modeling and (2) machine learning efforts will be an accelerating agent for scientific discovery.

Author(s): Mark Cheung[1]
Institution(s): *1. Lockheed Martin Solar and Astrophysics Laboratory*

303 – Corona: Magnetic Reconnection

303.01 – Using observations of slipping velocities to test the hypothesis that reconnection heats the active region corona

Numerous proposed coronal heating mechanisms have invoked magnetic reconnection in some role. Testing such a mechanism requires a method of measuring magnetic reconnection coupled with a prediction of the heat delivered by reconnection at the observed rate. In the absence of coronal reconnection, field line footpoints move at the same velocity as the plasma they find themselves in. The rate of coronal reconnection is therefore related to any discrepancy observed between footpoint motion and that of the local plasma — so-called slipping motion. We propose a novel method to measure this velocity discrepancy by combining a sequence of non-linear force-free field extrapolations with maps of photospheric velocity. We obtain both from a sequence of vector magnetograms of an active region (AR). We then propose a method of computing the coronal heating produced under the assumption the observed slipping velocity was due entirely to coronal reconnection. This heating rate is used to predict density and temperature at points along an equilibrium loop. This, in turn, is used to synthesize emission in EUV and SXR bands. We perform this analysis using a sequence of HMI vector magnetograms of a particular AR and compare synthesized images to observations of the same AR made by SDO. We also compare differential emission measure inferred from those observations to that of the modeled corona.

Author(s): Kai Yang[2], Dana Longcope[1], Yang Guo[2], Mingde Ding[2]
Institution(s): *1. Montana State University, 2. Nanjing University*

303.02 – Current Sheet Proliferation, Turbulence, and the Heating of the Magnetically-Closed Corona

Electric current sheets in the solar corona are essential to many theories of coronal heating and activity. They can form by a number of mechanisms. The magnetic field is known to be very clumpy in the photosphere, with approximately 100,000 elemental flux tubes in a single active region. Convection causes the tubes to become twisted and tangled, with current sheets forming unavoidably at their boundaries in the corona. Partial reconnections of the tubes as well as a patchiness of the reconnection process lead to a multiplication of the number of distinct sheets. Quasi-ideal instabilities, such as kinking, multiply the numbers even more. We conclude, therefore, that there will be a proliferation of current sheets in the corona. An important question is whether large-scale (active region size) models of the corona need to take this complexity into account to successfully predict the distribution of plasma and the resulting radiation. We discuss the picture of current sheet proliferation and compare and contrast it to MHD turbulence. We also discuss the implication of our results for coronal observations.

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Institution(s): *1. NASA GSFC*

303.03 – Reconnection Outflows in the Extended Corona and Magnetotail

Observational signatures of reconnection have been studied extensively in the lower corona for decades, successfully providing insight into energy release mechanisms in the region above post-flare arcade loops and below 1.5 solar radii. During large eruptive events, however, energy release continues to occur well beyond the presence of reconnection signatures at these low heights. Supra-arcade downflows (SADs) and downflowing loops (SADLs) are particularly useful measures of continual reconnection in the corona as they may indicate the presence and path of retracting post-reconnection loops. SADs and SADLs have been observed for days beyond the passage of corona mass ejections through the SOHO/LASCO field of view and for nearly a week after an eruption on 14 October 2014.

The association of these features with magnetic reconnection increases the significance of understanding their genesis. SADs have been interpreted as wakes behind newly reconnected and outflowing loops (SADLs). Models have shown the plausibility of this interpretation, though this interpretation has not yet been fully accepted. We will present a preliminary study of complementary observations of magnetic reconnection detected via in situ instruments in the magnetosphere. These observations, provided by five THEMIS spacecraft, reveal similar structures and conditions to those related to SADs. We compare data from multiple SADs and dipolarization fronts to test the similarity between these plasma regimes, strongly favoring the interpretation of SADs as instabilities trailing retracting loops. We will also use these observations to strengthen the case for the development of an EUV wide-field coronal imager.

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304 – Corona: Jets

304.01 – Solar Jetlets and Plumes

We present results of a careful deep-field (low-noise) analysis of evolution and structure of solar plumes using multiple wavelength channels from SDO/AIA. Using new noise-reduction techniques on SDO/AIA images, we reveal myriad small, heating events that appear to be the primary basis of plume formation and sustenance. These events ("jetlets") comprise a dynamic tapestry that forms the more distributed plume itself. We identify the "jetlets" with ejecta that have been previously observed spectroscopically, and distinguish them from the quasi-periodic slow mode waves that are seen as large collective motions. We speculate that the jetlets themselves, which are consistent with multiple interchange reconnection events near the base of the plume, are the primary energy driver heating plasma in the plume envelope.

Solar polar (and low-latitude) plumes have been analyzed by many authors over many years. Plumes are bright, persistent vertical structures embedded in coronal holes over quasi-unipolar magnetic flux concentrations. They are EUV-bright in the ~1MK lines, slightly cooler (by ionization fraction) than the surrounding coronal hole, persistent on short timescales of a few hours, and recurrent on timescales of a few days. Their onset has been associated with large X-ray jets, although not all plumes are formed that way. Plumes appear to comprise myriad small "threads" or "strands", and may (or may not) contribute significantly to the solar wind, though they have been associated with myriad small, frequent eruptive ejection events.

Our results are new and interesting because they are the lowest-noise, time-resolved observations of polar plumes to date; and they reveal the deep association between small-scale magnetic activity and the formation of the plumes themselves.

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Institution(s): *1. Catholic University, 2. Durham University, 3. JHU/APL, 4. NASA/GSFC, 5. Southwest Research Inst.*

304.02 – Flux Cancelation as the trigger of quiet-region coronal jet eruptions

Coronal jets are frequent transient features on the Sun, observed in EUV and X-ray emissions. They occur in active regions, quiet Sun and coronal holes, and appear as a bright spire with base brightenings. Recent studies show that many coronal jets are driven by the eruption of a *minifilament*. Here we investigate the magnetic cause of jet-driving minifilament eruptions. We study ten randomly-found on-disk quiet-region coronal jets using SDO/AIA intensity images and SDO/HMI magnetograms. For all ten events, we track the evolution of the jet-base region and find that (a) a cool (transition-region temperature) minifilament is present prior to each jet eruption; (b) the pre-eruption minifilament resides above the polarity-inversion line between majority-polarity and minority-polarity magnetic flux patches; (c) the opposite-polarity flux patches converge and cancel with each other; (d) the ongoing cancelation between the majority-polarity and minority-polarity flux patches eventually destabilizes the field holding the minifilament to erupt outwards; (e) the envelope of the erupting field barges into ambient oppositely-directed far-reaching field and undergoes external reconnection (interchange reconnection); (f) the external reconnection opens the envelope field and the minifilament field inside, allowing reconnection-heated hot material and cool minifilament material to escape along the reconnected far-reaching field, producing the jet spire. In summary, we found that each of our ten jets resulted from a minifilament eruption during flux cancelation at the magnetic neutral line under the pre-eruption minifilament. These observations show that flux cancelation is usually the trigger of quiet-region coronal jet eruptions.

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304.03 – Active Region Jets II: Triggering and Evolution of Violent Jets

We study a series of X-ray-bright, rapidly evolving active-region coronal jets outside the leading sunspot of AR 12259, using Hinode/XRT, SDO/AIA and HMI, and IRIS/SJ data. The detailed evolution of such rapidly evolving “violent” jets remained a mystery after our previous investigation of active region jets (Sterling et al. 2016, ApJ, 821, 100). The jets we investigate here erupt from three localized subregions, each containing a rapidly evolving (positive) minority-polarity magnetic-flux patch bathed in a (majority) negative-polarity magnetic-flux background. At least several of the jets begin with eruptions of what appear to be thin (thickness ~<2′′) miniature-filament (minifilament) “strands” from a magnetic neutral line where magnetic flux cancelation is ongoing, consistent with the magnetic configuration presented for coronal-hole jets in Sterling et al. (2015, Nature, 523, 437). For some jets strands are difficult/impossible to detect, perhaps due to their thinness, obscuration by surrounding bright or dark features, or the absence of erupting cool-material minifilaments in those jets. Tracing in detail the flux evolution in one of the subregions, we find bursts of strong jetting occurring only during times of strong flux cancelation. Averaged over seven jetting episodes, the cancelation rate was ~1.5×10^19 Mx/hr. An average flux of ~5×10^18 Mx canceled prior to each episode, arguably building up ~10^28—10^29 ergs of free magnetic energy per jet. From these and previous observations, we infer that flux cancelation is the fundamental process responsible for the pre-eruption buildup and triggering of at least many jets in active regions, quiet regions, and coronal holes.

