2016 SDO Workshop Abstracts – Oral & Poster Presentations
(Alphabetical by author, as of October 13, 2016)

The Source of the Slow Wind and the Origin of its Dynamics

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The origin of the slow solar wind has long been one of the major unsolved problems in solar physics. Recently, we have proposed the S-Web model in which the slow wind originates from a dense web of separatrices and quasi-separatrix layers that form the boundary between open and closed magnetic flux in the corona. The large-scale dynamics of the photosphere and corona drive this S-Web, causing closed field plasma to be released onto open field lines, which is observed in the heliosphere as the slow wind. The S-Web model, therefore, predicts that both the source and variability of the slow wind are due to the dynamics of the openclosed magnetic field boundary. We argue that two main processes drive these dynamics: photospheric motions and thermal nonequilibrium. We present simulations showing the form of the variability expected from the S-web dynamics and discuss the implications of our calculations for understanding the observed properties of the slow wind and especially for interpreting SDO observations of coronal hole evolution. This work was supported by the NASA LWS Program.

The Global Energetics of Solar Flares and CMEs

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We present statistical results of a global flare energetics project, in which the mass, the kinetic energy, and the gravitational potential energy of coronal mass ejections (CMEs) is measured in 399 M and X-class flare events observed during the first 3.5 years of the Solar Dynamics Observatory (SDO) mission, using a new method based on the EUV dimming effect. The EUV dimming is modeled in terms of a radial adiabatic expansion process, which is fitted to the observed evolution of the total emission measure of the CME source region. The model derives the evolution of the mean electron density, the emission measure, the bulk plasma expansion velocity, the mass, and the energy in the CME source region. The EUV dimming method is truly complementary to the Thomson scattering method in white light, which probes the CME evolution in the heliosphere at r >2 R_sun, while the EUV dimming method tracks the CME launch in the corona. We compare the CME parameters obtained in white light with the LASCO/C2 coronagraph with those obtained from EUV dimming with AIA) onboard SDO for all identical events in both data sets. We investigate correlations between CME parameters, the relative timing with flare parameters, frequency occurrence distributions, and the energy partition between magnetic, thermal, non-thermal, and CME energies. CME energies are found to be systematically lower than the dissipated magnetic energies, which is consistent with a magnetic origin of CMEs.

Fourier and Wavelet Analysis of Coronal Time Series

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Using Fourier and wavelet analysis, we critically re-assess the significance of our detection of periodic pulsations in coronal loops. We show that the proper identification of the frequency dependence and statistical properties of the different components of the power spectra provies a strong argument against the common practice of data detrending, which tends to produce spurious detections around the cut-off frequency of the filter. In addition, the white and red noise models built into the widely used wavelet code of Torrence & Compo cannot, in most cases, adequately represent the power spectra of coronal time series, thus also possibly causing false positives. Both effects suggest that several reports of periodic phenomena should be re-examined. The Torrence & Compo code nonetheless effectively computes rigorous confidence levels if provided with pertinent models of mean power spectra, and we describe the appropriate manner in which to call its core routines. We recall the meaning of the default confidence levels output from the code, and we propose new Monte-Carlo-derived levels that take into account the total number of degrees of freedom in the wavelet spectra. These improvements allow us to confirm that the power peaks that we detected have a very low probability of being caused by noise.

Thermal Non-Equilibrium Revealed by Periodic Pulses of Random Amplitudes in Solar Coronal Loops

Author(s): F. Auchère, C. Froment, K. Bocchialini, E. Buchlin, J. Solomon
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We recently detected variations in extreme ultraviolet intensity in coronal loops repeating with periods of several hours. Models of loops including stratified and quasi-steady heating predict the development of a state of thermal non-equilibrium (TNE): cycles of evaporative upflows at the footpoints followed by falling condensations at the apex. Based on Fourier and wavelet analysis, we demonstrate that the observed periodic signals are indeed not signatures of vibrational modes. Instead, superimposed on the power law expected from the stochastic background emission, the power spectra of the time series exhibit the discrete harmonics and continua expected from periodic trains of pulses of random amplitudes. These characteristics reinforce our earlier interpretation of these pulsations as being aborted TNE cycles.

Impact of Magnetic Carrington Synoptic and Spatial Variance Maps in Modeling of the Corona and Solar Wind

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Synoptic maps derived from the measured photospheric solar longitudinal magnetic field are routinely used to drive coronal and heliospheric models. The recent development of spatial variance maps has provided an additional resource to better understanding the limitation of these models. In addition, measurements of the vector magnetic field are now available from different instruments (e.g. SDO/HMI, SOLIS/VSM) and can be used to compute synoptic maps of the true radial field. However, due to the low sensitivity of these measurements in regions of weak magnetic field, the adoption of these maps has been very limited. An effort is underway at NSO to merge both longitudinal and vector measurements together and derive more reliable synoptic maps of the radial field. An even more ambitious project is ongoing to produce also the first radial synoptic maps derived from SOLIS/VSM chromospheric measurements. Validation and diagnostic capability of these products will be discussed.

Two-scale Analysis of Solar Magnetic Helicity

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The solar magnetic helicity has opposite signs not only in the two hemispheres, but also at large and small length scales. The latter can be detected by computing magnetic helicity spectra, but this must be done separately in each hemisphere. Here we utilize a two-scale method from mean-field dynamo theory that allows us to compute magnetic helicity spectra as a function of two different wavenumbers: one corresponding to rapidly varying scale and one corresponding to a slowly varying one. We generalize this method to spherical harmonics and compute in that way global magnetic helicity spectra for that part of the field that shows a global dipolar symmetry. We present results from simple one-dimensional model calculations, three dimensional dynamo simulations, and the two-dimensional magnetic field from synaptic vector magnetograms.

Seismology Tools for Studying the Solar-Stellar Connection

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Our knowledge of the Sun directly informs our understanding of stellar structure and evolution. For decades helioseismology has been a useful tool for characterising the Sun's internal structure and dynamics. Helioseismology has also been used to study the Sun's magnetic activity cycle and the impact of magnetic fields on the solar interior. More recently, missions such as Kepler and CoROT have provided high quality asteroseismic data for a large number of stars. I will discuss the synergies between helioseismology and asteroseismology of solar-like stars describing what we can learn about stars from the Sun and how observations of other stars are helping to establish just how typical a star the Sun is.

Doppler Speeds of the Hydrogen Lyman Lines in Solar Flares from EVE

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The hydrogen Lyman lines provide important diagnostic information about the dynamics of the chromosphere, but until recently there have been few systematic studies of their variability during flares. We investigate Doppler shifts in these lines in several flares, and use these to calculate plasma speeds. We use spectral data from the Multiple EUV Grating Spectrograph B (MEGS-B) detector on board the Extreme-Ultraviolet Variability Experiment (EVE) instrument on the Solar Dynamics Observatory. MEGS-B obtains full-disk spectra of the Sun at a resolution of 0.1nm in the range 37-105nm, which we analyse using three independent methods. The first method performs Gaussian fits to the lines, and compares the quiet-Sun centroids with the flaring ones to obtain the Doppler shifts. The second method uses cross-correlation to detect wavelength shifts between the quiet Sun and flaring line profiles. The final method calculates the "center-of-mass" of the line profile, and compares the quiet-Sun and flaring centroids to obtain the shift. In a study of 6 flares we find signatures of both upflow and downflow in the Lyman lines, with speeds of around 10 km s^−1 in the line profiles that have not undergone pre-flare subtraction, and speeds in the flare-excess profiles of around 30 km s^−1 . We include analysis of AIA images of these events in order to understand potential contributions from material ejections, and find that not all upflows can be explained by ejecta. We discuss current and future attempts at modelling these line profiles.

Towards the Automatic Detection and Analysis of Sunspot Rotation

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Torsional rotation of sunspots have been noted by many authors over the past century. Sunspots have been observed to rotate up to the order of 200 degrees over 8-10 days, and these have often been linked with eruptive behaviour such as solar flares and coronal mass ejections. However, most studies in the literature are case studies or small-number studies which suffer from selection bias. In order to better understand sunspot rotation and its impact on the corona, unbiased large-sample statistical studies are required (including both rotating and nonrotating sunspots). While this can be done manually, a better approach is to automate the detection and analysis of rotating sunspots using robust methods with well characterised uncertainties. The SDO/HMI instrument provide long-duration, high-resolution and high-cadence continuum observations suitable for extracting a large number of examples of rotating sunspots. This presentation will outline the analysis of SDI/HMI data to determine the rotation (and non-rotation) profiles of sunspots for the complete duration of their transit across the solar disk, along with how this can be extended to automatically identify sunspots and initiate their analysis.

The SDO AIA and HMI Archive at MEDOC

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MEDOC, created as the European data and operations center for SoHO, hosts also data from STEREO, SDO, and various other solar physics missions. The SDO archive at MEDOC represents more than 250TB of data, and covers the full length of the mission. It includes aia.lev1 data at a minimum cadence of 60s in the EUV channels (12s at specific periods of interest), and most of the 720s-cadence HMI series. It is complemented by a database of DEM maps derived from AIA, which will be presented at the mini-workshop on thermal diagnostics. MEDOC provides a reliable, convenient, and fast (especially for European users) access to these SDO data, by a web interface and webservices. We also provide IDL and Python clients to these webservices, allowing complex queries and automated analyses on large datasets to be made.

Automated Detection, Characterization, and Tracking of Filaments from SDO Data

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Thanks to the cadence and continuity of AIA and HMI observations, SDO offers unique data for detecting, characterizing, and tracking solar filaments, until their eruptions, which are often associated with coronal mass ejections. Because of the requirement of short latency when aiming at space weather applications, and because of the important data volume, only an automated detection can be worked out. We present the code "FILaments, Eruptions, and Activations detected from Space" (FILEAS) that we have developed for the automated detection and tracking of filaments. Detections are based on the analysis of AIA 30.4 nm He II images and on the magnetic polarity inversion lines derived from HMI. Following the tracking of filaments as they rotate with the Sun, filament characteristics are computed and a database of filaments parameters is built. We are currently building a database of filament detections by this code, covering the full SDO mission, and that will be made available to the community.

Energetic Characterisation and Statistics of Solar Coronal Brightenings

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To explain the high temperature of the corona, much attention has been paid to the distribution of energy in dissipation events. Indeed, if the event energy distribution is steep enough, the smallest, unobservable events could be the largest contributors to the total energy dissipation in the corona. Previous observations have shown a wide distribution of energies but remain inconclusive about the precise slope. Furthermore, these results rely on a very crude estimate of the energy. On the other hand, more detailed spectroscopic studies of structures such as coronal bright points do not provide enough statistical information to derive their total contribution to heating. We aim at getting a better estimate of the distributions of the energy dissipated in coronal heating events using high-resolution, multi-channel EUV data. To estimate the energies corresponding to heating events and deduce their distribution, we detected brightenings in five EUV channels of SDO/AIA. We combined the results of these detections and used maps of temperature and emission measure derived from the same observations to compute the energies. We obtain distributions of areas, durations, intensities, and energies (thermal, radiative, and conductive) of events. These distributions are power laws and we also find power-law correlations between event parameters. The energy distributions indicate that the energy from a population of events like the ones we detect represents a small contribution to the total coronal heating, even when extrapolating to smaller scales. The main explanations for this are how heating events can be extracted from observational data, and the incomplete knowledge of the thermal structure and processes in the coronal plasma attainable from available observations.

GAIA-DEM: A database providing AIA/SDO DEM maps

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The Gaussian AIA DEm Maps (GAIA-DEM) database at MEDOC (IAS) provides through a simple and intuitive web interface DEM inversions of the SDO/AIA data, computed every 30min. The Gaussian approximation is used to describe the main features of the true DEM(log T) by its first moments. For each date, maps of the three Gaussian fit parameters (central temperature, total emission measure and Gaussian width) and of the chi^2 are available in FITS format. Users can preview the maps before downloading them. In addition, users can display the initial SDO/AIA images using Helioviewer, and query the database through webservices accessible from IDL and Python clients. This presentation is for the "Thermal Diagnostics with SDO/AIA" mini-workshop.

Mass Diagnostics of Eruptive Filament Material

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Filament eruptions are not only breathtakingly beautiful, but also key to our understanding of the variable environment which is the solar atmosphere. From the distribution of the material and internal density structure, it is possible to learn about the associated magnetic field which drives the transient activity in the corona, and knowledge of the total mass can answer questions regarding the kinetic energy of coronal mass ejections (CMEs). My research centers around the development of a technique which uses multi-wavelength EUV images from SDO/AIA to determine the mass of any plasma which appears in absorption, as filaments and associated eruptions frequently do. This method is being continuously developed to not only increase the accuracy of results, but also to widen its applicability to a broader spectrum of data (figuratively and literally). I show how I have successfully examined several events using this technique, particularly focusing on partially failed eruptions. I also demonstrate how is possible to use these results to further analyse the material, for example, by constraining numerical experiments which aim to recreate observed plasma instability.

A Comprehensive Time-Distance Measurement of Deep Meridional Flow and its Temporal Variation

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We report our latest results on the Sun’s deep solar meridional-flow measurements by time-distance helioseismology technique using 6 years of SDO/HMI Doppler-velocity data. Determination of the meridional flow by time-distance helioseismology depends on a precise measurement of the flow-induced travel-time shifts of acoustic waves traveling in the solar interior. To resolve the weak travel-time-shift signals due to deep meridional flow, we need a high signal-to-noise ratio and a robust removal of the center-to-limb (CtoL) effect, which dominates the travel-time shifts. Here we perform an ultimately comprehensive measurement that tracks acoustic waves between any two points on solar surface. The travel-time shifts are composed of CtoL effect, which is a function of disk-centric distances, and contribution from the flow component parallel to wave traveling direction, which is a function of latitude and orientation. Assuming these two effects are independent, we can derive the CtoL effect and meridional-flow contributions by solving a set of linear equations in a leastsquare sense. We show the solved CtoL effect and the inversion results for the solar meridional flow, and analyze the annual variation of meridional flow from May 2010 to Apr 2016.

Emergence of Magnetic Flux Generated in a Solar Convective Dynamo

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We present a realistic numerical model of sunspot and active region formation through the emergence of flux tubes generated in a solar convective dynamo. 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 tubes through the upper most layer of the convection zone to the photosphere. The emerging flux tubes interact with the convection and break into small scale magnetic elements that further rise to the photosphere. At the photosphere, several bipolar pairs of sunspots are formed through the coalescence of the small scale magnetic elements. The sunspot pairs in the simulation successfully reproduce the fundamental observed properties of solar active regions, including the more coherent leading spots with a stronger field strength, and the correct tilts of the bipolar pairs. These asymmetries originate from the intrinsic asymmetries in the emerging fields imposed at the bottom boundary, where the horizontal fields are already tilted. The leading sides of the emerging flux tubes are up against the downdraft lanes of the giant cells and strongly sheared downward. This leads to the stronger field strength of the leading polarity fields. We find a prograde flow in the emerging flux tube, which is naturally inherited from the solar convective dynamo simulation. The prograde flow gradually becomes a diverging flow as the flux tube rises. The emerging speed is similar to upflow speed of convective motions. The azimuthal average of the flows around a (leading) sunspot reveals a predominant down flow inside the sunspots and a large-scale horizontal inflow at the depth of about 10 Mm. The inflow pattern becomes an outflow in upper most convection zone in the vicinity of the sunspot, which could be considered as moat flows.

