Triennial Earth-Sun Summit (TESS)

Indianapolis, IN – 27- 30 April, 2015

Meeting Abstracts

100 – Plenary Talk: Toward a Better Understanding of the Solar Atmosphere: Combining Observations and Numerical Modeling, Bart De Pontieu (Lockheed-Martin)

100.01 – Toward a Better Understanding of the Solar Atmosphere: Combining Observations and Numerical Modeling

The study of the Sun, our nearest star, is making rapid progress, through a combination of a host of new space-based and ground-based observatories coming online and major advances in numerical simulations that incorporate increasingly complex physical mechanisms. I will provide an overview of some recent exciting discoveries that highlight the synergy between numerical modeling and observations with the Interface Region Imaging Spectrograph (IRIS), Solar Dynamics Observatory (SDO) and Hinode spacecraft.
Some of the topics I will discuss include: 1. recent advances in understanding the dominant heating mechanism(s) of the solar atmosphere focusing on dissipation of Alfven waves, as well as the presence of non-thermal particles in small heating events resulting from magnetic reconnection; 2. heating and reconnection in the partially ionized chromosphere; 3. the origin of the slow solar wind; 4. the global nature and long-distance connections governing the instability of the solar atmosphere and driving eruptions such as coronal mass ejections.
Author(s): Bart De Pontieu[1]
Institution(s): *1. Lockheed Martin Solar & Astrophysics Laboratory*

101 – Plenary Talk: The Magnetosphere as a Component of the Interconnected Sun-Geospace System, Janet Kozyra (University of Michigan)

101.01 – The Magnetosphere as a Component of the Interconnected Sun-Geospace System

This presentation focuses on the magnetosphere as an essential component of a vast interlocking system that spans from the Sun to the upper atmosphere and beyond. The magnetosphere is itself a system, as are the other components. Each part of the magnetosphere feels the influence of the whole Sun-Geospace system and, in turn, the magnetosphere, as a component, feeds back to influence parts of the larger system. Solar disruptions that ultimately reach Earth are modified by propagation through the heliosphere sometimes changing from harmless disturbances into triggers for major space storms by the time they impact and disrupt the magnetosphere. The magnetosphere is so intimately connected to the ionosphere - upper atmosphere that they operate as one in response to changing solar conditions. Some recent results from remote sensing and multi-satellite observations as well as global models will be presented that give insights into the magnetosphere and its linkages during extreme events. These events are broadly defined to include super-storms, intense auroral activity, large radiation belt

disturbances, unusual features appearing during moderate activity, and/or conditions in the solar wind, that are far from the typical range. A challenge arises because much of the system behavior is contained in the coupling and not in the individual processes. In addition, extreme features can develop as a result of the chance overlap in space and/or time of usually isolated processes. To answer these challenges, the whole-system investigation of extreme events has emerged as an important research area in a variety of scientific disciplines. The whole-system approach makes it possible to start with an extreme feature in the magnetosphere and then track back through the Sun-Geospace system to identify the environmental conditions and interacting physical processes that produced it. New information about the magnetosphere and its linkages will be presented that resulted from a whole system investigation of the unusual 21 January 2005 magnetic storm. In addition, new discipline-focused questions will be described that arose about contributing processes because of this different perspective.
Author(s): Janet Kozyra[1]
Institution(s): *1. University of Michigan*

102 – Magnetic Reconnection Posters

102.01 – Magnetic Reconnection Onset and Energy Release at Current Sheets

Reconnection and energy release at current sheets are important at the Sun (coronal heating, coronal mass ejections, flares, and jets) and at the Earth (magnetopause flux transfer events and magnetotail substorms) and other magnetized planets, and occur also at the interface between the Heliosphere and the interstellar medium, the heliopause. The consequences range from relatively quiescent heating of the ambient plasma to highly explosive releases of energy and accelerated particles. We use the Adaptively Refined Magnetohydrodynamics Solver (ARMS) model to investigate the self-consistent formation and reconnection of current sheets in an initially potential 2D magnetic field containing a magnetic null point. Unequal stresses applied to the four quadrants bounded by the X-line separatrix distort the potential null into a double-Y-type current sheet. We find that this distortion eventually leads to onset of fast magnetic reconnection across the sheet, with copious production, merging, and ejection of magnetic islands due to plasmoid instability. In the absence of a mechanism for ideal instability or loss of equilibrium of the global structure, however, this reconnection leads to minimal energy release. Essentially, the current sheet oscillates about its force-free equilibrium configuration. When the structure is susceptible to a large-scale rearrangement of the magnetic field, on the other hand, the energy release becomes explosive. We identify the conditions required for reconnection to transform rapidly a large fraction of the magnetic free energy into kinetic and other forms of plasma energy, and to restructure the current sheet and its surrounding magnetic field dramatically. We discuss the implications of our results for understanding heliophysical activity, particularly eruptions, flares, and jets in the corona.
Our research was supported by NASA's Heliophysics Supporting Research and Living With a Star Targeted Research and Technology programs.
Author(s): C R DeVore[1], Spiro K Antiochos[1]
Institution(s): *1. NASA GSFC*

102.02 – The plasmoid instability during magnetic reconnection in partially ionized chromospheric plasmas

Magnetic reconnection is a ubiquitous process in the partially ionized solar chromosphere. Recent 2D simulations have shown that the plasmoid instability onsets during partially ionized reconnection [1-3].

We use the plasma-neutral module of the HiFi framework to simulate the nonlinear evolution of the plasmoid instability during symmetric and asymmetric reconnection. These simulations model the plasma and neutrals as separate fluids and include ionization, recombination, the Hall effect, charge exchange, thermal conduction, and optically thin radiative cooling. As in previous simulations [1,2], an enhancement of plasma density in the current sheet and plasmoids leads to recombination being an important loss term in the plasma continuity equation. The Hall term leads to the development of significant out-of-plane magnetic fields in the current sheet region, but we do not observe shortening of the current sheet or acceleration of the reconnection rate as a result. Secondary merging of magnetic islands is modified by inflow asymmetry and often results in an enhancement of the core field in the resulting islands.
[1] Leake et al. 2012, ApJ, 760, 109 [2] Leake et al. 2013, PhPl, 20, 062102 [3] Ni et al. 2015, ApJ, 799, 79
Author(s): Nicholas A Murphy[2], Vyacheslav S Lukin[1]
Institution(s): *1. National Science Foundation, 2. Smithsonian Astrophysical Observatory*

102.03 – Dynamical signatures of magnetic neutral lines in the geomagnetic tail

We consider dynamical signatures of charge particle motion that discriminate between a current sheet magnetic field reversal, characteristic of quiet times in the magnetosphere, and a magnetic neutral line field, which would be produced by magentic reconnection during active times. We concentrate on potential signatures that follow from the fundamental dynamics of ions or electrons. Previous work has shown such signatures to be both observable and robust. Dynamics in both the current sheet and neutral line fields exhibits chaotic scattering over a wide range of parameter values. In this work we consider the problem of discrimination between these two magnetic structures using the properties of this scattering. In particular we investigate the differences in resonance behavior as the particle energy is varied, as well as the possibility that fractal exit region structuring could discriminate the two fields. Application to the magnetotail will be presented.
Author(s): Richard F Martin[1], Daniel L Holland[1]
Institution(s): *1. Illinois State University*

103 – Solar Interior Posters

103.01 – Pixel Dynamics Analysis of Photospheric Spectral Data

Recent advances in solar observations have led to higher-resolution surface (photosphere) images that reveal bipolar magnetic features operating near the resolution limit during emerging flux events. Further improvements in resolution are expected to reveal even smaller dynamic features. Such photospheric features provide observable indications of what is happening before, during, and after flux emergence, eruptions in the corona, and other phenomena. Visible changes in photospheric active regions also play a major role in predicting eruptions that are responsible for geomagnetic plasma disturbances. A new method has been developed to extract physical information from photospheric data (e.g., SOLIS Stokes parameters) based on the statistics of pixel-by-pixel variations in spectral (absorption or emission) line quantities such as line profile Doppler shift, width, asymmetry, and flatness. Such properties are determined by the last interaction between detected photons and optically thick photospheric plasmas, and may contain extractable information on local plasma properties at sub-pixel scales. Applying the method to photospheric data with high spectral resolution, our pixel-by-pixel analysis is performed for various regions on the solar disk, ranging from quiet-Sun regions to active regions exhibiting eruptions, characterizing photospheric dynamics using spectral profiles. In particular, the method quantitatively

characterizes the time profile of changes in spectral properties in photospheric features and provides improved physical constraints on observed quantities.
Author(s): Anthony P Rasca[2], James Chen[2], Alexei A. Pevtsov[1]
Institution(s): *1. National Solar Observatory, 2. Naval Research Laboratory*

103.02 – Excitation of Resonant Helioseimic Modes by Solar Flares

Flares are known to excite propagating sound waves in the solar atmosphere, and Maurya et al. (2009), using a local analysis (ring diagrams) of the 2003 Halloween flare, showed that they excite resonant p-modes as well. We confirm and extend here these results by: applying the same analysis to other locations on the Sun at the time of the Halloween flare, analyzing other events also showing a signature of p-mode excitation, looking in detail at the results of the ring diagrams analysis in terms of noise fitting and the center-to-limb variation of ring-diagram power.
Author(s): John William Leibacher[2], Frédéric Baudin[1], Maria Cristina Rabello Soares[3]
Institution(s): *1. Institut d'Astronhysique Spatiale, 2. NSO, 3. Universidade Federal de Minas Gerais, Brazil*

103.03 – Deep Solar Meridional Flow Measurements

Large-scale plasma flows in the Sun's convection zone likely play a major role in solar dynamics on decadal time scales. Direct helioseismic measurements of the zonal flow is dominated by its poleward component near the surface. Relatively small magnitude of the Equator-ward reverse flow was not successful in the past due to presence of mainly observational limitations and artifacts like center-to-limb variations of acoustic travel time measurements. Recently developed approach to correct this variations made possible to see evidence of the reverse flow at approximately 60 Mm below the solar surface (Zhao et al., 2012 and Kholikov et al., 2014). In this study we will present inversion results of center-to-limb corrected measurements obtained using three years of GONG data. Also some additional analysis of deep meridional flow and comparison to HMI measurements will be discussed.

Author(s): Shukur Kholikov[2], Jason Jackiewicz[3], Alexander Serebryanskiy[1]
Institution(s): *1. Astronomical Institut, 2. National Solar Observatory, 3. New Mexico State University*

103.04 – Spectral Characteristics of Magnetic Field Emergence in the Photosphere

The photosphere is the innermost visible layer of the solar atmosphere, where the medium makes a transition from an optically thick to optically thin state. All forms of solar energy ultimately must traverse the photosphere from the solar interior. An important component of the energy budget is the magnetic energy, which is presumed to be generated deep in the convection zone by the solar dynamo. Recent high-resolution observations have revealed that the emergence of active regions is manifested as the rapid appearance of small bipolar magnetic features. It is expected that future observations with higher spatial and temporal resolution will show magnetic features on smaller spatial and faster temporal scales that are currently unresolved. It is therefore important to establish the quantitative relationship between the magnetic energy flux through the surface and observational data directly accessible by remote-sensing techniques. In order to achieve this, we construct a generic model in which an ensemble of magnetic flux ropes is prescribed to rise through the photosphere. The ensemble consists of flux ropes on a range of scales extending to sub-pixel levels, and potentially observable

spectral properties are related to the magnetic energy flux of the ensemble. The model is applied to photospheric absorption lines, and the magnetic energy flux implied by the data (e.g., SOLIS data) is calculated using a statistical method based on the pixel fluctuations in the spectral data (Stokes parameters) (Rasca et al. 2015).
Rasca, A., Chen, J., and Pevtsov, A., this meeting, 2015.
Author(s): James Chen[1], Anthony P Rasca[1]
Institution(s): *1. Plasma Physics Division, Naval Research Laboratory*

103.05 – Helioseismic Mode Parameters from 20 Years of Global Oscillation Network Group (GONG) Observations

The intermediate-degree mode parameters are used to study the variability of solar oscillations and their dependence on the magnetic-activity. We use uninterrupted observations from the 6-site network, Global Oscillation Network Group (GONG), for about 20 years that covers a period from the minimum of cycle 23 to the declining phase of cycle 24. Using the observations for cycle 23, it was demonstrated that the frequencies do vary in phase with the solar activity indices. However, the degree of correlation differs from phase to phase of the cycle; the mode frequency shifts are strongly correlated with the activity proxies during the rising and declining phases whereas this correlation is significantly lower during the high-activity period. Here we present and compare results for two solar cycles, and try to understand the origin of the differences between both cycles.
Author(s): Kiran Jain[2], Sushant C. Tripathy[2], Frank Hill[2], Rosaria Simoniello[1]
Institution(s): *1. Geneva Observatory, 2. National Solar Observatory*

103.06 – Tracking Active Region NOAA 12192 in Multiple Carrington Rotations

Active region NOAA 12192 appeared on the visible solar disk on October 18, 2014 and grew rapidly into the largest such region since 1990. During its entire transit across the Earth facing side of the Sun, it produced a significant number of X- and M-class flares. The combination of front-side and helioseismic far-side images clearly indicated that it lived through several Carrington rotations. In this paper, using Dopplergrams from GONG and HMI, we present a study on mode parameters, viz. oscillation frequencies, amplitude, and sub-surface flows and investigate how these vary with the evolution of active region in multiple rotations. We also present a detailed comparison between NOAA 10486 (the biggest active region in cycle 23) and NOAA 12192, and discuss the similarities/differences between them.
Author(s): Kiran Jain[1], Sushant C. Tripathy[1], Frank Hill[1]
Institution(s): *1. National Solar Observatory*

104 – Magnetic Reconnection I (the whole)

104.02 – How the Dynamics of Flare Ribbons Can Help Us Understand the Three-dimensional Structure of Reconnection

Magnetic reconnection occurs in magnetized plasmas in space and astrophysical environment and fusion experiments. It rapidly changes magnetic field converting magnetic energy into other forms. Energy release in solar flares is believed to be governed by reconnection taking place in the Sun's outer atmosphere, the corona. However, the corona is not always the easiest place to measure magnetic field and its change. During a flare, we also observe what happens at the boundary between the Sun's corona

and interior, the chromosphere, to learn about reconnection process in the corona. Magnetic field in the Sun's outer atmosphere is line-tied at this boundary; energy flux is largely streamlined by magnetic field to where the field is rooted at this boundary, and quickly heats up the chromosphere, in a way similar to how auroras are produced by charged particles reaching the Earth's atmosphere at geomagnetic poles. Therefore, observing the impacted chromosphere during the flare allows us to track how much and how quickly magnetic flux is reconnected. Whereas probes in fusion experiments or spacecrafts in the Earth's magnetosphere usually sample multiple points for direct in-situ measurements, all reconnection events in the Sun's corona resulting in significant atmosphere heating can be mapped at the boundary with imaging observations of the Sun. From this mapping, we seek to reconstruct the geometry and evolution of reconnection, to understand the dual property of reconnection that is both sporadic and organizable in a flare, and to find out how much energy is released by each burst of reconnection. This talk will discuss recent results and challenges in this practice, inspired by observations of ribbons and loops of solar flares obtained from the Solar Dynamic Observatory and Interface Region Imaging Spectrograph.
Author(s): Jiong Qiu[1]
Institution(s): *1. Montana State University*

104.03 – Magnetopause reconnection and the role of the magnetosphere

The Earth's dayside magnetopause provides a platform to study magnetic reconnection over a wide range of parameter space. The plasma and magnetic field on both sides of the magnetopause boundary can change significantly. The resulting boundary is the site of asymmetric reconnection spanning a host of parameters and with a range of effects on energy input into the magnetosphere. We present recent spacecraft observations from the THEMIS mission studying the impact of changes on the magnetosphere side of the boundary. This includes changes in plasma density by up to three orders of magnitude (0.1 to 100cm^-3). We find the reconnection structure agrees with asymmetric reconnection theory, however the local parameters in the magnetosheath do not adjust sufficiently to accommodate changes within the magnetoshere.
Author(s): Brian Walsh[3], David Sibeck[2], Tai Phan[3], Vitor Souza[1], John Bonnell[3]
Institution(s): *1. INPE, 2. NASA GSFC, 3. University of California, Berkeley*

104.04 – The Onset of Magnetic Reconnection

A fundamental question concerning magnetic energy release on the Sun is why the release occurs only after substantial stresses have been built up in the field. If reconnection were to occur readily, the released energy would be insufficient to explain coronal heating, CMEs, flares, jets, spicules, etc. How can we explain this switch-on property? What is the physical nature of the onset conditions? One idea involves the "secondary instability" of current sheets, which switches on when the rotation of the magnetic field across a current sheet reaches a critical angle. Such conditions would occur at the boundaries of flux tubes that become tangled and twisted by turbulent photospheric convection, for example. Other ideas involve a critical thickness for the current sheet. We report here on the preliminary results of our investigation of reconnect onset. Unlike our earlier work on the secondary instability (Dahlburg, Klimchuk, and Antiochos 2005), we treat the coupled chromosphere-corona system. Using the BATS-R-US MHD code, we simulate a single current sheet in a sheared magnetic field that extends from the chromosphere into the corona. Driver motions are applied at the base of the model. The configuration and chromosphere are both idealized, but capture the essential physics of the problem. The advantage of this unique approach is that it resolves the current sheet to the greatest extent possible while maintaining a realistic solar atmosphere. It thus bridges the gap between "reconnection in a box" studies and studies of large-scale systems such as active regions. One question

we will address is whether onset conditions are met first in the chromosphere or corona. We will report on the work done on the project.
Author(s): Lars K.S. Daldorff[3], James A Klimchuk[1], Bart van der Holst[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. University of Michigan , 3. University of Michigan/ NASA Goddard*

104.05 – FLARE (Facility for Laboratory Reconnection Experiments): A Major Next-Step for Laboratory Studies of Magnetic Reconnection

A new intermediate-scale plasma experiment, called the Facility for Laboratory Reconnection Experiments or FLARE (flare.pppl.gov), is under construction at Princeton as a joint project by five universities and two national labs to study magnetic reconnection in regimes directly relevant to heliophysical and astrophysical plasmas. The currently existing small-scale experiments have been focusing on the single X-line reconnection process in plasmas either with small effective sizes or at low Lundquist numbers, both of which are typically very large in natural plasmas. These new regimes involve multiple X-lines as guided by a reconnection "phase diagram", in which different coupling mechanisms from the global system scale to the local dissipation scale are classified into different reconnection phases [H. Ji & W. Daughton, Phys. Plasmas **18**, 111207 (2011)]. The design of the FLARE device is based on the existing Magnetic Reconnection Experiment (MRX) (mrx.pppl.gov) and is to provide experimental access to the new phases involving multiple X-lines at large effective sizes and high Lundquist numbers, directly relevant to magnetospheric, solar wind, and solar coronal plasmas. After a brief summary of recent laboratory results on the topic of magnetic reconnection, the motivating major physics questions, the construction status, and the planned collaborative research especially with heliophysics communities will be discussed.
Author(s): Hantao Ji[3], A. Bhattacharjee[3], S. Prager[3], W. Daughton[1], Stuart D Bale[6], T. Carter[7], N. Crocker[7], J. Drake[4], J. Egedal[5], J. Sarff[5], W. Fox[2], J. Jara-Almonte[2], C. Myers[2], Y. Ren[2], M. Yamada[2], J. Yoo[2]
Institution(s): *1. Los Alamos National Laboratory, 2. Princeton Plasma Physics Laboratory, 3. Princeton University, 4. U. Maryland, 5. U. Wisconsin - Madison, 6. UC Berkeley, 7. UCLA*

104.06 – Thermal Diagnostics of Reconnection Outflows with SDO/AIA

We present a new method for performing differential emission measure (DEM) inversions on narrow-band EUV images from the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO). The method yields positive-definite DEM solutions by solving a linear program. This method has been validated against a diverse set of thermal models of varying complexity and realism. These include (1) idealized gaussian DEM distributions, (2) 3D models of NOAA Active Region (AR) 11158 comprising quasi-steady loop atmospheres in a non- linear force-free field, and (3) thermodynamic models from a fully-compressible, 3D MHD simulation of AR corona formation following magnetic flux emergence. We illustrate the utility of the method by applying it to an offlimb, eruptive M7.7 flare from NOAA AR 11520. DEM inversions from this method allow us to study the thermal distribution and evolution of plasma expelled from the reconnection region and their relation to plasma heated at the footpoints of flare loops.
Author(s): Mark CM Cheung[1]
Institution(s): *1. Lockheed Martin Solar & Astrophysics Laboratory*

105 – Solar Interior/Dynamo/Helioseismology

105.01 – Modified Rossby Waves in the Solar Interior

Using a combination of STEREO/SECCHI/EUVI and SDO/AIA imaging we reveal patterns in the imaging data that are consistent in appearance with global scale rotationally driven waves on the activity bands of the solar magnetic polarity cycle.