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304.04 – Constraining reconnection region conditions using imaging and spectroscopic analysis of a coronal jet

Coronal jets typically appear as thin, collimated structures in EUV and X-ray wavelengths, and are understood to be initiated by magnetic reconnection in the lower corona or upper chromosphere. Plasma that is heated and accelerated upward into coronal jets may therefore carry indirect information on conditions in the reconnection region and current sheet located at the jet base. On 2017 October 14, the Interface Region Imaging Spectrograph (IRIS) and Solar Dynamics Observatory Atmospheric Imaging Assembly (SDO/AIA) observed a series of jet eruptions originating from NOAA AR 12599. The jet structure has a length-to-width ratio that exceeds 50, and remains remarkably straight throughout its evolution. Several times during the observation bright blobs of plasma are seen to erupt upward, ascending and subsequently descending along the structure. These blobs are cotemporal with footpoint and arcade brightenings, which we believe indicates multiple episodes of reconnection at the structure base. Through imaging and spectroscopic analysis of jet and footpoint plasma we determine a number of properties, including the line-of-sight inclination, the temperature and density structure, and lift-off velocities and accelerations of jet eruptions. We use these properties to constrain the geometry of the jet structure and conditions in reconnection region.

Author(s): Sean Brannon[1], Charles Kankelborg[1]
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304.05 – Coronal Jet Plasma Properties and Acceleration Mechanisms

Coronal jets are transient eruptions of plasma typically characterized by a prominent long spire and a bright base, and sometimes accompanied by a small filament. Jets are thought to be produced by magnetic reconnection when small-scale bipolar magnetic fields emerge into an overlying coronal field or move into a locally unipolar region. Coronal jets are commonly divided into two categories: standard jets and blowout jets, and are found in both quiet and active regions. The plasma properties of jets vary across type and location, therefore understanding the underlying acceleration mechanisms are difficult to pin down. In this work, we examine both blow-out and standard jets using high resolution multi-wavelength data. Although reconnection is commonly accepted as the primary acceleration mechanism, we also consider the contribution chromospheric evaporation to jet formation. We use seven coronal channels from SDO/AIA , Hinode/XRT Be-thin and IRIS slit-jaw data. In addition, we separate the Fe-XVIII line from the SDO/94Å channel. We calculate plasma properties including velocity, Alfven speed, and density as a function of wavelength and Differential Emission Measure (DEM). Finally, we explore the magnetic topology of the jets using Coronal Modeling System (CMS) to construct potential and non-linear force free models based on the flux rope insertion method.

Author(s): Samaiyah Farid[1], Kathy Reeves[1], Antonia Savcheva[1], Natalia Soto[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. University of Puerto Rico*

304.06 – High-cadence Hinode/XRT observations for studying coronal events with very short timescales

The Hinode X-Ray Telescope's capability for high time cadence observations makes it an excellent tool for probing highly variable conditions in the corona, including wave-like activity, dynamic plasma motions, and short-duration transient events. XRT is capable of producing images at cadences faster than one image per 10 seconds, which is comparable to the energy release timescales, and/or ionization evolution timescales, predicted by a range of models of coronal activity. In the present work, we demonstrate XRT's high-cadence capability through observations of active region AR 10923 (2006 November), with cadences of 6-20 seconds. The image sequences, made sequentially with multiple analysis filters, reveal many transient brightenings (i.e., microflares), for which we derive heating and cooling timescales. We also forward model the observed light curves to estimate the temperature, density, filling factors, and lengths of the observed loops. These estimates allow us to prioritize different heating mechanisms, and to better understand the unresolved structures within the observations. This study provides a test of capabilities, which have still not yet been fully utilized by the ten-year-old Hinode X-Ray Telescope, and thus provides a starting point for future investigations of short-timescale/high-frequency variations in coronal X-ray intensity.

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P7 – Thursday E-Posters Screen 1

P7.01 – Non Linear Force Free Field Modeling for a Pseudostreamer

In this study we present a magnetic configuration of a pseudostreamer observed on April 18, 2015 on southern west limb embedding a filament cavity. We constructed Non Linear Force Free Field (NLFFF) model using the flux rope insertion method. The NLFFF model produces the three-dimensional coronal magnetic field constrained by observed coronal structures and photospheric magnetogram. SDO/HMI magnetogram was used as an input for the model. The high spatial and temporal resolution of the SDO/AIA allows us to select best-fit models that match the observations. The MLSO/CoMP observations provide full-Sun observations of the magnetic field in the corona. The primary observables of CoMP are the four Stokes parameters (I, Q, U, V). In addition, we perform a topology analysis of the models in order to determine the location of quasi-separatrix layers (QSLs). QSLs are used as a proxy to determine where the strong electric current sheets can develop in the corona and also provide important information about the connectivity in complicated magnetic field configuration. We present the major properties of the 3D QSL and FLEDGE maps and the evolution of 3D coronal structures during the magnetofrictional process. We produce FORWARD-modeled observables from our NLFFF models and compare to a toy MHD FORWARD model and the observations.

Author(s): Nishu Karna[1], Antonia Savcheva[1], Sarah Gibson[2], Svetlin V. Tassev[1]
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114.02 – MHD simulation of solar wind and multiple coronal mass ejections with internal magnetic flux ropes

Solar wind and CMEs are the main drivers of various types of space weather disturbance. The profile of IMF Bz is the most important parameter for space weather forecasts because various magnetospheric disturbances are caused by the southward IMF brought on the Earth. Recently, we have developed MHD simulation of the solar wind, including a series of multiple CMEs with internal spheromak-type magnetic fields on the basis of observations of photospheric magnetic fields and coronal images. The MHD simulation is therefore capable of predicting the time profile of the IMF at the Earth, in relation to the passage of a magnetic cloud within a CME. In order to evaluate the current ability of our simulation, we demonstrate a test case: the propagation and interaction process of multiple CMEs associated with the highly complex active region NOAA 10486 in October to November 2003. The results of a simulation successfully reproduced the arrival at the Earth's position of a large amount of southward magnetic flux, which is capable of causing an intense magnetic storm, and provided an implication of the observed complex time profile of the solar wind parameters at the Earth as a result of the interaction of a few specific CMEs.

Author(s): Daiko Shiota[1]
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P7.03 – The Complexity of Solar and Geomagnetic Indices

How far in advance can the sunspot number be predicted with any degree of confidence? Solar cycle predictions are needed to plan long-term space missions. Fleets of satellites circle the Earth collecting science data, protecting astronauts, and relaying information. All of these satellites are sensitive at some level to solar cycle effects. Statistical and timeseries analyses of the sunspot number are often used to predict solar activity. These methods have not been completely successful as the solar dynamo changes over time and one cycle's sunspots are not a faithful predictor of the next cycle's activity. In some ways, using these techniques is similar to asking whether the stock market can be predicted. It has been shown that the Dow Jones Industrial Average (DJIA) can be more accurately predicted during periods when it obeys certain statistical properties than at other times. The Hurst exponent is one such way to partition the data. Another measure of the complexity of a timeseries is the fractal dimension. We can use these measures of complexity to compare the sunspot number with other solar and geomagnetic indices. Our concentration is on how trends are removed by the various techniques, either internally or externally. Comparisons of the statistical properties of the various solar indices may guide us in understanding how the dynamo manifests in the various indices and the Sun.

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P8 – Thursday E-Posters Screen 2

111.01 – Space-weather MDI Active Region Patches (SMARPs)

We are developing a new data product from the Michelson Doppler Imager (MDI) onboard the Solar and Heliospheric Observatory (SoHO) called Space-weather MDI Active Region Patches (SMARPs). The SMARP data series provide maps of the photospheric line-of-sight magnetic field in patches that encompass automatically tracked magnetic concentrations, or active regions, for their entire lifetime. These concentrations are automatically detected in the photospheric line-of-sight magnetic field data using a method described in Turmon et al. (2010) and, thus, are necessarily different from NOAA's definition of an active region. As such, these regions are assigned their own identification number, or SMARP number, which is also linked to a NOAA active region number should it exist. In addition, keywords in the SMARP data series include parameters that concisely characterize the magnetic field distribution. These parameters may be useful for active region event forecasting and for identifying regions of interest. These parameters are calculated per patch and are available on a 96 minute cadence.

The SMARP data product is designed to provide seamless coverage with its counterpart, the Space-weather HMI Active Region Patches (SHARPs), described in Bobra et al. (2014). Together, the SMARP and SHARP data series provide continuous coverage of tracked active regions for two solar cycles from 1996 to the present day. The SMARP data series, which runs from April 1996 to October 2010, contains 9496 unique active regions tracked throughout their lifetime. The SHARP data series, which runs from May 2010 to the present day, contains (as of May 30, 2017) 3883 unique active regions tracked throughout their lifetime. In addition, the two series contain 118 unique active regions during the overlap period between May and October 2010. SMARP data will be available at jsoc.stanford.edu and the photospheric line-of-sight magnetic field maps will be available in either of two different coordinate systems.