A Survey of Sunquake Events in Solar Cycle 24

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Sunquake events are transient acoustic emissions caused by solar flares. Many past efforts have used helioseismic holography method, which employs a theoretical Green's Function for quiet Sun, to reconstruct acoustic sources caused by flares. In this work, rather than a theoretical Green's Function based on a quiet-Sun model, we use an observational Green's Function constructed from time-distance measurements of outgoing waves from sunspots regions, to reconstruct acoustic emissions during solar flares. This is expected to give a better-determined sunquake location and timing. We apply this newly developed analysis method on 50 strongest solar flares observed by the SDO/HMI during the solar cycle 24, and study both the temporal and spatial relations among sunquake events, white-light enhancements and Doppler-velocity anomalies caused by the flares. Based on these studies, we discuss what causes sunquake events and why only a small fraction of flares are associated with sunquakes.

Investigation of the Role of Magnetic Cancellation in Triggering Solar Eruptions in NOAA AR12017

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During its evolution, NOAA AR12017 was the source of 3 Coronal Mass Ejections (CMEs) and a multitude of energetic flares. In its early stages of its evolution it appeared to emerge as a single bipole, which was followed by the emergence of a smaller (secondary) bipole near its pre-existing leading polarity, forming a new polarity inversion line (PIL) between the non-conjugated opposite polarities as well as an evolving magnetic topology in the solar corona. Using photospheric magnetic field observations from SDO/HMI, spectra and imaging from IRIS covering the photosphere and transition region, coronal observations from SDO/AIA and flare centroids from RHESSI, we investigate the cause(s) of activity associated with the new PIL. The time range of the observations spans several hours prior and up to the time of the X1.0 flare (associated with a CME eruption). Continuous photospheric cancellation correlates with flaring activity in the X-rays right at the new PIL, which suggests that cancellation is dominant mechanism for the activity of this extremely flare-productive AR.

8 years of Solar Spectral Irradiance Variability Observed from the ISS with the SOLAR/SOLSPEC Instrument

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Accurate measurements of Solar Spectral Irradiance (SSI) are of primary importance for a better understanding of solar physics and of the impact of solar variability on climate (via Earth's atmospheric photochemistry). The acquisition of a top of atmosphere reference solar spectrum and of its temporal and spectral variability during the unusual solar cycle 24 is of prime interest for these studies. These measurements are performed since April 2008 with the SOLSPEC spectro-radiometer from the far ultraviolet to the infrared (166 nm to 3088 nm). This instrument, developed under a fruitful LATMOS/BIRA-IASB collaboration, is part of the Solar Monitoring Observatory (SOLAR) payload, externally mounted on the Columbus module of the International Space Station (ISS). The SOLAR mission, with its actual 8 years duration, will cover almost the entire solar cycle 24. We present here the in-flight operations and performances of the SOLSPEC instrument, including the engineering corrections, calibrations and improved know-how procedure for aging corrections. Accordingly, a SSI reference spectrum from the UV to the NIR will be presented, together with its variability in the UV, as measured by SOLAR/SOLSPEC for 8 years. Uncertainties on these measurements and comparisons with other instruments will be briefly discussed.

EUV Cross-Calibration Strategies for the GOES-R SUVI

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The challenges of maintaining calibration for solar EUV instrumentation is well-known. The lack of standard calibration sources and the fact that most solar EUV telescopes are incapable of utilizing bright astronomical EUV sources for calibration make knowledge of instrument performance quite difficult. In the recent past, calibration rocket underflights have helped establish a calibration baseline. The EVE instrument on SDO for a time provided well-calibrated, high spectral resolution solar spectra for a broad range of the EUV, but has suffered a loss of coverage at the shorter wavelengths. NOAA's Solar UltraViolet Imager (SUVI), a solar EUV imager with similarities to SDO/AIA, will provide solar imagery over nearly an entire solar cycle. In order to maintain the scientific value of the SUVI's dataset, novel approaches to calibration are necessary. Here we demonstrate a suite of methods to cross-calibrate SUVI against other solar EUV instruments through the use of proxy solar spectra.

How Calibration and Reference Spectra Affect the Accuracy of Absolute Soft X-ray Solar Irradiance Measured by the SDO/EVE/ESP during High Solar Activity

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The Extreme ultraviolet Spectrophotometer (ESP), one of the channels of SDO’s Extreme ultraviolet Variability Experiment (EVE), measures solar irradiance in several EUV and soft x-ray (SXR) bands isolated using thin-film filters and a transmission diffraction grating, and includes a quad-diode detector positioned at the grating zeroth-order to observe in a wavelength band from about 0.1 to 7.0 nm. The quad diode signal also includes some contribution from shorter wavelength in the grating’s first-order and the ratio of zeroth-order to first-order signal depends on both source geometry, and spectral distribution. For example, radiometric calibration of the ESP zeroth-order at the NIST SURF BL-2 with a near-parallel beam provides a different zeroth-to-first-order ratio than modeled for solar observations. The relative influence of “uncalibrated” first-order irradiance during solar observations is a function of the solar spectral irradiance and the locations of large Active Regions or solar flares. We discuss how the “uncalibrated” first-order “solar” component and the use of variable solar reference spectra affect determination of absolute SXR irradiance which currently may be significantly overestimated during high solar activity.

The Extreme Ultraviolet Monitor (EUVM) on MAVEN: Observations of the EUV Irradiance from Mars

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Launched in November 2013 and arriving at Mars in September 2014, Mars Atmosphere and Volatile Evolution (MAVEN) mission has made nearly two years of observations of the atmosphere, near space environment, and solar and space weather drivers at Mars. Included in the complement of instruments on MAVEN is the Extreme Ultraviolet Monitor (EUVM), which measures the absolute solar irradiance in three bandpasses (0.1-7 nm, 17-22 nm, and 121-122 nm) every one second while pointed at the Sun. The EUVM data products include the calibrated irradiances in the three bands (Level 2) at measured cadence and a modeled full spectrum from 0-190 nm in 1-nm bins at daily and 1-minute cadences. Much of the MAVEN mission so far has been observing a different face of the Sun than Earth. We will present an overview of the EUVM observations at Mars so far, including variability from solar cycle, solar rotations, flares, and planetary orbit and describe how to access the MAVEN data.

Extreme Ultraviolet Irradiance of the Early Sun

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Knowledge of the irradiance of the Sun in the EUV over the age of the solar system helps unravel the evolution of planetary atmospheres. In particular, the primary objective of the NASA Mars Atmosphere and Volatile Evolution (MAVEN) mission is to understand how our nearest neighbor lost its early, thicker and wetter atmosphere with the solar EUV being one of the primary drivers of atmospheric escape. To allow for a better estimate of the early Sun's EUV output, the calibrated solar EUV spectral irradiance measurements of TIMEDSEE and SDO-EVE are put in context with measurements of sun-like stars of differing ages.

Long-period Intensity Pulsations as the Manifestation of the Heating Stratification and Timescale in Coronal Loops

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In solar coronal loops, thermal non-equilibrium (TNE) is a phenomenon that can occur when the heating is both highly-stratified and quasi-constant. Unambiguous observational identification of TNE would thus permit to strongly constrain heating scenarios. Up to now, while TNE is the standard interpretation of coronal rain, it was not believed to happen commonly in warm coronal loops. Recently, the detection of long-period intensity pulsations (periods of several hours) has been reported with SoHO/EIT. This phenomenon appears to be very common in loops (Auchère et al. 2014). In Froment et al. 2015, three intensity-pulsation events studied with SDO/AIA, show strong evidence for TNE in warm loops. We use realistic loop geometries from LFFF extrapolations for one of these events are used as input to a 1D hydrodynamic simulation of TNE. A highly-stratified heating function is chosen to reproduce the observed period of pulsation and temperature of the loops. With these conditions, the heating function has to be asymmetric. The magnetic topology of the LFFF extrapolations points to the presence of sites of preferred reconnection at one footpoint, supporting the presence of asymmetric heating. We compared the properties of the simulated loop with the properties deduced from observations. We found that the 1D hydrodynamic simulation can reproduce the large temporal scale intensity properties of the pulsating loops (Froment et al. 2016, submitted). This simulation further strengthen the interpretation of the observed pulsations as signatures of TNE. This implies that the heating for these loops is highly-stratified and that the frequency of the heating events must be high compared to the typical cooling time.

Mini-CME Eruptions in a Flux Emergence Event in a Coronal Hole Environment

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Small scale jets are observed to take place at the interface between the open magnetic field in coronal holes and bipolar magnetic field concentrations. A fraction of these shows an eruptive behavior, where a combination of cold dense and hot light plasma has been observed to propagate out along the jet region, combining traditional jets with what looks like the eruption of mini-CMEs. Here we discuss a simple model scenario for the explosive energy release process that leads to a mixture of hot and cold plasma being accelerated upwards simultaneously. The model explains both the typical steady state inverted-Y jet and the subsequent mini-CME eruptions found in blowout jets. The numerical experiment consists of a buoyant unstable flux rope that emerges into an overlying slanted coronal field, thereby creating a bipolar magnetic field distribution in the photosphere with coronal loops linking the polarities. Reconnection between the emerged and preexisting magnetic systems including the launching of a classical inverted-Y jet. The experiment shows that this simple model provides for a very complicated dynamical behavior in its late phases. Five independent mini-CME eruptions follow the initial near steady-state jet phase. The first one is a direct consequence of the reconnection of the emerged magnetic flux, is mediated by the formation of a strongly sheared arcade followed by a tether-cutting reconnection process, and leads to the eruption of a twisted flux rope. The final four explosive eruptions, instead, are preceded by the formation of a twisted torus-like flux rope near the strong magnetic concentrations at the photosphere. As the tube center starts emerging an internal current sheet is formed below it. This sheet experiences a tether cutting process that provides the important upwards kick of the newly formed mini-CME structure. As the fast rising cold and dense tube interacts with the overlying magnetic field, it reconnects at different spatial locations, either through a null region or through a local strong shear region without nulls. The restructuring of the magnetic field lines generate magneto-acoustic waves that transport twist and cold plasma out along the less stressed parts of the newly reconnected field lines. The emphasis of the talk will be on the physical forces responsible for the initial flux tube rising and the effects and reasons for the following destruction of the mini-CMEs.

The Complex Solar Polarity Reversal during Cycle 24

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The polarity reversal at solar poles is an important event with important implications for solar magnetism, the polarity of interplanetary coronal mass ejections, and even cosmic ray modulation. The poles often do not reverse simultaneously. During the several recent cycles, the north pole reversed first, followed by the south. During cycle 24, this trend has been broken in that the south pole reversed first. The polarity reversal is typically marked by the cessation of high-latitude eruptive activities such coronal mass ejections and prominence eruptions. Even though polar prominences started appearing as early as 2011, the reversal in the north was completed only by the end of 2015. On the other hand the south polar region behaved as in previous cycles and reversed over a shorter time scale, about a year before the reversal in the north. By combining prominence eruption detected automatically (Nobeyama Radioheliograph and SDO), the polar microwave brightness (Nobeyama Radioheliograph), and the magnetic butterfly diagram (SDO and NSO) we show that the complexity can be attributed to the emergence of active regions that violated the Hale polarity rule and Joy's law. The extended period of near-zero field in the north polar region should result in very weak and delayed sunspot activity in the northern hemisphere in cycle 25, the southern hemispheric activity should start early; the amplitude will depend on how the south polar fields will evolve in the declining phase of cycle (24).

The Evolution of Active Regions

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The solar corona is a highly dynamic environment which exhibits the largest releases of energy in the Solar System in the form of solar flares and coronal mass ejections. This activity predominantly originates from active regions, which store and release free magnetic energy and dominate the magnetic face of the Sun. Active regions can be long-lived features, being affected by the Sun's convective flows, differential rotation and meridional flows. The Sun's global coronal field can be seen as the superposed growth and subsequent diffusion of all previously formed active regions. This talk will look at active regions as an observable product of the solar dynamo and will discuss the physical processes that are at play which lead to the storage and release of free magnetic energy. What happens to flux that emerges into the corona so that it goes down an evolutionary path that leads to dynamic activity? And how does this activity vary with active region age? When an active region reaches the end of its lifetime, his much of the magnetic flux is recycled back into subsequent solar cycles? The current status of observations and modelling will be reviewed with a look to the future and fundamental questions that are still be be answered.

Filamentary Oscillations in the Penumbra of Sunspots

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The issue of long-term (on scales of several hours to days) morphological changes in sunspots, and particularly the possible existence of apparent rotational motions and oscillations, has drawn attention since the early 20th century. This kind of study requires data with high spatial resolution and good temporal sampling and coverage. The HMI instrument on board the Solar Dynamics Observatory routinely measures the full magnetic field vector in sunspots and allows us to track them with consistent image quality and high cadence during their entire disk passage. It is the ideal instrument to analyze the evolution of sunspots, and in particular the azimuthal component of the penumbral magnetic field. We carried out an analysis (Griñón-Marín et al. 2016 -Submitted-) looking for torsional oscillations in the penumbra of sunspots that led to no evidence of this kind of oscillation in the 25 sunspots analyzed. However, we detected filamentary-like oscillations in some areas of the penumbra with periods of several hours. In this contribution I will show their morphological analysis and discuss the possible sources for such oscillations.

Ellerman Bombs and IRIS Bombs; In the photosphere and above

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The lower Solar atmosphere, consisting of the photosphere and chromosphere, can occasionally show violent activity more often associated with the magnetically dominated outer layers of the Sun; the upper chromosphere, transition region and corona. However, in regions of strong flux emergence, where Solar active regions are being formed, one can see evidence of photospheric reconnection as the field struggles to emerge through the nonbuoyant photosphere and expand into the atmosphere above. Ellerman bombs, short lived, brightness enhancements in the outer wings of strong optical lines are thought to be a result of such reconnection. Observations made with the NASA's Interface Region Imaging Spectrograph, showed similar 'UV bursts' in lines usually associated with the outer Solar atmosphere, while at the same time clearly being situated below much cooler gas. We here present a numerical model of flux emergence in which both Ellerman bombs and perhaps IRIS bombs (UV bursts) are naturally and copiously produced.

Unraveling the Complexity of the Evolution of the Sun's Photospheric Magnetic Field

Author(s): Hathaway, David H.
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Given the emergence of tilted, bipolar active regions, surface flux transport has been shown to reproduce much of the complex evolution of the Sun's photospheric magnetic field. Surface flux is transported by flows in the surface shear layer – the axisymmetric differential rotation and meridional flow and the non-axisymmetric convective motions (granules, supergranules, and giant cells). We have measured these flows by correlation tracking of the magnetic elements themselves, correlation tracking of the Doppler features (supergranules), and by direct Doppler measurements using SDO/HMI data. These measurements fully constrain (with no free parameters) the flows used in our surface flux transport code – the Advective Flux Transport or AFT code. Here we show the up-to-date evolution of these flows, their impact on the detailed evolution of the Sun's photospheric magnetic field, and predictions for what the polar fields will be at the next minimum in 2020.

Comparing Travel Times within a Coronal Hole to the Quiet Sun

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Time-distance helioseismology studies perturbations in solar wave modes. We use these techniques with SDO/HMI time-distance velocity tracked data to investigate differences between f-mode wave propagation within a coronal hole feature and without. We use symmetry arguments to enhance the signal-to-noise ratio of the crosscorrelation results. We then look for phase discrepancies and signatures of backscattering across the coronal hole boundary, and compare travel times for the region within the coronal hole to a quiet sun region.