Author(s): Scott W McIntosh[1], Alan M Title[2], Robert J Leamon[3]
Institution(s): *1. HAO/NCAR, 2. LMSAL, 3. MSU*

105.02 – Temporal evolution of the solar torsional oscillation and implications for cycle 25

The zonal flow known as the torsional oscillation has been observed on the Sun's surface since 1980 and in its interior since 1995. It has two branches that migrate during the solar cycle, with one moving towards the equator and the other towards the poles. The rate at which these branches migrate in latitude is tightly correlated with the timing of the solar cycle, as seen during the long minimum between cycles 23 and 24. The poleward branch generally becomes visible 10 to 12 years before the appearance of the magnetic activity associated with the corresponding sunspot cycle as it did for the current cycle 24. However, the poleward flow for cycle 25, which was expected to appear in 2008-2010, was not observed. Subsequent analysis showed that it is a very weak flow, and is masked by an apparent change in the background solar differential rotation rate. We will present the latest observations of the zonal flow as determined from global helioseismology, and will discuss the implications for the strength and timing of cycle 25.

Author(s): Frank Hill[2], Rachel Howe[5], Rudolf Komm[2], Jesper Schou[1], Michael Thompson[4], Timothy Larson[3]
Institution(s): *1. Max Planck Institute for Solar System Research, 2. National Solar Observatory, 3. Stanford University, 4. UCAR, 5. University of Birmingham*

105.03 – Simulations of convective dynamo in the solar convective envelope: self-consistent maintenance of the solar differential rotation and emerging flux

We report the results of magneto-hydrodynamic (MHD) simulations of convective dynamo in a model solar convective envelope driven by the solar radiative diffusive heat flux. The convective dynamo produces a large-scale mean magnetic field that exhibits irregular cyclic behavior with oscillation time scales ranging from about 5 to 15 yr and undergoes irregular polarity reversals. The mean axisymmetric toroidal magnetic field is of opposite signs in the two hemispheres and is concentrated at the bottom of the convection zone. The presence of the magnetic fields is found to play an crucial role in the self-consistent maintenance of a solar-like differential rotation in the convective dynamo model. Without the magnetic fields, the convective flows drive a differential rotation with a faster rotating polar region. In the midst of magneto-convection, we found the emergence of strong super-equipartition flux bundles at the surface, exhibiting properties that are similar to emerging solar active regions. We vary the viscosity, magnetic diffusivity and the lower boundary conditions and discuss their effects on the cyclic behavior.

Author(s): Yuhong Fan[1], Fang Fang[1]
Institution(s): *1. National Center for Atmospheric Research*

105.04 – Detection of Fast-Moving Waves Propagating Outward from Sunspots in the Photosphere

Helioseismic and magnetohydrodynamic waves are abundant in and above sunspots. Through cross-correlating oscillation signals at various locations, we are able to reconstruct how waves propagate away from a wave source inside a sunspot in the photospheric level. Before helioseismic waves are visible propagating away from the source, a surprisingly fast-moving wave is detected traveling along the sunspot's radial direction
from inside of the sunspot to the outside, extending about 15 Mm beyond the sunspot boundary. The wave has a frequency range of 2.5 - 4.0 mHz, and appears dispersionless with a phase velocity of 45.3 km/s, a few times faster than typical speeds of sound and magnetohydrodynamic waves in the photosphere. The observed wave is consistent with a magnetoacoustic wave, excited at approximately 5 Mm beneath the sunspot surface, sweeping across the photosphere, although it is not clear how this wave is excited at that depth. If the fast-moving wave is truly excited in the sunspot's subsurface area, this will help open a new window to study the internal structure and dynamics of sunspots.
Author(s): Junwei Zhao[3], Ruizhu Chen[3], Thomas Hartlep[1], Alexander Kosovichev[2]
Institution(s): *1. NASA Ames Research Cente, 2. New Jersey Institute of Technology, 3. Stanford University*

105.05 – Exploring the Solar-stellar connection with the CHARA Array

It is well understood that in order to better understand solar magnetism it is of key importance that we have detailed data on magnetic activity of stars that are very much like our Sun. Georgia State's University Center for High Resolution Astronomy's (CHARA) Array is a diffraction limited interferometer with a baseline of over 300 m, located on Mount Wilson. CHARA has resolved the disk of larger early-type stars and observed starspots. It has the potential of detecting spots (and eclipsing exoplanets) on nearby solar-type stars, and thus adding significant in-depth magnetic cycle information to the long time series of chromospheric data from MWO and Lowell.
We will describe the main characteristics of CHARA, highlight science results, and describe our plans to contribute to the renewed effort from the NASA Heliophysics division to study the solar-stellar connection, with the goal of improving long-term solar activity forecasts.
URL: http://www.chara.gsu.edu/
Author(s): Petrus C Martens[1], Hal McAlister[1], Russel White[1]
Institution(s): *1. Georgia State University*

105.06 – Subsurface helicity of active regions 12192 and 10486

The active region 10486 that produced the Halloween flares in 2003 initiated our interest in the kinetic helicity of subsurface flows associated with active regions. This lead to the realization that the helicity of subsurface flows is related to the flare activity of active regions. Eleven years later, a similarly enormous active region (12192) appeared on the solar surface. We plan to study the kinetic helicity of the subsurface flows associated with region 12192 and compare it to that of region 10486. For 10486, we have analyzed Dopplergrams obtained with the Michelson Doppler Imager (MDI) onboard the Solar and Heliospheric Observatory (SOHO) and the Global Oscillation Network Group (GONG) with a dense-pack ring-diagram analysis. For 12192, we have analyzed Dopplergrams from GONG and the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO). We will present the latest results.
Author(s): Rudolf Komm[1], Sushant Tripathy[1], Rachel Howe[2], Frank Hill[1]
Institution(s): *1. National Solar Observatory, 2. University of Birmingham*

106 – Upper Atmosphere Research

106.01 – Modes of high-latitude conductance variability derived from DMSP F6-F8 and F16-F18 energetic electron precipitation observations: Empirical Orthogonal Function (EOF) analysis

Energy redistribution in the magnetosphere-ionosphere-thermosphere (MIT) system is largely controlled by a complex system of field-aligned, Hall, and Pedersen currents, and the electrodynamics underlying their distributions. According to Ohm's law, the electrodynamics relationships rely on knowledge of the ionospheric conductivity. We present the results of an empirical orthogonal function (EOF) analysis of the horizontal (Pedersen and Hall) ionospheric conductances, using multiple years of Defense Meteorological Satellite (DMSP) data. Our results represent the dominant modes of variability of the Pedersen and Hall conductivities.

We show that the mean patterns together with the first four EOFs represent ~70 and 68% of the total Pedersen and Hall conductance variabilities, respectively. We find each of the first four EOFs for both conductances represent clear and distinguishable geophysical phenomena. The first EOF represents variation in the quasi-permanent aurora associated with diffuse electron precipitation. The second and third EOFs, in varying order for each horizontal conductance, show features of an expanded auroral zone due to geomagnetic activity and distinct MLT `hot spots' associated with northward IMF conditions. The fourth EOF shows a signature of the substorm current wedge in the post-dusk to pre-midnight sector. Finally, we compare the results of EOFs estimated from DMSP satellite data with those obtained using electron precipitation data from the Fast Auroral SnapshoT Explorer (FAST) satellite.

Author(s): Ryan Michael McGranaghan[5], Delores J. Knipp[5], Tomoko Matsuo[1], Humberto Godinez[2], Robert Redmon[4], Steve Morley[2], Stanley Solomon[3]
Institution(s): *1. Cooperative Institute for Research in Environmental Sciences, 2. Los Alamos National Laboratories, 3. National Center for Atmospheric Research, 4. National Oceanic and Atmospheric Administration, 5. University of Colorado Boulder*

106.02 – High Latitude Data Solutions for Specifying Magnetosphere Ionosphere Thermosphere Coupling

In this presentation we will discuss methods for merging and comparing ground- and space-based data with the long-operating satellite constellation system: Defense Meteorological Satellite Program (DMSP). DMSP spacecraft have been on orbit since the mid 1980's. Since the program's beginning the constellation has had at least two, and sometimes four, spacecraft simultaneously in orbit. The particle sensors have accumulated approximately 100-satellite years worth of data. Additionally, the boom-mounted magnetometers have flown since 2000 and have contributed approximately 30 years of magnetometer data. We will describe our efforts to bring these data into common data formats for community use. We will show: 1) how the magnetometer data are providing a basis for comparison with other spacecraft measurements in low Earth orbit, in particular the 2006 Space Technology-5 Demonstration mission and the Iridium constellation; and 2) how the particle data are providing new insights into particle energy deposition in the thermosphere. Our efforts have resulted in the widespread availability of high-quality data for the ITM community and in this presentation we will showcase a few ways these data can be utilized for upper atmosphere research.

Author(s): Delores J. Knipp[2], Liam kilcommons[2], Ryan Michael McGranaghan[2], Robert Redmon[1]
Institution(s): *1. National Geophysical Data Center, 2. University of Colorado*

106.03 – Time-delayed upper atmospheric responses to solar EUV irradiation

It is well recognized that solar EUV irradiations at various wavelengths are the dominant driver of the quiet-time upper atmospheric variations, including thermospheric temperature and densities, as well as ionospheric density and temperatures. However, responses of the upper atmosphere have been found not as straightforward as expected, but rather complicated with time-delays for approximately 2 days relative to solar flux proxy F10.7. Using measurements of TIMED/SEE solar UV flux at various wavelengths and incoherent scatter radar-based ionospheric and thermospheric parameters, this paper addresses characteristic upper atmospheric variability on the time scales from hours to days, and the associated solar UV variations. It is found that exospheric temperature Tex is most sensitive to solar EUV flux with an approximately 2-day delay at wavelengths of 27--34 nm (including 30.4 nm). In fact, a 20--60-hour time delay occurs in Tex response to EUV flux at the 27-34 nm band, with shorter delays in the morning and longer delays in the afternoon and at night. Ionospheric electron delays are altitude dependent: in the E-region, there is no time delay, and in the F2 region, there exist delays for 2-3 days in both electron density and ion temperature. These delays are perhaps representatives of the upper atmospheric memory and will be discussed in the paper.
Author(s): Shunrong Zhang[1], Philip Erickson[1], Larisa Goncharenko[1]
Institution(s): *1. MIT Haystack Observatory*

106.04 – The impact of energetic electron precipitation on mesospheric OH and O3 during weak to moderate recurrent geomagneic storms in 2008

We investigate the impact of energetic electron precipitation (EEP) on mesospheric OH during 2008 using data measured by the NOAA Polar Orbiting Environmental Satellites (POES) and the AURA satellite. The MEPED particle spectrometers on the POES include two collimated electron detectors, which are pointing approximately towards zenith and in the horizontal plane, respectively. At medium and high geomagnetic latitudes one detector measures particle within the bounce loss cone and the other detector measures particles outside or near the edge of the loss cone. The electron fluxes often show strong pitch angle anisotropy which causes large uncertainty in the estimate of energy deposition based on these measurements. To overcome this problem, we have used a method for calculating the flux versus pitch angle in the loss cone based on the measured electron fluxes and modeled flux profiles from pitch angle scattering by wave particle interactions.
We calculate the electron energy deposition based on the estimated fluxes and compare the result with the mesospheric OH composition measured by AURA during a sequence of weak to moderate geomagnetic storms in 2008. Significant OH enhancement is seen both in the northern and southern hemispheres poleward of 55 degrees CGM latitude. O3 depletions due to odd hydrogen catalytic cycles were seen in both hemispheres. Our findings emphasize the importance of the EEP effect on mesospheric ozone even during minimum solar activity.
Author(s): Johan Stadsnes[1], Hilde Nesse Tyssøy[1], Annet Eva Zawedde[1], Linn-Kristine Glesnes Ødegaard[1], Marit Irene Sandanger[1], Yvan Orsolini[1]
Institution(s): *1. University of Bergen*

106.05 – A combined solar and geomagnetic index for thermospheric climate

Infrared radiation from nitric oxide (NO) at 5.3 µm is a primary mechanism by which the thermosphere cools to space. The SABER instrument on the NASA TIMED satellite has been measuring thermospheric cooling by NO for over 13 years. Physically, changes in NO emission are due to changes in temperature, atomic oxygen, and the NO density. These physical changes however are driven by changes in solar irradiance and changes in geomagnetic conditions. We show that the SABER time series of globally integrated infrared power (Watts) radiated by NO can be replicated accurately by a multiple linear

regression fit using the F10.7, Ap, and Dst indices. This fit enables several fundamental properties of NO cooling to be determined as well as their variability with time, permitting reconstruction of the NO power time series back nearly 70 years with extant databases of these indices. The relative roles of solar ultraviolet and geomagnetic processes in determining the NO cooling are derived and shown to be solar cycle dependent. This reconstruction provides a long-term time series of an integral radiative constraint on thermospheric climate that can be used to test climate models.
Author(s): Linda A Hunt[2], Martin G. Mlynczak[1]
Institution(s): *1. NASA Langley Research Center, 2. SSAI*

106.06 – Challenges in Simulating the Indirect Effect of Energetic Particle Precipitation on the Atmosphere

A comprehensive description of Sun-Earth connections requires quantifying the atmospheric processes that indirectly amplify the effects of solar and magnetospheric input. The atmospheric response to energetic particle precipitation (EPP) is a key driver of these processes. EPP during the 2003-2004 Arctic winter led to the production and subsequent descent of reactive odd nitrogen (NO_x) from the mesosphere and lower thermosphere (MLT) into the stratosphere. This caused NO_x enhancements in the polar upper stratosphere in April 2004 that were unprecedented in the satellite record. Simulations of the 2003-2004 Arctic winter with the Whole Atmosphere Community Climate Model using Specified Dynamics (SD-WACCM) are compared to satellite measurements to assess how well SD-WACCM captures the observed NO_x enhancements. The comparisons show that SD-WACCM clearly displays the descent of NO_x produced by EPP, but underestimates the enhancements by a factor of four. The results suggest that problems simulating the atmosphere's recovery from a sudden stratospheric warming, as well as the lack of high energy electron precipitation in the model, both contribute to the inability of SD-WACCM to simulate the NO_x enhancements. The work highlights the importance of measuring the full spectrum of precipitating electrons in order to understand the impact of EPP on the atmosphere, and suggests a need for more and higher quality meteorological data and measurements of NO_x throughout the polar winter MLT.
Author(s): Cora Randall[2], Scott Bailey[3], V. Lynn Harvey[2], Daniel Marsh[1]
Institution(s): *1. NCAR, 2. University of Colorado, 3. Virginia Tech*

107 – Magnetic Reconnection II (fragments)

107.01 – Exploring the Microscales of Magnetic Reconnection: The Exciting Prospects of the MMS Satellite Mission

Magnetic reconnection is a multiscale process in which the dynamics at electron scales ultimately allow energy release with global consequences. The Magnetospheric Multiscale Mission (MMS) is poised to make measurements of unprecedented spatial and temporal accuracy in the Earth's magnetosphere. For the first time, measurement of plasma distribution functions will be possible at electron scales where magnetic field lines are allowed to break and reform. This will allow a view of the "machinery" that allows magnetic reconnection to occur. In this talk, aspects of our current understanding of the electron scales during magnetic reconnection will first be reviewed and then the prospects for breakthroughs due to MMS will be discussed. Relevant topics include: The structure of the electron diffusion region and the process or processes breaking the frozen-in constraint, the acceleration and heating of electrons during magnetic reconnection, the role of instabilities in mediating magnetic reconnection and its

effects, and the role of turbulence in generating magnetic reconnection and the turbulent dissipation that occurs at electron scales.
Author(s): Michael Shay[1]
Institution(s): *1. University of Delaware*

107.02 – Characteristics of Magnetic Reconnection in High-Lundquist Number MHD Simulations of Coronal Mass Ejections

We present a detailed analysis of the properties of magnetic reconnection at large-scale current sheets in a very high cadence 2.5D MHD simulation of sympathetic magnetic breakout coronal mass ejections (CMEs) from a pseudostreamer source region. We examine the resistive tearing and breakup of the three main current sheets into chains of X- and O-type null points and follow the dynamics of magnetic island growth, their merging, transit, and ejection with the reconnection exhaust. For each current sheet, we quantify the evolution of the length-to-width aspect ratio (up to ~100:1), Lundquist number (~10^4), and reconnection rate (inflow-to-outflow ratios reaching ~0.15). We examine the statistical and spectral properties of the fluctuations in the current sheets resulting from the plasmoid instability, including the distribution of magnetic island width, mass, and flux content. We show that the temporal evolution of the spectral index of the reconnection-generated magnetic energy density fluctuations appear to reflect global properties of the current sheet evolution. Our results are in excellent agreement with recent, high resolution reconnection-in-a-box simulations even though our current sheets' formation, growth, and dynamics are intrinsically coupled to the global evolution of sequential sympathetic CME eruptions.
Author(s): Ben Lynch[2], Justin K Edmondson[3], Maria D Kazachenko[2], Silvina E Guidoni[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. University of California, Berkeley, 3. University of Michigan*

107.03 – Quantifying Reconnection in Fragmented 3D Current Layers

There is growing evidence that when magnetic reconnection occurs in high Lundquist number plasmas such as in the Solar Corona or the Earth's Magnetosphere it does so within a fragmented, rather than a smooth current layer. Within the extent of these fragmented current regions the associated magnetic flux transfer and energy release occurs simultaneously in many different places. This simultaneous energy release and flux transfer has been postulated as a possible resolution to the problem of obtaining “fast” reconnection rates in such high conductivity plasmas. But how does one measure the reconnection rate in such fragmented current layers?
In 2D the reconnection rate is simply given by the electric field at the dominant X-point, typically then normalized by the product of the upstream magnetic field strength and Alfven speed. However, the continuous nature of connection change in 3D makes measuring the reconnection rate much more challenging. Building on the analytical work of previous investigations (e.g. Hesse & Schindler 1988, Hesse & Birn 1993, Hesse et al. 2005) we present recently derived expressions providing, for the first time, a quantitative measure of reconnection rate in fragmented 3D current layers. We show that in 3D two measures actually characterize the rate of flux transfer; a total rate which measures the true rate at which new connections are formed and a net rate which measures the net change of connection associated with the largest value of $\int E \, dl$ through all of the non-ideal regions. Some simple examples will be used to illustrate how each expression may be applied and what it quantifies. This work was supported by an appointment to the NASA Postdoctoral Program and by NASA’s Magnetospheric Multiscale mission.
Author(s): Peter Fraser Wyper[1], Michael Hesse[1]

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

107.04 – Does Flare Reconnection Occur Before or After Explosive Coronal Mass Ejection Acceleration?