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305 – Instrumentation: Corona

305.01 – First Results from the Solar Ultraviolet Imager on GOES-16

The Solar Ultraviolet Imager, launched November 19, 2016, on the GOES-16 spacecraft, is the first in a line of four identical instruments that will image the Sun's atmosphere in the extreme ultraviolet for the next 20 years. SUVI's six passbands — 94, 131, 171, 195, 284, and 304 Å — provide images of the solar chromosphere and corona over a temperature range from about 50,000 K to 10 million K. SUVI's primary mission is to support space weather forecasting operations at NOAA's Space Weather Prediction Center, but its unique properties — most notably its relatively large large 53×53 arcmin field of view — offer several opportunities for new research. These unique opportunities include the both study of the large-scale structure of the solar corona and the process of magnetic reconnection that powers solar flares and eruptions. Here, we will present an overview the instrument and its capabilities, ways to access its data, and some highlights from its early results.

Author(s): Daniel B. Seaton[3], Jonathan Darnel[3], Steven M. Hill[2], Chris Edwards[1], Dnyanesh Mathur[1], David Sabolish[1], Ralph Sequin[1], Margaret Miller Shaw[1], Lawrence Shing[1], Gregory L. Slater[1], Vasudevan Gopal[1]
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305.02 – Design of MiSolFA Hard X-Ray Imager

Advances in the study of coronal electron-accelerating regions have so far been limited by the dynamic range of X-ray instruments. A quick and economical alternative to desirable focusing optics technology is stereo observation. The micro-satellite MiSolFA (Micro Solar-Flare Apparatus) is designed both as a stand-alone X-ray imaging spectrometer and a complement to the Spectrometer/Telescope for Imaging X-rays (STIX) mission. These instruments will be the first pair of cross-calibrated X-ray imaging spectrometers to look at solar flares from very different points of view. MiSolFA will achieve indirect imaging between 10 and 60 keV and provide spectroscopy up to 100 keV, equipped with grids producing moiré patterns in a similar way to STIX. New manufacturing techniques produce gold gratings on a graphite or silicon substrate, with periods ranging from 15 to 225 micrometers, separated by a distance of 15.47 cm, to achieve a spatial resolutions from 10" to 60" (as compared to RHESSI's separation of 150 cm and 1" resolution). We present the progress of the imager design, the performance of the first prototypes, and reach out to the community for further scientific objectives to consider in optimizing the final design.

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305.03 – The CubeSat Imaging X-ray Solar Spectrometer (CubIXSS) Mission Concept

Solar soft X-ray (SXR) observations provide important diagnostics of plasma heating, during solar flares and quiescent times. Spectrally- and temporally-resolved measurements are crucial for understanding the dynamics, origins, and evolution of these energetic processes, providing probes both into the temperature distributions and elemental compositions of hot plasmas; spatially-resolved measurements are critical for understanding energy transport and mass flow. A better understanding of the thermal plasma improves our understanding of the relationships between particle acceleration, plasma heating, and the underlying release of magnetic energy during reconnection. We introduce a new proposed small satellite mission, the CubeSat Imaging X-ray Solar Spectrometer (CubIXSS), to measure spectrally- and spatially-resolved SXRs from the quiescent and flaring Sun from a 6U CubeSat platform in low-Earth orbit during a nominal 1-year mission. CubIXSS includes the Amptek X123-FastSDD silicon drift detector, a low-noise, commercial off-the-shelf (COTS) instrument enabling solar SXR spectroscopy from ~0.5 to ~30 keV with ~0.15 keV FWHM spectral resolution with low power, mass, and volume requirements. Multiple detectors and tailored apertures provide sensitivity to a wide range of solar conditions, optimized for a launch during solar minimum. The precise spectra from these instruments will provide detailed measurements of the coronal temperature distribution and elemental abundances from the quiet Sun to active regions and flares. CubIXSS also includes a novel spectro-spatial imager -- the first ever solar imager on a CubeSat -- utilizing a custom pinhole camera and Chandra-heritage X-ray transmission diffraction grating to provide spatially- resolved, full-Sun imaging spectroscopy from ~0.1 to ~10 keV, with ~25 arcsec and ~0.1 Å FWHM spatial and spectral resolutions, respectively. MOXSI's unique capabilities enable SXR spectroscopy and temperature diagnostics of individual active regions and flares. Through its groundbreaking new measurements, CubIXSS will improve our physical understanding of thermal plasma processes and impulsive energy release in the solar corona, from quiet Sun to solar flares.

Author(s): Amir Caspi[9], Albert Y. Shih[6], Harry Warren[7], Craig DeForest[9], Glenn Thomas Laurent[9], Richard A. Schwartz[6], Thomas N. Woods[3], James Mason[3], Scott Palo[2],Marek Steslicki[8], Janusz Sylwester[8], Szymon Gburek[8], Tomasz Mrozek[8], Miroslaw Kowalinski[8], Gabriele Torre[4], Geoffrey Crowley[1], Mark Schattenburg[5]
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305.04 – Methods for reducing ghost rays on the Wolter-I focusing figures of the FOXSI rocket payload

In high energy solar astrophysics, imaging hard X-rays by direct focusing offers higher dynamic range and greater sensitivity compared to past techniques that used indirect imaging. The Focusing Optics X-ray Solar Imager (FOXSI) is a sounding rocket payload which uses seven sets of nested Wolter-I figured mirrors that, together with seven high-sensitive semiconductor detectors, observes the Sun in hard X-rays by direct focusing. The FOXSI rocket has successfully flown twice and is funded to fly a third time in summer 2018.

The Wolter-I geometry consists of two consecutive mirrors, one paraboloid, and one hyperboloid, that reflect photons at grazing angles. Correctly focused X-rays reflect twice, once per mirror segment. For extended sources, like the Sun, off-axis photons at certain incident angles can reflect on only one mirror and still reach the focal plane, generating a pattern of single-bounce photons, or 'ghost rays' that can limit the sensitivity of the observation of focused X-rays. Understanding and cutting down the ghost rays on the FOXSI optics will maximize the instrument's sensitivity of the solar faintest sources for future flights. We present an analysis of the FOXSI ghost rays based on ray-tracing simulations, as well as the effectiveness of different physical strategies to reduce them.

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306 – Solar Dynamo

306.01 – Observing and modelling the poloidal and toroidal magnetic fields of the global dynamo

The large scale solar dynamo is a cycle where poloidal flux is generated from toroidal flux, and toroidal flux is generated from poloidal flux. The toroidal and poloidal fields can be inferred from observations, and the Babcock-Leighton model shows how differential rotation and flux emergence explain the observed evolution of the fields.

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306.02 – Data Assimilation and Uncertainties in Early Solar Cycle Predictions

Stochastic nature of solar activity variations together with our limited knowledge of the dynamo mechanism and subsurface dynamics causes uncertainty in predictions of the solar cycle. For improving the physics-based predictions we can take advantage of the mathematical data assimilation approach that allows us to take into account both, observational errors and model uncertainties, and provide estimates of the next solar cycle along with prediction uncertainties. In this study we use the Parker's migratory dynamo model together with the equation of magnetic helicity balance, which reproduces main properties of the sunspot cycles and allow us to minimize discrepancies between the observed global activity variations and the model solution. The test simulation runs show that a reliable prediction can be obtained for two phases of preceding solar cycle: 1) if the polar field reversals shortly after the solar maxima (strong toroidal field and weak poloidal field), and 2) during the solar minima (strongest poloidal and weak toroidal fields). The early estimate of Cycle 25 obtained by this method shows that this cycle will start in 2019 – 2020, reach the maximum in 2023 – 2024, and that the mean sunspot number at the maximum will be about 90 (for the v2.0 sunspot number series).

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306.03 – Solar Cycle Variability and Grand Minima Induced by Joy's Law Scatter

The strength of the solar cycle varies from one cycle to another in an irregular manner and the extreme example of this irregularity is the Maunder minimum when Sun produced only a few spots for several years. We explore the cause of these variabilities using a 3D Babcock--Leighton dynamo. In this model, based on the toroidal flux at the base of the convection zone, bipolar magnetic regions (BMRs) are produced with flux, tilt angle, and time of emergence all obtain from their observed distributions. The dynamo growth is limited by a tilt quenching.
The randomnesses in the BMR emergences make the poloidal field unequal and eventually cause an unequal solar cycle. When observed fluctuations of BMR tilts around Joy's law, i.e., a standard deviation of 15 degrees, are considered, our model produces a variation in the solar cycle comparable to the observed solar cycle variability. Tilt scatter also causes occasional Maunder-like grand minima, although the observed scatter does not reproduce correct statistics of grand minima. However, when we double the tilt scatter, we find grand minima consistent with observations. Importantly, our dynamo model can operate even during grand minima with only a few BMRs, without requiring any additional alpha effect.