Towards a Physics-Based Flare Irradiance Model

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The Extreme UltraViolet (EUV) irradiance from solar flares is a critical driver of short term variability in the Earth's upper atmosphere. The EUV Variability Experiment (EVE) onboard NASA's Solar Dynamics Observatory (SDO) has been making moderate spectral resolution (0.1 nm), high time cadence (10 s) measurements of the solar EUV irradiance (5-105 nm) since 2010. A key observation from EVE is that flares of the same magnitude at one wavelength (e.g. GOES XRS) have different peak intensities and time profiles in other wavelengths. As it is impractical to measure the entire EUV spectrum with sufficient spectral resolution and temporal cadence to capture these differences for space weather operations, the next generation of flare irradiance models must be able to capture these variations. We have developed a framework for a physics-based flare irradiance model based on the EBTEL model. At present, this Multi-Strand Flare Irradiance Model (MS-FIM) is able to predict EUV lightcurves over a range of coronal temperatures given the lightcurves from two EVE lines as inputs. In this paper, we present an overview of the Multi-Strand Flare Irradiance Model as well as initial results showing its ability to predict the irradiances for a diverse range of flares, including EUV late phase flares. We also describe preliminary efforts to drive the model with parameters derived from images of the flaring region instead of EUV lightcurves.

Vector Magnetic Field Synoptic Maps from HMI

Author(s): Hoeksema, J. Todd; Liu, Y.ang; Sun, Xudong; Hayashi, Keiji
Affiliation(s): Stanford University, Stanford, CA

The Helioseismic and Magnetic Imager (HMI) project has made full-disk vector magnetograms every 12 minutes since beginning of regular operation in May 2010. Synoptic maps of the vector magnetic field that cover most of Solar Cycle 24 have now been created. Like previously created line-of-sight synoptic maps, the size in longitude and sine-latitude is 3600 x 1440. Maps of radial and horizontal field components are created from near-central-meridian observations that combine data from 20 full-disk magnetograms. We compare the effects on synoptic maps of using different methods for determining the disambiguation in weak-field regions – annealing, random, radial acute, and potential field. Data in the polar regions is of high quality. We compare these new maps with standard line-of-sight synoptic maps. Next steps include generation of more frequent vector-field synchronic frames.

On-orbit Performance and Calibration of the HMI Instrument

Author(s): Hoeksema, J. Todd; Bush, Rock; HMI Calibration Team
Affiliation(s): Stanford University (mostly), Stanford, CA

The Helioseismic and Magnetic Imager (HMI) on the Solar Dynamics Observatory (SDO) has observed the Sun almost continuously since the completion of commissioning in May 2010, returning more than 100,000,000 filtergrams from geosynchronous orbit. Diligent and exhaustive monitoring of the instrument's performance ensures that HMI functions properly and allows proper calibration of the full-disk images and processing of the HMI observables. We constantly monitor trends in temperature, pointing, mechanism behavior, and software errors. Cosmic ray contamination is detected and bad pixels are removed from each image. Routine calibration sequences and occasional special observing programs are used to measure the instrument focus, distortion, scattered light, filter profiles, throughput, and detector characteristics. That information is used to optimize instrument performance and adjust calibration of filtergrams and observables.

Project for Solar-Terrestrial Environment Prediction (PSTEP): Towards Predicting Next Solar Cycle

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It is believed that the longer-term variations of the solar activity can 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 activity level of the next solar cycle is a key for the long-term space weather study. Although three-year prediction can be almost achieved, the prediction of next solar cycle is very limited, so far. We are developing a five-years prediction scheme by combining the Surface Flux Transport (SFT) model and the most accurate measurements of solar magnetic fields as a part of the PSTEP (Project for SolarTerrestrial Environment Prediction),. We estimate the meridional flow, differential rotation, and turbulent diffusivity from recent modern observations (Hinode and Solar Dynamics Observatory). These parameters are 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. We also report the present status and the future perspective of our project.

What would you like to see next from the Helioviewer Project?

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This year saw the release of major new upgrades to the capabilities of helioviewer.org and JHelioviewer. We review the new features of this software and report our latest usage statistics. We will also be soliciting bug reports, requests for new features and comments on the effectiveness of helioviewer.org and JHelioviewer. What would you like to see next from the Helioviewer Project?

AWARE - The Automated EUV Wave Analysis and REduction algorithm

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Extreme ultraviolet (EUV) waves are large-scale propagating disturbances observed in the solar corona, frequently associated with coronal mass ejections and flares. Since their discovery over two hundred papers discussing their properties, causes and physics have been published. However, their fundamental nature and the physics of their interactions with other solar phenomena are still not understood. To further the understanding of EUV waves, and their relation to other solar phenomena, we have constructed the Automated Wave Analysis and REduction (AWARE) algorithm for the detection of EUV waves over the full Sun. The AWARE algorithm is based on a novel image processing approach to isolating the bright wavefront of the EUV as it propagates across the corona. AWARE detects the presence of a wavefront, and measures the distance, velocity and acceleration of that wavefront across the Sun. Results from AWARE are compared to results from other algorithms for some well-known EUV wave events. Suggestions are also give for further refinements to the basic algorithm presented here.

Motions Near and Above the Solar Surface captured in the SDO Era

Author(s): Jess, David B.
Affiliation(s): Queen's University Belfast

Since its launch in 2010, the Solar Dynamics Observatory has helped make rapid progress in the detection, identification, characterization and understanding of dynamic motions near and above the solar surface, ranging from the photosphere through to the outermost extremities of the solar corona. The ability to capture a variety of solar features through optical and extreme-ultraviolet filters at high spatial and temporal resolutions has allowed for unprecedented studies of both large- and small-scale phenomena, including those present in sunspot umbrae/penumbrae, filaments, plumes and coronal loops. Here I will outline some of the landmark publications that have employed crucial SDO observations, before highlighting some of the most recent results concerning dynamic phenomena in our Sun’s atmosphere.

Data Constrained Coronal Mass Ejections in A Global Magnetohydrodynamics Model

Author(s): M. Jin(1,2), W. B. Manchester(3), B. van der Holst(3), I. Sokolov(3), G. Toth(3), R. E. Mullinix(4), A. Taktakishvili(4,5), A. Chulaki(4), and T. I. Gombosi(3)
Affiliation(s): (1) Lockheed Martin/SAL; (2) UCAR; (3) CLaSP, University of Michigan; (4) CCMC, NASA; (5) Catholic University of America

We present a first-principles-based coronal mass ejection (CME) model suitable for both scientific and operational purposes by combining a global magnetohydrodynamics (MHD) solar wind model with a flux ropedriven CME model. Realistic CME events are simulated self-consistently with high fidelity and forecasting capability by constraining initial flux rope parameters with observational data from GONG, SDO/HMI, SOHO/LASCO, and STEREO/COR. We automate this process so that minimum manual intervention is required in specifying the CME initial state. With the newly developed data-driven Eruptive Event Generator Gibson-Low (EEGGL), we present a method to derive Gibson-Low (GL) flux rope parameters through a handful of observational quantities so that the modeled CMEs can propagate with the desired CME speeds near the Sun. A test result with CMEs launched with different Carrington rotation magnetograms are shown. Our study shows a promising result for using the first-principles-based MHD global model as a forecasting tool, which is capable of predicting the CME direction of propagation, arrival time, and ICME magnetic field at 1 AU.

On the Formation Mechanism of a Long-lived Polar Crown Cavity

Author(s): Karna, Nishu (1,2); Pesnell, William D. (1); Zhang, Jie (2)
Affiliation(s): (1) NASA Goddard Space Flight Center; (2) George Mason University

We report the study of the longest-lived polar crown cavity of Solar Cycle 24th observed in the year 2013 and propose a physical mechanism to explain the sustained existence. We used high temporal and spatial resolution observations from the Atmospheric Imaging Assembly (AIA) and the Helioseismic Magnetic Imager (HMI) instruments on board the Solar Dynamics Observatory (SDO) to explore the structure and evolution. We examined the circumpolar cavity in great detail from March 21, 2013, till October 31, 2013, while it existed for more than one year. Our study suggests two necessary conditions to form a long stable circumpolar cavity or any polar crown cavity. First, the underlying polarity inversion line (PIL) of the circumpolar cavity is formed between the trailing part of dozens of decayed active regions distributed in different longitudes and the unipolar magnetic field in the polar coronal hole. Second, the long life of the cavity is sustained by the continuing flux cancellation along the polarity inversion line. The flux is persistently transported toward the polar region through surface meridional flow and diffusion, which also leads to the shrinking of the polar coronal hole. Comparing with the existing theory of the formation of polarity inversion lines, we introduce a new category named as “Diffused trailing flux and polar coronal hole interaction region” to explain the polar crown cavity. The existence of such region also helps explain the process of polar reversal, which provides insight into the solar cycle.

The Discovery of an Electron Current at Earth's McIlwain L=6

Author(s): A. C. Katsiyannis (1), M. Dominique (1), V. Pierrard(2), K. Borremans(2), J. De Keyser(2), D. Berghmans (1), M. Kruglanski (2), I. Dammasch (1), E. De Donder (2)
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The Large Yield RAdiometer (LYRA) is an ultraviolet solar radiometer on-board ESA's PROBA2 microsatellite. Since its launch in 2009 to an altitude of 735km, one of the most peculiar and intriguing results of LYRA is the detection of short, strong, bursts that do not directly correlate with solar coronal events, nor with pointing of the instrument to Earth's upper atmosphere, but correlate well with high a_p index on Earth's surface and the crossing by the satellite of the L=6 shell. Very similar detections were more recently made by the Energetic Particles Telescope (EPT) on board the PROBA-V micro-satellite, establishing the identification of the detections as relativistic electrons of the 2.4-8 MeV energy range. Several attributes of those detections, including their dependency to various space weather indexes (ap, D_st, etc), their geographical distribution, a dawn/dusk asymmetry and others will be presented. Open questions related to the discovery of this phenomenon will also be discussed.

Determining ICME Magnetic Field Orientation with the ForeCAT In Situ Data Observer

Author(s): Kay, Christina (1); Gopalswamy, N. (1); Reinard, A. (2); Opher, M. (3)
Affiliation(s): NASA GSFC (1); University of Colorado – Boulder/NOAA (2); Boston University (3)

CMEs drive the strongest space weather events at Earth and throughout the solar system. At Earth, the amount of southward magnetic field in a CME is a major component in determining the severity of an impact. We present results from ForeCAT (Forecasting a CME's Altered Trajectory, Kay et al. 2015), which predicts the deflection and rotation of CMEs based on magnetic forces determined by the background magnetic field. Using HMI magnetograms to reconstruct the background magnetic field and AIA images to constrain the early evolution of CMEs, we show that we can reproduce the deflection and rotation of CMEs observed in the corona. Using this CME location and orientation from ForeCAT results and a simple force-free flux rope model we show that we can reproduce the in situ magnetic profiles of Earth-impacting CMEs. We compare these results with the in situ profiles obtained assuming that no deflection or rotation occurs, and find that including these nonradial effects is essential for accurate space weather forecasting.

Estimating and Separating Noise from AIA Images

Author(s): Kirk, Michael S. (1); Ireland, Jack (2); Young, C. Alex (3); Pesnell, W. Dean (3)
Affiliation(s): (1) NASA GSFC / CUA; (2) NASA GSFC / Adnet; (3) NASA GSFC

All digital images are corrupted by noise and SDO AIA is no different. In most solar imaging, we have the luxury of high photon counts and low background contamination, which when combined with carful calibration, minimize much of the impact noise has on the measurement. Outside high-intensity regions, such as in coronal holes, the noise component can become significant and complicate feature recognition and segmentation. We create a practical estimate of noise in the high-resolution AIA images across the detector CCD in all seven EUV wavelengths. A mixture of Poisson and Gaussian noise is well suited in the digital imaging environment due to the statistical distributions of photons and the characteristics of the CCD. Using state-of-the-art noise estimation techniques, the publicly available solar images, and coronal loop simulations; we construct a maximum-aposteriori assessment of the error in these images. The estimation and mitigation of noise not only provides a clearer view of large-scale solar structure in the solar corona, but also provides physical constraints on fleeting EUV features observed with AIA.

Subsurface Zonal and Meridional Flows from SDO/HMI

Author(s): Komm, Rudolf (1); Howe, Rachel (2); Hill, Frank (1)
Affiliation(s): (1) National Solar Observatory; (2) University of Birmingham

We study the solar-cycle variation of the zonal and meridional flows in the near-surface layers of the solar convection zone from the surface to a depth of about 16 Mm. The flows are determined from SDO/HMI Dopplergrams using the HMI ring-diagram pipeline. The zonal and meridional flows vary with the solar cycle. Bands of faster-than-average zonal flows together with more-poleward-than-average meridional flows move from mid-latitudes toward the equator during the solar cycle and are mainly located on the equatorward side of the mean latitude of solar magnetic activity. Similarly, bands of slower-than-average zonal flows together with less-poleward-than-average meridional flows are located on the poleward side of the mean latitude of activity. Here, we will focus on the variation of these flows at high latitudes (poleward of 50 degree) that are now accessible using HMI data. We will present the latest results.

Temporal Changes of pModes Properties Derived from Nearly 20 Year of Observations

Author(s): Sylvain G. Korzennik
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I present a detailed comparison of the temporal changes of the characteristics of the low and intermediate pmodes oscillations derived from nearly 20 years of observations acquired from three instruments: GONG, MDI and HMI. These characteristics were estimated using three quite different data reduction pipe-lines. The comparisons are both at the level of mode characteristics (frequency, linewidth, amplitude and asymmetry) and at the level of inferred properties of the solar interior (i.e., changes in the solar internal rotation), and for co-eval observations.

The Efffect of Image Apodization on Global Mode Parameters and Rotational Inversions

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It has long been known that certain systematic errors in the global mode analysis of data from both MDI and HMI depend on how the input images were apodized. Recently it has come to light, while investigating a six-month period in f-mode frequencies, that mode coverage is highest when B0 is maximal. Recalling that the leakage matrix is calculated in the approximation that B0=0, it comes as a surprise that more modes are fitted when the leakage matrix is most incorrect. It is now believed that the six-month oscillation has primarily to do with what portion of the solar surface is visible. Other systematic errors that depend on the part of the disk used include high-latitude anomalies in the rotation rate and a prominent feature in the normalized residuals of odd a-coefficients. Although the most likely cause of all these errors is errors in the leakage matrix, extensive recalculation of the leaks has not made any difference. Thus we conjecture that another effect may be at play, such as errors in the noise model or one that has to do with the alignment of the apodization with the spherical harmonics. In this poster we explore how differently shaped apodizations affect the results of inversions for internal rotation, for both maximal and minimal absolute values of B0.

Quantitative Estimation of the Energy Flux during an Explosive Chromospheric Evaporation in a White Light Flare Kernel Observed by Hinode, IRIS, SDO, and RHESSI

Author(s): Kyoung-Sun Lee (1); Shinsuke Imada (2); Watanabe Kyoko (3); Yumi Bamba (4); David H. Brooks (5)
Affiliation(s): (1) NAOJ; (2) Nagoya University; (3) National Defense Academy of Japan; (4) ISAS/JAXA; (5) George Mason University

An X1.6 flare occurred at the AR 12192 on 2014 October 22 at14:02 UT was observed by Hinode, IRIS, SDO, and RHESSI. We analyze a bright kernel which 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 found that explosive evaporation was observed when the WL emission occurred, even though the intensity enhancement in hotter lines is quite weak. The temporal correlation of the WL emission, HXR peak, and evaporation flows indicate that the WL emission was produced by accelerated electrons. To understand the white light emission processes, we calculated the deposited energy flux from the non-thermal electrons observed by RHESSI and compared it to the dissipated energy estimated from the chromospheric line (Mg II triplet) observed by IRIS. The deposited energy flux from the non-thermal electrons is about 3.1 × 1010erg cm−2 s−1 when we consider a cut-off energy 20 keV. The estimated energy flux from the temperature changes in the chromosphere measured from the Mg II subordinate line is about 4.6−6.7×109erg cm−2 s−1, ∼ 15−22% of the deposited energy. By comparison of these estimated energy fluxes we conclude that the continuum enhancement was directly produced by the non-thermal electrons.