The mechanism for producing fast coronal mass ejections/eruptive flares (CME/EFs) is hotly debated. Most models rely on ideal instability/loss of equilibrium or magnetic reconnection; these two categories of models predict different causal relationships between CMEs and flares. In both cases, flare reconnection disconnects the bulk of the CME from the Sun, but in the former models, flare reconnection onset is a consequence of the fast outward motion of the CME while in the later models reconnection is what causes the CME acceleration. Discriminating between these models requires continuous, high-cadence observations and state-of-the-art numerical simulations that enable the relative timing of key stages in the events to be determined. With the advent of SDO, STEREO, and massively parallel supercomputers, we are well poised to tackle this major challenge to our understanding of solar activity. In recent work (Karpen et al. 2012), we determined the timing and location of triggering mechanisms for the breakout initiation model (Antiochos et al. 1999), using ultra-high-resolution magnetohydrodynamic simulations with adaptive mesh refinement and high-cadence analysis. This approach enabled us to resolve as finely as possible the small scales of magnetic reconnection and island formation in the current sheets, within the global context of a large-scale solar eruption. We found that the explosive acceleration of the fast CME occurs only *after* the onset of rapid reconnection at the flare current sheet formed in the wake of the rising CME flux rope. In the present work, we compare flare reconnection rates, measured from flare ribbon UV brightenings observed by SDO/AIA and magnetograms from SDO/HMI, with the height evolution of CME fronts and cores, measured from STEREO/SECCHI EUV and coronagraph images. We also calculate these quantities from numerical simulations and compare them to observations, as a new test of the breakout initiation model. This work was supported by NASA's Heliophysics Supporting Research and Living With a Star Targeted Research and Technology programs.

Author(s): Silvina E Guidoni[2], Judith T. Karpen[2], C R DeVore[2], Jiong Qiu[1]
Institution(s): *1. Montana State University, 2. NASA Goddard Space Flight Center*

107.05D – Spectroscopic observations of evolving flare ribbon substructure suggesting origin in current sheet waves

A flare ribbon is the chromospheric image of reconnection at a coronal current sheet. The dynamics and structure of the ribbon can thus reveal properties of the current sheet, including motion of the reconnecting flare loops. We present imaging and spectroscopic observations from the Interface Region Imaging Spectrograph (IRIS) of the evolution of a flare ribbon at high spatial resolution and time cadence. These reveal small-scale substructure in the ribbon, which manifest as oscillations in both position and Doppler velocities. We consider various alternative explanations for these oscillations, including modulation of chromospheric evaporation flows. Among these we find the best support for some form of elliptical wave localized to the coronal current sheet, such as a tearing mode or Kelvin-Helmholtz instability.
IRIS is a NASA Small Explorer mission developed and operated by Lockheed Martin Solar and Astrophysics Laboratory. This work is supported by contract 8100002702 from Lockheed Martin to Montana State University, a Montana Space Grant Consortium fellowship, and by NASA through HSR.
Author(s): Sean R Brannon[1], Dana Longcope[1], Jiong Qiu[1]
Institution(s): *1. Montana State University*

108 – Solar Wind Plasma and Magnetic Fields

108.01 – The effect of reconnection on the structure of the Sun's open-closed-flux boundary, and implications for the structure of the solar wind

Global magnetic field extrapolations are now revealing the huge complexity of the Sun's corona, and in particular the structure of the boundary between open and closed magnetic flux. Moreover, recent developments indicate that magnetic reconnection in the corona likely occurs in highly fragmented current layers, and that this typically leads to a dramatic increase in the topological complexity beyond that of the equilibrium field. Here we investigate the consequences of reconnection at the open-closed flux boundary ("interchange reconnection") in a fragmented current layer. We demonstrate that it leads to a situation in which magnetic flux (and therefore plasma) from open and closed field regions is efficiently mixed together. This corresponds to an increase in the length and complexity of the open-closed boundary. Thus, whenever reconnection occurs at a null point or separator of the open-closed boundary, the associated separatrix arc of the so-called *S-web* in the high corona becomes not a single line but a band of finite thickness within which the open-closed flux boundary is highly structured. This has significant implications for the structuring of the solar wind.
Author(s): David I Pontin[2], Peter Fraser Wyper[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. University of Dundee, UK*

108.02 – Using the fingerprints of solar magnetic reconnection to identify the elemental building blocks of the slow solar wind

While the source of the fast solar wind is well understood to be linked to coronal holes, the source of the slow solar wind has remained elusive. Many previous studies of the slow solar wind have examined trends in the composition and charge states over long time scales and found strong relationships between the solar wind velocity and these plasma parameters. These relationships have been used to constrain models of solar wind source and acceleration. In this study, we take advantage of high time resolution (12 min) measurements of solar wind composition and charge-state abundances recently reprocessed by the ACE Solar Wind Ion Composition Spectrometer (SWICS) science team to probe the timescales of solar wind variability at relatively small scales. We study an interval of slow solar wind containing quasi-periodic 90 minute structures and show that they are remnants of solar magnetic reconnection. Each 90-minute parcel of slow solar wind, though the speed remains steady, exhibits the complete range of charge state and composition variations expected for the entire range of slow solar wind, which is repeated again in the next 90-minute interval. These observations show that previous statistical results break down on these shorter timescales, and impose new and important constraints on models of slow solar wind creation. We conclude by suggesting these structures were created through interchange magnetic reconnection and form elemental building blocks of the slow solar wind. We also discuss the necessity of decoupling separately the process(es) responsible for the release and acceleration.
Author(s): Larry Kepko[1], Nicholeen M. Viall[1], Justin Kasper[2], Sue Lepri[2]
Institution(s): *1. NASA GSFC, 2. University of Michigan*

108.03 – Slow solar wind boundaries and implication for its formation

Solar wind and the associated magnetic field permeate the heliosphere. Their temporal and spatial variations contribute significantly in the large range of variations in related geomagnetic effects as well

as in the properties of solar energetic particles. Among the least understood is the slow solar wind for how it is formed at the Sun and what causes the large variations in its physical properties. This work investigates the variations in the slow solar wind streams measured in-situ at 1 AU and the correlations among the protons, heavy ions, suprathermal electrons, and magnetic field properties. Besides well-established correlations among the proton speed, proton temperature and ion charge states, we also found certain distinct characteristics in the correlation and temporal relationship between the ion charge states, proton velocity fluctuations and, in many cases, suprathermal electron halos. The implications from our findings in the slow wind formation and whether the slow wind has a distinct boundary with the fast wind will be discussed.
Author(s): Yuan-Kuen Ko[2], Aaron Roberts[1], Susan Lepri[3], Manan Kocher[3]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Naval Research Laboratory, 3. University of Michigan*

108.04 – 3D Simulations of Helmet Streamer Dynamics and Implications for the Slow Solar Wind

The source of the slow solar wind at the Sun is still an issue of intense debate in solar and heliospheric physics. Because the majority of the solar wind observed at Earth is slow wind, understanding its origin is essential for understanding and predicting Earth's space weather environment. In-situ and remote observations show that, when compared to the fast wind, the slow solar wind corresponds to higher freeze-in temperatures, as indicated by charge-state ratios, and more corona-like elemental abundance ratios. These results indicate that the most likely source for the slow wind is the hot plasma in the closed-field corona, but the release mechanism(s) for the wind from the closed-field regions is far from understood. We perform fully dynamic, 3D MHD simulations in order to the study the opening and closing of the Sun's magnetic field that leads to the escape of the slow solar wind. In particular, we calculate the dynamics of helmet streamers that are driven by photospheric motions such as supergranular flows. We determine in detail the opening and closing of coronal flux, and discuss the implications of our results for theories of slow wind origin, especially the S-Web model. We also determine observational signatures for the upcoming inner heliosphere missions Solar Orbiter and Solar Probe Plus.
This work was supported by the NASA SR&T and TR&T Programs.
Author(s): Aleida K. Higginson[2], Spiro K Antiochos[1], C R DeVore[1], Thomas H Zurbuchen[2]
Institution(s): *1. Goddard Space Flight Center, NASA, 2. University of Michigan*

108.05 – Element Abundances in the Sun and Solar Wind Along the Solar Cycle

Element abundances are a critical parameter in almost every aspect of solar physics, from regulating the energy flow and the structure of the solar interior, to shaping the energy losses of the solar atmosphere, ruling the radiative output of the UV, EUV and X-rays solar radiation which impacts the Earth's upper atmosphere, and determining the composition of the solar wind.
In this work we study the evolution of the element abundances in the solar corona and in the solar wind from 1996 to date using data from SoHO, Hinode, Ulysses and ACE satellites, in order to determine their variability along the solar cycle, and the relationship between solar abundance variations in the solar wind and in its source regions in the solar atmosphere. We study all the most abundant elements, with a special emphasis on Ne and O. We discuss our results in light of the source region of the solar wind, and of the radiative output of the solar corona.
Author(s): Enrico Landi[1]
Institution(s): *1. University of Michigan*

108.06 – Measuring the Turbulent Solar Wind

The slow solar wind is turbulent, a fact that may explain the variability of the slow wind at Earth. But the nature and strength of the turbulence has been hard to quantify because measurements have been limited to in-situ detection of variations in measurable parameters. Remote imaging of comet tails offers a unique opportunity to study the paths of localized "test particles" in the solar wind, and to analyze the motion in the same way that hydrodynamicists might study turbulence in water with test particles. We report on a careful analysis of the motion of 230 individually tracked features in the tail of a comet observed with STEREO/HI-1, which interacted strongly with the solar wind between 0.2 and 0.3 AU during the observation period, and draw deep conclusions about the nature of solar wind variability.
Author(s): Craig DeForest[1], William Matthaeus[2], Tim Howard[1]
Institution(s): *1. SwRI, 2. University of Delaware*

109 – ITM New Mission Concepts

109.01 – Global-scale Observations of the Limb and Disk (GOLD) Mission – Observing Forcing of the Thermosphere-Ionosphere System from Above and Below

The GOLD mission will provide unprecedented imaging of the Earth's space environment and its response to forcing from the Sun and the lower atmosphere. The mission will fly a far ultraviolet imaging spectrograph and is scheduled for launch into geostationary (GEO) orbit in October 2017 as a hosted payload on a commercial communications satellite flying over eastern South America. From this vantage point GOLD will repeatedly image the American hemisphere at a thirty-minute cadence. Fundamental parameters that will be derived from these measurements include composition (O/N_2) and temperature of the neutral atmosphere on the dayside disk. Imaging of atmospheric composition, at only a daily cadence, has already provided many new insights into the behavior of the Thermosphere-Ionosphere (T-I) system. Combining composition with simultaneous temperature images will provide revolutionary insights into the behavior of the T-I system and its response to external forcing. Since GOLD will repeatedly observe the same geographic locations, it can distinguish between spatial and temporal variations in the TI system caused by geomagnetic storms, variations in solar EUV, and forcing from the lower atmosphere. GOLD's measurements and observing approach will give the scientific community a new understanding of the T-I system.
Author(s): Richard Eastes[2], William McClintock[3], Alan Burns[1]
Institution(s): *1. NCAR, 2. University of Central Florida, 3. University of Colorado*

109.02 – Understanding Ionospheric Connections to Sun and Earth

Earth's ionosphere is the dense plasma environment that dominates the boundary between our atmosphere and space. In contrast with long-standing understanding of the ionosphere as a phenomenon influenced by changes in solar radiation and solar wind, observations over the past decade have shown us that its large day-to-day variability likely originates with forcing from the lower atmosphere. This realization came with a combination of key observations utilizing pioneering measurement techniques, the emergence of sophisticated whole-atmosphere modeling approaches, and the development and application of innovative analysis techniques. The large and unexpected signatures in the ionosphere drove real ingenuity in the development of modeling and analysis techniques, in part for the lack of needed measurements of key aspects of Earth's space environment. Still, the causal links are incomplete and a significant effort is now being mounted to make these

necessary measurements and build a more complete view of the coupled space-atmosphere system. Here we will review these efforts, including the upcoming NASA missions ICON and GOLD, and discuss recent results that offer further promise for future ground-breaking observations and discovery.
Author(s): Thomas J. Immel[3], Doug Rowland[1], Scott England[3], Elsayed Talaat[2], Sarah Jones[1]
Institution(s): *1. Goddard Space Flight Center, 2. NASA Headquarters, 3. UC Berkeley*

109.03 – The Limb-Imaging Ionospheric and Thermospheric Extreme-Ultraviolet Spectrograph (LITES) on the ISS

The Limb-imaging Ionospheric and Thermospheric Extreme-ultraviolet Spectrograph (LITES) is being prepared for flight in early 2016 aboard the Space Test Program Houston 5 (STP-H5) experiment pallet to the International Space Station (ISS). LITES is an imaging spectrograph that spans 60–140 nm and will obtain limb profiles of the ionosphere, along with the key upper atmospheric constituents O and N_2. During the day, LITES measures the OII 83.4 and 61.7 nm emissions that are produced by solar photoionization of atomic oxygen in the lower thermosphere. The 83.4 nm emission is resonantly scattered by ionospheric O^+, and thus its altitude profile is formed by both the initial ionization brightness and the ionospheric content. The 61.7 nm emission is not scattered and is used to constrain the photoionization brightness in the retrieval. At night, recombination of O^+ and electrons produces optically thin emissions at 91.1 and 135.6 nm that are used to tomographically reconstruct the two-dimensional ionosphere in the orbital plane.
These observations will be complemented and validated by ground-based data from an international network of digisondes, visible spectrographs, and imagers, which will provide ground truth for the space-based measurements. Additionally, the STP-H5 mission includes the GPS Radio Occultation and Ultraviolet Photometer Co-located (GROUP-C) experiment that consists of a high-sensitivity, nadir-viewing photometer that measures the nighttime ionospheric airglow at 135.6 nm, and a GPS receiver that measures ionospheric electron content and scintillation. We will discuss the LITES measurements and science goals, and how LITES data will be combined with these other experiments to study low and middle latitude ionospheric structures on a global scale.
Author(s): Andrew W Stephan[1], Susanna C Finn[2], Timothy A Cook[2], Supriya Chakrabarti[2], Scott A Budzien[1]
Institution(s): *1. Naval Research Laboratory, 2. University of Massachusetts Lowell*

109.04 – The GPS Radio Occultation and Ultraviolet Photometry—Colocated (GROUP-C) Experiment on the ISS

The GPS Radio Occultation and Ultraviolet Photometry—Colocated (GROUP-C) Experiment is an ionospheric remote sensing experiment manifested to fly on the International Space Station in early 2016. GROUP-C will operate aboard the Space Test Program Houston 5 (STP-H5) experiment pallet and provide ionospheric measurements in real-time. GROUP-C includes two sensors: the Fast Orbital TEC, Observables, and Navigation (FOTON) L1/L2 GPS receiver, which provides vertical electron density profiles and scintillation; and the Tiny Ionospheric Photometer (TIP), a far-ultraviolet photometer for measuring horizontal ionosphere gradients. The FOTON receiver includes a capability for multipath mitigation using a multi-antenna array. The TIP photometer is similar to the photometers aboard the COSMIC satellites with minor improvements in optical performance.
Ionospheric irregularities, also known as ionospheric bubbles, are transient features of the low and middle latitude ionosphere with important implications for operational systems. Understanding irregularity formation, development, and evolution is vital for efforts within NASA and DoD to forecast scintillation. Irregularity structures have been studied primarily using ground-based systems, though

some spaced-based remote and in-situ sensing has been performed. In combination with GROUP-C, the Limb-imaging Ionospheric and Thermospheric Extreme-ultraviolet Spectrograph (LITES) experiment on STP-H5 will serve as an interactive ionospheric observatory on the ISS. These experiments would provide new capability to study low- and mid-latitude ionospheric structures on a global scale. By combining for the first time high-sensitivity in-track photometry with vertical ionospheric airglow spectrographic imagery, and simultaneous GPS TEC and scintillation measurements, high-fidelity optical tomographic reconstruction of bubbles can be performed from the ISS. Ground-based imagery can supplement the tomography by providing all-sky images of ionospheric structures (e.g. bubbles and TIDs) and of signatures of lower atmospheric dynamics, such as gravity waves, that may play a role in irregularity formation.
Author(s): Scott A Budzien[3], Steven P Powell[1], Mark Psiaki[1], Brady O'Hanlon[2], Andrew W Stephan[3], Rebecca L Bishop[4]
Institution(s): *1. Cornell University, 2. MITRE Corp, 3. Naval Research Laboratory, 4. The Aerospace Corp.*

110 – Space Weather Posters

110.01 – Inter-Relationship of Solar and interplanetary Phenomena During Solar Cycles 23 and 24

We examine the variation of various phenomena, for example, the sunspot number and area, occurrence rate of solar energetic particle events, coronal mass ejections and interplanetary coronal mass ejections, the interplanetary magnetic field, solar magnetic field (“Sun as a star”), geomagnetic activity and the cosmic ray intensity during solar cycles 23 to 24. As we have discussed for previous cycles, there is a close association between these phenomena. For example, the onset of long-term cosmic ray modulation in cycle 24 is closely associated with not only an increase in the tilt angle of the heliospheric current sheet but also with abrupt increases in the solar and interplanetary magnetic field intensity at the Earth and the STEREO spacecraft, a temporary increase in the rate of interplanetary coronal mass ejections, an increase in the occurrence of corotating streams and solar energetic particle events, including the first 25 MeV proton event observed at both STEREO spacecraft and at Earth, and increases in geomagnetic activity (e.g., Dst, Kp, aa). Subsequent “steps down” in the cosmic ray intensity are associated with increases in the IMF strength, as is typical for the rising phases of cycles when the global solar field has A $\langle$ 0. We also note the remarkably different time development of activity in the northern and southern hemispheres during cycle 24 compared to cycle 23, and evidence of short term (~6 month) quasi-periodicities in several of these phenomena that appear to characterize the development of this solar cycle, with periods of enhanced activity separated by intervals of lower activity.
Author(s): Ian Richardson[2], Tycho von Rosenvinge[1], Hilary Cane[3]
Institution(s): *1. NASA/GSFC, 2. University of Maryland, 3. University of Tasmania*

110.02 – Causes of Major Change in the Heliospheric Field

The fundamental polarity structure of the heliospheric magnetic field is determined in the solar corona and depends on the photospheric magnetic field. Most of the time the shape of the field evolves slowly from one solar rotation to the next. Modest perturbations are caused by the emergence of new flux, whose configuration generally matches the large-scale patterns that already exist. However, a few times during the solar cycle a radical change occurs when new flux permanently disrupts the large-scale pattern. Such times are often associated with increased numbers of coronal mass ejections. The new pattern typically strengthens and can endure for many years. This investigation identifies the

reconfigurations detected in the modeled coronal field during the last several solar cycles and investigates their photospheric sources in Cycles 23 and 24 using magnetic field observations from WSO, MDI, and HMI.
Author(s): Todd Hoeksema[1]
Institution(s): *1. Stanford University*

110.03 – Uncertainties Associated to Near Real-Time Synoptic Magnetic maps and Implications for Solar Wind Models

Beginning with May 2006 data, the National Solar Observatory is providing uncertainty (spatial-variance) maps to accompany its database of magnetic flux synoptic charts. Early studies using few selected integral Carrington rotation maps have shown the impact of these uncertainty maps on the outcome numerical models of the coronal magnetic field and the solar wind (e.g., Bertello et al. 2014, Solar Physics, 289 (7), 2419). Here we discuss the evolution of solar wind parameters at Earth computed from the WSA-ENLIL model using the more suitable near real-time magnetic flux synoptic charts and their corresponding uncertainty maps. We investigated the short-term variations in these parameters during periods of low and high levels of solar activity to determine the predictive capabilities of these maps at different phases of the solar cycle. Our preliminary analysis based on integral synoptic maps suggests that during the period of low solar activity the short-term variations in solar wind parameters are within the scatter of the ensemble modeling. When the activity is high, the short-term variations in the observed parameters are larger than the scatter from the modeling. The results of this investigation will help to get a better understanding about some aspects of existing models of the solar wind that may require further improvements.
Author(s): Luca Bertello[2], Alexei A. Pevtsov[2], Peter Macniece[1]
Institution(s): *1. NASA/GSFC, 2. National Solar Observatory*

110.04 – Understanding Magnetic Reconnection: The Physical Mechanism Driving Space Weather