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306.04 – Strong Hemispheric Asymmetry can Trigger Parity Changes in the Sunspot Cycle

Although sunspots have been systematically observed on the Sun's surface over the last four centuries, their magnetic properties have been revealed and documented only since the early 1900s. Sunspots typically appear in pairs of opposite magnetic polarity which have a systematic orientation. This polarity orientation is opposite across the equator – a trend that has persisted over the last century since observations of sunspot magnetic fields exist. Taken

together with the configuration
of the global poloidal field of the Sun – that governs the heliospheric open flux and cosmic ray flux at Earth – this phenomena is consistent with the dipolar parity state of an underlying magnetohydrodynamic dynamo mechanism. Although, hemispheric asymmetry in the emergence of sunspots is observed in the Sun, a parity shift has never been observed. We simulate hemispheric asymmetry through introduction of random fluctuations in a computational dynamo model of the solar cycle and demonstrate that changes in parity are indeed possible over long time-scales. In particular, we find that a parity shift in the underlying nature of the sunspot cycle is more likely to occur when sunspot activity dominates in any one hemisphere for a time which is significantly longer compared to the sunspot cycle period. Our simulations suggest that the sunspot cycle may have resided in quadrupolar parity states in the distant past, and provides a possible pathway for predicting parity flips in the future.

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400 – Flares: Modeling II

400.01 – Realistic radiative MHD simulation of a solar flare

We present a recently developed version of the MURaM radiative MHD code that includes coronal physics in terms of optically thin radiative loss and field aligned heat conduction. The code employs the "Boris correction" (semi-relativistic MHD with a reduced speed of light) and a hyperbolic treatment of heat conduction, which allow for efficient simulations of the photosphere/corona system by avoiding the severe time-step constraints arising from Alfven wave propagation and heat conduction. We demonstrate that this approach can be used even in dynamic phases such as a flare. We consider a setup in which a flare is triggered by flux emergence into a pre-existing bipolar active region. After the coronal energy release, efficient transport of energy along field lines leads to the formation of flare ribbons within seconds. In the flare ribbons we find downflows for temperatures lower than ~5 MK and upflows at higher temperatures. The resulting soft X-ray emission shows a fast rise and slow decay, reaching a peak corresponding to a mid C-class flare. The post reconnection energy release in the corona leads to average particle energies reaching 50 keV (500 MK under the assumption of a thermal plasma). We show that hard X-ray emission from the corona computed under the assumption of thermal bremsstrahlung can produce a power-law spectrum due to the multi-thermal nature of the plasma. The electron energy flux into the flare ribbons (classic heat conduction with free streaming limit) is highly inhomogeneous and reaches peak values of about $3x10^{11}$ $erg/cm^2/s$ in a small fraction of the ribbons, indicating regions that could potentially produce hard X-ray footpoint sources. We demonstrate that these findings are robust by comparing simulations computed with different values of the saturation heat flux as well as the "reduced speed of light".

Author(s): Matthias D. Rempel[2], Mark Cheung[4], Georgios Chintzoglou[4], Feng Chen[2], Paola Testa[5], Juan Martinez-Sykora[1], Alberto Sainz Dalda[1], Marc L. DeRosa[4], Anna Viktorovna Malanushenko[2], Viggo H Hansteen[3], Bart De Pontieu[4], Mats Carlsson[3], Boris Gudiksen[3], Scott W. McIntosh[2]
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400.02 – MHD simulations of formation and eruption of a magnetic flux rope in an active region with a delta-sunspot

Active regions holding a delta-sunspot are known to produce the largest class of solar flares. How, where, and when such large flares occur above a delta-sunspot are still under debate. For studying this, 3D MHD simulations of the emergence of a subsurface flux tube at two locations in a simulation box modeling the convection zone to the corona were conducted. We found that a flux rope is formed as a consequence of magnetic reconnection of two bipolar loops and sunspot rotation caused by the twist of the subsurface flux tube. Moreover, the flux rope stops ascending when the initial background is not magnetized, whereas it rises up to the upper boundary when a reconnection favorably oriented pre-existing field is introduced to the initial background.

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400.03D – The analysis and the three-dimensional, forward-fit modeling of the X-ray and the microwave emissions of major solar flares

It is well known that the time profiles of the hard X-ray (HXR) emission and the microwave (MW) emission during the impulsive phase of the solar flare are well correlated, and that their analysis can lead to the understandings of the flare-accelerated electrons. In this work, we first studied the source locations of seven distinct temporal peaks observed in HXR and MW lightcurves of the 2011-02-15 X2.2 flare using the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and Nobeyama Radioheliograph. We found that the seven emission peaks did not come from seven spatially distinct sites in HXR and MW, but rather in HXR we observed a sudden change in location only between the second and the third peak, with the same pattern occurring, but evolving more slowly in MW, which is consistent with the tether-cutting model of solar flares. Next, we closely examine the widely-used notion of a "common population" of the accelerated electrons producing the HXR and the MW, which has been challenged by some studies suggesting the differences in the inferred energy spectral index and emitting energies of the HXR- and MW- producing electrons. We use the Non-linear Force Free Field model extrapolated from the observed photospheric magnetogram in the three-dimensional, multi-wavelength modeling platform *GX Simulator*, and attempt to create a unified electron population model that can simultaneously reproduce the observed X-ray and MW observations of the 2015-06-22 M6.5 flare. We constrain the model parameters by the observations made by the highest-resolving instruments currently available in two wavelengths, the RHESSI for X-ray and the Expanded Owens Valley Solar Array for MW. The results suggest that the X-ray emitting electron population model fits to the standard flare model with the broken, hardening power-law spectrum at ~300 keV that simultaneously produces the HXR footpoint emission and the MW high frequency emission, and also reveals that there could be a “X-ray invisible” population of nonthermal electrons that are trapped in a large magnetic field volume above the X-ray emitting loops, that emits gyrosynchrotron radiation mainly in MW low frequency range.

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400.04 – Multi-instrument observations of sub-minute quasi-periodic pulsations in solar flares

Since a decade, quasi-periodic pulsations (QPPs) have been regularly reported to be observed in EUV and SXR during solar flares, while they were previously mostly observed in HXR and radio wavelengths. These new detections can be credited to a new generation of EUV space radiometers (SDO/EVE, PROBA2/LYRA, etc.) that significantly enhanced the instrument performances in terms of signal-to-noise ratio and time resolution. These new instruments allow us to perform statistical analysis of QPPs, which could ultimately help solving the long-debated question of their origin. However, recently, the methods (mainly the way to pre-process data and to account for the noise) used to detect QPPs in those wavelengths were questioned. In this presentation, we will discuss our current understanding of QPPs and the difficulties inherent to their detection. I will particularly address the sub-minute QPPs in the EUV and analyze them in the broader picture of multi-wavelength detection. How do they compare to the pulsations observed in other wavelength ranges? Are sub-minute QPPs and QPPs with longer periods produced by the same processes? What can we learn from the analysis of QPPs? Possible answers to these questions will be presented and discussed.

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400.05 – Searching for evidence of quasi-periodic pulsations in solar flares using the AFINO code

The AFINO (Automated Flare Inference of Oscillations) code is a new tool to allow analysis of temporal solar data in search of oscillatory signatures. Using AFINO, we carry out a large-scale search for evidence of signals consistent with quasi-periodic pulsations (QPP) in solar flares, focusing on the 1-300 s timescale. We analyze 675 M- and X-class flares observed by GOES in 1-8 Å soft X-rays between 2011 February 1 and 2015 December 31. Additionally, over the same era we analyze Fermi/GBM 15-25 keV X-ray data for each of these flares associated with a GBM solar flare trigger, a total of 261 events. Using a model comparison method and the Bayesian Information Criterion statistic, we determine whether there is evidence for a substantial enhancement in the Fourier power spectrum that may be consistent with a QPP-like signature.

Quasi-steady periodic signatures appear more prevalently in thermal soft X-ray data than in the counterpart hard X-ray emission: according to AFINO ~30% of GOES flares but only ~8% of the same flares observed by GBM show strong signatures consistent with classical interpretations of QPP, which include MHD wave processes and oscillatory reconnection events. For both datasets, preferred characteristic timescales of ~5-30 s were found in the QPP-like events, with no clear dependence on flare magnitude. Individual events in the sample also show similar characteristic timescales in both GBM and GOES data sets, indicating that the same phenomenon is sometimes observed simultaneously in soft and hard X-rays. We discuss the implications of these survey results, and future developments of the analysis method. AFINO continues to run daily on new flares observed by GOES, and the full AFINO catalogue is made available online.

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401 – Helioseismology

401.01 – Interactions of Oscillations with Near Surface Convection

There are a number of large but unexplained effects in helioseismic observations. One is the so-called surface effect, which manifests itself as a difference between the theoretical and observed frequencies, and which appears to originate close to the surface. Another is a large apparent phase shift in the oscillations depending on the center-to-

limb distance and the observable used.
Both of these effects are likely due to interactions of the waves with the near surface convection.
Here I will discuss one of the directly observable consequences of these interactions, namely the change in the properties of the modes depending on where in the granulation they are observed. To that end I will use both observations from HMI and results from hydrodynamic simulations.