Influence of the Sun on the Space Weather Conditions: Cycle 24 Observations from 1 AU to Mars

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Motivated by future crewed missions to Mars, there is a growing need to advance our knowledge of the heliospheric conditions between the Earth (~1 AU) orbit and Mars (~1.5 AU) orbit locations. Comparative conditions at these locations are of special interest since they are separated by the interplanetary region where most solar wind stream interaction regions develop. These regions alter the propagation of solar-heliospheric disturbances, including the interplanetary CME-driven shocks that create the space radiation (via solar energetic particles) that are hazardous to humans. Although the deep Cycle 23 minimum and the modestly active Cycle 24 maximum have produced generally weaker solar events and heliospheric conditions, observations from solar and planetary missions during the SDO era provide a unique opportunity to study how and to what extent the solar eruptive events impact the local space environments at Earth (and/or STEREO-A) and Mars, and for a given solar-heliospheric event period how the geospace and near-Mars space conditions compare and contrast with one another. Such observations include those from SDO, L1 observers (ACE,WIND,SOHO) and STEREO-A at 1 AU, and Mars Express, MSL, and MAVEN at ~1.5 AU. Using these observations, we will highlight a number of Cycle 24 space weather events observed along the 1-AU orbit (at Earth and/or STEREO-A) and Mars that are triggered by CMEs, SEPs, flares, and/or CIRs. Numerical 3D simulations from WSA-Enlil-cone will also be presented to provide global context to the events discussed.

Direct Imaging of a Classical Solar Eruptive Flare

Author(s): Li, Y.(1,2); Sun, X. D.(3); Ding, M. D.(1); Qiu, J.(2); Priest, E. R. (4); Longcope, D. W.(2)
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Solar flares are the most energetic events in the solar system that have a potential hazard on Earth. Although a standard model for the eruptive flare accompanied by a coronal mass ejection has been outlined and elaborated for decades, some key aspects are still under debate, such as what drives the eruption, what is the role of magnetic reconnection, and how the flare loops evolve. Here we present an excellent event exhibiting nearly all the key elements involved in the standard flare model. Using extreme-ultraviolet imaging observations, we detect the unambiguous rise and eruption of a magnetic flux rope, solid evidence for magnetic reconnection, and evident slipping and rising motions in flare loops. Modeled coronal magnetic field supports the interpretation of a preexisting flux rope that persists after the eruption with reduced twist. This flare, from the observational view, shows a clear and comprehensive picture of how a classical solar eruptive flare occurs and evolves, and helps to clarify some of the controversial topics in the standard flare model.

Are Dynamical Sources Essential for the Production of the Ambient Solar Wind?

Author(s): Linker, Jon; Downs, Cooper; Lionello, Roberto; Titov, Viacheslav; Caplan, Ronald; Riley, Pete; Mikic, Zoran
Affiliation(s): Predictive Science Inc., San Diego, CA

At a basic level, the large structure of the solar corona and its connection to the solar wind has been known for many years. In the classic (near-solar minimum) picture, the slow solar wind is associated with the streamer belt at low latitudes, while the fast solar wind arises from coronal holes at higher latitudes. At a deeper level, important aspects of this connection still puzzle us. One such controversy is the origin of the slow solar wind. One group of theories assume that the slow wind primarily arises quasi-statically from regions of large expansion factor near the boundaries of coronal holes, while a contrasting set of theories argue that the slow solar wind is primarily dynamic in origin and involves the reconnection and exchange of open and closed fields. In this talk, we describe evidence for both sets of theories, and ongoing and future work that may help to resolve this question.
Work supported by NASA, NSF and AFOSR.

Modeling the Energization and Eruption of Flux Ropes and Sheared Arcades

Author(s): Linton, Mark G.
Affiliation(s): Naval Research Laboratory, Washington DC

Solar magnetic eruptions are dramatic sources of solar activity, and dangerous sources of space weather hazards. Observations of the solar photosphere and overlying atmosphere by the Solar Dynamics Observatory have given us new views, measurements, and modeling constraints for understanding these eruptions. This presentation will review the current state of the art in modeling the energization and eruption of sheared magnetic arcades and of magnetic flux ropes in the corona, and will review the critical role that observations play in the motivation, development, and application of these models.

The Thermodynamics of Coronal Jets and Their Contribution to the Solar Wind

Author(s): Lionello, Roberto (1); Török, Tibor (1); Titov, Viacheslav (1); Linker, Jon A. (1); Mikic, Zoran (1); Leake, James E. (2); Linton, Mark (2)
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Coronal (or X-ray) jets are transient, collimated plasma eruptions that are observed low in the corona in EUV and soft X-ray bands. It is widely accepted that they are triggered by reconnection between closed and open magnetic fields, but their detailed formation mechanisms are still under debate. Since coronal jets are often seen to extend to several solar radii, it has been suggested that they may contribute to powering the solar wind, but the amount of this contribution remains largely uncertain. Here we present the first MHD simulations of coronal jets that include the solar wind and a realistic description of the energy transfer in the corona ("thermodynamic MHD"). The evolution in our model is driven by the emergence of a magnetic flux rope into an open magnetic field. We find different types of jets in our simulations, and discuss their respective formation mechanisms, morphologies, and emission properties. We also analyze their energy and mass contributions to the solar wind, and compare them with existing estimations obtained from observations.

What Produce Energetic Flares with X-Shaped Ribbons on the Outskirts of Solar Active Region?

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Typical solar flares display two quasi-parallel, bright ribbons on the chromosphere. In between is the polarity inversion line separating concentrated magnetic fluxes of opposite polarities in active regions (ARs). Intriguingly a series of flares exhibiting X-shaped ribbons occur at the similar location on the outskirts of NOAA AR 11967, where magnetic fluxes are scattered, yet three of them are alarmingly energetic. The X shape is similar in UV/EUV with hard X-ray emission projected in the center, which cannot be accommodated in the standard flare model. Mapping out magnetic connectivities in potential fields, we found that the X morphology is dictated by the intersection of two quasi-separatrix layers, i.e., a hyperbolic flux tube (HFT), within which a separator connecting a double null is embedded. This topology is not purely local but regulated by fluxes and flows over the whole AR. The nonlinear force-free field model suggests the formation of a current layer at the HFT, where the current dissipation can be mapped to the X-shaped ribbons via field-aligned heat conduction. These results highlight the critical role of structural skeletons in 3D magnetic reconnection.

Joint SDO and IRIS Observations of a Novel, Hybrid Prominence-Coronal Rain Complex

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Solar prominences and coronal rain are intimately related phenomena, both involving cool material at chromospheric temperatures within the hot corona and both playing important roles as part of the return flow of the chromosphere-corona mass cycle. At the same time, they exhibit distinct morphologies and dynamics not yet well understood. Quiescent prominences consist of numerous long-lasting, filamentary downflow threads, while coronal rain is more transient and falls comparably faster along well-defined curved paths. We report here a novel, hybrid prominence-coronal rain complex in an arcade-fan geometry observed by SDO/AIA and IRIS, which provides new insights to the underlying physics of such contrasting behaviors. We found that the supra-arcade fan region hosts a prominence sheet consisting of meandering threads with broad line widths. As the prominence material descends to the arcade, it turns into coronal rain sliding down coronal loops with line widths 2-3 times narrower. This contrast suggests that distinct local plasma and magnetic conditions determine the fate of the cool material, a scenario supported by our magnetic field extrapolations from SDO/HMI. Specifically, the supra-arcade fan (similar to those in solar flares; e.g., McKenzie 2013) is likely situated in a current sheet, where the magnetic field is weak and the plasma-beta could be close to unity, thus favoring turbulent flows like those prominence threads. In contrast, the underlying arcade has a stronger magnetic field and most likely a low-beta environment, such that the material is guided along magnetic field lines to appear as coronal rain. We will discuss the physical implications of these observations beyond prominence and coronal rain.

Flare-associated Fast-mode Coronal Wave Trains Detected by SDO/AIA: Recent Observational Advances

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Quasi-periodic Fast Propagating wave trains (QFPs) are new observational phenomena discovered by SDO/AIA in extreme ultraviolet (EUV). They were interpreted as fast-mode magnetosonic waves using MHD modeling, and also found to be closely related to quasi-periodic pulsations in solar flare emission ranging from radio to X-ray wavelengths. The significance of QFPs lies in their diagnostic potential (and possibly in flare energy transport), because they can provide critical clues to flare energy release and serve as new tools for coronal seismology. In this presentation, we report recent advances in observing QFPs. In particular, using differential emission measure (DEM) inversion, we found clear evidence of heating and cooling cycles that are consistent with alternating compression and rarefaction expected for magnetosonic wave pulses. We also found that different local magnetic and plasma environments can lead to two distinct types of QFPs located in different spatial domains with respect to their accompanying coronal mass ejections (CMEs). More interestingly, from a statistical survey of over 100 QFP events, we found a preferential association with eruptive flares rather than confined flares. We will discuss the implications of these results and the potential roles of QFPs in coronal heating, energy transport, and solar eruptions.

Evolution and Distribution of Electric Currents in Solar Active Regions

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It is now well established that solar eruptions are powered by the free energy stored in electric currents in the corona, but it remains an open question to which degree those currents are neutralized (i.e., shielded by return currents). While the degree of current neutralization appears to be closely related to the capability of active regions to produce eruptions, this relationship has not yet been investigated. In this work, we use HMI vector magnetic field data to study evolution and distribution of electric currents in several selected active regions, and further explore difference in quiet and eruptive active regions. We will also place a discussion on whether current-neutralization affects onset of CMEs.

Understanding the Physical Nature of Coronal "EIT Waves"

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For almost 20 years the physical nature of globally-propagating waves in the solar corona (commonly called "EIT waves") has been controversial and subject to debate. Additional theories have been proposed throughout the years to explain observations that did not fit with the originally proposed fast-mode wave interpretation. However, the incompatibility of observations made using the Extreme-ultraviolet Imaging Telescope (EIT) on the Solar and Heliospheric Observatory with the fast-mode wave interpretation have been challenged by differing viewpoints from the Solar Terrestrial Relations Observatory spacecraft and higher spatial/temporal resolution data from the Solar Dynamics Observatory. In this paper, we reexamine the theories proposed to explain "EIT waves" to identify measurable properties and behaviours that can be compared to current and future observations. Most of us conclude that "EIT waves" are best described as fastmode large-amplitude waves/shocks, which are initially driven by the impulsive expansion of an erupting coronal mass ejection in the low corona.

Measuring the Magnetic Field of a Trans-equatorial Loop System using Coronal seismology

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Affiliation(s): University College London/MSSL

First observed by SOHO/EIT, "EIT waves" are strongly associated with the initial evolution of coronal mass ejections (CMEs) and after almost 20 years of investigation a consensus is being reached which interprets them as freely-propagating waves produced by the rapid expansion of a CME in the low corona. An "EIT wave" was observed on 6 July 2012 to erupt from active region AR11514 into a particularly structured corona that included multiple adjacent active regions as well as an adjacent trans-equatorial loop system anchored at the boundary of a nearby coronal hole. The eruption was well observed by SDO/AIA and CoMP, allowing the effects of the "EIT wave" on the trans-equatorial loop system to be studied in detail. In particular, it was possible to characterise the oscillation of the loop system using Doppler velocity measurements from CoMP. These Doppler measurements were used to estimate the magnetic field strength of the trans-equatorial loop system via coronal seismology. It was then possible to compare these inferred magnetic field values with both extrapolated magnetic field values from a Potential Field Source Surface extrapolation as well as the direct measurements of magnetic field provided by CoMP. These results show that the magnetic field strength of loop systems in the solar corona may be estimated using loop seismology.

Successive CMEs, Particle Acceleration and Geo-Effective Events

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Series of coronal mass ejections (CMEs) may be associated with sympathetic, homologous or unrelated eruptions. Previous works have shown that the presence of a previous CME before a fast, wide and western limb CME increases the likelihood of having a large solar energetic particle events. In addition, successive CMEs can now be tracked through coronagraphs and heliospheric imagers and their interaction studied. Such interacting CMEs often result in strong geo-effects. Here, we present some coronal and heliospheric observations of successive CMEs and discuss which kind of eruptions results in more geo-effective CMEs.

Large-Amplitude Oscillations in Prominences

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Large-amplitude oscillations in prominences are among the most spectacular phenomena of the solar atmosphere. Such an oscillations involve motions with velocities above 20 km/s, and large portions of the filament that move in phase. These are triggered by energetic disturbances as flares and jets. The AIA/SDO instrument offers an unprecedented view of the processes that trigger the oscillations and the subsequent dynamics. These oscillations are an excellent tool to probe the not directly measurable filament morphology. In addition, the damping of these motions can be related with the process of evaporation of chromospheric plasma associated to coronal heating. In these talk I will review recent observational and theoretical progress on large amplitude seismology on prominences.

The New SDO/EVE Coronal Dimming Catalog

Author(s): Mason, James Paul; Woods, Thomas N
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Coronal dimmings are hours-long voids in the solar corona that can be indicative of plasma density depletion from CMEs. Much prior work has established the theoretical case for this link – tying the emission measure to the mass of the departing CME. These studies have always relied primarily on spectral images of the corona (e.g., SDO/AIA). Our recent work has demonstrated that coronal dimming is observable with irradiance data using SDO/EVE, which can provide higher temperature resolution than relatively broadband spectral imagers. We extend our prior studies which focused on a handful of events to the entire 4 history of SDO/EVE/MEGS-A data, which includes hundreds to thousands of events. We characterize the dimming light curves in terms of dimming depth and slope and compare this statistically sized sample to CME masses and speeds determined with SOHO/LASCO coronagraph data in the CDAW catalog. We will present preliminary statistics on this new extensive dimming catalog and its comparison to the CDAW CME catalog.

Inferring Magnetic Fields and Electron Densities from Coronal Seismology

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The solar corona oscillates at many different spatial sizes and temporal size scales. However, much remains unknown about many of these oscillations: they are intermittent for unknown reasons; appear on some coronal features and not on others; and may, or may not, be magnetohydrodynamic (MHD) wave modes. Using a series of automated oscillation detection routines, we extract space-time-density maps from a quagmire of oscillating loops. From these data products, we extract coronal magnetic fields and densities in order to to differentiate between potential excitation mechanisms and between potential damping mechanisms. The spread of periods, amplitudes, and damping times, allow us to map the spatial distribution of these parameters. Initial periods of P~300-500s, result in inferred coronal magnetic field of B~20G-50G. The decrease in the oscillation period of the loop position corresponds to a drop in number density inside each coronal loop, as predicted by MHD. As the the period drops below a threshold of P~300s, our MHD model cannot explain the sudden observed decrease in both period and density and so a secondary dissipation mechanism must occur at this point in time and space.