The explosive energy release in solar eruptive events is believed to be due to magnetic reconnection. In the standard model for coronal mass ejections (CME) and/or solar flares, the free energy for the event resides in the strongly sheared magnetic field of a filament channel. The pre-eruption force balance consists of an upward force due to the magnetic pressure of the sheared field countered by the downward tension of the overlying unsheared field. Magnetic reconnection disrupts this force balance. Therefore, to understand CME/flare initiation, it is critical to model the onset of reconnection driven by the build-up of magnetic shear. In MHD simulations, the application of a magnetic-field shear is trivial. However, kinetic effects are important in the diffusion region and thus, it is important to examine this process with PIC simulations as well. The implementation of such a driver in PIC methods is nontrivial, however, and indicates the necessity of a true multiscale model for such processes in the solar environment. The field must be sheared self-consistently and indirectly to prevent the generation of waves that destroy the desired system. In the work presented here, we show reconnection in an X-Point geometry due to a velocity shear driver perpendicular to the plane of reconnection.
This material is based upon work supported by the National Science Foundation under Award No. AGS-1331356 and NASA's Living With a Star Targeted Research and Technology program.
Author(s): Carrie Black[1], Spiro K Antiochos[1], Judith T. Karpen[1], Kai Germaschewski[3], Naoki Bessho[2]
Institution(s): *1. NASA/GSFC, 2. UMBC, 3. UNH*

110.05 – Day-to-Day Variability of H Component of Geomagnetic Field in Central African Sector Provided by YACM (Yaoundé-Cameroon) Amber Magnetometer Station

The geomagnetic data obtained from Amber Network station in Cameroon has been used for this study. The variability of H component of geomagnetic field has been examined by using geomagnetic field data of X and Y components recorded at AMBER magnetometer station hosted by the Department of Physics of University of Yaoundé (3.87°N, 11.52°E). The day-to-day variability of the horizontal intensity of the geomagnetic field has been examined and shows that the scattering of H component of magnetic field variation is more on disturbed than on quiet days. The signatures H of geomagnetic Sq and Sd variations in intensities in the geomagnetic element, has been studied. This paper shows that the daytime variations in intensities of geomagnetic elements H, Sq(H) and Sd(H) respectively are generally greater at diurnal-times than at night-times. This study mainly interests to answer to two questions: 1) how can geomagnetic variations be used to study the equatorial ionosphere electrodynamics and electrojet equatorial over Africa in general and Cameroon in particular? 2) How can geomagnetic variations be used to monitor and predict Space weather events in Cameroon? This study presents and interprets the results of H component of geomagnetic field variations during magnetic storms and on quiet days.
Author(s): Honoré Etoundi Messanga[1]
Institution(s): *1. University of Yaoundé 1*

111 – Magnetic Fields Posters

111.01 – Coronal Open Magnetic Flux - Comparing two models to the IMF at 1 AU

We present results of two extrapolation techniques for modeling the magnitude of solar coronal open magnetic flux at 1 AU: PFSS (Potential field – source surface) and HCCSSS (Horizontal current – current sheet – source surface). SDO/HMI photospheric magnetic field data from August 2010 through July 2014 are used as input. We compare the modeling results to the interplanetary magnetic field (IMF) data contained in the OMNI database. We discuss temporal variations in magnitude over the rising part of solar cycle 24.
Author(s): William Arden[2], Aimee A Norton[1]
Institution(s): *1. Stanford University, 2. University of Southern Queensland*

111.02 – Vitalizing four solar cycles of Kitt Peak synoptic magnetograms

Solar magnetism spans many decades of spatial and temporal scales. Studies of the larger end of these ranges requires frequent observations of the full solar disk over long durations. To aid investigations of the solar cycle and individual active region evolution, nearly daily magnetograms have been observed from Kitt Peak during solar cycles 20-23. These data were used in real time for space weather predictions, and archived observations have so far served more than 1500 refereed research publications. Some of the observations suffered from various instrumental problems. We report ongoing efforts to restore and correct observations from 1970-2003 in order to maximize the scientific value of the observations. The main improvements are reductions of certain instrumental noise, signal biases, and imperfect scanning geometry. The improved data will be used the make synchronic and diachronic synoptic maps, a catalog of active region properties, and estimates of tracer flow patterns.

In addition to base funding from NSF, NASA and NOAA provided substantial support of the Kitt Peak synoptic observations.
Author(s): John Harvey[2], Andres Munoz-Jaramillo[1]
Institution(s): *1. Montana State University, 2. National Solar Observatory*

111.03 – Polar Field Reversals and Active Region Decay

We study the relationship between polar field reversals and decayed active region magnetic flux. Photospheric active region flux is dispersed by differential rotation and turbulent diffusion, and is transported poleward by meridional flows and diffusion. Using NSO Kitt Peak synoptic magnetograms, we investigate in detail the relationship between the transport of decayed active region flux to high latitudes and changes in the polar field strength, including reversals in the magnetic polarity at the poles. By means of stack plots of low- and high-latitude slices of the synoptic magnetograms, the dispersal of flux from low to high latitudes is tracked, and the timing of this dispersal is compared to the polar field changes. In the most abrupt cases of polar field reversal, a few activity complexes (systems of active regions) are identified as the main cause. The poleward transport of large quantities of decayed lagging-polarity flux from these complexes is found to correlate well in time with the abrupt polar field changes. In each case, significant latitudinal displacements were found between the positive and negative flux centroids of the complexes, consistent with Joy's law bipole tilt with lagging-polarity flux located poleward of leading-polarity flux. This work is carried out through the National Solar Observatory Summer Research Assistantship (SRA) Program. The National Solar Observatory is operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation.
Author(s): Gordon Petrie[1], Sophie Ettinger[2]
Institution(s): *1. National Solar Observatory, 2. University of Chicago*

111.04 – Numerical investigation of convection-induced MHD waves interacting with a null point in 2D

We use the LaRe2D MHD code to investigate the propagation of waves in a 2D geometry that includes a quadrupolar magnetic field with a single nullpoint. The simulation box spans the upper convection zone to the corona (y=[-3Mm,35.4Mm]) and includes a stratified atmosphere. We model the upper convection zone by introducing an energy flux at the lower boundary, an ad-hoc Newton-cooling term to simulate the effect of radiation at the photosphere (y=0), and an initial condition that includes density and internal energy perturbations throughout the convection zone. This sets up the superadiabatic temperature gradient necessary to sustain convection and generate waves. We discuss the dynamic properties of these waves as they propagate through the atmosphere and interact at topologically important features of the magnetic field. This work is funded by the Chief of Naval Research.
Author(s): Lucas A Tarr[1], Mark G Linton[1], James Leake[1]
Institution(s): *1. Naval Research Lab*

111.05 – Photospheric Magnetic Energy Input and the Atmospheric Response

How are the chromospheres and coronae of the Sun and solar-like stars heated to much higher temperatures than their photospheres? Understanding atmospheric heating has been a major, unsolved problem in solar and stellar astrophysics for many decades now. Convective motions at the photosphere acting on the footpoints of coronal magnetic fields are presumed to inject magnetic energy into the Sun's atmosphere, where it is later released as heat. To investigate this hypothesis, the upward flux of magnetic energy across the photosphere --- quantified by the Poynting flux --- can be estimated by combining photospheric vector magnetic field measurements with horizontal photospheric velocities inferred by local correlation tracking (LCT) applied to magnetogram sequences. Recently published estimates of the net upward Poynting flux were roughly consistent with the expected energy demand required for chromospheric and coronal heating. But how are variations in magnetic energy injected across the photosphere related to variations in emission in the chromosphere, transition region, and

corona? Comparisons between the estimated upward transport of magnetic energy and the atmospheric response are an essential step toward a comprehensive understanding of the physical processes that drive chromospheric and coronal heating. To address this issue, we have begun efforts to compare variations in chromospheric, transition region, and coronal emission observed by IRIS and SDO/AIA with estimates of the photospheric Poynting flux derived from sequential Hinode/SOT SpectroPolarimeter and Narrowband Filter Imager magnetograms of plage magnetic fields in active regions. Here, we will present initial results of our comparisons. This work is supported by NASA under contract NNG09FA40C (IRIS).
Author(s): Brian T Welsch[1]
Institution(s): *1. University of California, Berkeley*

111.06 – Spatio-temporal Patterns in Arcsecond-scale Flux Emergence Events

Active regions’ pattern of magnetic flux emergence across latitude and time has been well described for nearly a century, and is generally understood in the context of the solar cycle. The pattern of emergence at smaller scales is thought to be basically random in space and time. Case studies of certain small-scale emergence events have suggested the possibility that some of these events are related to others in some way: the observations typically show simultaneous emergence events in close proximity to each other, and in some cases also with a similarity in the geometric orientation of the events. Whether these events are merely chance encounters, or signify a subsurface topological connection has not been addressed. Here we present SDO/HMI observations of some case studies of this clustered flux emergence, as well as a catalog of flux emergence events over a short time period, obtained through both manual and automated methods. Finally, we present a preliminary statistical analysis of the flux emergence events to determine whether these are simply an effect of an acute, imaginative human visual system or significantly unlikely to be chance encounters.
Author(s): Derek A Lamb[1], Craig DeForest[1]
Institution(s): *1. Southwest Research Institute*

112 – Space Weather I

112.01 – Challenges in Forecasting SEP Events

A long-standing desire of space weather prediction providers has been the ability to forecast SEP (Solar Energetic Particle) events as a part of their offerings. SEPs can have deleterious effects on the space environment and space hardware, that also impact human exploration missions. Developments of observationally driven, physics based models in the last solar cycle have made it possible to use solar magnetograms and coronagraph images to simulate, up to a month in advance for solar wind structure, and up to days in advance for interplanetary Coronal Mass Ejection (ICME) driven shocks, time series of upstream parameters similar in content to those obtained by L1 spacecraft. However, SEPs have been missing from these predictions. Because SEP event modeling requires different physical considerations it has typically been approached with cosmic ray transport concepts and treatments. However, many extra complications arise because of the moving, evolving nature of the ICME shock source of the largest events. In general, a realistic SEP event model for these so-called 'gradual' events requires an accurate description of the time-dependent 3D heliosphere as an underlying framework. We describe some applications of an approach to SEP event simulations that uses the widely-applied ENLIL heliospheric model to describe both underlying solar wind and ICME shock characteristics. Experimentation with this set-up illustrates the importance of knowing the shock connectivity to the observer, and of the need to include even non-observer-impacting CMEs in the heliospheric model. It also provides a possible path forward toward the goal of having routine SEP forecasts together with the other heliospheric predictions.

Author(s): Janet Luhmann[4], M. Leila Mays[2], Dusan Odstrcil[3], Hazel Bain[4], Yan Li[4], Richard Leske[1], Christina Cohen[1]
Institution(s): *1. Caltech, 2. Catholic University of America, 3. George Mason University, 4. University of California, Berkeley*

112.02 – Forecasting ionospheric space weather with applications to satellite drag and radio wave communications and scintillation

The development of quantitative models that describe physical processes from the solar corona to the Earth's upper atmosphere opens the possibility of numerical space weather prediction with a lead-time of a few days. Forecasting solar wind-driven variability in the ionosphere and thermosphere poses especially stringent tests of our scientific understanding and modeling capabilities, in particular of coupling processes to regions above and below. We will describe our work with community models to develop upper atmosphere forecasts starting with the solar wind driver. A number of phenomena are relevant, including high latitude energy deposition, its impact on global thermospheric circulation patterns and composition, and global electrodynamics. Improved scientific understanding of this sun to Earth interaction ultimately leads to practical benefits. We will focus on two ways the upper atmosphere affects life on Earth: by changing satellite orbits, and by interfering with long-range radio communications. Challenges in forecasting these impacts will be addressed, with a particular emphasis on the physical bases for the impacts, and how they connect upstream to the sun and the heliosphere.

Author(s): Anthony J Mannucci[1], Bruce T Tsurutani[1], Olga P Verkhoglyadova[1], Xing Meng[1], Xiaoqing Pi[1], Da Kuang[1], Chunming Wang[4], Gary Rosen[4], Aaron Ridley[2], Erin Lynch[3], Surja Sharma[3], Ward B Manchester[2], Bart van der Holst[2]
Institution(s): *1. Jet Propulsion Laboratory, 2. Univerity of Michigan, 3. University of Maryland, 4. University of Southern California*

112.03 – The structure and dynamics of the radiation belts from 10 keV to 2 MeV

The Van Allen Probes mission measures the Earth's radiation belts with very high spatial, temporal, and energy resolution. Recent analysis has taken advantage of the capability of the ECT/MagEIS instrument's ability to directly measure penetrating background radiation contributions to the electron count rates - and subtract it - providing spectral measurements that are essentially free of background contamination [Claudepierre et al., 2014]. The "background-subtracted" measurements show a surprising lack of MeV electrons in inner zone of the radiation belt [Fennell et al., 2014]. However at energies below ~1 MeV electrons can be injected through the slot region into the inner belt.
Our analysis of these deep particle injections shows (1) there is great variability in the location of the inner edge of the outer zone - both from one event to another and from one energy to another, (2) lower energy electrons (e.g. <300 keV) are injected into the inner zone (e.g. L<2) more often than higher energy electrons (3) electrons with energies as low as 50 keV are frequently injected into the inner zone. We discuss the implications of these new observations for our understanding of radiation belt acceleration and transport.

Author(s): Geoffrey D Reeves[1], Brian A Larsen[1], Reiner H. W. Friedel[1], Seth G. Claudepierre[2], Joseph F. Fennell[2], Harlan E. Spence[3], Drew L. Turner[2]
Institution(s): *1. Los Alamos National Laboratory, 2. The Aerospace Corp., 3. University of New Hampshire*

112.04 – Characteristics of Operational Space Weather Forecasting: Observations and Models

In contrast to research observations, models and ground support systems, operational systems are characterized by real-time data streams and run schedules, with redundant backup systems for most elements of the system. We review the characteristics of operational space weather forecasting, concentrating on the key aspects of ground- and space-based observations that feed models of the coupled Sun-Earth system at the NOAA/Space Weather Prediction Center (SWPC). Building on the infrastructure of the National Weather Service, SWPC is working toward a fully operational system based on the GOES weather satellite system (constant real-time operation with back-up satellites), the newly launched DSCOVR satellite at L1 (constant real-time data network with AFSCN backup), and operational models of the heliosphere, magnetosphere, and ionosphere/thermosphere/mesophere systems run on the Weather and Climate Operational Super-computing System (WCOSS), one of the worlds largest and fastest operational computer systems that will be upgraded to a dual 2.5 Pflop system in 2016. We review plans for further operational space weather observing platforms being developed in the context of the Space Weather Operations Research and Mitigation (SWORM) task force in the Office of Science and Technology Policy (OSTP) at the White House. We also review the current operational model developments at SWPC, concentrating on the differences between the research codes and the modified real-time versions that must run with zero fault tolerance on the WCOSS systems. Understanding the characteristics and needs of the operational forecasting community is key to producing research into the coupled Sun-Earth system with maximal societal benefit.
Author(s): Thomas Berger[2], Rodney Viereck[2], Howard Singer[2], Terry Onsager[2], Doug Biesecker[2], Robert Rutledge[2], Steven Hill[2], Rashid Akmaev[2], George Milward[1], Tim Fuller-Rowell[1]
Institution(s): *1. CIRES, 2. NOAA/SWPC*

113 – Magnetic Fields I

113.01 – Radio Coronal Magnetography of a Large Active Region

Quantitative knowledge of coronal magnetic fields is fundamental to understanding energetic phenomena such as solar flares. Flares occur in solar active regions where strong, non-potential magnetic fields provide free energy. While constraints on the coronal magnetic field topology are readily available through high resolution SXR and EUV imaging of solar active regions, useful quantitative measurements of coronal magnetic fields have thus far been elusive. Recent progress has been made at infrared (IR) wavelengths in exploiting both the Zeeman and Hanle effects to infer the line-of-sight magnetic field strength or the orientation of the magnetic field vector in the plane of the sky above the solar limb. However, no measurements of coronal magnetic fields against the solar disk are possible using IR observations. Radio observations of gyroresonance emission from active regions offer the means of measuring coronal magnetic fields above the limb and on the solar disk. In particular, for plasma plasma conditions in the solar corona, active regions typically become optically thick to emission over a range of radio frequencies through gyroresonance absorption at a low harmonic of the electron gyrofrequency. The specific range of resonant frequencies depends on the range of coronal magnetic field strengths present in the active region.

The Karl G. Jansky Very Large Array was used in November 2014 to image NOAA/USAF active region AR12209 over a continuous frequency range of 1-8 GHz, corresponding to a wavelength range of 3.75-30 cm. This frequency range is sensitive to coronal magnetic field strengths ranging from ~120-1400G. The active region was observed on four different dates - November 18, 20, 22, and 24 - during which the

active region longitude ranged from -15 to +70 degrees, providing a wide range of aspect angles. In this paper we provide a preliminary description of the coronal magnetic field measurements derived from the radio observations.
Author(s): Timothy S Bastian[4], Dale E. Gary[3], Stephen White[1], Gregory Fleishman[3], Bin Chen[2]
Institution(s): *1. Air Force Research Lab, 2. Harvard-Smithsonian Center for Astrophysics, 3. New Jersey Institute of Technology, 4. NRAO*

113.02 – Active Region Morphologies Selected From Near-side Helioseismic Data

We estimate the morphology of near-side active regions using near-side helioseismology. Active regions from two data sets, ADAPT synchronic maps and GONG near-side helioseismic maps, were matched and their morphologies compared. Our algorithm recognizes 382 helioseismic active regions between 2002 April 25 and 2005 December 31 and matches them to their corresponding magnetic active regions with 100% success. A magnetic active region occupies 30% of the area of its helioseismic signature. Recovered helioseismic tilt angles are in good agreement with magnetic tilt angles. Approximately 20% of helioseismic active regions can be decomposed into leading and trailing polarity. Leading polarity components show no discernible scaling relationship, but trailing magnetic polarity components occupy approximately 25% of the area of the trailing helioseismic component. A nearside phase-magnetic calibration is in close agreement with a previous far-side helioseismic calibration and provides confidence that these morphological relationships can be used with far-side helioseismic data. Including far-side active region morphology in synchronic maps will have implications for coronal magnetic topology predictions and solar wind forecasts.
Author(s): Gordon Andrew MacDonald[4], Carl Henney[1], Manuel Diaz Alfaro[2], Irene Gonzalez Hernandez[3], Nick Arge[1], Charles Lindsey[5], James McAteer[4]
Institution(s): *1. AFRL, 2. Institute of Astrophysics Canary Island, 3. National Solar Observatory, 4. New Mexico State University, 5. Northwest Research Associates*

113.03D – Electric current neutralization in solar active regions

There is a recurring question in solar physics of whether or not photospheric vertical electric currents are neutralized in solar active regions, i.e., whether or not the total electric current integrated over a single magnetic polarity of an active region vanishes. While different arguments have been proposed in favor of, or against, the neutralization of electric currents, both theory and observations are still not fully conclusive. Providing the answer to this question is crucial for theoretical models of solar eruptions. Indeed, if currents are neutralized in active regions, then any eruption model based on net - i.e., non-zero - electric currents, such as the torus instability, requires further consideration. We address the question of electric current neutralization in active regions using 3D zero-beta MHD simulations of line-tied, slow photospheric driving motions imposed on an initially potential magnetic field. We compare our results to a recent study of the build-up of coronal electric currents in an MHD simulation of the emergence of a current-neutralized twisted flux tube into the solar atmosphere. Our parametric study shows that, in accordance with the flux emergence simulation, photospheric motions are associated with the formation of both direct and return currents. It further shows that both processes (flux emergence and photospheric flows) can lead to the formation of strong net currents in the solar corona, and that the non-neutralization of electric currents is related to the presence of magnetic shear at the polarity inversion line. We discuss the implications of our results for the observations and for theoretical models of solar eruptions.
Author(s): Kévin Dalmasse[3], Guillaume Aulanier[2], Tibor Török[4], Pascal Démoulin[2], Etienne Pariat[2], Bernhard Kliem[1]

Institution(s): *1. Institute of Physics and Astronomy, 2. LESIA - Paris Observatory, 3. NCAR, 4. Predictive Science Inc.*