Author(s): Jesper Schou[1]
Institution(s): *1. Max Planck Institute for Solar System Research*

401.02 – Supergranular waves revisited

Solar supergranules remain a mysterious phenomenon, half a century after their discovery. One particularly interesting aspect of supergranulation is its wave-like nature detected in Fourier space. Using SDO/HMI local helioseismology and granulation tracking, we provide new evidence for supergranular waves. We also discuss their influence on the evolution of the network magnetic field using cork simulations.

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401.03 – Comparison of acoustic travel-time measurement of solar meridional circulation from SDO/HMI and SOHO/MDI

Time-distance helioseismology is one of the primary tools for studying the solar meridional circulation. However, travel-time measurements of the subsurface meridional flow suffer from a variety of systematic errors, such as a center-to-limb variation and an offset due to the P-angle uncertainty of solar images. Here we apply the time-distance technique to contemporaneous medium-degree Dopplergrams produced by SOHO/MDI and SDO/HMI to obtain the travel-time difference caused by meridional circulation throughout the solar convection zone. The P-angle offset in MDI images is measured by cross-correlating MDI and HMI images. The travel-time measurements in the south-north and east-west directions are averaged over the same observation period for the two data sets and then compared to examine the consistency of MDI and HMI travel times after correcting the systematic errors.
The offsets in the south-north travel-time difference from MDI data induced by the P-angle error gradually diminish with increasing travel distance. However, these offsets become noisy for travel distances corresponding to waves that reach the base of the convection zone. This suggests that a careful treatment of the P-angle problem is required when studying a deep meridional flow. After correcting the P-angle and the removal of the center-to-limb effect, the travel-time measurements from MDI and HMI are consistent within the error bars for meridional circulation covering the entire convection zone. The fluctuations observed in both data sets are highly correlated and thus indicate their solar origin rather than an instrumental origin. Although our results demonstrate that the ad hoc correction is capable of reducing the wide discrepancy in the travel-time measurements from MDI and HMI, we cannot exclude the possibility that there exist other systematic effects acting on the two data sets in the same way.

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401.04 – Comparison of Far-side Helioseismic Predictions of Active Regions from SDO/HMI with Far-side Observations of Solar Activity from STEREO/EUVI

Doppler data from the *Helioseismic and Magnetic Imager* (HMI) aboard the *Solar Dynamics Observatory* (SDO) are now being used routinely to detect strong magnetic field regions on the far side of the Sun (http:/jsoc.stanford.edu/data/farside/). To test the reliability of these active regions predictions, the far-side seismic region detections are compared with far-side observation of solar activity from the *Solar TErrestrial RElations Observatory* (STEREO), using brightness in extreme ultraviolet light as a proxy for strong magnetic fields. Two approaches are used here to compare and analyze approximately six months of STEREO and HMI data. In the first approach, after determining whether or not new large East-limb active regions were detected seismically on the far side of the Sun before they appeared Earth side, we analyze how the ability to detect these regions seismically relates to their integrated extreme ultraviolet intensity. We find that, while there is a range of intensities where far-side regions may or may not be detected seismically, there appears to be an intensity level above which they are always detected and an intensity level below which they are never detected. In the second approach, we analyze concurrent extreme ultraviolet and helioseismic far-side maps for the same six month period. We find that 100% (22) of the far-side seismic regions correspond to an extreme ultraviolet plage; 95% of these either became a NOAA-designated magnetic region when reaching the east limb or were one before crossing to the far side. A low but significant correlation is found between the seismic signature strength and the EUV intensity of a far-side region.

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401.05 – A possible selection rule for flares causing sunquakes

Sunquakes are helioseismic power enhancements initiated by strong solar flares, but not all strong flares are associated with sunquakes. It is curious why some flares cause sunquakes while others do not. We propose a hypothesis to explain the disproportion between strong solar flares and sunquakes: during a flare's impulsive phase when shock waves or energetic particles reach the photosphere from the higher atmosphere, a sunquake occurs if the background oscillation at the flare footpoint happens to oscillate downward and gets enhanced by the downward particles or shock waves.

To verify this hypothesis, we examine the sunquake oscillation velocity during a flare's impulsive phase. We do helioseismic analysis on 50 strong solar flares above M7.0 in Solar Cycle 24. Since the source signals at the sunquake origins are usually invisible due to anomalies of Doppler data caused by solar flares, we reconstruct the oscillation wave fields in the flare sites using observation-based Green's functions. Sixteen flares are found to be helioseismic active, giving a total of 19 sunquakes. We then study the temporal and spatial relations between sunquakes and flares. It is found 15 out of 19 detected sunquake events have downward oscillation velocities during the flares' impulsive phases in low acoustic frequency, and 17 out of 19 have downward velocities in high frequency. This is consistent with our hypothesis.
Author(s): Ruizhu Chen[1], Junwei Zhao[1]
Institution(s): *1. Stanford University*

402 – Coronal Thermal Behavior

402.01 – Observations and modeling of the fine structure of loops in the transition region and corona

The physical dimensions of loops hold important clues to the coronal heating process. Theoretical arguments universally indicate that coronal heating should operate on very small spatial scales and loops should be unresolvable by current instrumentation. There are a number of observational results, however, that suggest that coronal loops are organized on spatial scales of several hundred km. For example, recent observations from IRIS have discovered a new class of low-lying dynamic loops structures, and it has been argued that they are the long-postulated unresolved fine structures (UFS) that dominate the emission of the solar transition region. Here we show that the properties of the UFS (intensities, lengths, widths, lifetimes) are consistent with 1-D non-equilibrium ionization simulations of an impulsively heated single strand, suggesting that they are resolved, and that the distribution of UFS widths implies that like coronal loops they are also structured on a spatial scale of a few hundred km. Spatial scales of a few hundred kilometers appear to be typical for a range of chromospheric and coronal structures, but it is unclear whether the true distribution of loop widths is normalized around this scale, or whether it extends to much smaller scales - perhaps by a power-law - below the resolution of current instruments. We have extended our previous modeling of the cross-field intensity profiles of coronal loops observed by EIS and AIA, to investigate what the modeled profiles would look like at Hi-C resolution, what they would look like if loops are composed only of < 10km threads, and what they would look like if there is a power-law distribution of loop widths. We find that the models with strands on spatial scales of a few hundred km are most consistent with the data. Very small threads do not produce smooth profiles when their properties are driven by the measured temperatures and densities, and the intensity profiles from the power-law simulations are dominated by emission from the largest strands.
Author(s): David Brooks[1]
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402.02 – Diagnosing Coronal Heating in a Survey of Active Regions using the Time Lag Method

In this paper we examine 15 different active regions observed with the Solar Dynamics Observatory and analyze their nanoflare properties using the time lag method. The time lag method is a diagnostic of whether the plasma is maintained at a steady temperature, or if it is dynamic, undergoing heating and cooling cycles. An important aspect of our technique is that it analyses both observationally distinct coronal loops as well as the much more prevalent diffuse emission surrounding them. Warren et al. (2012) first studied these same 15 active regions, which are all quiescent and exhibit a broad range of characteristics, including age, total unsigned magnetic flux, area, hot emission, and emission measure distribution. We find that widespread cooling is a generic property of both loop and diffuse emission from all 15 active regions. However, the range of temperatures through which the plasma cools varies between active regions and within each active region, and only occasionally is there full cooling from above 7 MK to well below 1 MK. We find that the degree of cooling is not well correlated with slopes of the emission measure distribution measured by Warren et al. (2012). We show that these apparently contradictory observations can be reconciled with the presence of a distribution of nanoflare energies and frequencies along the line of sight, with the average delay between successive nanoflare events on a single flux tube being comparable to the plasma cooling timescale.

Warren, H. P., Winebarger, A. R., & Brooks, D. H. 2012, ApJ, 759, 141
Author(s): Nicholeen Viall[1], James A. Klimchuk[1]

Institution(s): *1. NASA Goddard Space Flight Center*

402.03 – Thermal Time Evolution of Non-Flaring Active Regions Determined by *SDO*/AIA

We present the pixel-level time evolution of DEM maps from *SDO*/AIA data using two different methods (Hannah et al. 2012; Cheung et al. 2015). These sets of Differential Emission Measure (DEM) maps allow us to determine the slopes of the DEM throughout non-flaring structures, and investigate how this changes with time, a crucial parameter in terms of how these flux tubes are being heated. We present this analysis on both real and synthetic data allowing us to understand how robustly we can recover the thermal time evolution. As this analysis also produces the time series in different temperature bands we can further investigate the underlying heating mechanisms by applying a variety of techniques to probe the frequency and nature of the heating, such as time-lag analysis (Viall & Klimchuck 2012; 2016), power spectrum analysis (Ireland et al. 2015), and Local Intermittency Measure (Dinkelaker & MacKinnon 2013a,b).