Quasi-Periodic Pulsations in Hydrogen Emission during Solar Flares

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There have been increasing reports of quasi-periodic pulsations (QPPs) during solar flares in the literature recently. These recurrent variations in intensity have been detected over a wide range of wavelengths, most prevalently in X-rays and radio waves. The nature of these pulsations is still in dispute but they are widely agreed to be evidence for either a form of periodic driver of nonthermal electrons (such as magnetic reconnection) or magnetohydrodynamic oscillations. Flare observations of QPPs at EUV wavelengths have been scarce in recent years, and those in the literature are often derived from broadband measurements leaving some ambiguity as to whether the periodic behavior was occurring in the line(s) or the continuum. Here we present evidence for synchronous QPPs in the Lyman continuum (from SDO/EVE) and the Lyman-alpha line (from GOES/EUVS) during the well-studied 15 February 2011 X-class flare. The data were detrended using a Savitzky-Golay filter to reveal a periodicity of 2-3 minutes during the impulsive phase. Similar values were found in the SDO/AIA 1600A and 1700A channels despite being saturated, although no such evidence was found in the higher order Lyman lines (Lyman-beta, Lyman-gamma, Lyman-delta, etc). The formation temperature of the Lyman series of hydrogen suggests this emission is coming from the chromospheric footpoints, implying a quasi-periodic heating response due to a bursty energy release mechanism in the corona.

A Method for Finding Solar Flares Jointly Observed by Multiple Instruments

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Our current fleet of space-based solar observatories offer us a wealth of opportunities to study solar flares over a range of wavelengths, and the greatest advances in our understanding of flare physics often come from coordinated observations between different instruments. However, finding or keeping track of which flares have been observed by specific combinations of instruments can be cumbersome and time consuming. To alleviate this issue, and provide access to a broader range of flaring events observed by GOES, RHESSI, Hinode (EIS, SOT, and XRT), SDO/EVE (MEGS-A and MEGS-B), and IRIS, a new interface has been developed and incorporated into SSWIDL (IDL> solar_flare_finder). This tool allows the user to search for solar flares that have been observed by a chosen combination of instruments in order to answer a specific science question. The user can also narrow their search by GOES class, location on the solar disk, maximum energy observed by RHESSI, etc. The routine searches a pre-generated lookup table to instantly return a list of events conforming to the user's specifications, along with a (downloadable) plot of the flare lightcurves (GOES and RHESSI) with the timing of longer wavelength observations overlaid. A RHESSI quicklook image is also shown along with the pointing information of other instruments. Future improvements to the solar_flare_finder service will include adding flares that were not observed by RHESSI, adding additional instruments (e.g. Fermi, NoRH, GOES/EUVS, etc), and direct access to the data itself. This tool also enables us to determine how many flares have been co-temporally and co-spatially observed by various combinations of instruments over the current solar cycle. We present and discuss these statistics.

Solar Acoustic Oscillations Observations in SDO AIA and HMI around AR 12192

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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 such mode is to observe flares in different frequency bands at different depths and study their temporal evolution through the flaring event. In this project we obtain acoustic observations of an X3 flare occurring on October 24, 2014 at 21:41UT. We employ the study of active regions, near sunspots, in which flaring activity is taking place. 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 compare the measurements to magnetograms to search for any correlation, we combine observations of oscillations in three SDO AIA wavelengths: the 1600Å, 1700 Å and 304Å, and combine them with HMI data. We then study how the frequency distribution evolves temporally by constructing a Power Map Movie (PMM) of the regions. From these PMMs we can partition sub-regions in our main flaring region and take a survey of the oscillations for each frequency band.

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

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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) 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 ⌷-loop fields of an ongoing sunspot cycle is swept poleward to cancel and replace the oppositepolarity 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 ongoingcycle 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 of the above title and authors, giving a full description of the solar dynamo scenario of this, is available at 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.

A Class of 3-Dimensional MHD Models for Coronal Bright Points

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The coronal bright points (CBPs) are classical features in solar physics: their first detection, in X Rays, dates back to almost half a century ago. They are also observed in the EUV, have lifetimes in a wide range between several minutes and a few days, and typical size 20 to 30 arc seconds. The recent space missions (like SDO) have provided a wealth of detailed information about their structure and time evolution. The CBPs seem to be related in many/most cases to processes of magnetic cancellation. The classical theoretical model by Priest et al (1994) explains a number of their features by way of the convergence of opposite-sign magnetic polarities in the photosphere, with ensuing reconnection of the overlying structures in the corona. That model is essentially 2D and, therefore, has clear limitations concerning the mutual photospheric motion of the two polarities. Also, it cannot study the complicated magnetic topology and reconnection patterns associated with three-dimensional null points in an evolving magnetic configuration. In this lecture we present first results of a project of three-dimensional modeling of the evolution of null-point structures overlying network-like magnetic configurations that can plausibly lead to the creation of hot regions in the corona, possibly observable as bright points in the EUV or X-Rays. Our model includes the time evolution of the plasma and magnetic structures from the lower atmosphere to the corona. It is strongly idealized, in that no radiation transfer, thermal conduction, nor partial ionization effects are included. The model solves the compressible MHD equations with, in particular, the electrical current and Lorentz force evolving in a self-consistent manner: no limitation to potential nor force-free structures is imposed. In this lecture, the focus will be set on the basic physical magnetohydrodynamical phenomena taking place in the different levels and regions of the atmosphere included in the model, rather than on providing observational proxies for comparison with satellite data.

The Photospheric Footprints of Coronal Hole Jets

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Coronal jets are transient, collimated ejections of plasma that are a common feature of solar X-ray and EUV image sequences. Of special interest are jets in coronal holes due to their possible contribution to the solar wind outflow. From a sample of 35 jet events I will investigate the photospheric signatures at the footpoints of these jets. White light images from the HMI on board SDO are used to derive the plane-of-sky flow field using local correlation tracking, and HMI magnetograms show the development of the magnetic flux. Both the evolution of the magnetic field and flows allow one to study the photospheric driver of these jets. One particularly interesting example demonstrates that the untwisting jet involves a tiny filament whose eruption is most likely triggered by the emergence of a small magnetic bipole close to one of its legs.

Advances on Our Understanding of Solar Cycle Propagation and Predictability

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As solar cycle 24 winds down and we start looking forward to the coming cycle 25, we are steadily approaching the time in which a new host of solar cycle predictions will be made. The point of this talk is to highlight some of the most important advances in our understanding of cycle propagation and its predictability (made since the last round of cycle predictions). In particular, this presentation will focus on theoretical and observational evidence in favor of a dynamo that relies on active region emergence and decay for its operation, and on evidence of a causal disconnection that takes place between one cycle and the next (making inter-cyclic prediction difficult)

Stealth CMEs and Stealthy Geomagnetic Storms

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We sometimes encounter coronal mass ejections (CMEs) whose low coronal signatures are apparently missing, especially when viewed on the disk. They are called stealth CMEs, which are usually slow and diffuse. Some of them result in medium geomagnetic storms. Similarly, there are orphan interplanetary CMEs (ICMEs) that lack a parent CME in coronagraph data but could cause geomagnetic storms when strong and sustained southward magnetic field is present. In addition, some geomagnetic storms may be attributable to a fast solar wind and stream interaction region, but it is often hard to rule out a trace of ICME (coming from a solar eruption) in in situ data. These events present a major challenge not only in heliophysics research but also in space weather prediction. We summarize our recent attempt to understand the origins of stealth CMEs and stealthy geomagnetic storms, making extensive use of SDO/AIA data in comparison with SOHO/LASCO and STEREO/EUVI/COR data. In situ data from Wind, ACE and STEREO are also examined. We discuss the relations of these events with coronal holes and sector boundaries.

The Cool Surge Following Flux Emergence in a Radiation-MHD Experiment

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Cool and dense ejections, typically Hα surges, often appear alongside EUV or X-ray coronal jets as a result of the emergence of magnetized plasma from the solar interior. Idealized numerical experiments explain those ejections as being indirectly associated with the magnetic reconnection taking place between the emerging and preexisting systems. However, those experiments miss basic elements that can importantly affect the surge phenomenon. In this paper we study the cool surges using a realistic treatment of the radiation transfer and material plasma properties. To that end, the Bifrost code is used, which has advanced modules for the equation of state of the plasma, photospheric and chromospheric radiation transfer, heat conduction, and optically thin radiative cooling. We carry out a 2.5D experiment of the emergence of magnetized plasma through (meso) granular convection cells and the low atmosphere to the corona. Through detailed Lagrange tracing we study the formation and evolution of the cool ejection and, in particular, the role of the entropy sources; this allows us to discern families of evolutionary patterns for the plasma elements. In the launch phase, many elements suffer accelerations well in excess of gravity; when nearing the apex of their individual trajectories, instead, the plasma elements follow quasi-parabolic trajectories with accelerations close to the solar gravity. We show how the formation of the cool ejection is mediated by a wedge-like structure composed of two shocks, one of which leads to the detachment of the surge from the original emerged plasma dome.

HMI Data Corrected for Stray Light Now Available

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The form of the point spread function (PSF) derived for HMI is an Airy function convolved with a Lorentzian. The parameters are bound by observational ground-based testing of the instrument conducted prior to launch (Wachter et al., 2012), by full-disk data used to evaluate the off-limb behavior of the scattered light, as well as by data obtained during the Venus transit. The PSF correction has been programmed in both C and cuda C and runs within the JSOC environment using either a CPU or GPU. A single full-disk intensity image can be deconvolved in less than one second. The PSF is described in more detail in Couvidat et al. (2016) and has already been used by Hathaway et al. (2015) to forward-model solar-convection spectra, by Krucker et al. (2015) to investigate footpoints of off-limb solar flares and by Whitney, Criscuoli and Norton (2016) to examine the relations between intensity contrast and magnetic field strengths. In this presentation, we highlight the changes to umbral darkness, granulation contrast and plage field strengths that result from stray light correction. A twenty-four hour period of scattered-light corrected HMI data from 2010.08.03, including the isolated sunspot NOAA 11092, is currently available for anyone. Requests for additional time periods of interest are welcome and will be processed by the HMI team.

MHD Waves at Umbral-Penumbral Boundary Observed with Hinode/SOTSP and SDO/HMI

Author(s): A. A. Norton (1), T. D. Tarbell (2), P. H. Scherrer (1), C. S. Baldner (1)
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The conversion of p-modes and other perturbations in the near-surface layers into MHD waves that can propagate along and across magnetic field lines is a topic of interest for energy transport. The photospheric signatures of MHD waves are weak due to low amplitudes at the beta=1 equipartion level where modeconversion occurs. We report on oscillations observed with Hinode SOT/SP and HMI in which we have time series for sunspots 12186 (11.10.2014) and 12434 (17.10.2015). In the Milne-Eddington inversion results from SP, oscillations in the inclination angle and velocity are found at the umbral-penumbral boundary with ~5 minute periods. HMI data also shows distinct umbral-penumbral boundary oscillations consistent with the SP data. We discuss surface versus body modes that might explain these observations.

Space Oddities: The Search for Ephemeral Coronal Holes

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Ephemeral coronal holes are short-lived, volatile counterparts to equatorial coronal holes. Very little is known about their characteristics and behavior aside from their definition: open, unipolar magnetic field lines resulting in darkened regions of the corona. The first exemplar of this phenomenon was observed by NASA's Solar Dynamics Observatory (SDO) on October 26, 2010, which spurred our search for other occurrences in order to understand the frequency and evolution of these phenomena. To accomplish this, we visually evaluated SDO 211 Å images on a 12-hour cadence between June 2010 and June 2016. Each compact and isolated dim region we encountered was flagged as a potential ephemeral coronal hole for further analysis. This preliminary effort resulted in 149 candidate holes. For further analysis of their characteristics, we applied a strict definition criterion of an ephemeral coronal hole. This criterion was a set of four factors that were created in order to ensure events being observed were isolated, individual events-- the candidates had to be dark relative to the surrounding material, not influenced by a nearby eruption, not obviously connected to other coronal hole structures, and their lifetime had to occur completely within the disk crossing. This criterion was designed so that events could be completely analyzed, from beginning to end, to better understand the origins. Application of this criterion eliminated all candidates but 5 of the original 149. True ephemeral coronal holes are rare occurrences, appearing only five times in six years. Future research in this area is needed to both locate additional events and study the underlying driving forces behind these rare phenomena.

Coronal and Flare Diagnostic with SDO/AIA-discovered Fast MHD Wave Trains in Active Regions

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Recently, SDO/AIA discovered quasi-periodic, fast-mode propagating MHD wave trains (QFPs) that propagate at high speeds of more than 1000 km/s. The waves provide a new diagnostic tool for coronal seismology that includes information on the flare energy release and the magnetic structure of the active regions. Many events are now available in a statistical study. However, for improved accuracy of coronal seismology, 3D MHD modeling is required and simple wave-mode analysis may be insufficient. We present new results of observationally constrained models of QFPs using our recently upgraded radiative, thermally conductive, visco-resistive 3D MHD code. The waves are excited by time-depended boundary conditions constrained by the spatial (localized) and quasi-periodic temporal evolution of a C-class flare typically associated with QFPs, and produce observable density and temperature fluctuations. We investigate parametrically the excitation, propagation, and damping of the waves for a range of key model parameters, such as the background temperature, density, magnetic field structure, and the location of the flaring site within the active region. We synthesize EUV intensities in multiple AIA channels and then 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 and flare pulsations.

Prediction of in-situ magnetic structure of flux ropes from coronal observations

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Coronal Mass Ejections (CMEs) are built at the Sun as nearly force-free (J x B = 0) magnetic flux ropes. It is well-established that CMEs are the main drivers of intense magnetic storms and various space weather phenomena at Earth. The most important parameter that defines the ability of a CME to drive geomagnetic storms is the north-south magnetic field component. One of the most significant problems in current long-term space weather forecasts is that there is no method to directly measure the magnetic structure of CMEs before they are observed in situ. However, due to their influence on the coronal plasma environment, the magnetic structure of CME flux ropes can be indirectly estimated based on the properties of the source active region and characteristics of the nearby structures, such as filament details, coronal EUV arcades and X-ray sigmoids. We present here a study of two CME flux ropes, aiming at determining their magnetic properties (magnetic helicity sign, flux rope tilt, and direction of the flux rope axial field) when launched from the Sun by using a synthesis of indirect proxies based on multi-wavelength remote sensing observations. In addition, we employ a data-driven magnetofrictional method that models the CME initiation in the corona to determine the magnetic structure in the two case studies. Finally, the predictions given by the observational synthesis and coronal modeling are compared with the structure detected in situ at Earth.

The Solar Dynamics Observatory, Six Years of Science

Author(s): Pesnell, W. Dean
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The Solar Dynamics Observatory has been producing science and science data since May 2010. I will describe some highlights of SDO results, including filament eruptions, flares, and comets. The status of the observatory hardware will also be discussed. The future of SDO will be a series of extended missions, each lasting two years. Our next extended mission proposal will be due early next year and I will discuss part of that process.

The Amplitude of the Deep Solar Convection and the Origin of the Solar Supergranulation

Author(s): Mark Rast
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Recent observations and models have raised questions about our understanding of the dynamics of the deep solar convection. In particular, the amplitude of low wavenumber convective motions appears to be too high in both local area radiative magnetohydrodynamic and global spherical shell magnetohydrodynamic simulations. In global simulations this results in weaker than needed rotational constraints and consequent non solar-like differential rotation profiles. In deep local area simulations it yields strong horizontal flows in the photosphere on scales much larger than the observed supergranulation. We have undertaken numerical studies that suggest that solution to this problem is closely related to the long standing question of the origin of the solar supergranulation. Two possibilities have emerged. One suggests that small scale photospherically driven motions dominate convective transport even at depth, descending through a very nearly adiabatic interior (more nearly adiabatic than current convection models achieve). Convection of this form can meet Rossby number constraints set by global scale motions and implies that the solar supergranulation is the largest buoyantly driven scale of motion in the Sun. The other possibility is that large scale convection driven deep in the Sun dynamically couples to the near surface shear layer, perhaps as its origin. In this case supergranulation would be the largest non-coupled convective mode, or only weakly coupled and thus potentially explaining the observed excess power in the prograde direction. Recent helioseismic results lend some support to this. We examined both of these possibilities using carefully designed numerical experiments, and weigh their plausibilities in light of recent observations.