113.04 – A very strong magnetic field region in NOAA 11035

NOAA 11035 was a fairly typical active region that emerged near the central meridian 13-14 December 2009, early in solar cycle 24. During the active region's rapid emergence and evolution, a deeply-rooted magnetic bipole emerged into the pre-existing leading polarity with spectacular consequences. Multi-wavelength imaging and spectropolarimetry from FIRS, IBIS, Hinode, TRACE, and SOHO allow for a comprehensive investigation of the physical processes present in this region. Intrusion of the opposite polarity into the leading sunspot's penumbra resulted in a region of highly concentrated horizontal magnetic field, with a peak field strength larger than 3600 G based on Milne-Eddington inversion of Fe I spectropolarimetry at 6302 and 15650 Å. Photospheric velocity measurements show blueshifts of 4 km/sec along the neutral line, which are coincident with a dark chromospheric structure in He I 10830 and H I 6563 Å. We conclude that these signatures are the result of continuous magnetic reconnection near photospheric heights.
Author(s): Sarah Amelia Jaeggli[1]
Institution(s): *1. Montana State University*

113.05 – Filament Channel Formation Via Magnetic Helicity Condensation

A major unexplained feature of the solar atmosphere is the accumulation of magnetic shear, in the form of filament channels, at photospheric polarity inversion lines (PILs). In addition to free energy, this shear also represents magnetic helicity, which is conserved under reconnection. In this work, we address the problem of filament channel formation and show how they acquire their shear and magnetic helicity. The results of 3D simulations using the Adaptively Refined Magnetohydrodynamics Solver (ARMS) are presented that support the model of filament channel formation by magnetic helicity condensation developed by Antiochos (2013). We consider the convective twisting of a quasi-potential flux system that is bounded by a PIL and contains a coronal hole (CH). The magnetic helicity injected by the small-scale photospheric motions is shown to inverse-cascade up to the largest allowable scales that defined the closed flux system: the PIL and the CH. This process produces field lines that are both sheared and smooth, and are sheared in opposite senses at the PIL and the CH. The accumulated helicity and shear flux are shown to be in excellent quantitative agreement with the helicity-condensation model. We present a detailed analysis of the simulations, including comparisons of our analytical and numerical results, and discuss their implications for observations. Our research was supported by NASA's Earth and Space Science Fellowship (K.J.K.) and Heliophysics Supporting Research (S.K.A. and C.R.D.) programs.
Author(s): Kalman Joshua Knizhnik[2], Spiro K Antiochos[1], C. Richard DeVore[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. The Johns Hopkins University*

114 – CMEs: Propagation & Particles

114.01 – VLA Measurements of Faraday Rotation through a Coronal Mass Ejection

Coronal mass ejections (CMEs) are large scale eruptions of plasma from the Sun that play an important role in space weather. Although CMEs have been an active field of research since their discovery in the 1970s, there is still much to understand. While the plasma structure of a CME is typically modeled as a

magnetic flux rope, there is no consensus on the effective trigger that initiates a CME. Other issues include identifying what causes the shift towards non-equilibrium and how CMEs are accelerated after initiation. Faraday rotation (FR) is the rotation of the plane of polarization that results when a linearly polarized signal passes through a magnetized plasma such as a CME. FR observations of a source near the Sun can provide information on the plasma structure of a CME shortly after launch and shed light on the initiation process. We made sensitive Very Large Array (VLA) full-polarization observations in August, 2012, using L band (1 − 2 GHz) frequencies of a "constellation" of radio sources through the solar corona at heliocentric distances that ranged from 6 − 15 solar radii. Because is it difficult to predict whether any given line of sight to a background source will be occulted by a CME, we were only successful in capturing a single CME occultation out of three sessions. In LASCO C3 coronagraph images, the CME clearly occults a few of our sources, the most promising being 0843+1547. The line of sight for this latter source is clearly occulted by the outer loop structure and may also be occulted by the inner cavity most closely associated with the flux rope structure. Preliminary data analysis shows a Faraday rotation transient for 0843+1547; the Faraday rotation measure changes from ~ 0 before CME occultation, to a value of about -12 rad/m^2 before declining after CME passage. In this paper, we discuss the results of these FR observations and their implications in terms of models for the plasma structure of CMEs. This work was supported at the University of Iowa by grant ATM09-56901.
Author(s): Jason E Kooi[1], Patrick D. Fischer[1], Jacob J. Buffo[1], Steven R Spangler[1]
Institution(s): *1. University of Iowa*

114.02 – Coronal electron density distributions estimated from deca-hectometer type II radio bursts and coronal mass ejections

In this study, we estimate coronal electron density distributions by analyzing DH type II radio observations based on the assumption: a DH type II radio burst is generated by the shock formed at a CME leading edge. For this, we consider 11 Wind/WAVES DH type II radio bursts (from 2000 to 2003 and from 2010 to 2012) associated with SOHO/LASCO limb CMEs using the following criteria: (1) the fundamental and second harmonic emission lanes are well identified in the frequency range of 1 to 14 MHz; (2) its associated CME is clearly identified at least twice in the LASCO-C2 or C3 field of view during the time of type II observation. For these events, we determine the lowest frequencies of their fundamental emission lanes and the heights of their leading edges. Coronal electron density distributions are obtained by minimizing the root mean square error between the observed heights of CME leading edges and the heights of DH type II radio bursts from assumed electron density distributions. We find that the estimated coronal electron density distribution range from 2.5 to 10.2-fold Saito's coronal electron density models.
Author(s): Jae-Ok Lee[4], Yong-Jae Moon[4], Jin-Yi Lee[1], Kyoung-Sun Lee[2], Rok-Soon Kim[3]
Institution(s): *1. Astronomy and Space Science, Kyung Hee University, 2. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3. Korea Astronomy and Space Science Institute, 4. Kyung Hee Univ. School of Space Research*

114.03 – Eruptive Current Sheets Trailing SOHO/LASCO CMEs

Current sheets are important signatures of magnetic reconnection during the eruption of solar magnetic structures. Many models of eruptive flare/Coronal Mass Ejections (CMEs) involve formation of a current sheet connecting the ejecting CME flux rope with the post-eruption magnetic loop arcade. Current sheets have been interpreted in white light images as narrow rays trailing the outward-moving CME, in ultraviolet spectra as narrow, bright hot features, and with different manifestations in other wavebands. This study continues that of Webb et al. (2003), who analyzed SMM white light CMEs having candidate

magnetic disconnection features at the base of the CME. About half of those were followed by coaxial, bright rays suggestive of newly formed current sheets, and Webb et al. (2003) presented detailed results of analysis of those structures. In this work we extend the study of white light eruptive current sheets to the more sensitive and extensive SOHO/LASCO coronagraph data on CMEs. We comprehensively examined all LASCO CMEs during two periods that we identify with the minimum and maximum activity of solar cycle 23. We identified ~130 ray/current sheets during these periods, nearly all of which trailed CMEs with concave-outward backs. The occurrence rate of the ray/current sheets is 6-7% of all CMEs, irrespective of the solar cycle. We analyze the rays for durations, speeds, alignments, and motions and compare the observational results with some model predictions.
Author(s): David F Webb[1]
Institution(s): *1. Boston College*

114.04 – Flare Particle Escape in 3D Solar Eruptive Events

Among the most important, but least understood forms of space weather are the so-called Impulsive Solar Energetic Particle (SEP) events, which can be especially hazardous to deep-space astronauts. These energetic particles are generally believed to be produced by the flare reconnection that is the primary driver of solar eruptive events (SEE). A key point is that in the standard model of SEEs, the particles should remain trapped in the coronal flare loops and in the ejected plasmoid, the CME. However, flare-accelerated particles frequently reach the Earth long before the CME does. In previous 2.5D calculations we showed how the external reconnection that is an essential element of the breakout model for CME initiation could lead to the escape of flare-accelerated particles. The problem, however, is that in 2.5D this reconnection also tends to destroy the plasmoid, which disagrees with the observation that SEP events are often associated with well-defined plasmoids at 1 AU known as “magnetic clouds”. Consequently, we have extended our model to a fully 3D topology that includes a multi-polar coronal field suitable for a breakout SEE near a coronal hole region. We performed high-resolution 3D MHD numerical simulations with the Adaptively Refined MHD Solver (ARMS). Our results demonstrate that the model allows for the effective escape of energetic particles from deep within an ejecting well-defined plasmoid. We show how the complex interactions between the flare and breakout reconnection reproduce all the main observational features of SEEs and SEPs. We discuss the implications of our calculations for the upcoming Solar Orbiter and Solar Probe Plus missions, which will measure SEEs and SEPs near the Sun, thereby, mitigating propagation effects.
This research was supported, in part, by the NASA SR&T and TR&T Programs.
Author(s): Spiro K Antiochos[2], Sophie Masson[1], C R DeVore[2]
Institution(s): *1. LEISA Paris Obervatory, 2. NASA/GSFC*

114.05 – Observations and Analysis of the Non-Radial Propagation of Coronal Mass Ejections Near the Sun

Coronal Mass Ejection (CME) trajectories are often observed to deviate from radial propagation from the source while within the coronagraph fields-of-view ($R < 15\text{-}30\ R_{sun}$). To better understand non-radial propagation within the corona, we analyze the trajectories of five CMEs for which both the source and 3-D trajectory can be well determined from solar imaging observations, primarily using observations from the twin *Solar TErrestrial RElations Observatory* (STEREO) spacecraft. A potential field source surface model is used to determine the direction of the magnetic pressure force exerted on the CMEs at various heights in the corona. One case shows the familiar gradual deflection of a polar crown filament CME towards the heliospheric current sheet and streamer belt by the large-scale coronal magnetic fields. In two cases, we find that strong active region fields cause an initial asymmetric expansion of the

CME that gives rise to apparent rapid deflection and non-radial propagation from the source. For all five cases, within the limitations of the potential field source surface model, the coronal magnetic fields appear to guide the CMEs out through the weak field region around the heliospheric current sheet even when the current sheet is highly inclined and warped.
Author(s): Paulett C Liewer[2], Robin Colaninno[4], Olga Panasenco[1], Angelos Vourlidas[3]
Institution(s): *1. Advanced Heliophysics, 2. Jet Propulsion Laboratory, California Institute of Technology, 3. John Hopkins Universtiy, 4. Naval Research Laboratory*

114.06 – Are Halo-Like Solar Coronal Mass Ejections Merely a Matter of Geometric Projection Effect?

We investigated the physical nature of halo coronal mass ejections (CMEs) based on the stereoscopic observations from two *STEREO Ahead* and *Behind* (hereafter *A* and *B*) and *SOHO* spacecraft. There occurred 62 halo CMEs as observed by *SOHO* LASCO C2 for the three-year period from 2010 to 2012 during which the separation angles between *SOHO* and *STEREO*s were nearly 90 degrees. In such quadrature configuration, the coronagraphs of *STEREO*s, COR2-*A* and -*B*, showed the side view of those halo CMEs seen by C2. It has been widely believed that the halo appearance of a CME is caused by the geometric projection effect, i.e., a CME moves along the Sun-observer line. In other words, it would appear as a non-halo CME if viewed from the side. However, to our surprise, we found that 41 out of 62 events (66%) were observed as halo CMEs by all coronagraphs. This result suggests that a halo CME is not only a matter of the propagating direction. In addition, we show that a CME propagating normal to the line of sight can be observed as a halo CME due to the associated fast magnetosonic wave or shock front. We conclude that the apparent width of CMEs, especially halos or partial halos is driven by the existence, and the extent, of the associated waves or shocks and does not represent an accurate measure of the CME ejecta size. This effect needs to be taken into careful consideration in Space Weather predictions and modeling efforts.
Author(s): Ryun Young Kwon[2], Angelos Vourlidas[1], Jie Zhang[2]
Institution(s): *1. Applied Physics Laboratory, The Johns Hopkins University , 2. George Mason University*

200 – Space Weather II

200.01 – How Reliable Is the Prediction of Solar Wind Background?

The prediction of solar wind background is a necessary part of space weather forecasting. Multiple coronal and heliospheric models have been installed at the Community Coordinated Modeling Center (CCMC) to produce the solar wind, including the Wang-Sheely-Arge (WSA)-Enlil model, MHD-Around-a-Sphere (MAS)-Enlil model, Space Weather Modeling Framework (SWMF), and heliospheric tomography using interplanetary scintillation (IPS) data. By comparing the modeling results with the OMNI data over 7 Carrington rotations in 2007, we have conducted a third-party validation of these models for the near-Earth solar wind. This work will help the models get ready for the transition from research to operation. Besides visual comparison, we have quantitatively assessed the models’ capabilities in reproducing the time series and statistics of solar wind parameters. Using improved algorithms, we have identified magnetic field sector boundaries (SBs) and slow-to-fast stream interaction regions (SIRs) as focused structures. The success rate of capturing them and the time offset vary largely with models. For this period, the 2014 version of MAS-Enlil model works best for SBs, and the heliospheric tomography works best for SIRs. General strengths and weaknesses for each model are identified to provide an unbiased reference to model developers and users.

Author(s): Lan K Jian[6], Peter MacNeice[3], Aleksandre Taktakishvili[1], Dusan Odstrcil[2], Bernard Jackson[5], Hsiu-Shan Yu[5], Pete Riley[4], Igor Sokolov[7]
Institution(s): *1. Catholic University of America, 2. George Mason University, 3. NASA Goddard Space Flight Center, 4. Predictive Science Inc., 5. University of California, San Diego, 6. University of Maryland, College Park, 7. University of Michigan*

200.02 – Interaction between Coronal Mass Ejections and Implications for Space Weather

Coronal mass ejections (CMEs) are large-scale expulsions of plasma and magnetic field from the solar atmosphere. One of the most intriguing questions concerning CMEs is how they interact between each other during their propagation in interplanetary space. Interactions between CMEs are of importance for both space weather studies and basic plasma physics. First, CME-CME interactions can produce or enhance southward magnetic fields, a key factor in geomagnetic storm generation. Second, the interaction may reveal interesting shock physics in case a shock is overtaking a CME, including modifications in the shock strength, particle acceleration and transport. Third, the interaction implies significant energy and momentum transfer between the interacting CMEs where magnetic reconnection may take place. This talk will focus on some recent progresses in understating CME-CME interactions based on merged wide-angle imaging and in situ observations: (1) shock-ejecta interaction and formation of complex ejecta; (2) formation of an extreme storm in interplanetary space; and (3) evolution of CMEs in the outer heliosphere.
Author(s): Ying Liu[1]
Institution(s): *1. National Space Science Center, CAS*

200.03 – Shocks Progating Inside CMEs: Properties and Impact on Earth's Magnetosheath and Magnetosphere

Fast forward shocks propagating inside coronal mass ejections (CMEs) are a relatively frequent occurrence with about 50 such cases measured at Earth during solar cycle 23 (SC23). We first report on the general properties of these shocks and the CMEs they propagate into. In particular, we find that shocks inside CMEs are fast but weak and compress the magnetic field by a factor of about 2. During SC23, 19 of these shocked CMEs were associated with an intense geomagnetic storm (peak Dst under -100~nT) within 12 hours of the shock detection at Wind, and 15 were associated with a drop of the storm-time Dst index of more than 50 nT between 3 and 9 hours after shock detection. As most of these shocks are measured in the back half of a CME, we conclude that about half the shocks may not remain fast-mode shocks as they propagate through an entire CME due to the large upstream and magnetosonic speeds.
One of the particularities of such shocks is that they occur in low Mach number and low beta regime, which can have a direct effect on the magnetospheric response. We discuss specific cases with a particular focus on the response of Earth's bow shock and magnetopause to shocks in this unusual solar wind regime.
Author(s): Noe Lugaz[1], Charles Farrugia[1]
Institution(s): *1. University of New Hampshire*

200.04 – CCMC: Serving research and space weather communities with unique space weather services, innovative tools and resources

With the addition of Space Weather Research Center (a sub-team within CCMC) in 2010 to address NASA's own space weather needs, CCMC has become a unique entity that not only facilitates research

through providing access to the state-of-the-art space science and space weather models, but also plays a critical role in providing unique space weather services to NASA robotic missions, developing innovative tools and transitioning research to operations via user feedback. With scientists, forecasters and software developers working together within one team, through close and direct connection with space weather customers and trusted relationship with model developers, CCMC is flexible, nimble and effective to meet customer needs. In this presentation, we highlight a few unique aspects of CCMC/SWRC's space weather services, such as addressing space weather throughout the solar system, pushing the frontier of space weather forecasting via the ensemble approach, providing direct personnel and tool support for spacecraft anomaly resolution, prompting development of multi-purpose tools and knowledge bases, and educating and engaging the next generation of space weather scientists.
Author(s): Yihua Zheng[1], Maria M Kuznetsova[1], Antti Pulkkinen[1], Marlo Maddox[1]
Institution(s): *1. NASA Goddard Space Flight Center*

200.05 – Real-time SWMF-Geospace: A New Website Enabling Community Use

An experimental real-time simulation of the Space Weather Modeling Framework (SWMF) is conducted at the Community Coordinated Modeling Center (CCMC), (http://ccmc.gsfc.nasa.gov/realtime.php) and also through the CCMC's Integrated Space Weather Analysis (iSWA) site (http://iswa.ccmc.gsfc.nasa.gov/IswaSystemWebApp/). Presently, two configurations of the SWMF are running in real time at CCMC, both focusing on the geospace modules, using the BATS-R-US magnetohydrodynamic model, the Ridley Ionosphere Model, and with and without the Rice Convection Model for inner magnetospheric drift physics. The model output includes result extractions along satellite trajectories as well as magnetic perturbation vectors at ground-based station locations. Here we unveil a new website (http://csem.engin.umich.edu/realtime) to highlight these real-time model results conducted by the CCMC, present some basic data-model comparisons with real-time observations, and archive the accuracy of this continuously-available simulation.
Author(s): Michael Liemohn[2], Darren De Zeeuw[2], Jeff Kopmanis[2], Natalia Ganushkina[2], Daniel Welling[2], Gabor Toth[2], Aaron Ridley[2], Raluca Ilie[2], Tamas Gombosi[2], Maria M Kuznetsova[1], Marlo Maddox[1], Lutz Rastaetter[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. University of Michigan*

200.06 – Forecasting and Remote Sensing Relativistic Electron Dynamics from Low-Earth-Orbits

Relativistic electrons trapped in the Earth's outer radiation belt present a highly hazardous radiation environment for electronic hardware on board satellites and spacecraft. Thus developing a forecasting capability for MeV electron levels as well as understanding the physics have been deemed critical for both space research and industry communities. In this work, we first demonstrate that a high cross-energy, cross-pitch-angle and time-delayed coherence (with correlation values up to ~0.85) exists between the trapped MeV electrons and precipitating >~100s KeV electrons—observed respectively by Van Allen Probes and NOAA POES satellites in very different orbits—by conducting a survey on measurements from both high- and low-altitudes. Then, based upon the coherence, we further test the feasibility of using linear prediction filter models, driven by POES observations from low-Earth-orbits (LEOs), to predict the energization of MeV electrons during geomagnetic storms, as well as the evolving distributions of MeV electrons afterwards. These models predict MeV electron levels with high fidelity and have performance efficiency of ~0.74 (0.66) for 5-hour (1-day) forecasts. Last, after further investigating the high coherence by using pitch-angle resolved electron data from Van Allen Probes, we provide our explanations based upon case calculations from an analytic wave-particle resonance model. Results from this study unveil new knowledge of radiation belt dynamics, add new science significance

to a long existing space infrastructure, and provide practical and powerful tools to the whole space community.
Author(s): Yue Chen[1], Geoffrey Reeves[1], Weichao Tu[1], Gregory Cunningham[1], Michael Henderson[1], Craig Keltzing[3], Rob Redmon[2]
Institution(s): *1. Los Alamos National Lab, 2. NOAA NGDC, 3. University of Iowa*

201 – Magnetic Fields II

201.01 – A Method for Measuring Active Region Filling Factors on Solar-Type Stars