Author(s): Paul James Wright[4], Iain Hannah[4], Nicholeen Viall[2], Alexander MacKinnon[4], Jack Ireland[1], Stephen Bradshaw[3]
Institution(s): *1. ADNET Systems, Inc., 2. NASA Goddard Space Flight Center, 3. Rice University, 4. University of Glasgow*

402.04D – The Slowly Varying Corona: Findings using DEMs from the EVE MEGS-A Dataset

We present analysis of the complete spectral dataset from the Extreme-ultraviolet (EUV) Variability Experiment (EVE) MEGS-A instrument. With these data we construct daily differential emission measures (DEMs) and use them to analyze the long-term variability of the global corona. We identify a discontinuity in the DEMs separating solar minimum and maximum conditions that suggests a fundamental change in the coronal temperature structure with solar activity. Using the DEMs, we also study the relationship between EUV and $F_{10.7}$, the 10.7 cm (2.8 GHz) solar activity proxy. We compare the $F_{10.7}$ predictions from the DEMs and photospheric magnetic field observations with irradiance microwave observations to constrain the source mechanisms of $F_{10.7}$ and their relative contribution as a function of solar activity. This has serious implications for the use of $F_{10.7}$ as an activity proxy in terrestrial atmospheric modeling and we discuss our results in the context of previous work. Comparing the DEMs with microwave observations also allows for a determination of the coronal iron abundance and a measurement of the FIP effect.

Author(s): Samuel J. Schonfeld[2], Stephen M. White[1], Rachel A Hock[1], Carl John Henney[1], James McAteer[2]
Institution(s): *1. Air Force Research Laboratory, 2. New Mexico State University*

403 – Solar Interior Dynamics and Helioseismology

403.01 – Exploring the Flux Tube Paradigm in Solar-like Convection Zones

In the solar context, important insight into the flux emergence process has been obtained by assuming the magnetism giving rise to sunspots consists partly of idealized flux tubes. Global-scale dynamo models are only now beginning to capture some aspects of flux emergence. In certain regimes, these simulations self-consistently generate magnetic flux structures that rise buoyantly through the computational domain. How similar are these dynamo-generated, rising flux structures to traditional flux tube models? The work we present here is a step toward addressing this question. We utilize the thin flux tube (TFT) approximation to simply model the evolution of flux tubes in a global, three-dimensional geometry. The TFTs are embedded in convective flows taken from a global dynamo simulation of a rapidly rotating Sun within which buoyant flux structures arise naturally from wreaths of magnetism. The initial conditions of the TFTs are informed by rising flux structures identified in the dynamo simulation. We compare the trajectories of the dynamo-generated flux loops with those computed through the TFT approach. We also assess the nature of the relevant forces acting on both sets of flux structures, such as buoyancy, the Coriolis force, and external forces imparted by the surrounding convection. To achieve the fast <15 day rise of the buoyant flux structures, we must suppress the large retrograde flow established inside the TFTs which occurs due to a strong conservation of angular momentum as they move outward. This tendency is common in flux tube models in solar-like convection zones, but is not present to the same degree in the dynamo-generated flux loops. We discuss the mechanisms that may be responsible for suppressing the axial flow inside the flux tube, and consider the implications this has regarding the role of the Coriolis force in explaining sunspot latitudes and the observed Joy's Law trend of active regions. Our work aims to provide constraints, and possible calibrations, on the traditional flux tube model as it pertains to the Sun and other spotted stars.

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403.02 – Effects of the enhanced subadiabatic layer in effectively high-Prandtl number thermal convection

It has been recently suggested, both from theoretical and observational points of view, that the convective velocities achieved in global solar convection simulations might be over-estimated (e.g., Hanasoge et al. 2016). The effects of the prevailing small-scale magnetic field generated by small-scale dynamo which cannot be fully resolved in the current MHD simulations may contain promising solutions to this problem (Hotta et al. 2015). The small-scale magnetic fields can reduce the convective amplitude not only through the Lorentz-force feedback but also via the increase in the effective Prandtl number, as recently pointed out by O'Mara et al (2016). In this talk, we propose and numerically confirm another suppression mechanism of the convective velocities that can also be achieved in high-Prandtl number thermal convection. This mechanism can be understood as follows. If the effective horizontal thermal diffusivity decreases due to the existence of small-scale magnetic fields, the subadiabatic layer which is formed near the base by depositions of low entropy fluids of adiabatically downflowing cold plumes is enhanced and extended. The global convective amplitude in high-Prandtl thermal convection is thus decreased via the change in the mean entropy profile, which is more subadiabatic near the base and less superadiabatic in the bulk.
Author(s): Yuto Bekki[2], Hideyuki Hotta[1], Takaaki Yokoyama[2]
Institution(s): *1. Chiba University, 2. The University of Tokyo*

403.03 – Solar-Cycle Variations Observed by Helioseismology and Constraints on Solar Dynamo

Helioseismology data from the SOHO and SDO, obtained in 1996-2017 for almost two solar cycles, provide a unique opportunity to investigate variations of the solar interior structure and dynamics, and link these variations to the current dynamo models and simulations. The solar oscillation frequencies and frequency splitting of medium-degree p- and f-modes, as well as helioseismic inversions have been used to analyze the differential rotation and global asphericity. By comparing the helioseismology results with the synoptic surface magnetic fields we identify characteristic changes associated the initiation and evolution of the solar cycles, 23 and 24. The observational results are compared with the current mean-field dynamo models and 3D MHD dynamo simulations. It is shown that the helioseismology inferences provide important constraints on the dynamics of the tachocline and near-surface shear layer, and also may explain the fundamental difference between the two solar cycles and detect the onset of the next cycle.
Author(s): Alexander G. Kosovichev[2], Timothy P. Larson[3], Gustavo Guerrero[4], Valery Pipin[1]
Institution(s): *1. Institute of Solar-Terrestrial Research, 2. New Jersey Institute of Technology, 3. Stanford University, 4. Universidade Federal de Minas Gerais*

403.04 – Probing Magnetic Fields Near the Base of the Convection Zone with Meridional Flows

We study the solar-cycle variations of the meridional flows near the base of the convection zone to probe the solar-cycle variations of magnetic fields. Using SOHO/MDI data, we measure the acoustic travel-time difference on the meridional plane for different latitudes and different travel distances over 15 years, including two minima and one maximum. The measured travel-time differences averaged over two minima are similar, but significantly different from that at the maximum. The measured travel-time difference is inverted to obtain the meridional flow at the minimum and maximum. The flow at the minimum has a two-cell pattern in the convection zone: poleward flow in the upper layer (above 0.86R), equator-ward flow in the mid-layer (0.74-0.86R), and poleward flow again in the lower layer (below 0.74R). The two-cell pattern is changed to a more complicated pattern at the maximum. The active latitudes appear to play a key role in the changes.
Author(s): DEAN-YI CHOU[1]
Institution(s): *1. National Tsing Hua University*

403.05 – Convective overshoot at the solar tachocline

At the base of the solar convection zone lies the solar tachocline. This internal interface is where motions from the unstable convection zone above overshoot and penetrate downward into the stiffly stable radiative zone below, driving gravity waves, mixing, and possibly pumping and storing magnetic fields. Here we study the dynamics of convective overshoot across very stiff interfaces with some properties similar to the internal boundary layer within the Sun. We use the Dedalus pseudospectral framework and study fully compressible dynamics at moderate to high Peclet number and low Mach number, probing a regime where turbulent transport is important, and where the compressible dynamics are similar to those of convective motions in the deep solar interior. We find that the depth of convective overshoot is well described by a simple buoyancy equilibration model, and we consider implications for dynamics at the solar tachocline and for the storage of magnetic fields there by overshooting convection.
Author(s): Benjamin Brown[4], Jeffrey S. Oishi[1], Evan H Anders[4], Daniel Lecoanet[3], Keaton Burns[2], Geoffrey M Vasil[5]
Institution(s): *1. Bates College, 2. Massachusetts Institute of Technology, 3. Princeton University, 4. University of Colorado, 5. University of Sydney*

404 – Solarterrestrial/Heliosphere

404.01 – Simulations and Observations of the Structured Variability in the Slow Solar Wind

In addition to the long-term heliospheric evolution on timescales of months to years, the slow solar wind exhibits significant variability on much shorter timescales—from minutes to days. This short-term variability in the magnetic field, bulk plasma, and composition properties of the slow solar wind likely results from magnetic reconnection processes in the extended solar corona. Here, we continue our analysis of the Higginson et al. (2017, ApJ 840, L10) numerical MHD simulation to investigate the following sources of *structured* slow solar wind variability. First, we examine the formation and evolution of 3D "streamer blob" magnetic flux ropes from the cusp of the helmet streamer belt by reconnection in the heliospheric current sheet (HCS). Second, we examine the large-scale torsional Alfven wave that propagates to high latitudes along the Separatrix-Web (S-Web) arc. We argue that the in-situ Alfven wave signatures in our simulation should be representative of the field and plasma signatures associated with interchange reconnection process in the corona. Therefore, we predict that streamer blob magnetic island flux ropes should be found primarily near the HCS but the torsional Alfven wave signatures should be present in both the streamer belt/HCS slow wind and in the slow wind in the S-Web arcs of pseudostreamers. We present preliminary results of our analysis of the field, plasma, and composition variability in select intervals of slow solar wind in Carrington Rotation 2002 and show these are in excellent agreement with the numerical simulation predictions.