3D MHD simulation of a Solar Flare

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We present results from a numerical 3D simulation of a solar flare triggered by flux emergence into a preexisting bipolar active region. The simulation is performed with a recently developed version of the MURaM radiative MHD code and includes coronal physics in terms of optically thin radiative loss and field-aligned heat conduction. Severe time-step constraints arising from Alfven wave propagation and heat conduction are avoided through the use of the Boris correction and a hyperbolic treatment of heat conduction. In the simulation we find a flare releasing about 5x10^30 erg over a time of about 1-2 minutes. The efficient transport of energy along field lines leads to the formation of flare ribbons within seconds and at later times to chromospheric evaporation filling coronal flare loops. Since the efficiency of energy transport by electrons (classic heat conduction vs. non-thermal electrons) is one of the main uncertainties, we compare simulations with different values for the saturation of the heat flux. We present synthetic observables in the form of UV, EUV and soft and hard X-ray emission.

Global Energetics of Solar Particle Events

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In a solar eruptive event, energy is released in many forms such flare emissions (X-rays, gamma-rays radio, thermal), kinetic and potential energy in coronal mass ejections and other mass motions, and solar energetic particles (SEPs). New insight into the global energetic of eruptive events may be obtained by incorporating multi-point observations from STEREO, and improved solar observations from SDO. We discuss ongoing efforts to estimate the global energy content of the solar energetic particles (protons, heavy ions and electrons) associated with the 398 M and X class flares that occurred between June, 2010 and January, 2014. A number of challenges will be discussed. In particular, many of these flares do not have a detectable SEP event, or they occur when another SEP event is in progress; only around 14% of these flares have an SEP event at Earth and/or the STEREO spacecraft that is a candidate for this analysis. We also discuss the various corrections that may be made, for example to account for multiple crossings of 1 AU due to scattering, and sources of uncertainty in the energy estimates. We present estimates of the energy in different particle types for a number of these events.

Measuring Flows in the Solar Interior: Current developments, results, and outstanding problems

Author(s): Schad, Ariane
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I will present an overview of the current developments to determine flows in the solar interior and recent results from helioseismology. I will lay special focus on the inference of the deep structure of the meridional flow, which is one of the most challenging problems in helioseismology. In recent times, promising approaches have been developed for solving this problem. The time-distance analysis made large improvements in this after becoming aware of and compensating for a systematic effect in the analysis, the origin of which is not clear yet. In addition to this, a different approach is now available, which directly exploits the distortion of mode eigenfunctions by the meridional flow as well as rotation. These methods have presented us partly surprisingly complex meridional flow patterns, which, however, do not provide a consistent picture of the flow. Resolving this puzzle is part of current research since this has important consequences on our understanding of the solar dynamo. Another interesting discrepancy was found in recent studies between the amplitudes of the large- and small-scale dynamics in the convection zone estimated from helioseismology and those predicted from theoretical models. This raises fundamental questions how the Sun, and in general a star, maintains its heat transport and redistributes its angular momentum that lead, e.g., to the observed differential rotation.

HMI Measured Doppler Velocity Contamination from the SDO Orbit Velocity

Author(s): Scherrer, Phil and the HMI Team
Affiliation(s): Stanford University, Stanford, CA

The Problem: The SDO satellite is in an inclined Geo-sync orbit which allows uninterrupted views of the Sun nearly 98% of the time. This orbit has a velocity of about 3,500 m/s with the solar line-of-sight component varying with time of day and time of year. Due to remaining calibration errors in wavelength filters the orbit velocity leaks into the line-of-sight solar velocity and magnetic field measurements. Since the same model of the filter is used in the Milne-Eddington inversions used to generate the vector magnetic field data, the orbit velocity also contaminates the vector magnetic products. These errors contribute 12h and 24h variations in most HMI data products and are known as the 24-hour problem. Early in the mission we made a patch to the calibration that corrected the disk mean velocity. The resulting LOS velocity has been used for helioseismology with no apparent problems. The velocity signal has about a 1% scale error that varies with time of day and with velocity, i.e. it is non-linear for large velocities. This causes leaks into the LOS field (which is simply the difference between velocity measured in LCP and RCP rescaled for the Zeeman splitting). This poster reviews the measurement process, shows examples of the problem, and describes recent work at resolving the issues. Since the errors are in the filter characterization it makes most sense to work first on the LOS data products since they, unlike the vector products, are directly and simply related to the filter profile without assumptions on the solar atmosphere, filling factors, etc. Therefore this poster is strictly limited to understanding how to better understand the filter profiles as they vary across the field and with time of day and time in years resulting in velocity errors of up to a percent and LOS field estimates with errors up to a few percent (of the standard LOS magnetograph method based on measuring the differences in wavelength of the line centroids in LCP and RCP light). We expect that when better filter profiles are available it will be possible to generate improved vector field data products as well.

SDO/HMI Overview of Recent Findings

Author(s): Scherrer, Phil
Affiliation(s): Stanford University, Stanford, CA

Achieving Consistent Vector Magnetic Field Measurements from SDO/HMI

Author(s): P. W. Schuck (1), Phil Scherrer (2), Spiro Antiochos (1), and Todd Hoeksema (2)
Affiliation(s): (1) NASA GSFC, (2) Stanford University

NASA's Solar Dynamics Observatory (SDO) is delivering vector magnetic field observations of the full solar disk with unprecedented temporal and spatial resolution; however, the satellite is in a highly inclined geosynchronous orbit. The relative spacecraft-Sun velocity varies by ±3 km/s over a day which introduces significant orbital artifacts in the Helioseismic Magnetic Imager (HMI) data. We have recently demonstrated that the orbital artifacts contaminate all spatial and temporal scales in the data and developed a procedure for mitigating these artifacts in the Doppler data obtained from the Milne-Eddington inversions in the HMI Pipeline. Simultaneously, we have found that the orbital artifacts may be introduced by inaccurate estimates for the free-spectral ranges (FSRs) of the optical elements in HMI. We describe our approach and attempt to minimize orbital artifacts in the hmi.V_720 Dopplergram series by adjusting the FSRs for the optical elements of HMI within their measurement uncertainties of ±1%. introduces major orbital artifacts in the Helioseismic Magnetic Imager (HMI) data. We have recently demonstrated that the orbital artifacts contaminate all spatial and temporal scales in the data and developed a procedure for mitigating these artifacts in the Doppler data obtained from the Milne-Eddington inversions in the HMI Pipeline. Simultaneously, we have found that the orbital artifacts may be introduced by inaccurate estimates for the free-spectral ranges (FSRs) of the optical elements in HMI. We describe our approach and attempt to minimize orbital artifacts in the hmi.V_720 Dopplergram series by adjusting the FSRs for the optical elements in HMI within their measurement uncertainties of ±1%.

Constraining the Common Properties of Active Region Formation using the SDO/HEAR Dataset

Author(s): Schunker, H.(1); Braun, D. C.(2); Birch, A. C.(1)
Affiliation(s): (1) Max-Planck-Institut fur Sonnensystemforschung; (2) NorthWest Research Associates

Observations from the Solar Dynamics Observatory (SDO) have the potential for allowing the helioseismic study of the formation of hundreds of active regions, which enable us to perform statistical analyses. We collated a uniform data set of emerging active regions (EARs) observed by the SDO/HMI instrument suitable for helioseismic analysis, where each active region can be observed up to 7 days before emergence. We call this dataset the SDO Helioseismic Emerging Active Region (SDO/HEAR) survey. We have used this dataset to understand the nature of active region emergence. The latitudinally averaged line-of-sight magnetic field of all the EARs shows that the leading (trailing) polarity moves in a prograde (retrograde) direction with a speed of 110 ± 15 m/s (−60 ± 10 m/s) relative to the Carrington rotation rate in the first day after emergence. However, relative to the differential rotation of the surface plasma the East-West velocity is symmetric, with a mean of 90 ± 10 m/s. We have also compared the surface flows associated with the EARs at the time of emergence with surface flows from numerical simulations of flux emergence with different rise speeds. We found that the surface flows in simulations of emerging flux with a low rise speed of 70 m/s best match the observations.

Active Region Formation and Subsurface Structure

Author(s): Stein, Robert F.; Nordlund, A.
Affiliation(s): Michigan State University; Niels Bohr Institute

We present results from emerging magnetic flux simulations showing how several different active regions form and their very different subsurface structures. The simulations assumed an infinite sheet of uniform, untwisted, horizontal field advected into the computational domain by inflows at a depth of 20 Mm. Results from two different horizontal field strengths, 1 and 5 kG, will be presented. Convective up and down flows buckle the horizontal field into Omega and U loops. Upflows and magnetic buoyancy carry the field toward the surface, while fast downflows pin down the field. Small (granular) convective motions, near the surface, shred the emerging field into fine filaments that emerge as the observed "pepper and salt" pattern. The large (supergranular) motions, at depth, keep the overall loop structure intact, so that as the overall omega-loop emerges through the surface the opposite polarity fields counter-stream into large unipolar flux concentrations producing first pores which then coalesce into spots. These tend to be located over the supergranular downflow lanes near the bottom of the domain. The pores and spots exhibit a great variety of subsurface field structures -- from monolithic but twisted bundles to intertwined separate spaghetti structures. We will show movies of the surface evolution of the field and emergent continuum intensity and of the subsurface evolution of the magnetic field lines.

Study of Plasma Heating in Solar Eruptive Events

Author(s): Su, Yang (1); Veronig, Astrid M. (2); Hannah, Iain G.(3); Gan, Weiqun (1)
Affiliation(s): (1) Purple Mountain Obs., Chinese Academy of Sciences (CAS); (2) Univ. of Graz; (3) Univ. of Glasgow

The temperature of plasma is usually heated to over 10 MK by magnetic reconnection in Solar Eruptive Events. However, the details of the process are not known. With an improved way of DEM calculation, we are able to constrain the high-temperature DEMs using SDO/AIA data alone and study the heating process from the beginning to the end of SEEs. The results are also compared with other observations from RHESSI and GOES.

Unexpectedly Strong Lorentz-Force Impulse Observed During a Solar Eruption

Author(s): Sun, X. (1); Fisher, G. (2); Torok, T. (3), Hoeksema, J. T. (1); Li, Y. (2), and the CGEM Team (1,2,4)
Affiliation(s): (1) HEPL/Stanford Univ.; (2) SSL/Univ. of Cal.-Berkeley; (3) Predictive Science Inc.; (4) Lockheed Martin

For fast coronal mass ejections (CMEs), the acceleration phase takes place in the low corona; the momentum process is presumably dominated by the Lorentz force. Using ultra-high-cadence vector magnetic data from the Helioseismic and Magnetic Imager (HMI) and numerical simulations, we show that the observed fast-evolving photospheric field can be used to characterize the impulse of the Lorentz force during a CME. While the peak Lorentz force concurs with the maximum ejecta acceleration, the observed total force impulse surprisingly exceeds the CME momentum by over an order of magnitude. We conjecture that most of the Lorentz force impulse is "trapped" in the thin layer of the photosphere above the HMI line-formation height and is counter-balanced by gravity. This implies a consequent upward plasma motion which we coin "gentle photospheric upwelling". The unexpected effect dominates the momentum processes, but is negligible for the energy budget, suggesting a complex coupling between different layers of the solar atmosphere during CMEs.

The Asymmetric Polar Field Reversal of Solar Cycle 24

Author(s): Sun, X.; Hoeksema, J. T.; Liu, Y.; Zhao, J.; Bobra, M.
Affiliation(s): HEPL, Stanford University

As each solar cycle progresses, remnant magnetic flux from active regions (ARs) migrates poleward to cancel the old-cycle polar field. We describe this polarity reversal process during Cycle 24 using over six years of magnetic field measurements from the Helioseismic and Magnetic Imager. The total flux associated with ARs reached maximum in the north in 2011, more than two years earlier than the south; the maximum is significantly weaker than Cycle 23. The process of polar field reversal is relatively slow, north–south asymmetric, and episodic. We estimate that the global axial dipole changed sign in 2013 October; the northern and southern polar fields (mean above 60 deg latitude) reversed in 2012 November and 2014 March, respectively, about 16 months apart. Notably, the poleward surges of flux in each hemisphere alternated in polarity, giving rise to multiple reversals in the north. The southern polar field, on the other hand, kept increasing in strength. As of 2016 July it has become almost 80% higher than the 2010 level, suggesting that Cycle 25 is at least as strong as Cycle 24. We discuss the heliospheric consequences of such north-south asymmetric evolution, and the prospect of utilizing HMI vector field measurement at the polar region.

Prediction of Cycle 25 based on Polar Fields

Author(s): Svalgaard, Leif; Sun, Xudong; Bobra, Monica
Affiliation(s): Stanford University, Stanford, CA

WSO: The pole-most aperture measures the lineof-sight field between about 55° and the poles. Each 10 days the usable daily polar field measurements in a centered 30-day window are averaged. A 20nHz low pass filter eliminates yearly geometric projection effects. SDO-HMI: Line-of-sight magnetic observations (Blos above 60° lat.) at 720s cadence are converted to radial field (Br), under the assumption that the actual field vector is radial. Twice-per-day values are calculated as the mean weighted by de-projected image pixel areas for each latitudinal bin within ±45-deg longitude. These raw (12-hour) data have been averaged into the same windows as WSO's and reduced to the WSO scale taking saturation (1.8) and projection (COS(72°)) into account. We have argued that the 'poloidal' field in the years leading up to solar minimum is a good proxy for the size of the next cycle (SNmax≈ DM [WSO scale μT]). The successful prediction of Cycle 24 seems to bear that out, as well as the observed corroboration from previous cycles. As a measure of the poloidal field we used the average 'Dipole Moment', i.e. the difference, DM, between the fields at the North pole and the South pole. The 20nHz filtered WSO DM matches well the HMI DM on the WSO scale using the same 30-day window as WSO. So, we can extend WSO using HMI into the future as needed. Preliminarily, the polar fields now are as strong as before the last minimum and may increase further, so Cycle 25 may be at least a repeat of Cycle 24, not any smaller and possible a bit stronger.

SDO-HMI Magnetic Field Matches the F10.7 Record

Author(s): Svalgaard, Leif; and Sun, Xudong
Affiliation(s): Stanford University, Stanford, CA

In 1947 the Canadian Covington discovered microwave emission from the Sun at 2800 Mhz or 10.7 cm wavelength. The F10.7 record of the flux density extends unbroken from 1947 to the present. Observations in Japan agree closely with the Canadian values and it is generally accepted that the microwave flux is an excellent [and objective] measure of solar activity. As we believe that solar activity has its origin in the Sun's magnetic field, it is of interest to see how observations of the magnetic field agree with the [suitably scaled] F10.7 flux. This actually works both ways as the magnetic field is difficult to measure and the observing instruments are difficult to calibrate. The two space-borne magnetometers, MDI on SOHO at L1 at more than 1 million km distance, and HMI on SDO in geosynchronous orbit much nearer the Earth measure the magnetic flux. We use the latest versions of magnetic measurements of from the two instruments to form a composite dataset of the unsigned disk-averaged flux from 1996 to the present. There is a remarkable agreement between the observed and calculated microwave fluxes, lending credence to the accuracy and physical significance of both. Repeating the analysis using the radial magnetic flux yields the same amazing agreement; in fact, even slightly better. Using the magnetic data from Wilcox Solar Observatory (WSO) yields a similar result, attesting to the stability of the measurements at Stanford. We have also used the SOLIS series with the same good agreement. We suggest that the F10.7 record can serve as an [almost] absolute reference scale for the solar magnetic field.