Radiative diagnostics of “activity” in the Sun and solar-type stars are spatially associated with sites of emergent magnetic flux. The magnetic fields themselves are widely regarded as the surface manifestations of a dynamo mechanism. The further development of both dynamo theory and models of the non-radiative heating of outer stellar atmospheres requires a knowledge of stellar magnetic field properties. In this context, it becomes important to determine the surface distribution, or at least the fractional coverage of, magnetic active regions as one critical constraint for dynamo models. But, while information on the spatial distribution of activity on stellar surfaces can be gathered in some special cases (mostly rapid rotators), such measurements have always been elusive in more solar-like stars. We discuss the challenges and results obtained from a method that relies on the non-linear response of the two principal He I triplet lines <!--StartFragment-->(at 1083 nm and 587.6 nm) to<!--EndFragment--> infer useful constraints on the fractional area coverage of magnetic active regions on solar-type stars. <!--EndFragment-->
Author(s): Mark Steven Giampapa[4], Vincenzo Andretta[2], Benjamin Beeck[3], Ansgar Reiners[1], Manfred Schussler[3]
Institution(s): *1. Georg-August University, 2. INAF, 3. MPI, 4. National Solar Observatory*

201.02 – Formation of δ-Sunspot in Simulations of Active-Region-Scale Flux Emergence

δ-sunspots, with highly complex magnetic structures, are very productive in energetic eruptive events, such as X-class flares and homologous eruptions. We here study the formation of such complex magnetic structures by numerical simulations of magnetic flux emergence from the convection zone into the corona in an active-region-scale domain. In our simulation, two pairs of bipolar sunspots form on the surface, originating from two buoyant segments of a single subsurface twisted flux rope. Expansion and rotation of the emerging fields in the two bipoles drive the two opposite polarities into each other with apparent rotating motion, producing a compact δ-sunspot with a sharp polarity inversion line. The formation of the δ-sunspot in such a realistic-scale domain produces emerging pattherns similar to those formed in observations, e.g. the inverted polarity against Hale’s law, the curvilinear motion of the spot, strong transverse field with highly sheared magnetic and velocity fields at the PIL. Strong current builds up at the PIL, giving rise to reconnection, which produces a complex coronal magnetic connectivity with non-potential fields in the -spot overlaid by more relaxed fields connecting the two polarities at the two ends.
Author(s): Fang Fang[1], Yuhong Fan[1]
Institution(s): *1. High Altitude Observatory*

201.03 – Optimization of Coronal Magnetic Field Extrapolations Using Images

The coronal magnetic field plays a significant role in every major question we have asked about the corona, as well as about other systems and bodies throughout the heliosphere. Knowledge of the magnetic field is essential for understanding and predicting many phenomena. Despite its importance, the coronal magnetic field is not well measured, due to the tenuous nature of the coronal plasma. In the absence of reliable coronal measurements, solar physicists have developed many methods for extrapolating the photospheric magnetic field out into the corona. However, these extrapolation methods must incorporate many assumptions, and it has been shown that they do not always match observed coronal features well.
Here we present a new method we are developing for altering an extrapolated magnetic field to better agree with features identified in coronal images. Our method proceeds by iteratively altering the boundary condition (the photospheric magnetogram) and comparing the extrapolated field to features observed in coronal images until optimal agreement is reached. This technique can be used in combination with any extrapolation method, depending on computational capabilities. By comparing the extrapolations with coronagraph images (see related submission by Uritsky et al.), it will be possible to improve determination of sources of open flux in the inner heliosphere.
Author(s): Shaela Jones[1], Joseph M. Davila[1], Vadim M Uritsky[1]
Institution(s): *1. Goddard Space Flight Center*

201.04 – On the long-term evolution of solar active regions from full Sun observations, magnetic flux transport and hydrodynamic modeling

With their multiple vantage points around the Sun, STEREO and SDO observations provide a unique opportunity to view the solar surface continuously. We use data from these observatories to study the long-term evolution of solar active regions in He II 304 A. We show that active regions follow a universal pattern of emergence over several days followed by a decay that is proportional to the peak intensity in the region. We find that magnetic surface flux transport simulations are able to reproduce this evolution. Since STEREO does not make direct observations of the magnetic field, we use the flux-luminosity relationship to infer the total unsigned magnetic flux from the He 304 A images. We also illustrate the use of far-side imaging to introduce solar active regions into magnetic surface flux transport simulations. We finally show how these models can be used to determine the long-term coronal emission evolution in active regions by coupling extrapolations of the magnetic flux transport simulations field with EBTEL solutions to the hydrodynamic loop equations.
Author(s): Ignacio Ugarte-Urra[1], Lisa Upton[2], Harry Warren[4], David H Hathaway[3]
Institution(s): *1. George Mason University, 2. Independent Researcher, 3. NASA/MSFC, 4. Naval Research Laboratory*

201.05 – Merging of small-size magnetic elements observed at the Swedish Solar Tower

We investigate the evolution of physical properties of small-size magnetic elements of the same polarity during merging. We found that at the merging the line of sight velocity and magnetic flux abruptly change, while the photometric contrast increases with a delay proportional to the formation height of the observed wavelength range. These results suggest that the merging causes MHD perturbations propagating from the photosphere to the higher layers of the atmosphere.
Author(s): Serena Criscuoli[1]
Institution(s): *1. National Solar Observatory*

201.06 – Reconstructing the open-field magnetic geometry of solar corona using coronagraph images

The upcoming Solar Probe Plus and Solar Orbiter missions will provide an new insight into the inner heliosphere magnetically connected with the topologically complex and eruptive solar corona. Physical interpretation of these observations will be dependent on the accurate reconstruction of the large-scale coronal magnetic field. We argue that such reconstruction can be performed using photospheric extrapolation codes constrained by white-light coronagraph images. The field extrapolation component of this project is featured in a related presentation by S. Jones et al. Here, we focus on our image-processing algorithms conducting an automated segmentation of coronal loop structures. In contrast to the previously proposed segmentation codes designed for detecting small-scale closed loops in the vicinity of active regions, our technique focuses on the large-scale geometry of the open-field coronal features observed at significant radial distances from the solar surface. Coronagraph images are transformed into a polar coordinate system and undergo radial detrending and initial noise reduction followed by an adaptive angular differentiation. An adjustable threshold is applied to identify candidate coronagraph features associated with the large-scale coronal field. A blob detection algorithm is used to identify valid features against a noisy background. The extracted coronal features are used to derive empirical directional constraints for magnetic field extrapolation procedures based on photospheric magnetograms. Two versions of the method optimized for processing ground-based (Mauna Loa Solar Observatory) and satellite-based (STEREO Cor1 and Cor2) coronagraph images are being developed.
Author(s): Vadim M Uritsky[1], Joseph M. Davila[3], Shaela Jones[1], Joan Burkepile[2]
Institution(s): *1. CUA at NASA/GSFC, 2. High Altitude Observatory, 3. NASA/GSFC*

202 – Planetary Aeronomy: Mars and Other Planets

202.01 – Currents and Electrojets in the Ionosphere of Mars

How the solar wind interacts with a planetary object depends upon the object's properties such as the presence of a magnetic field or an atmosphere. An unmagnetized object cannot stand-off the solar wind unless it possess a substantial atmosphere which can be ionized by solar radiation creating a conductive ionosphere. Currents can then be induced in the ionosphere; these currents act to cancel out the external solar wind magnetic field preventing it from reaching the surface. Here we present simple analytical calculations of such induced currents in the ionosphere of Mars. We consider currents in the ionospheric dynamo region which can be driven by thermospheric winds as well as currents driven by electric fields (i.e., plasma motion through the neutrals). We include in these estimates the effects of "equatorial-type" electrojets due to vertical conductivity gradients in the presence of horizontal magnetic fields. In addition, we consider "auroral-type" electrojets due to horizontal conductivity gradients resulting from particle precipitation and/or large variations in the magnetic field strength near vertical cusps in strong crustal field regions. The direction of the external driver is important. In some cases, the secondary current adds to the primary current creating electrojets. In other cases, the secondary current can cancel or nearly cancel the primary current resulting in very weak net currents. These results can give us insights into how external magnetic fields are effectively screened out by induced currents and how these induced currents can influence ionospheric dynamics around unmagnetized objects.
Author(s): Matthew O. Fillingim[1], Robert Lillis[1], D. A. Brain[2]
Institution(s): *1. University of California, 2. University of Colorado*

202.02 – Photoelectron reflection and scattering at Venus: an upper limit on the "polar wind" ambipolar electric field, and a new source of top-side ionospheric heating

An important mechanism in the generation of Earth's polar wind is the ambipolar potential generated by the outflow along open field lines of superthermal electrons. This ≈20V electric potential assists ions in overcoming the gravitational potential, and is a key mechanism for Terrestrial ionospheric escape. At Venus, except in rare circumstances, every field line is open, and a similar outflow of ionospheric electrons is observed. It is thus hypothesized that a similar electric potential may be present at Venus, contributing to global ionospheric loss. However, a very sensitive electric field instrument would be required to directly measure this potential, and no such instrument has yet been flown to Venus. In this pilot study, we examine photoelectron spectra measured by the ASPERA-ELS instrument on the Venus Express to put an initial upper bound on the total potential drop above 350km of $\Phi < 10$V, weaker than at the Earth despite a comparable gravity field. We thus hypothesize that contrary to our current understanding, a "polar wind" like ambipolar electric field may not be as important a mechanism for atmospheric escape as previously suspected. Additionally, we find our spectra are consistent with the scattering of photoelectrons, the heating from which which we hypothesize may act as a source of top-side ionospheric heating, and may play a role in influencing the scale height of the ionosphere.
Author(s): Glyn Collinson[3], Alex Glocer[3], Joe Grebowsky[3], William Peterson[1], Rudy Frahm[4], Thomas Moore[3], Lin Gilbert[2], Andrew Coates[2]
Institution(s): *1. Laboratory for Space Physics, 2. Mullard Space Science Laboratory, 3. NASA Goddard Space Flight Center, 4. Southwest Research Institute*

202.03 – Relationship of High-Altitude Photoelectron Fluxes and Solar Zenith Angle

Numerous studies have shown the ionosphere quantities' dependence on solar zenith angle (SZA), following Chapman theory. One would assume that photoelectron fluxes are also SZA dependent. However, high-altitude (~400 km) electron observations from magnetometer/electron reflectometer (MAG/ER) on board Mars Global Surveyor (MGS) show that the high energy (>100 eV) photoelectron fluxes are better correlated with the solar irradiance solely, without SZA factored in, while the low energy is somehow insensitive to SZA. Such counterintuitive results are due to the existence of a photoelectron exobase, only above which the photoelectrons are able to transport and escape to high altitudes. Through our SuperThermal Electron Transport (STET) model, we have determined that this exobase is around an altitude of 150-160 km, above which the production rate is rather independent of SZA.
Author(s): Shaosui Xu[2], Michael Liemohn[2], Stephen W Bougher[2], David L. Mitchell[1]
Institution(s): *1. Space Sciences Laboratory, University of California, Berkeley, 2. University of Michigan Ann Arbor*

202.04 – A Lumped Element Thermal Model of Solar Flare Gradual Phase EUV Emissions for Planetary Atmosphere Studies

Gradual phase solar flare EUV emissions show a time dependence related to the cooling of the flare plasma where emission lines with higher formation temperatures peak earlier than cooler emission lines. Because photon absorption height in a planetary atmosphere is wavelength dependent, being able to spectrally model this time dependence using available wavelengths is necessary to accurately characterize the temporal response of an atmosphere to a flare when high time cadence measurements of the EUV spectrum are unavailable. Furthermore, both the spectral and wavelength dependent temporal behavior of a flare impact where the total flare energy is absorbed in an atmosphere.
To address this challenge, we have developed a Lumped Element Thermal Model (LETM) which can accurately model the flare gradual phase time evolution for emission lines with peak formation temperatures above 10^6 K based on a cooling rate derived from only two emission lines. We will show

that the 13.3 nm Fe XX and 9.4 nm Fe XVIII emission lines can be used to determine a cooling rate. This cooling rate can then be used to calculate a time constant, τ_i, associated with a i^{th} EUV emission; and the i^{th} emission's time-response can then be modeled by passing the measured Fe XX time-series through a digital low pass filter with time constant τ_i. An implication of the LETM, is that it constrains the time evolution of the volume integrated flare irradiance which is directly related to the flare emission measure. Detailed analysis suggests that the LETM provides a method to measure the flare thermal conductance and specific heat, and constrains the flare cooling rate and differential emission measure. To broaden the utility of the LETM, correlations between the emission line derived cooling rate and broadband measurements made by MAVEN EUV or other commonly available Earth assets must be found. Therefore, in addition to introducing the LETM, we will review progress towards finding correlations with properties of broadband soft x-ray measurements, as well as relevant multi-channel instruments.
Author(s): Edward Thiemann[1], Francis G Eparvier[1]
Institution(s): *1. University of Colorado*

203 – Chromosphere-Transition Region-Corona Posters

203.01 – More Macrospicule Jets in On-Disk Coronal Holes

We examine the magnetic structure and dynamics of multiple jets found in coronal holes close to or at disk center. All data are from the Atmospheric Imaging Assembly (AIA) and the Helioseismic and Magnetic Imager (HMI) of the Solar Dynamics Observatory (SDO). We report on observations of about ten jets in an equatorial coronal hole spanning 2011 February 27 and 28. We show the evolution of these jets in AIA 193 Å, examine the magnetic field configuration and flux changes in the jet area, and discuss the probable trigger mechanism of these events. We reported on another jet in this same coronal hole on 2011 February 27, ~13:04 UT (Adams et al 2014, ApJ, 783: 11). That jet is a previously unrecognized variety of blowout jet, in which the base-edge bright point is a miniature filament-eruption flare arcade made by internal reconnection of the legs of the erupting field. In contrast, in the presently-accepted "standard" picture for blowout jets, the base-edge bright point is made by interchange reconnection of initially-closed erupting jet-base field with ambient open field. This poster presents further evidence of the production of the base-edge bright point in blowout jets by internal reconnection. Our observations suggest that most of the bigger and brighter EUV jets in coronal holes are blowout jets of the new-found variety.
Author(s): Mitzi Adams[1], Alphonse Sterling[1], Ronald Moore[2]
Institution(s): *1. NASA/MSFC, 2. University of Alabama in Huntsville*

203.02 – Simulated In Situ Measurements and Structural Analysis of Reconnection-Driven Solar Polar Jets

Solar polar jets are observed to originate in regions within the open field of solar coronal holes. These so called "anemone" regions are associated with an embedded dipole topology, consisting of a fan-separatrix and a spine line emanating from a null point occurring at the top of the dome shaped fan surface (Antiochos 1998). In this study, we analyze simulations using the Adaptively Refined MHD Solver (ARMS) that take into account gravity, solar wind, and spherical geometry to generate polar jets by reconnection between a twisted embedded bipole and the surrounding open field (Karpen et al. 2015). These new simulations confirm and extend previous Cartesian studies of polar jets based on this mechanism (Pariat et al. 2009, 2010, 2015). Focusing on the plasma density, velocity, and magnetic field,

we interpolate the adaptively gridded simulation data onto a regular grid, and analyze the signatures that the jet produces as it propagates outward from the solar surface. The trans-Alfvénic nature of the jet front is confirmed by temporally differencing the plasma mass density and comparing the result with the local Alfvén speed. We perform a preliminary analysis of the magnetized plasma turbulence, and examine how the turbulence affects the overall structure of the jet. We also conduct simulated spacecraft fly-throughs of the jet, illustrating the signatures that spacecraft such as Solar Probe Plus may encounter in situ as the jet propagates into the heliosphere. These fly-throughs are performed in several different velocity regimes to better model the changing velocity of Solar Probe Plus relative to the Sun and its jets over the course of the mission.
This research was supported by NASA grant NNG11PL10A 670.036 to CUA/IACS (M.A.R. and V.M.U.) and the Living With a Star Targeted Research and Technology (J.T.K. and C.R.D.) program.
Author(s): Merrill A Roberts[1], Vadim M Uritsky[1], Judith T. Karpen[2], C R DeVore[2]
Institution(s): *1. CUA at NASA/GSFC, 2. NASA/GSFC*

203.03 – Modeling Reconnection-driven Polar Jets from the Sun to the Heliosphere

Jets from coronal holes on the Sun have been observed in EUV and white-light emissions since the launch of SOHO, but the physical mechanism responsible for these events remains elusive. An important clue about their origin lies in their association with small intrusions of minority polarity within the large-scale open magnetic field, strongly suggesting that these jets are powered by interchange reconnection between embedded bipoles (closed flux) and the surrounding open flux (Antiochos 1999). We have explored this model for polar jets through a series of computational investigations of the embedded-bipole paradigm. The results demonstrate that energetic, collimated, Alfvénic flows can be driven by explosive reconnection between twisted closed flux of the minority polarity and the unstressed external field (e.g., Pariat et al. 2009, 2010, 2015). Our previous studies were focused on the dynamics and energetics of this process close to the solar surface, utilizing Cartesian geometry without gravity or wind. In the present study, we compare new simulations of reconnection-driven polar jets in spherical geometry and an isothermal solar wind with Cartesian, gravity- and wind-free simulations. Our new, more realistic simulations strongly support the interchange reconnection model as the explanation for observed polar jets. We pay particular attention to identifying observable signatures and measuring the evolving mass, wave, and energy fluxes as the jet extends toward heights comparable to the perihelion of Solar Probe Plus.
This research was supported by NASA's Living With a Star Targeted Research and Technology program.
Author(s): Judith T. Karpen[1], C R DeVore[1], Spiro K Antiochos[1]
Institution(s): *1. Goddard Space Flight Center*

203.04 – Imaging Spectroscopy of Transition Region Explosive Events from *MOSES* Sounding Rocket Data

The Multi-Order Solar EUV Spectrograph (*MOSES*) forms 304 Å EUV images at three spectral orders from an objective multilayer grating. The images encode spatial and spectral data over a 20 x 10 arc minute field of view. Numerous examples of compact transient brightenings are present in data obtained during a 2006 flight. We employ an inversion algorithm which incorporates the instrument point spread functions and noise model and present spectra derived thereby which show strong doppler shifts associated with these brightenings. Spatial structure (0.5" pixels) and temporal evolution (~10 s cadence) of these events will be presented.
Author(s): Thomas Rust[1], Charles Kankelborg[1]
Institution(s): *1. Montana State University*

203.05 – Diagnostics of Coronal Heating in Solar Active Regions

We aim to develop a diagnostic method for the coronal heating mechanism in active region loops. Observational constraints on coronal heating models have been sought using measurements in the X-ray and EUV wavelengths. Statistical analysis, using EUV emission from many active regions, was done by Fludra and Ireland (2008) who studied power-law relationships between active region integrated magnetic flux and emission line intensities. A subsequent study by Fludra and Warren (2010) for the first time compared fully resolved images in an EUV spectral line of OV 63.0 nm with the photospheric magnetic field, leading to the identification of a dominant, ubiquitous variable component of the transition region EUV emission and a discovery of a steady basal heating, and deriving the dependence of the basal heating rate on the photospheric magnetic flux density. In this study, we compare models of single coronal loops with EUV observations. We assess to what degree observations of individual coronal loops made in the EUV range are capable of providing constraints on the heating mechanism. We model the coronal magnetic field in an active region using an NLFF extrapolation code applied to a photospheric vector magnetogram from SDO/HMI and select several loops that match an SDO/AIA 171 image of the same active region. We then model the plasma in these loops using a 1D hydrostatic code capable of applying an arbitrary heating rate as a function of magnetic field strength along the loop. From the plasma parameters derived from this model, we calculate the EUV emission along the loop in AIA 171 and 335 bands, and in pure spectral lines of Fe IX 17.1 nm and Fe XVI 33.5 nm. We use different spatial distributions of the heating function: concentrated near the loop top, uniform and concentrated near the footpoints, and investigate their effect on the modelled EUV intensities. We find a diagnostics based on the dependence of the total loop intensity on the shape of the heating function and discuss its range of applicability for loops of different length.
Author(s): Andrzej Fludra[1], Christopher Hornsey[1], Valery Nakariakov[2]
Institution(s): *1. Science and Technology Facilities Council, 2. University of Warwick*