Author(s): Benjamin J. Lynch[2], Aleida K Higginson[3], Liang Zhao[3], Nicholeen Viall[1], Susan T. Lepri[3]
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404.02 – The 2015 St Patrick's Day Storm: Origins

The magnetic storm experienced at Earth on St. Patrick's Day 2015 had been the strongest of cycle 24 (at that time) with a measured DST of -223 nT, though it was not expected to cause much of a disturbance. In this work we study the solar source region of several peculiar eruptions, leading to the formation and destruction of various structures, in the week leading up to the storm, and determine the true sequence of events.

The evolution of the magnetic flux at the solar surface is examined in order to place suspected flux-ropes into context, and the evolution of the magnetic connectivities is described alongside a PFSS model of the surrounding region. The balance between positive and negative flux directly before two key eruptions is investigated in detail, in order to ascertain whether particular trigger mechanisms are feasible explanations. As well as these magnetic investigations, the column density of plasma involved is calculated from extreme ultraviolet images, and this is used to estimate the total mass of one filament, as well as select other features relevant to the eruptions. This information is then used to comment on the energy budgets and requirements of several processes in order to best understand the underlying drivers of this event.

Previous studies on the St. Patrick's Day Storm are also incorporated into this work, and an attempt is made to reconcile the disparate conclusions drawn by the scientific community as to why this storm was not only so effective, but also a major forecasting failure.

Author(s): Jack Carlyle[2], Lidia van Driel-Gesztelyi[3], Francesco Zuccarello[4], Alexander James[5], David Williams[1]
Institution(s): *1. ESAC, ESA, 2. ESTEC, ESA, 3. Observatoire de Paris, 4. Royal Observatory of Belgium, 5. UCL*

404.03 – Implications of the S-Web Model for Impulsive SEPs

One of the most important discoveries of the STEREO mission is that impulsive Solar Energetic Particle (SEP) events frequently exhibit large longitudinal spread in the heliosphere, up to 100 degrees or more. This result is especially puzzling given the long-standing observations that impulsive SEPs originate in highly localized regions in the corona, angular extent less than one degree, and that the SEPs frequently show so-called drop-outs, effectively ruling out diffusion as a mechanism for the observed spread. We discuss the implications of the S-Web slow solar wind model for the propagation of SEPs and their distribution in the heliosphere. We present results from 3D MHD simulations demonstrating that for commonly-observed coronal magnetic topologies, the connectivity of the corona to heliosphere will be quasi-singular, with small regions near the Sun dynamically connecting to giant arcs in the heliosphere that span tens of degrees in both latitude and longitude. We show that the S-Web model can account for both SEP longitudinal spread and dropouts, and discuss implications for observations from the upcoming Solar Orbiter and Solar Probe Plus missions.

This research was supported, in part, by the NASA LWS Program.

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Institution(s): *1. NASA GSFC*

404.04 – Different Responses of Solar Wind and Geomagnetism to Solar Activity during Quiet and Active Periods

It is well known that there are good relations of coronal hole (CH) parameters such as the size, location, and magnetic field strength to the solar wind conditions and the geomagnetic storms. Especially in the minimum phase of solar

cycle, CHs in mid- or low-latitude are one of major drivers for geomagnetic storms, since they form corotating interaction regions (CIRs). By adopting the method of Vrsnak et al. (2007), the Space Weather Research Center (SWRC) in Korea Astronomy and Space Science Institute (KASI) has done daily forecast of solar wind speed and Dst index from 2010. Through years of experience, we realize that the geomagnetic storms caused by CHs have different characteristics from those by CMEs. Thus, we statistically analyze the characteristics and causality of the geomagnetic storms by the CHs rather than the CMEs with dataset obtained during the solar activity was very low. For this, we examine the CH properties, solar wind parameters as well as geomagnetic storm indices. As the first result, we show the different trends of the solar wind parameters and geomagnetic indices depending on the degree of solar activity represented by CH (quiet) or sunspot number (SSN) in the active region (active) and then we evaluate our forecasts using CH information and suggest several ideas to improve forecasting capability.
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Institution(s): *1. CNU, 2. KASI*

404.05 – Automatic near-real-time detection of CMEs in Mauna Loa K-Cor coronagraph images

A simple algorithm has been developed to detect the onset of coronal mass ejections (CMEs), together with an estimate of their speed, in near-real-time using images of the linearly polarized white-light solar corona taken by the K-Cor telescope at the Mauna Loa Solar Observatory (MLSO). The algorithm used is a variation on the Solar Eruptive Event Detection System (SEEDS) developed at George Mason University. The algorithm was tested against K-Cor data taken between 29 April 2014 and 20 February 2017, on days which the MLSO website marked as containing CMEs. This resulted in testing of 139 days worth of data containing 171 CMEs. The detection rate varied from close to 80% in 2014–2015 when solar activity was high, down to as low as 20–30% in 2017 when activity was low. The difference in effectiveness with solar cycle is attributed to the difference in relative prevalance of strong CMEs between active and quiet periods. There were also twelve false detections during this time period, leading to an average false detection rate of 8.6% on any given day. However, half of the false detections were clustered into two short periods of a few days each when special conditions prevailed to increase the false detection rate. The K-Cor data were also compared with major Solar Energetic Particle (SEP) storms during this time period. There were three SEP events detected either at Earth or at one of the two STEREO spacecraft where K-Cor was observing during the relevant time period. The K-Cor CME detection algorithm successfully generated alerts for two of these events, with lead times of 1–3 hours before the SEP onset at 1 AU. The third event was not detected by the automatic algorithm because of the unusually broad width of the CME in position angle.
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405 – Corona: Misc.

405.01 – Realistic simulation of the emergence of magnetic field generated in a solar convective dynamo from the convection zone into the corona

We present a comprehensive realistic numerical model of emergence of magnetic flux generated in a solar convective dynamo from the convection zone to the corona. The magnetic and velocity fields in a horizontal layer near the top boundary of the solar convective dynamo simulation are used as a time-dependent bottom boundary to drive the radiation magnetohydrodynamic simulations of the emergence of the flux bundles through the upper most convection zone to more than 100 Mm above the surface of the Sun. The simualtion allows a direct comparison bewtween model synthesized observable and real obervations of flux emergence processes through different layers of the solar atmopshere.

Emerging flux bundles bring more than 1e23 Mx flux to the photosphere in a period of about 50 hours and give rise to several active regions in a horizontal domain of 200 Mm. The mean corona temperature is about 1 MK for the quiet Sun and is significantly increased after active regions form at the photosphere. The flux emergence process produces a lot of dynamical features, such as coronal bright points, jets, waves and propagating disturbances, as well as flares and mass ejections. The biggest flare reaches M2.5 as indicated by synthetic GOES-15 soft X-ray flux. The total magnetic energy released during the eruption is about 5e31 ergs. The flare leads to a significant corona heating. The mean temperature in the coronal reaches more than 5 MK. And plasma in cusp-shaped post-flare loops is heated to several tens MK. The flare is accompanied by the ejection of a giant flux rope that carries cool and dense plasma. The flux rope is formed during the eruption by the reconnection between a sheared arcade that rises up from the low atmosphere above a bipolar sunspot pair and overlying fieldlines that are mostly perpendicular to the axis of the sheared arcade.
Author(s): Feng Chen[1], Matthias D. Rempel[1], Yuhong Fan[1]
Institution(s): *1. HAO / NCAR*

405.02 – Modeling Active Region Evolution – at the Sun's Surface and into the Corona

The STEREO mission provides the first opportunity to track the long-term evolution of Active Regions over multiple rotations. The Advective Flux Transport (AFT) model is a state of the art Surface Flux Transport model, which simulates the observed near-surface flows to model the transport of magnetic flux over the entire Sun. Combining STEREO observations with AFT has allowed us to characterize the flux-luminosity relationship for He 304 Å and to validate the far-side evolution of individual active regions produced with AFT. Here, we present recent results in which we extend this radiance - magnetic flux power-law relationship to the AIA 335 Å passband, and the Fe XVIII 93.93 Å spectral line in the 94 Å passband. We use these results to test our current understanding of magnetic flux evolution and coronal heating by modeling the hydrodynamics of individual field lines with the Enthalpy-based Thermal Evolution of Loops (EBTEL) model including steady heating scaled as the ratio of the average field strength and the length (B/L). We find that steady heating is able to partially reproduce the EUV radiance - magnetic flux relationships and their observed temporal evolution. We also discuss how time-dependent heating may be able to explain the remaining discrepancies. This study demonstrates that combined models of magnetic flux transport, magnetic topology and heating can yield realistic estimates for the decay of active region radiances with time.