Validating the New Sunspot Series for the 18th Century

Author(s): Svalgaard, Leif
Affiliation(s): Stanford University, Stanford, CA

Observations with telescopes suffering from the same spherical and chromatic aberrations as we think Staudach's 'sky tube' did, validate the factor of about three that we previously found was needed to normalize the 18th century amateur observations to the modern scale, and hence that there has been no steady increase of solar activity the past 300 years.

Variation of EUV matches that of the solar magnetic field

Author(s): Svalgaard, Leif
Affiliation(s): Stanford University, Stanford, CA

Comparing the XUV-EUV flux from SDO-SEM, TIMED-SEE and SDO-EVE with the unsigned magnetic flux measured by SOHO-MDI and SDO-HMI shows a very close relationship confirming that the EUV is an excellent proxy for the solar magnetic field. Because the XUV-EUV flux can be derived from the geomagnetic diurnal variation we can infer the flux and the magnetic field back to the 1740s.

Coronal Response to EUV Jets Modeled with the Alfvén Wave Solar Model

Author(s): Szente, Judit(1); Toth, Gabor(1); Manchester IV, Ward B.(1); van der Holst, Bartholomeus(1); Landi, Enrico(1); Gombosi, Tamas I.(1); DeVore, Carl R.(2); Antiochos, Spiro K.(2)
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We study the thermodynamics of jet phenomena with the use of multiple wavelength SDO-AIA observations [e.g. Adams (2014) and Moore (2015)] combined with advanced numerical simulations made with AWSoM coronal model [van der Holst (2014)]. AWSoM provides a fully three-dimensional, magnetohydrodynamic description of the solar atmosphere heated by the dissipation of kinetic Alfvén waves in a self-consistent manner. In addition, the model's multi-species thermodynamics with electron heat conduction provides for the accurate construction of synthetic line-of-sight images of phenomena. We implement our jets in the solar wind with a magnetic dipole twisted about axis, resulting in EUV jets similar in topology and dynamics as being observed. We show that the coronal atmosphere responds at a large-scale as torsional Alfvén waves propagate into the outer corona (up to 24 solar radii and 40 degrees in latitude), introduced by the small-scale eruptive reconnection events at the footpoint of the jet.

Trapped modes of a cylindrical waveguide in the Sun's corona.

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Affiliation(s): The University of Sheffield, UK

By modelling coronal-loop oscillations within three-dimensional magnetic arcades, it has been shown that MHD fast waves can be trapped within a 3D waveguide comprised of two shells with sharp discontinuities, the overlaying one being of denser plasma (Hindman & Jain, 2015). We extend this model to that of a three shell waveguide, with the outermost shell denser than the innermost, to study the effect of less sharp discontinuities. Deriving the governing equation for the MHD waves and finding semi-analytic solutions for the eigenfunctions, we find that the nature of propagating and evanescent waves as obtained in the two shell model changes. We will show that the eigenfrequencies and eigenfunctions depend on the thickness of the middle shell, and its position in the cylindrical arcade. The investigation has implications for identification of fast MHD waves in the solar coronal loops.

Improving Flare Irradiance Models with the Low Pass Filter Relation between EUV Flare Emissions with Differing Formation Temperatures

Author(s): Thiemann, Edward M. B.; Eparvier, Francis G.
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Solar flares are the result of magnetic reconnection in the solar corona which converts magnetic energy into kinetic energy resulting in the rapid heating of solar plasma. As this plasma cools, extreme ultraviolet (EUV) line emission intensities evolve as the plasma temperature passes through line formation temperatures, resulting in emission lines with cooler formation temperatures peaking after those with hotter formation temperatures. At the 2016 American Astronomical Society Solar Physics Division Meeting in Boulder (SPD2016), we showed that Fe XVIII solar flare light curves are highly correlated with Fe XXIII light curves that have been subjected to the single-pole Low Pass Filter Equation (LPFE) with a time constant equal to the time difference between the peak emissions. The single-pole (or equivalently, RC) LPFE appears frequently in analyses of systems which both store and dissipate heat, and the flare LPFE effect is believed to be related to the underlying cooling processes. Because the LPFE is constrained by a single parameter, this effect has implications for both operational EUV flare irradiance models and understanding thermal processes that occur in post-flare loops. At the time of SPD2016, it was ambiguous as to whether the LPFE effect relates hot thermal bremsstrahlung soft x-ray (SXR) or EUV line emissions with cooler EUV line emissions since Fe XXIII flare light curves are highly correlated with SXR flare light curves. In this study, we present new results characterizing the LPFE relation between multiple emission lines with differing formation temperatures ranging from 107.2 to 105.7 K observed by SDO/EVE and SXR thermal bremsstrahlung emissions observed by GOES/XRS. We show that the LPFE equation relates Fe XVIII with cooler EUV line emissions, providing unambiguous evidence that the LPFE effect exists between EUV line emissions rather than thermal bremsstrahlung and line emissions exclusively.

The exact nature of this effect remains an open question and we will discuss possible underlying causes. Regardless of its origin, this effect can be used to improve operational flare irradiance models if the LPFE time constants can be predicted independently. To make progress towards this, we quantify how well the LPFE time-constants can be predicted with independent measurements of the flare cooling rate, and give examples of modeled EUV flare light curves derived from space weather assets such as GOES/XRS at Earth and the EUV Monitor (EUVM) on the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission at Mars.

Interpreting Coronal Dimmings

Author(s): Thompson, Barbara J.(1); Allred, Joel C.(1); Downs, Cooper(2) Kay, Christina(1); Kraaikamp, Emil(3); Krista, Larisza D.(4); Mason, James P.(4); Nieves-Chinchilla, Teresa(1,5); Reinard, Alysha A.(4); Verbeeck, Cis(3); Webb, David F.(6)
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Large regions of coronal dimming often accompany coronal mass ejections (CMEs). Of all of the EUV signatures of CMEs, dimmings (when present) are the best match to the location and extent of the coronagraph CME observations. They last on timescales from minutes to hours, are sometimes patchy in appearance, and can extend far (>1 RSun) from the flaring region. They are known to be good indicators of the site of evacuated material, and have been extensively studied as a CME mass source. Dimmings can also serve as a magnetic footprint of CMEs. Dimmings develop during or soon after the eruption, and may trace field lines locally opened during the CME. These dimming regions can be extensive, representing at least part of the "base" of a CME and the mass and magnetic flux transported outward by it. However, the timing and development of dimmings can be extremely complex. We report on three-dimensional observations of the codevelopment of dimmings in EUV and coronagraph images, magnetic field topologies represented by the dimmings, and the variation of dimming manifestations in different detection methods.

Dynamic Mapping of Prominence Activity

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We present the results of a prominence mapping effort designed to extract the dynamics of erupting prominences. The material from partially erupting prominences can fall back to the sun, tracing out the topology of the mid- and post-eruptive corona. One question involving the range of observed behavior is the role of magnetic field topology and evolution in determining the motion of the erupting prominence material. A variable-g ballistic approximation is applied to study the motion of the material, using the deviations from constant angular momentum as a means of quantifying the local Lorentz (and other) forces on each piece of material. Variations in dynamic behavior can be traced back to changes in the local magnetic field and the formation of instabilities such as Rayleigh-Taylor. We discuss the use of the prominence trajectories as a means of diagnosing eruptive topologies.

Properties and Developments of Flaring Active Regions

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Larger flares and CMEs are often produced from active regions (ARs). In order to better understand the magnetic properties and evolutions of such ARs, we picked up all flare events with GOES levels >M5.0 with heliocentric angles of <45 deg in the period of May 2010 to April 2016, which led to a total of 29 ARs with 51 flares. We analyzed the observational data obtained by SDO and found that more than 80% of the 29 ARs have delta-sunspots. Most of them can be classified depending on their magnetic structures into (1) spot-spot, where a long sheared polarity inversion line (PIL: characterized by flare ribbons) is formed between two major sunspots, and (2) spot-satellite, where a newly-emerging minor bipole next to a pre-existing spot creates a compact PIL. The remaining minor groups are (3) quadrupole, where two emerging bipoles produce a PIL in between, and (4) inter-AR, which produces flares not from delta-spots but from between two separated ARs. From statistical investigations we found for example that the spot-spot group generally shows long-duration events due to large coronal structures, while the spot-satellite has impulsive events because of their compact magnetic nature. We will also present flux emergence simulations and discuss their formation processes.

Cross-Spectral Fitting of HMI Velocity and Intensity Data

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The simultaneous HMI velocity and intensity observations are used to obtain better estimates of solar acoustic mode parameters. This is achieved by fitting four spectra simultaneously viz. velocity, intensity, the phase difference and the coherence between the intensity and velocity spectra. We further compare the oscillation mode parameters obtained from the single-observable fitting and those from the cross-spectral fitting method. We find that the mode frequencies derived from the cross-spectral procedure are lower than those derived from the velocity spectrum fitted with an asymmetrical profile. We further note a clear solar cycle dependence in the mode frequencies while other mode parameters e.g. amplitudes and line widths do not show significant variation with solar activity. This corroborates earlier findings that the interpretation of model fit parameters based on measurements of a single spectra should be examined critically.

Magnetoseismology of Active Regions using Multi-wavelength Observations from SDO

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The structure and dynamics of active regions beneath the surface show significant uncertainties due to our limited understanding of the wave interaction with magnetic field. Recent numerical simulations further demonstrate that the atmosphere above the photospheric levels also modifies the seismic observables at the surface. Thus the key to improve helioseismic interpretation beneath the active regions requires a synergy between models and helioseismic inferences from observations. In this context, using data from Helioseismic Magnetic Imager and Atmospheric Imaging Assembly onboard Solar Dynamics Observatory, we characterize the spatio-temporal power distribution in and around active regions. Specifically, we focus on the power enhancements seen around active regions as a function of wave frequencies, strength, inclination of magnetic field and observation height as well as the relative phases of the observables and their cross-coherence functions. It is expected that these effects will help us to comprehend the interaction of acoustic waves with fast and slow MHD waves in the solar photosphere.

Image-based reconstruction of the Newtonian dynamics of solar coronal ejecta

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We present a new methodology for analyzing rising and falling dynamics of unstable coronal material as represented by high-cadence SDO AIA images. The technique involves an adaptive spatiotemporal tracking of propagating intensity gradients and their characterization in terms of time-evolving areas swept out by the position vector originated from the Sun disk center. The measured values of the areal velocity and acceleration are used to obtain quantitative information on the angular momentum and acceleration along the paths of the rising and falling coronal plasma. In the absence of other forces, solar gravitation results in purely ballistic motions consistent with the Kepler's second law; non-central forces such as the Lorentz force introduce non-zero torques resulting in more complex motions. The developed algorithms enable direct evaluation of the line-of-sight component of the net torque applied to a unit mass of the ejected coronal material which is proportional to the image-plane projection of the observed areal acceleration. The current implementation of the method cannot reliably distinguish torque modulations caused by the coronal force field from those imposed by abrupt changes of plasma mass density and nontrivial projection effects. However, it can provide valid observational constraints on the evolution of large-scale unstable magnetic topologies driving major solar-coronal eruptions as demonstrated in the related talk by B. Thompson et al.

Model of the Global Corona Powered by Alfven Wave Turbulence: A Validation Study

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We present a global magnetohydrodynamic model of the solar corona and solar wind that uses Alfven wave turbulence. The outward propagating waves experience partial reflection and the nonlinear interaction between the oppositely propagating Alfven waves results in an energy cascade to the gyro-radius scales, where the turbulent energy dissipates. This mechanism heats and accelerates the solar wind. Some of the excess energy in the lower corona is transported back to the upper chromosphere via electron heat conduction where it is lost via radiative cooling. A faster than real time performance of this model is achieved by numerically solving the lower corona in 1D on multiple magnetic field lines. We validate this model by comparing the synthesized EUV images with the observations from STEREO and SDO. Additionally, we compare 1AU results with ACE/Wind via time accurate simulations over several Carrington rotations.

Placing the Sun in Stellar Context: Rotation, Magnetism, and Aging Dynamos

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Data from the Kepler satellite has given us the opportunity to study stars other than the Sun in unprecedented detail, and to use them to place the Sun in stellar context. The emerging picture is tantalizing, and suggests that the Sun may in fact be in the midst of a magnetic transition. Precise stellar ages from asteroseismology and rotation periods from stellar spot modulation have revealed that old stars appear to shift to a mode with very inefficient angular momentum loss, and furthermore that the Sun sits very near to the transition between "normal" spin-down and weakened braking. We consider the magnetic activity of this seismic sample, combined with well-studied solar analogs and the Mt Wilson Survey stars, and propose a unifying picture in which a shift in the character of differential rotation begins a cascade of events that results in a change in the magnetic and braking properties of star. In this larger stellar context, the Sun is in transition state, on its way to displaying the relative inactivity of old stars. I will present the observational evidence for this scenario, as well as discuss upcoming observational tests.

Shock-drift Accelerated Electrons and n-distribution

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Recently soft X-ray spectra observed during the impulsive phase of several solar flares have been explained by the presence of the n-distribution function of superthermal electrons. We examine if electrons with such a distribution function can be produced in a shock, e.g. in a flare termination shock. The distribution functions of reflected electrons at quasi-perpendicular shocks are analytically derived and compared with the n-distributions. We consider an influence of the electrostatic cross-shock potential, shock curvature, and a role of the upstream seed population on these distributions. We found that a high-energy part of the distribution of electrons reflected at a quasi-perpendicular shock could be very well fitted by the n-distribution. It gives a chance to detect the flare termination shock.

Using SDO/AIA to Understand the Thermal Evolution of Solar Prominence Formation

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In this study, we investigate prominence formation using time series analysis of Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO/AIA) data. We investigate the thermal properties of forming prominences by analyzing observed light curves using the same technique that we have already successfully applied to active regions to diagnose heating and cooling cycles. This technique tracks the thermal evolution using emission formed at different temperatures, made possible by AIA's different wavebands and high time resolution. We also compute the predicted light curves in the same SDO/AIA channels of a hydrodynamic model of thermal nonequilibrium formation of prominence material, an evaporation-condensation model. In these models of prominence formation, heating at the foot-points of sheared coronal flux-tubes results in evaporation of material of a few MK into the corona followed by catastrophic cooling of the hot material to form cool (~10,000 K) prominence material. We demonstrate that the SDO/AIA light curves for flux tubes undergoing thermal nonequilibrium vary at different locations along the flux tube, especially in the region where the condensate forms, and we compare the predicted light curves with those observed. Supported by NASA's Living with a Star program.

Photospheric Magnetic Fields in Six Magnetographs

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Photospheric magnetic field has been routinely observed since 1950s, but calibrated digital data exist only since 1970s. The longest uniform data set is measured at the Wilcox Solar Observatory (WSO), covering 40 years from 1976 onwards. However, the WSO instrument operates in very low spatial resolution and suffers from saturation of strong fields. Other, higher resolution instruments like those at NSO Kitt Peak (KP) offer a more detailed view of the solar magnetic field, but several instrument updates make the data less uniform. While the different observatories show a similar large scale structure of the photospheric field, the measured magnetic field intensities differ significantly between the observatories. In this work we study the photospheric magnetic fields and, especially, the scaling of the magnetic field intensity between six independent data sets. We use synoptic maps constructed from the measurements of the photospheric magnetic field at Wilcox Solar Observatory, Mount Wilson Observatory (MWO), Kitt Peak (KP), SOLIS, SOHO/MDI and SDO/HMI. We calculate the harmonic expansion of the magnetic field from all six data sets and investigate the scaling of harmonic coefficients between the observations. We investigate how scaling depends on latitude and field strength, as well as on the solar cycle phase, and what is the effect of polar field filling in KP, SOLIS and MDI. We find that scaling factors based on harmonic coefficients are in general smaller than scaling factors based on pixel-by-pixel comparison or histogram techniques. This indicates that a significant amount of total flux is contained in the high harmonics of the higher resolution observations that are beyond the resolution of WSO. We note that only scaling factors based on harmonic coefficients should be used when using the PFSS-model, since the other methods tend to lead to overestimated values of the magnetic flux. The scaling of the low order harmonic coefficients is typically different than for higher terms. The most problematic harmonic is the axial quadrupole term, which is known to be noisy and to suffer from observational limitations (e.g., the vantage point effect). We did not find significant solar cycle variation in the scaling factors.