203.06 – Non-negative Matrix Factorization as a Method for Studying Coronal Heating

Many theoretical efforts have been made to model the response of coronal loops to nanoflare heating, but the theory has long suffered from a lack of direct observations. Nanoflares, originally proposed by Parker (1988), heat the corona through short, impulsive bursts of energy. Because of their short duration and comparatively low amplitude, emission signatures from nanoflare heating events are often difficult to detect. Past algorithms (e.g. Ugarte-Urra and Warren, 2014) for measuring the frequency of transient brightenings in active region cores have provided only a lower bound for such measurements. We present the use of non-negative matrix factorization (NMF) to analyze spectral data in active region cores in order to provide more accurate determinations of nanoflare heating properties. NMF, a matrix deconvolution technique, has a variety of applications , ranging from Raman spectroscopy to face recognition, but, to our knowledge, has not been applied in the field of solar physics. The strength of NMF lies in its ability to estimate sources (heating events) from measurements (observed spectral emission) without any knowledge of the mixing process (Cichocki et al., 2009). We apply our NMF algorithm to forward-modeled emission representative of that produced by nanoflare heating events in an active region core. The heating events are modeled using a state-of-the-art hydrodynamics code (Bradshaw and Cargill, 2013) and the emission and active regions are synthesized using advanced forward modeling and visualization software (Bradshaw and Klimchuk, 2011; Reep et al., 2013). From these active region visualizations, our NMF algorithm is then able to predict the heating event frequency and amplitudes. Improved methods of nanoflare detection will help to answer fundamental questions regarding the frequency of energy release in the solar corona and how the corona responds to such impulsive heating. Additionally, development of reliable, automated nanoflare detection methods such

as NMF will become ever more important as higher resolution instruments continue to provide increasingly vast amounts of data.
Author(s): Will Barnes[1], Stephen Bradshaw[1]
Institution(s): *1. Rice University*

203.07 – Correlation and scaling properties of non-stationary intensity fluctuations in coronal EUV time series in different physical environments

Previously we have used EUV observations from AIA/SDO to examine properties of energy deposition into coronal-loops in non-flaring active region (AR) cores. The evolution of the loop apex intensity, temperature, and electron density indicate that the loops are impulsively heated in a mode compatible with high intensity nanoflare storms characterized by a progressive cooling pattern in the EUV lines with the hot channels leading the emission. Spectra of the hot 131 Å intensity (basically Fe XXI) and of the energy dissipation in a 2D model of loop magneto-turbulence compatible with nanoflare statistics, both exhibit three scaling regimes with low frequencies corresponding to 1/f noise, the intermediate range indicating a persistent process, and high frequencies corresponding to white noise. The varying power law behavior in these spectra indicates that both the observational and the simulated time series are not stationary. Therefore to extend the analysis beyond the AR loops we apply the method of detrended fluctuation analysis (DFA) that was developed to study the long-range correlations in non-stationary signals. DFA provides a scaling exponent that characterizes the correlation properties of the signal and which can be related both to the spectral exponents and to the Hurst exponent. In areas of diffuse emission and for all the spectral channels the time series of intensity fluctuations are characterized by scaling exponents that indicate a weak positive correlation across all time scales. In regions with intermittent intensity brightenings a cross-over occurs at timescales near 10 - 20 min with different exponents describing the degree of positive correlation of the intensity fluctuations at short and long time scales. Qualitative differences exist between the exponents of the hotter and the cooler channels. We have further compared the scaling properties of the time series associated with different physical environments distinguished by the possibility of underlying nanoflare storms, or by the strength of the magnetic field in contemporaneous HMI images. Another comparison is made to the scaling properties of simulations of energy dissipation in magnetoturbulence.
Author(s): Ana Cristina Cadavid[1], John Lawrence[1], Yeimy Rivera[1]
Institution(s): *1. California State University Northirdge*

203.08 – Key Aspects of Coronal Heating

We highlight ten key aspects of coronal heating that must be understood before we can consider the problem to be solved. (1) All coronal heating is impulsive. (2) The details of coronal heating matter. (3) The corona is filled with elemental magnetic stands. (4) The corona is densely populated with current sheets. (5) The strands must reconnect to prevent an infinite buildup of stress. (6) Nanoflares repeat with different frequencies. (7) What is the characteristic magnitude of energy release? (8) What causes the collective behavior responsible for loops? (9) What are the onset conditions for energy release? (10) Chromospheric nanoflares are not a primary source of coronal plasma. Significant progress in solving the coronal heating problem will require a coordination of approaches: observational studies, field-aligned hydrodynamic simulations, large-scale and localized 3D MHD simulations, and possibly also kinetic simulations. There is a unique value to each of these approaches, and the community must strive to coordinate better.
Author(s): James A Klimchuk[1]
Institution(s): *1. NASA/GSFC*

203.09 – Intensity Conserving Spline Interpolation (ICSI): A New Tool for Spectroscopic Analysis

Spectroscopy is an extremely powerful tool for diagnosing astrophysical and other plasmas. For example, the shapes of line profiles provide valuable information on the distribution of velocities along an optically thin line-of-sight and across the finite area of a resolution element. A number of recent studies have measured the asymmetries of line profiles in order to detect faint high-speed upflows, perhaps associated with coronal nanoflares or perhaps associated with chromospheric nanoflares and type II spicules. Over most of the Sun, these asymmetries are very subtle, so great care must be taken. A common technique is to perform a spline fit of the points in the profile in order to extract information at a spectral resolution higher than that of the original data. However, a fundamental problem is that the fits do not conserve intensity. We have therefore developed an iterative procedure called Intensity Conserving Spline Interpolation that does preserve the observed intensity within each wavelength bin. It improves the measurement of line asymmetries and can also help with the determination of line blends.
Author(s): James A Klimchuk[2], Spiros Patsourakos[3], Durgesh Tripathi[1]
Institution(s): *1. Inter-University Centre for Astronomy and Astrophysics, 2. NASA/GSFC, 3. University of Ioannina*

203.10 – Hinode/XRT Measurements of Turbulent Velocities in Flare Plasma Sheets

The turbulent, dynamic motions that we observe in the hot plasma surrounding current sheets very likely distort the embedded magnetic fields, resulting in reduced length scales and locally augmented resistivities. These conditions may help to accelerate and/or prolong the reconnection in solar flares. Although we cannot as yet measure directly the magnetic fields in the corona, the velocity fields within the flare plasma sheets provide a means to study the conditions that control the spatial and temporal scales of reconnection, in the locations and at the times that are relevant to structuring the magnetic fields.
The plasma sheets are observable in many flares in soft X-ray and EUV wavelengths, due to their high temperatures. For two recent flares observed with the Hinode X-Ray Telescope (XRT), we have analyzed the velocity fields with a local correlation tracking technique, and compared to measurements from the Solar Dynamics Observatory Atmospheric Imaging Assembly (SDO/AIA).
This work is supported by NASA under contract NNM07AB07C with the Smithsonian Astrophysical Observatory, and by grant NNX14AD43G.
Author(s): David McKenzie[1], Michael Freed[1]
Institution(s): *1. Montana State University*

203.11 – Observations of a Steady-State Supersonic Downflow in the Transition Region above a Sunspot Umbra

Sunspots have been an area of intense research ever since Hale's discovery of strong magnetic fields in these structures. Here we report on the detection of a particular sunspot phenomenon: a small-scale (~ 1.5 Mm), supersonic downflow of about 90 km/s in the transition region above a light-bridged sunspot umbra. The observations were obtained with the Interface Imaging Region Spectrograph (IRIS) on 2 September 2013 from 16:39 to 17:58 UT in the sunspot of AR 11836 near disk center. Slit length and width were 68” and 0.166”, respectively. The cadence of the time series was 3 s, with exposure times of 2 s. The observations comprise nine spectral windows: C II 1336, Fe XII 1349, Cl I 1352, O I 1356, Si IV 1394, Si IV 1403, NUV at 2786 and 2831, and Mg II h and k 2796. The spectral window containing the Si IV 1403 line also includes the O IV 1400, 1401, and 1405 lines, the last one blended with a S IV line. The downflow shows up as red-shifted, well-separated “satellite” lines of the Si IV and O IV transition region

lines and is remarkably steady over the observing period of nearly 80 min. The satellite lines do not participate in the 3-min shock wave Doppler maneuvres of the main component. The downflow is not visible in the chromospheric lines, which only show an intensity enhancement at the location of the downflow. The density inferred from the line ratio of the redshifted satellites of the O IV lines ($N_e=10^{10.5 \pm 0.3}$ cm^{-3}) is only a factor 2.5 smaller than the one inferred from the main components ($N_e=10^{10.9 \pm 0.2}$ cm^{-3}). Consequently, this implies a substantial mass flux (~ 4×10^{-7} g cm^{-2} s^{-1}), which would evacuate the overlying corona on time scales of the order of 10 s. We interpret these findings as evidence of a stationary termination shock of a supersonic siphon flow in a cool loop rooted in the central umbra of the spot. Such stationary shocks have been predicted for siphon flows in hot coronal loops by Noci (1981).
Author(s): Bernhard Fleck[1], Thomas Straus[2], Vincenzo Andretta[2]
Institution(s): *1. ESA, 2. INAF/OAC*

203.12 – MHD Simulations of the Evolution of the Coronal Magnetic Field: First Steps in Using the Realistic Initial State Model

We present the first results of simulations of a realistic coronal magnetic field evolution. The initial state of the field is a non-linear force-free model (NLFFF) which matches the observed coronal features by design (see Malanushenko et al, 2012). We evolve this field model using an ideal MHD code (see Fan, 2009). We use the model of AR 11158 shortly before X2.2 class flare on February 15th. This model was shown by Malanushenko et al (2014) to possess both the correct morphology of the coronal field (compared to the EUV images), and free magnetic energy sufficient for a flare of this class. We demonstrate stability of the twisted current bundle in the core of the region when no photospheric driving is present, and the first results of the evolution of the model corona when the photospheric driving roughly corresponds to that observed at the photosphere.
Author(s): Anna V Malanushenko[1], Yuhong Fan[1]
Institution(s): *1. UCAR*

203.13 – Full-Sun IRIS observations and what they reveal about chromosphere and transition region variation across the disk

The recent launch of the Interface Region Imaging Spectrometer (IRIS) has resulted in the first high-resolution spectroscopy of the chromosphere and transition region. The wavelength range sampled by IRIS allows us to measure emission and absorption lines across a range of heights in the lower solar atmosphere. However, the IRIS field-of-view is limited to 175 $arcsec^2$, so simultaneous observations of these spectral lines is not possible across the entire disk. To overcome this problem we have performed full-disk mosaics, where we build up observations of the entire Sun using 184 different IRIS pointings. An analysis of these mosaics has highlighted interesting variations in the spectral line profiles across the disk. In this presentation we will summarize these findings and speculate on what physical insights they reveal.
Author(s): Paul Bryans[1], Scott W McIntosh[1]
Institution(s): *1. HAO*

203.14 – Observations of the Solar Faculae at San Fernando Observatory and Solar Dynamics Observatory

In this paper we compare the full disk images of the Sun obtained in 393.4 nm Ca II K line from Cartesian Full Disk Telescopes (CFDT) of San Fernando Observatory (SFO) and 1600Å and 1700Å images from Solar

Dynamic Telescope (SDO). The facular excess and facular area are determined for these two types of images using the data reduction procedure developed at SFO. We find strong correlation between the derived quantities from SFO and SDO images. Also, the facular excess and facular area show a very good correlation with the sunspot numbers. The sunspot numbers derived from the SDO images from our model agrees well with tabulated values.
Author(s): Debi Prasad Choudhary[1], Angie Cookson[1], Gary Chapman[1], Kemal Yassin[1]
Institution(s): *1. California State University Northridge*

203.15 – Investigating the Thermal Evolution of Solar Prominence Formation

We present a study of prominence formation using time series analysis of Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO/AIA) data. In evaporation-condensation models of prominence formation, heating at the foot-points of sheared coronal flux-tubes results in evaporation of hot (a few MK) material into the corona and subsequent catastrophic cooling of the hot material to form the cool (~10,000 K) prominence material. We present the results of a time-lag analysis that tracks the thermal evolution using emission formed at different temperatures. This analysis is made possible by AIA's many wavebands and high time resolution, and it allows us to look for signs of the evaporation-condensation process and to study the heating time scales involved. Supported by NASA's Living with a Star program.
Author(s): Therese A. Kucera[1], Nicholeen M. Viall[1], Judith T. Karpen[1]
Institution(s): *1. NASA GSFC*

203.16 – Survey of high-altitude partially erupting prominences

Solar prominences exhibit a range of eruptive-like dynamic activity, including in some cases the confined or 'failed' ejection of prominence material from the solar atmosphere. Many prominences exhibit a partial eruption in which some mass escapes while the remaining mass drains back to the photosphere. This process may involve the formation of an X-type neutral line in this region, which allows disconnection of part of the prominence material. In a previous study (Gilbert et al. 2000) it was found that this separation tends to occur in the height range from 1.20 to 1.35 R_{sun}. More recently, the separation point in these types of partial eruptions has been observed to occur at much larger heights. We investigate a selection of these higher partial eruptions, exploring the characteristics of the prominences and their associated CMEs to better understand the dynamical processes in the solar atmosphere associated with eruption.
Author(s): Holly Gilbert[1], O. C. St Cyr[1], Andrew Inglis[2], Hong Xie[2], Barbara J. Thompson[1]
Institution(s): *1. NASA GSFC, 2. The Catholic University of America*

203.17 – Complex Flare Dynamics Initiated by a Filament-Filament Interaction

We report on a filament eruption that led to a relatively rare filament-filament interaction event. The filaments were located at different heights above the same segment of a circular polarity inversion line (PIL) around a condensed leading sunspot. The onset of the eruption of the lower of the two filaments was accompanied by a simultaneous descent of the upper filament resulting in a convergence and direct interaction of the two filaments. The interaction led to the subsequent merger of the filaments into a single magnetically complex structure that erupted to create a large solar flare and an array of complex dynamical activity. A hard X-ray coronal source and an associated enhancement of hot plasma are observed at the interface between the two interacting filaments. These phenomena are related to the production of a small C flare and the subsequent development of a much stronger M flare. Magnetic

loop shrinkage and descending dark voids were observed at different locations as part of the large flare energy release giving us a unique insight into these dynamic flare phenomena.
Author(s): Chunming Zhu[1], Rui Liu[4], David Alexander[2], Xudong Sun[3], James McAteer[1]
Institution(s): *1. New Mexico State University, 2. Rice University, 3. Stanford University, 4. University of Science and Technology of China*

203.18 – Observations of a Coronal Cavity and Prominence with Hinode, IRIS, and AIA

Coronal cavities are low emission regions above quiescent prominences. The interaction of the prominence material and coronal cavity is still poorly understood. We present observations of a coronal cavity and prominence system observed on 9 October 2014. The observations are part of a joint observation program (HOP264) including Hinode and the Interface Region Imaging Spectrograph (IRIS). A small cavity is seen just above the prominence in the Hinode X-ray Telescope (XRT) images. Using data from the Solar Dynamic Observatory (SDO) Atmospheric Imaging Assembly (AIA), Hinode Solar Optical Telescope (SOT) and IRIS, multi-thermal plasma can be seen traveling along the cavity loops. During this time, a brightening is seen near the center of the cavity in the XRT images suggesting hot material has been trapped inside the cavity. In addition to presenting the cavity dynamics, we characterize the cavity velocity structures using the Hinode EUV Imaging Spectrometer (EIS) and discuss the magnetic structure of the cavity using data from the Coronal Multichannel Polarimeter (CoMP). This work is supported by under contract SP02H1701R from Lockheed-Martin to SAO, contract NNM07AB07C from NASA to SAO and grant number NNX12AI30G from NASA to SAO.
Author(s): Patricia R Jibben[1], Katharine Reeves[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics*

203.19 – The Solar Corona at the 2015 Total Solar Eclipse

We report on our successful observations of the solar corona at the 20 March 2015 total solar eclipse from our site at a latitude of about 78° on the Svalbard archipelago, and related observations by colleagues aloft. Our equipment included cameras for imaging at a variety of scales for use in making high-contrast composites, as reported our Astrophysical Journal article (2015) about our 2012 total solar eclipse observations and similar articles about the corona and changes in it at previous total eclipses. Our Svalbard equipment also included a spectrograph, with which we continued our monitoring of the ratio of the Fe XIV and Fe X coronal lines, which has recently been >1 with the solar maximum, a reversal from <1 at earlier eclipses closer to the last solar minimum. Our 2013 observations from Gabon showed two coronal mass ejections and an erupting prominence; the 2015 eclipse showed an erupting prominence and some unusual coronal structure in an overall coronal shape typical of solar maximum. We use our ground-based eclipse observations to fill the gap in imaging between the SDO and SWAP (17.4 nm) EUV observations on the solar disk and the inner location of the LASCO C2 occultation disk, with STEREO observations providing the possibility of three-dimensional interpretations. Our expedition was supported by a grant (9616-14) from the Committee for Research and Exploration of the National Geographic Society.
Author(s): Jay M. Pasachoff[1], Allison L. Carter[1]
Institution(s): *1. Williams College*

203.20 – Elemental Abundance Variations in Coronal Hole Structures

Plumes are a structure found within coronal holes in which the density is greater than in the surrounding interplume plasma. Previous spectroscopic measurements of plumes have reached contradictory results

as to whether the elemental abundances in plumes are the same as or different from interplume regions. We have studied data from the Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode and inferred the relative elemental abundances in plumes and interplumes over an ~24 hour period. We find that some plumes do show different elemental abundances relative to interplumes. Moreover, the abundance anomaly in plumes can be time dependent. If previous studies observed plumes at different stages in their evolution, this time dependence may explain the lack of consistency among previous results. Our work on the elemental composition of plumes and interplumes may also enable in situ measurements to answer the longstanding question of whether or not plumes contribute to the fast solar wind, which originates from coronal holes.
Author(s): Michael Hahn[1], Chloe Guennou[1], Daniel Wolf Savin[1]
Institution(s): *1. Columbia University*

203.21 – Tracing Solar Fiber Bursts Spatially and Spectrally with Microwave Imaging Spectroscopy

We report observations of fiber fine structures during type IV decimetric radio bursts on March 3, 2012 using the recently upgraded Karl G. Jansky Very Large Array (VLA). For the first time, the technique of microwave imaging spectroscopy with high temporal and spectral resolution allowed us to image the fiber bursts over a continuous frequency range from 1-2 GHz, and precisely measure the centroid trajectories in the heliocentric coordinate. We found that the burst source originates at lower height near the footpoint, and streams upward through the corona along some field lines, whose trend is similar to some coronal loops seen in extreme ultra violet (EUV) wavelengths. In the dynamic spectrum, we also studied the average drift rates of different groups. Using an automatic fiber-tracing algorithm, we obtained the normalized drift rates between -0.1 and -0.025 s^{-1} from over 2000 fiber samples. Together with an appropriate coronal density model, we determined a subset of 3D field lines in the extrapolated coronal magnetic field, provided by the potential field source surface model (PFSS). As a result, we obtained the 3D source velocity of the fiber bursts at more than 2000 km/s above 1.1 GHz. The derived velocity can be used to discriminate between the two competing theories, the whistler wave model and Alfvén wave model.
Author(s): Zhitao Wang[2], Bin Chen[1], Dale E. Gary[2]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. New Jersey Institute of Technology*

203.22 – In search of the radio signatures on SEP-productive solar active regions

Solar active regions may produce a wide variety of transients in the meter-decameter wavelength range.Some of these bursts result from mildly relativistic electron beams traveling along closed (type I) or open (type III) magnetic field lines or from energized electrons trapped in coronal magnetic fields (IV). The energization of these electron populations may be achieved through magnetic field reconnection. Reconnection may also be the driver which creates populations of suprathermal electrons. These suprathermals are now viewed as a prerequisite for the efficient production of solar energetic particles through shock-driven acceleration. We here present work done towards deriving a radio indicator for levels of reconnection correlated with large SEP storms. Working mostly with data from the Nançay Radioheliograph, spatio-spectral analysis is carried out on SEP-rich AR and a control group that is not. We discuss the most promising candidates of the sought after signature.
Author(s): Samuel D Tun Beltran[1], Martin Laming[1]
Institution(s): *1. Naval Research Laboratory*

203.23 – Solar Observations with the Atacama Large Millimeter/submillimeter Array (ALMA)

The Atacama Large Millimeter/Submillimeter Array (ALMA) is a joint North American, European, and East Asian project that opens the mm-submm wavelength part of the electromagnetic spectrum for general astrophysical exploration, providing high-resolution imaging in frequency bands currently ranging from 84 GHz to 950 GHz (300 microns to 3 mm). Despite being a general purpose instrument, provisions have been made to enable solar observations with ALMA. Radiation emitted at ALMA wavelengths originates mostly from the chromosphere, which plays an important role in the transport of matter and energy, and the in heating the outer layers of the solar atmosphere. Despite decades of research, the solar chromosphere remains a significant challenge: both to observe, owing to the complicated formation mechanisms of currently available diagnostics; and to understand, as a result of the complex nature of the structure and dynamics of the chromosphere. ALMA has the potential to change the scene substantially as it serves as a nearly linear thermometer at high spatial and temporal resolution, enabling us to study the complex interaction of magnetic fields and shock waves and yet-to-be-discovered dynamical processes. Moreover, ALMA will play an important role in the study of energetic emissions associated with solar flares at sub-THz frequencies.