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405.03 – Realistic Modeling of Fast MHD Wave Trains in Coronal Active Regions

Motivated by recent SDO/AIA observations we have developed realistic modeling of quasi-periodic, fast-mode propagating MHD wave trains (QFPs) using 3D MHD model initiated with potential magnetic field extrapolated from the solar coronal boundary. Localized quasi-periodic pulsations associated with C-class flares that drive the waves (as deduced from observations) are modeled with transverse periodic displacement of magnetic field at the lower coronal boundary. The modeled propagating speed and the form of the wave expansions matches the observed fast MHD waves speed >1000 km/s and topology. We study the parametric dependence of the amplitude, propagation, and damping of the waves for a range of key model parameters, such as the background temperature, density, and the location of the flaring site within the active region. We investigate the interaction of multiple QFP wave trains excited by adjacent flaring sources. We use the model results to synthesize EUV intensities in multiple AIA channels and obtain the model parameters that best reproduce the properties of observed QFPs, such as the recent DEM analysis. We discuss the implications of our modeling results for the seismological application of QFPs for the diagnostic of the active region field, flare pulsations, end estimate the energy flux carried by the waves.

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405.04 – Polarization of Forbidden Coronal Emission Lines

Since the magnetic field is responsible for most manifestations of solar ac- tivity in the corona, one of the most challenging problems in solar physics is the diagnostics of solar magnetic fields. We present our investigation on polarization of forbidden coronal emission lines (Fe XIV 5303 A, Fe X 6374 A Fe XI 7892 A, Fe XIII 10747 A, Si X 14300 A, Mg VIII 30280 A and Si IX 39290 A), which shows that Si IX 39290 A line may be a suitable line for future observation.

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406 – Flares: Magnetic Configuration

406.01 – Witnessing a Large-scale Slipping Magnetic Reconnection along a Dimming Channel during a Solar Flare

We report the intriguing large-scale dynamic phenomena associated with the M6.5 flare~(SOL2015-06-22T18:23) in NOAA active region 12371, observed by RHESSI, Fermi, and the Atmospheric Image Assembly (AIA) and Magnetic Imager (HMI) on the Solar Dynamic Observatory (SDO). The most interesting feature of this event is a third ribbon (R3) arising in the decay phase, propagating along a dimming channel (seen in EUV passbands) towards a neighboring sunspot. The propagation of R3 occurs in the presence of hard X-ray footpoint emission, and is broadly visible at temperatures from 0.6 MK to over 10 MK through the Differential Emission Measure (DEM) analysis. The coronal loops then undergo an apparent slipping motion following the same path of R3, after a ~80 min delay. To understand the underlying physics, we investigate the magnetic configuration and the thermal structure of the flaring region. Our results are in favor of a slipping-type reconnection followed by the thermodynamic evolution of coronal loops. In comparison with those previously reported slipping reconnection events, this one proceeds across a particularly long distance (~60 Mm) over a long period of time ~50 min), and shows two clearly distinguished phases: the propagation of the footpoint brightening driven by nonthermal particle injection and the apparent slippage of loops governed by plasma heating and subsequent cooling.

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406.02 – Modeling a Propagating Sawtooth Flare Ribbon Structure as a Tearing Mode in the Presence of Velocity Shear

On April 18, 2014 (SOL2014-04-18T13:03) an M-class flare was observed by IRIS. The associated flare ribbon contained a quasi-periodic sawtooth pattern that was observed to propagate perpendicular the the IRIS spectral slit with a phase velocity of approximately 15 km/s (Brannon et al. 2015). This motion resulted in periodicities in both intensity and Doppler velocity along the slit. These periodicities were reported by Brannon et al. (2015) to be approximately plus-minus .5 arcseconds in position and plus-minus 20 km/s in velocity and were measured to be approximately 180 degrees out of phase with one another. This quasi-periodic behavior has been attributed by others to bursty or patchy reconnection (Brosius & Daw 2015; Brosius et al. 2016) and slipping occurring during three-dimensional magnetic reconnection (Li & Zhang 2015; Li et al. 2016). While able to account for periodicities in both intensity and Doppler velocity these suggestions do not explicitly account for the phase velocity of the entire sawtooth structure, or for the relative phasing of the oscillations. Here we propose that the observations can be explained by a tearing mode instability occurring at a current sheet across which there is also a velocity shear. We suggest a geometry and local plasma parameters for the April 18 flare which would support our hypothesis. Under this proposal the IRIS observations of this flare may provide the most compelling evidence to date of a tearing mode occurring in the solar magnetic field.

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406.04 – High-Resolution Observations of Flares in an Arch Filament System

We present high-resolution observations of five sequential solar flares occurring in NOAA Active Region (AR) 12396 taken with the 1.6-m New Solar Telescope at the Big Bear Solar Observatory, complemented by IRIS and SDO observations. The main flaring region is an arch filament system (AFS) consisting of multiple bundles of dark filament threads enclosed by scattered flare brightenings. We study the magnetic configuration and evolution of the active region by constructing coronal magnetic field models based on SDO/HMI magnetograms using two independent methods, i.e., the nonlinear force-free field (NLFFF) extrapolation and the flux rope insertion method. We are able to identify multiple flux ropes based on magnetic twist derived from the extrapolated NLFFF, which is consistent with the NST observations of multiple filaments. Both models suggest that the filament bundles may posses mixed signs of helicity, i.e., positive (negative) in the north (south). The footprints of quasi-separatrix layers (QSLs) derived from the extrapolated NLFFF compare favorably with the observed flare ribbons. Moreover, magnetic field lines traced along the semi-circular footprint of a dome-like QSL surrounding the flaring region are connected to the regions of significant helicity and Poynting flux injection. An interesting double-ribbon fine structure located at the east border of the AFS is consistent with the fine structure of the QSL's footprint. The maps of magnetic twist show that positive twist became dominant as time progressed, which is consistent with the injection of positive helicity during a 26 hour interval before the flares. The trigger mechanisms and detailed dynamics of the observed flares are also discussed.

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406.05 – Driving Solar Eruptions via Helicity Condensation

One of the important questions in solar physics is, “How does the Sun store and release energy in coronal mass ejections"? Key to answering this question is understanding how the sun (a) stores magnetic energy in the form of a solar filament and (b) suddenly releases this energy as a coronal mass ejection. An important model for the energy release is the ‘magnetic breakout’ - a positive-feedback mechanism between filament ejection and magnetic reconnection. Recent theory and numerical calculations have demonstrated that helicity injected into the corona via photospheric driving can accumulate in the form of a filament channel of strongly sheared magnetic fields that can provide the free energy for a coronal mass ejection. We present preliminary calculations that, for the first time, incorporate helicity injection in a breakout topology to model a fully self-consistent eruption, from filament formation to ejection.

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406.06 – Regularized Biot-Savart Laws for Modeling Magnetic Flux Ropes

Many existing models assume that magnetic flux ropes play a key role in solar flares and coronal mass ejections (CMEs). It is therefore important to develop efficient methods for constructing flux-rope configurations constrained by observed magnetic data and the initial morphology of CMEs. As our new step in this direction, we have derived and implemented a compact analytical form that represents the magnetic field of a thin flux rope with an axis of arbitrary shape and a circular cross-section. This form implies that the flux rope carries axial current I and axial flux F, so that the respective magnetic field is a curl of the sum of toroidal and poloidal vector potentials proportional to *I* and *F*, respectively. The vector potentials are expressed in terms of Biot-Savart laws whose kernels are regularized at the rope axis. We regularized them in such a way that for a straight-line axis the form provides a cylindrical force-free flux rope with a parabolic profile of the axial current density. So far, we set the shape of the rope axis by tracking the polarity inversion lines of observed magnetograms and estimating its height and other parameters of the rope from a calculated potential field above these lines. In spite of this heuristic approach, we were able to successfully construct pre-eruption configurations for the 2009 February13 and 2011 October 1 CME events. These applications demonstrate that our regularized Biot-Savart laws are indeed a very flexible and efficient method for energizing initial configurations in MHD simulations of CMEs. We discuss possible ways of optimizing the axis paths and other extensions of the method in order to make it more useful and robust.

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406.07 – Magnetic Field Modeling of Hot Channels in four Flare/CME Events

We study the magnetic structure and 3D geometrical morphology of four active regions with sigmoidal hot channels which produced flare/CME events. Observational study has been done by Cheng & Ding (2016). Using the flux rope insertion method developed by van Ballegooijen (2004), we construct a series of magnetic field models of the four flare/CME events. Through comparing with non-potential coronal loops observed by SDO/AIA , we find that the critical stable model (i.e.,a magnetic field configuration at the boundary between stable and unstable states in parameter space) and the best-fit preflare model (unstable model) which best matches observations for every case, and we think that the real preflare magnetic field configuration may lie between the two models. Finally we calculate the magnetic energy free energy and magnetic helicity of the two selected models,and study the eruption mechanism.

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