The Impact of Sunspot Rotation on Energetic Solar Flares

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Sunspot rotation can be an efficient mechanism for injecting helicity into the solar corona. This twists the coronal magnetic field, potentially creating magnetic configurations favourable for triggering solar flares. SDO/HMI continuum observations provide reliable data sequences to analyse the long-term rotation of sunspots, of which there are several examples in the literature. However, there is a need to carry out statistical studies to uncover the link between sunspot rotation and solar flares. This work provides such a study focusing on all active regions that have produced at least one X-class flare since the launch of SDO. This includes 26 active regions containing over 70 sunspots, giving rise to a total of 42 X-class solar flares. For each sunspot, rotation properties such as total rotation and rotational velocities are calculated using sequences of SDO/HMI continuum images running over several days. Twenty-five out of 26 of these active regions contain at least one sunspot exhibiting significant (greater than 30 degrees) rotation, enough to power a high M or low X-class solar flare. The majority of these active regions have a combined sunspot rotation of over 100 degrees, suggesting that rotation may be a viable mechanism for injecting into the corona the energy required to trigger high-power solar flares.

Determination of Transport Coefficients from Flare-excited Standing Slow-mode Waves Observed by SDO/AIA

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The flare-excited longitudinal intensity oscillations in hot flaring loops have been recently detected by SDO/AIA in 94 and 131 Angstrom bandpasses. These oscillations show similar physical properties (such as period, decay time, and trigger) as the Doppler shift oscillations previously detected by the SOHO/SUMER spectrometer in flare lines formed above 6 MK, which were mostly interpreted as the slow-mode standing waves. By applying the coronal seismology method we have, for the first time, found quantitative evidence of thermal conduction suppression in a hot (>9 MK) flare-heated loop with SDO/AIA (Wang et al. 2015, ApJL, 811, L13). This result has significant implications in two aspects. The first aspect is that the conduction suppression suggests the need of greatly enhanced compressive viscosity to interpret the observed strong wave damping. The second aspect is that the conduction suppression provides a reasonable mechanism for explaining the long-duration events where the hot plasma detected in X-rays or EUV in many flares cools much slower than expected from the classical Spitzer conductive cooling. In this presentation, we first review the observational results of the event, and then discuss possible causes for conduction suppression and viscosity enhancements. In addition, we will 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, as an application of our analysis, we will demonstrate how the observationally-constrained transport coefficients are crucial in providing a self-consistent explanation for the rapid excitation of standing slow-mode waves in a coronal loop by a footpoint flare.

High Resolution He I 10830 angstrom Narrow-band Imaging of an M-class flare. I-analysis of sunspot dynamics during flaring

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We report our first-step results of high resolution He I 1083 nm narrow-band imaging of an M 1.8 class two-ribbon flare on July 5, 2012. The flare was observed with the 1.6 meter aperture New Solar Telescope at Big Bear Solar Observatory. For this unique data set, sunspot dynamics during flaring were analyzed for the first time. By directly imaging the upper chromosphere, running penumbral waves are clearly seen as an outward extention of umbral flashes, both take the form of absorption in our 1083 nm narrow-band images. From a space-time image made of a slit cutting across the ribbon and the sunspot, we find that dark lanes for umbral flashes and penumbral waves are obviously broadened after the flare. The most prominent feature is the sudden appearance of an oscillating absorption strip inside one ribbon of the flare when it sweeps into sunspot's penumbral and umbral regions. During each oscillation, outwardly propagating umbral flashes and subsequent penumbral waves rush out into the inwardly sweeping ribbon, followed by a returning of the absorption strip with similar speed. We tentatively explain the phenomenon as the result of a sudden increase in the density of ortho-Helium atoms in the area of the sunspot area being excited by the flare's EUV illumination. This explanation is based on the observation that 1083 nm absorption in the sunspot area gets enhanced during the flare. Nevertheless, questions are still open and we need further well-devised observations to investigate the behavior of sunspot dynamics during flares.

Evolution of 3D Electron Density of the Solar Corona from the Minimum to Maximum of Solar Cycle 24

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The variability of the solar white-light corona and its connection to the solar activity has been studied for more than a half century. It is widely accepted that the temporal variation of the total radiance of the K-corona follows the solar cycle pattern (e.g., correlated with sunspot number). However, the origin of this variation and its relationships with regard to coronal mass ejections and the solar wind are yet to be clearly understood. COR1-A and –B instruments onboard the STEREO spacecraft have continued to perform high-cadence (5 min) polarized brightness (pB) measurements from two different vantage points from the solar minimum to the solar maximum of Solar Cycle 24. With these pB observations we have reconstructed the 3D coronal density between 1.5-4.0 solar radii for 100 Carrington rotations (CRs) from 2007 to 2014 using the spherically symmetric inversion (SSI) method. We validate these 3D density reconstructions by other means such as tomography, MHD modeling, and pB inversion of LASCO/C2 data. We analyze the solar cycle variations of total coronal mass (or average density) over the global Sun and in two hemispheres, as well as the variations of the streamer area and mean density. We find the short-term oscillations of 8-9 CRs during the ascending and maximum phases through wavelet analysis. We explore the origin of these oscillations based on evolution of the photospheric magnetic flux and coronal structures.

Studies Using a Newly Digitized Archive of Global Solar Magnetic Field Patterns

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In 1964 (Solar Cycle 20) Patrick McIntosh began creating hand-drawn synoptic maps of solar activity, based on Hα imaging measurements. These synoptic maps were unique in that they traced the polarity inversion lines (PILs), connecting widely separated filaments, fibril patterns and plage corridors to reveal the large-scale organization of the solar magnetic field. Coronal hole (CH) boundaries were later added to the maps which were produced, more or less continuously, into 2009 (start of SC 24), yielding more than 40 years (~ 540 Carrington rotations) or nearly four complete solar cycles of synoptic maps. Under an NSF grant, these maps are being scanned, digitized and archived and the final, searchable versions are now publicly available at NOAA's National Centers for Environmental Information (NCEI) at: http://www.ngdc.noaa.gov/stp/spaceweather/solar-data/solar-imagery/composites/synoptic-maps/mc-intosh/). We will outline the project and the current status of the archive, and present some preliminary results demonstrating scientific applications. For example, computer codes permit efficient searches of the map arrays. The maps for SC 23 have been completed and we will show examples of the global evolution of features including filaments, large-scale positive and negative polarity regions, CHs of each polarity, CH boundaries, PILs, major sunspots, and plage areas.

SDO/EVE Data Product Improvements, Additions, and Algorithms Updates

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The EUV Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO) provides full-disk integrated solar irradiance at high cadence and 0.1 nm resolution. Here we present improvements in data reduction for creation of the solar irradiance spectrum to improved routine data products. This includes improved degradation corrections to remove instrumental effects, 1-minute data products to accommodate longer integration times, and also a new data filtering technique to reduce the internal and external noise in the CCD detector measurements. We also demonstrate that new data products could be produced including higher resolution flare spectra with improved wavelength registration from the MEGS-A detector.

New Solar Soft X-Ray (SXR) Spectral Irradiance Measurements Bridge the SDO and RHESSI Spectral Gap to Study Flare Energetics

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The extreme ultraviolet (EUV) spectrum is rich in many different emission lines that reveal plasma characteristics concerning active region evolution and explosive energy release during coronal eruptions. Solar EUV imagers, such as SDO AIA, provide insight into the location, thermal structure, and dynamics of the coronal eruptions and associated flares. In addition, the solar EUV spectral irradiance from SDO EVE, with its higher spectral resolution, provides more detailed thermal evolution of the eruption and has better characterized some aspects of the eruptions such as relationship of coronal dimming and mass loss and post-eruption coronal loop cooling. Complementary to SDO are hard x-ray (HXR) measurements by RHESSI that have clarified the initiation of energy release from magnetic reconnection in the corona. New solar soft x-ray (SXR) spectral irradiance from the Miniature X-ray Solar Spectrometer (MinXSS) CubeSat is now bridging this spectral gap between SDO EUV and RHESSI HXR observations. MinXSS-1 was deployed from the ISS in May 2016 for a 1-year mission, and MinXSS-2 is being launched in October 2016 for a 5-year mission. The energy release during solar flares is expected to peak in the SXR and thus the SXR has been monitored with GOES broadband photometers for decades, but there has been very limited SXR spectral measurements. With the new and unique MinXSS measurements of the SXR spectral variability during flares, coupled with solar SXR images from Hinode, EUV data from SDO, and HXR data from RHESSI, the processes for releasing energy during an eruption and affecting posteruption thermal evolution can be explored in more detail. Furthermore, the new SXR spectral irradiance measurements can help improve the accuracy of broad band SXR measurements by GOES XRS, SDO EVE ESP, and XPS aboard TIMED and SORCE. Such improvements can lead to better understanding the solar impacts in Earth's ionosphere and thermosphere and how they might affect some of our space-based communication and navigation systems. This presentation will focus on how these new solar SXR spectral measurements can enhance the SDO studies of eruptive flares.

Overview of Key Results from SDO Extreme ultraviolet Variability Experiment (EVE)

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The SDO Extreme ultraviolet Variability Experiment (EVE) includes several channels to observe the solar extreme ultraviolet (EUV) spectral irradiance from 1 to 106 nm. These channels include the Multiple EUV Grating Spectrograph (MEGS) A, B, and P channels from the University of Colorado (CU) and the EUV SpectroPhometer (ESP) channels from the University of Southern California (USC). The solar EUV spectrum is rich in many different emission lines from the corona, transition region, and chromosphere. The EVE full-disk irradiance spectra are important for studying the solar impacts in Earth's ionosphere and thermosphere and are useful for space weather operations. In addition, the EVE observations, with its high spectral resolution of 0.1 nm and in collaboration with AIA solar EUV images, have proven valuable for studying active region evolution and explosive energy release during flares and coronal eruptions. These SDO measurements have revealed interesting results such as understanding the flare variability over all wavelengths, discovering and classifying different flare phases, using coronal dimming measurements to predict CME properties of mass and velocity, and exploring the role of nanoflares in continual heating of active regions.

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

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Hydrodynamical models of unresolved flux tubes are able to reproduce observed coronal loops under the condition that each strand is impulsively heated and subsequently cools. It is the frequency of this heating and cooling that determines the temperature distribution within a loop, and is recoverable by determination of the low-temperature slope of the differential emission measure (DEM). Alternatively, the cross-correlation of pixel-level SDO/AIA light curves (time-lag analysis; Viall & Klimchuck, 2012; 2013; 2015; 2016) is becoming an increasingly popular analysis technique in order to investigate coronal heating. While the observed time-lag between two AIA channels can be indicative of heating or cooling, the inherent multi-thermal nature of the AIA responses can mask the true dynamical situation of the underlying plasma. We therefore recover the thermal time evolution at the pixel-level by producing DEM maps (Hannah et al, 2012; Cheung et al, 2015). We present this analysis on both real and synthetic AIA maps of non-flaring active regions, the latter approach allowing us to understand how robustly we can recover the true thermal time evolution. However a single DEM alone does not provide information about how the plasma is heating/cooling or how the different components are related. We therefore investigate the time evolution using a variety of complementary techniques such as time-lag analysis, power spectrum analysis (Ireland et al, 2015), as well as studying the temporal evolution of the DEM slope.

A New Characteristic Boundary Condition Formulation for a Data-Driven Magnetohydrodynamic Model of Global Solar Corona Using SDO Vector Magnetogram Data

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The solar wind which is the plasma emerging from the Sun is the main driving mechanism of the solar storms which can lead to geomagnetic storms that are the primary causes of the space weather disturbances that affect the magnetic environment of the Earth and can have hazardous effects on the space-borne and ground-based technological systems as well as human health. Therefore, accurate modeling of the solar wind is very important in order to be able to understand the underlying mechanisms of solar storms. In this study, we present a data-driven magnetohydrodynamic (MHD) model of the global solar corona which utilizes a new characteristic boundary condition formulation implemented within the Multi-Scale FluidKinetic Simulation Suite (MS-FLUKSS). Our global solar corona model can be driven by both timedependent and Carrington-rotation averaged vector magnetogram synoptic map data obtained by the Solar Dynamics Observatory/Helioseismic and Magnetic Imager (SDO/HMI) and the horizontal velocity data on the photosphere obtained by applying the Differential Affine Velocity Estimator for Vector Magnetograms (DAVE4VM) method on the HMI-observed vector magnetic fields. We will present our global solar corona model, in particular focus on the formulations for our characteristic boundary conditions and demonstrate results of our model.

M dwarf Energetic Proton Flux on Exoplanets during Flares: Estimates using solar UV-proton relations

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UV and X-ray stellar radiation impacts planetary atmospheres through heating and photochemistry, even regulating production of potential biomarkers. The surface conditions on M dwarf planets are not greatly affected by flares in the emission line-dominated far-UV spectra of M dwarfs (M < 0.5 Msun), however, theoretical investigations have largely ignored the additional influence of stellar energetic particles (SEPs) released during flares. Magnetospheric compression and atmospheric stripping by SEPs could allow lifedamaging (or catalyzing) radiation to reach the planetary surface and cause atmospheric heating closer to the surface. For the sun, a relationship between >10 MeV proton flux and 1-8 Å irradiance has been established with data from the GOES satellites (Belov et al. 2005), however, only a few X-ray observations of M-dwarf flares covering the complete 1-8 Å bandpass exist. Current M dwarf SEP estimates (Segura et al. 2010) employ the Neupert effect to first estimate the average X-ray flux over a broad band (1-62 Å) from the observed near- and far-UV flare flux (Mitra-Kraev et al. 2005). To improve the quality of proton flux estimates, we have analyzed the GOES >10 MeV observed proton flux and SDO EVE's solar spectral irradiance measurements to define relationships between SEPs and extreme-UV emission lines with formation temperatures similar to far-UV lines directly accessible by the Hubble Space Telescope (HST). Under the necessary assumption that an M dwarf's SEP production mechanism is similar to the sun's, we estimate SEP fluxes during M-dwarf flares observed with HST as part of the MUSCLES (Measurements of the Ultraviolet Spectral Characteristics of Low-mass Exoplanetary Systems) Treasury Survey.

Determining Ray Paths of Upward Propagating Helioseismic Waves above Sunspots from the Photosphere to Corona

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Recently, through applying a time-distance helioseismic analysis technique on a suite of observations covering from the photosphere to the corona, we have found that the p-mode waves in sunspots are able to channel up through different atmospheric layers into the corona. The waves show a clear frequency dependence along the paths they travel through. Study of these waves is expected to help determine the properties of atmosphere above sunspots, such as temperature, density, and magnetic field strength and inclination. However, a precise determination of the ray paths for waves of different frequencies is an important first step leading to the investigation of the atmospheric properties. Through applying a ray-tracing method on the wavefront, obtained through our previous analyses, we are able to determine the ray-paths along which waves of different frequencies channel up into the corona.