In this paper we describe recent efforts to ensure that ALMA can be usefully exploited by the scientific community to address outstanding questions in solar physics. We summarize activities by the ALMA solar development team comprised of scientists from the East Asia, North America, and Europe. These activities include instrument testing, development of calibration and imaging strategies, software requirements development, and science simulations. Opportunities for the wider community to contribute to these efforts will be highlighted.
Author(s): Timothy S Bastian[1]
Institution(s): *1. NRAO*

203.24 – Faraday Rotation Fluctuations of MESSENGER radio signals through the Corona during the 2009 Solar Minimum.

Faraday rotation (FR) techniques have been used to probe variations of coronal plasma velocity, density and magnetic field. The plane of polarization for an electromagnetic wave rotates in proportion to the integrated product of parallel magnetic field components and electron density along the radio signal line-of-sight as directed towards the receiving antenna. Fluctuations in FR through the corona thus represent the evolution of these line-integrated plasma parameters, providing a unique measurement of regional corona physics. The MESSENGER spacecraft radio 8 GHz radio beacon, transmitting through the corona at offsets 1.6 to 1.9 solar radii and near-equatorial heliolatitude, was recorded on the Green Bank radio telescope during the solar minimum of 2009. Here we reanalyze at higher temporal resolution the data previously published (Jensen et al 2013, Solar Physics 285:83-95). Combinations of coherent and incoherent integration were used to estimate Stokes parameters, from which the FR phase differences were obtained for serial one-second frames. Results were concatenated and corrected for phase wrap-around to produce a continuous FR phase curve. The general FR phase curve was broad and sweeping, with greatest spectral power observed in periods of hours. Also, finer wave-like fluctuations were noted with periods on the order of 100's of seconds. With the lowest-frequency components removed by detrending techniques, spectral analysis revealed a power spectrum of form P=k
Author(s): David Wexler[3], Juha Vierinen[1], Anthea Coster[1], Elizabeth A. Jensen[2]
Institution(s): *1. MIT Haystack Observatory, 2. PSI, 3. University of Southern Queensland*

203.25 – Sub-Milli Arcsecond Resolution Observations of the Optical Solar Limb with RHESSI/SAS

The Solar Aspect System (SAS) of the RHESSI satellite measures the optical solar limb with a cadence typically set at 100 samples/s. RHESSI has observed the Sun continuously since its launch in early 2002, and we have acquired a unique data set ranging over more than a full 11-year solar cycle and consisting of about 4x10^10 single data points. The optics has a point spread of about 4.5 arcsec FWHM imaging the red continuum onto three linear CCD sensors with a pixel resolution of 1.7 arcsec. However, careful study of systematics, masking of contaminated data, and accumulation of data over appropriate time intervals has led to measurements with sub-milli arcsec accuracy. Analyzing data for an initial period in 2004, these measurements have led to the most accurate oblateness measurement to date, 8.01+-0.14 milli arcsec (Fivian et al., 2008), a value consistent with models predicting an oblateness from surface rotation. An excess oblateness term can be attributed to magnetic elements possibly located in the enhanced network. We also study photometric properties of our data. Previous observations of latitude-dependent brightness variations at the limb had suggested the presence of a polar temperature excess as large as 1.5 K. The RHESSI observations, made with a rotating telescope in space, have great advantages in the rejection of systematic errors in the very precise photometry required for such an observation. Our measurements of latitude-dependent brightness variations at the limb lead to a quadrupolar term (a pole-to-equator temperature variation) of the order of 0.1 K, an order of magnitude smaller than previously reported. We present the analysis of these unique data, an overview of some results and we report on our progress as we apply our developed analysis method to the whole 13 years of data.
Author(s): Martin D Fivian[1], Hugh Hudson[1], Sam Krucker[1]
Institution(s): *1. Space Sciences Lab / UC-Berkeley*

204 – Coronal Heating I

204.01 – EUNIS 2013: Unambiguous Evidence for Impulsive Coronal Heating, Data Available

The broad spectral coverage (303-370 Å, 527-635 Å) and unprecedented dynamic range of the Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) 2013 sounding rocket observations includes emission lines of ionization stages from He I to Fe XX, and thus a wide temperature range of 0.03 to 10 MK. Pervasive, faint Fe XIX 592 Å line emission was observed in active regions. Comparison of observed line intensities with calculations demonstrates that the Fe XIX emission, formed at temperatures around 8 MK, is evidence of the faint hot emission predicted by impulsive heating models of the solar corona (e.g., 'nano-flares'). The calibration and availability of the EUNIS-2013 dataset is discussed as well.
Author(s): Adrian Daw[1], Jeffrey Brosius[1], J. Patrick Haas[1], Thomas Plummer[1], Douglas Rabin[1]
Institution(s): *1. NASA Goddard Space Flight Center*

204.02 – Hard X-ray imaging spectroscopy of hot coronal sources and active regions with NuSTAR

We present imaging spectroscopy of the Sun with the NuSTAR hard X-ray (HXR) telescope, searching for high temperature and non-thermal emission in the "non-flaring" Sun. Launched in 2012, NASA's astrophysics mission NuSTAR uses focusing optics to directly image X-rays between ~2-80 keV. In the band below ~50 keV the field of view is 12'x12' and the instrument has an energy resolution of ~0.4 keV. Although not optimized for solar observations, NuSTAR's high sensitivity can probe previously inaccessible X-ray emission from the Sun. NuSTAR observed the Sun three times during late 2014 and we present these first directly imaged hard X-rays from non-flaring active regions. Using NuSTAR's imaging spectroscopy capabilities we are able to derive the active region's multi-thermal characteristics. We will

also discuss a hot (>3MK) source that appears to linger high in the corona and could be associated with the occulted active region AR12192.

Author(s): Iain Hannah[6], Andrew Marsh[5], Lindsay Glesener[4], David Smith[5], Brian Grefenstette[2], Kristin Madsen[2], Sam Krucker[4], Hugh Hudson[4], Stephen White[1], Albert Y. Shih[3]

Institution(s): *1. Air Force Research Laboratory, 2. Caltech, 3. NASA/GSFC, 4. UC Berkeley, 5. UC Santa Cruz, 6. University of Glasgow*

204.03 – Spectrally-resolved Soft X-ray Observations and the Temperature Structure of the Solar Corona

Solar X-ray observations provide important diagnostics of plasma heating and particle acceleration, during solar flares and quiescent periods. How the corona is heated to its ~1-3 MK nominal temperature remains one of the fundamental unanswered questions of solar physics; heating of plasma to tens of MK during solar flares -- particularly to the hottest observed temperatures of up to ~50 MK -- is also still poorly understood. Soft X-ray emission (~0.1-10 keV; or ~0.1-10 nm) is particularly sensitive to hot coronal plasma and serves as a probe of the thermal processes driving coronal plasma heating. Spectrally- and temporally-resolved measurements are crucial for understanding these energetic processes, but there have historically been very few such observations. We present new solar soft X-ray spectra from the Amptek X123-SDD, measuring quiescent solar X-ray emission from ~0.5 to ~30 keV with ~0.15 keV FWHM resolution from two SDO/EVE calibration sounding rocket underflights in 2012 and 2013. Combined with observations from RHESSI, GOES/XRS, SDO/EVE, and SDO/AIA, the temperature distribution derived from these data suggest significant hot (5-10 MK) emission from active regions, and the 2013 spectra suggest a low-FIP enhancement of only ~1.6 relative to the photosphere, 40% of the usually-observed value from quiescent coronal plasma. We explore the implications of these findings on coronal heating. We discuss future missions for spectrally-resolved soft X-ray observations using the X123-SDD, including the upcoming MinXSS 3U CubeSat using the X123-SDD and scheduled for deployment in mid-2015, and the CubIXSS 6U CubeSat mission concept.

Author(s): Amir Caspi[2], Harry Warren[1], James McTiernan[3], Thomas N. Woods[4]

Institution(s): *1. Naval Research Laboratory, 2. Southwest Research Institute, Boulder, 3. University of California, Berkeley, 4. University of Colorado, Boulder*

204.04 – Evidence of suppressed heating of coronal loops rooted in opposite polarity sunspot umbrae

Observations of active region (AR) coronae in different EUV wavelengths reveal the presence of various loops at different temperatures. To understand the mechanisms that result in hotter or cooler loops, we study a typical bipolar AR, near solar disk center, which has moderate overall magnetic twist and at least one fully developed sunspot of each polarity. From AIA 193 and 94 A images we identify many clearly discernible coronal loops that connect opposite-polarity plage or a sunspot to a opposite-polarity plage region. The AIA 94 A images show dim regions in the umbrae of the spots. To see which coronal loops are rooted in a dim umbral area, we performed a non-linear force-free field (NLFFF) modeling using photospheric vector magnetic field measurements obtained with the Heliosesmic Magnetic Imager (HMI) onboard SDO. After validation of the NLFFF model by comparison of calculated model field lines and observed loops in AIA 193 and 94 A, we specify the photospheric roots of the model field lines. The model field then shows the coronal magnetic loops that arch from the dim umbral area of the positive-polarity sunspot to the dim umbral area of a negative-polarity sunspot. Because these coronal loops are not visible in any of the coronal EUV and X-ray images of the AR, we conclude they are the coolest loops in the AR. This result suggests that the loops connecting opposite polarity umbrae are the least heated because the field in umbrae is so strong that the convective braiding of the field is strongly suppressed.

From this result, we further hypothesize that the convective freedom at the feet of a coronal loop, together with the strength of the field in the body of the loop, determines the strength of the heating. In particular, we expect the hottest coronal loops to have one foot in an umbra and the other foot in opposite-polarity penumbra or plage (coronal moss), the areas of strong field in which convection is not as strongly suppressed as in umbrae. Many transient, outstandingly bright, loops in the AIA 94 A movie of the AR do have this expected rooting pattern.
Author(s): Sanjiv K. Tiwari[1], Julia K. Thalmann[3], Amy R. Winebarger[1], Navdeep K Panesar[2], Ronald Moore[1]
Institution(s): *1. NASA's MSFC, 2. University of Alabama in Huntsville, 3. University of Graz*

204.05 – Pinning Down Coronal Heating Properties in the Presence of Non-Equilibrium Ionization

We examine the effects that non-equilibrium ionization can have on the evolution of light curves emitted by transition region and coronal ions during impulsive heating, and how this can lead to the plasma and heating properties being misdiagnosed. Furthermore, through detailed numerical and forward modeling we demonstrate how the effects of non-equilibrium ionization can be mitigated and accounted for so that robust diagnostics can be developed.
Author(s): Stephen Bradshaw[1], Paola Testa[2]
Institution(s): *1. Rice University, 2. Smithsonian Astrophysical Observatory*

204.06 – Influence of Multiple Ionization on Studies of Nanoflare Heated Plasmas

The spectrum emitted by a plasma depends on the charge state distribution (CSD) of the gas. This, in turn, is determined by the corresponding rates for electron-impact ionization and recombination. Current CSD calculations for solar physics do not account for electron-impact multiple ionization (EIMI), a process in which multiple electrons are ejected by a single electron-ion collision. We have estimated the EIMI cross sections for all charge states of iron using a combination of the available experimental data and semi-empirical formulae. We then modeled the CSD and observed the influence of EIMI compared to only including single ionization. One case of interest for solar physics is nanoflare heating. Recent work has attempted to predict the spectra of impulsively heated plasmas in order to identify diagnostics arising from non-equilibrium ionization that can constrain the nanoflare properties, but these calculations have ignored EIMI. Our findings suggest that EIMI can have a significant effect on the CSD of a nanoflare-heated plasma, changing the ion abundances by up to about 50%.
Author(s): Michael Hahn[1], Daniel Wolf Savin[1]
Institution(s): *1. Columbia University*

205 – Acceleration and Transport of Solar Energetic Particles

205.01 – Small-scale magnetic islands near the heliospheric current sheet and their role in particle acceleration

Increases of ion fluxes in the keV-MeV range are sometimes observed near the heliospheric current sheet (HCS) during periods when other sources are absent. These resemble solar energetic particle (SEP) events, but the events are weaker and apparently local. Conventional explanations based on either shock acceleration of charged particles or particle acceleration due to magnetic reconnection at interplanetary current sheets are not persuasive. We suggest instead that recurrent magnetic reconnection occurs at the HCS and smaller current sheets in the solar wind (Zharkova & Khabarova,

ApJ, 2012), of which a consequence is particle energization by the dynamically evolving secondary current sheets and magnetic islands (Zank et al., ApJ, 2014; Drake et al., JRL, 2006). The effectiveness of the trapping and acceleration process associated with magnetic islands depends in part on the topology of the HCS. We show that the HCS possesses ripples superimposed on the large-scale flat or wavy structure. We conjecture that the ripples can efficiently confine plasma and provide tokamak-like conditions that are favorable for the appearance of small-scale magnetic islands that merge and/or contract. Particles trapped in the vicinity of merging islands and experiencing multiple small-scale reconnection events are accelerated by the induced electric field, and experience first-order Fermi acceleration in contracting magnetic islands (Zank et al., ApJ, 2014). We present multi-spacecraft observations of magnetic island merging and particle energization in the absence of other sources, providing support for theory and simulations that show particle energization by reconnection related processes of magnetic island merging and contraction.
Author(s): Olga Khabarova[1], Gary Zank[4], Gang Li[4], Jakobus A. le Roux[4], Gary M. Webb[4], Alexander Dosch[4], Olga E. Malandraki[2], Valentina V. Zharkova[3]
Institution(s): *1. IZMIRAN, 2. National Observatory of Athens, 3. Northumbria University, 4. University of Alabama in Huntsville*

205.02 – Effects of Solar Energetic Particle deceleration due to drift

Solar Energetic Particles (SEPs) experience deceleration during their propagation through the interplanetary magnetic field (IMF). Adiabatic deceleration has been known for decades to be an important process that influences SEP intensity profiles and spectra, and needs to be properly accounted for in models.
Recently we have shown that drifts due to the gradient and curvature of the large scale Parker IMF cause SEP cross-field transport of a nearly symmetric nature in the heliolongitudinal direction and asymmetric in the heliolatitudinal one. As a result of the latitudinal drift, SEPs move in the direction opposite to that of the solar wind electric field and experience deceleration.
Drift-induced deceleration is not accounted for by focussed transport approaches that neglect drift velocities within their spatial convection term, i.e. it is not included in the majority of current SEP models, on which interpretations of SEP data are based.
Here we use 3D full orbit test particle simulations to demonstrate the effect of drift-induced deceleration on SEP populations injected near the Sun at different energies. Protons injected at 100 MeV experience latitudinal drifts of about 5 to 10 degrees and the associated deceleration reduces their kinetic energy by between 20 and 55% of the initial value, after four days. At lower energies (1 MeV) the spatial drift is of the order of 0.1 of a degree, however the effect of drift-induced deceleration is stronger, with particles losing between 35 and 90% of the initial kinetic energy during the same time.
We show that the magnitude of drift-induced deceleration is similar to that of standard adiabatic deceleration, indicating that it needs to be accounted for in models. While adiabatic energy change is strongly influenced by the scattering conditions, the dependence of drift-induced deceleration on the level of pitch-angle scattering is weak. We discuss ways in which deceleration associated with drift could be included within SEP models.
Author(s): Silvia Dalla[1], Micheal S. Marsh[1], Timo Laitinen[1]
Institution(s): *1. University of Central Lancashire, UK*

205.03 – Unseen GLEs (Ground Level Events)

Over the last seventy years, solar energetic particle (SEP) ground level events (GLEs) have been observed by ground-based neutron monitors and muon telescopes at a rate of slightly more than one per year.

Ground-based detectors only measure secondary particles, and matching their observations with SEP in-situ measurements from spacecraft has been difficult. Now, the Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) instrument provides in-situ measurements that also include composition and pitch-angle distribution and bridge the energy between long-term SEP monitors in space (e.g. ACE and GOES) and the ground-based observations. The PAMELA data show that there are a few SEP events (e.g. 23 Jan 2012) where PAMELA sees high-energy (> 1 GeV) particles, yet these are not registered as GLEs. We will present evidence that the anisotropic distribution of these SEPs may miss the global network of neutron monitors.

Author(s): Eric R. Christian[3], M. Boezio[2], Ulisse Bravar[6], A. Bruno[5], Georgia de Nolfo[3], M. Martucci[1], M. Merge[1], E. Mocchiutti[2], R Munini[2], M. Ricci[1], James Michael Ryan[6], Steven Stochaj[4]
Institution(s): *1. INFN Rome, 2. INFN Trieste, 3. NASA/GSFC, 4. New Mexico State University, 5. University of Bari, 6. University of New Hampshire*

205.04 – Properties of Long Duration High-Energy Gamma-Ray Flares

Long duration high-energy gamma-ray flares, recognized the first time in the 1982 June 3 flare, were thought to be rare. However, the Fermi mission with superior gamma-ray sensitivity, has registered almost two dozen such flares. This number allows for investigations into the distribution of the relevant parameters governing these events, in part mitigating some of the observational bias due to instrument sensitivity. We report progress in quantifying key solar parameters that characterize these events. The context for interpreting the gamma-ray data is a stochastic acceleration diffusion model that predicts the precipitation of high-energy ions accelerated in large loops. Two versions of this model are used: a leaky box and one that explicitly includes the spatial diffusion into the denser parts of the solar atmosphere.
Author(s): James Michael Ryan[2], Martin A Lee[2], Georgia de Nolfo[1], Emily Anderson[2], Arvind Nair[2]
Institution(s): *1. NASA/GSFC, 2. University of New Hampshire*

205.05 – Observations and Interpretation of Behind the Limb Solar Flares Detected by Fermi-LAT and Other Instruments

The Fermi Large Area Telescope (LAT) is the most sensitive instrument ever deployed in space for observing > 30 MeV gamma-rays. During the past active period of the Sun the LAT has detected more than 40 flares up to GeV energies some of which occur behind the limb as determined by STEREO observations. We will present the observations on two such flares with significant flux of > 100 MeV (and some indication of 1 to 10 MeV detected by Fermi-GBM) gamma-rays coming from the visible disk while the flare and associated CMEs are initiated in active regions tens of degrees behind the visible limb of the Sun. We will consider acceleration of particles, their transport and radiative signatures, and the transfer of these radiation in the solar atmosphere to distinguish between (i) acceleration in the low corona, in a high corona trap, and/or in the CME driven shock; (ii) between continuous and prompt acceleration; and (iii) between electron bremsstrahlung and decay of pions produced by accelerated ions.
Author(s): Vahe Petrosian[1], Nicola Omodei[1], Melissa Pesce-Rollins[1], Fatima Rubio da Costa[1], Wei Liu[1]
Institution(s): *1. Stanford University*

205.06 – PAMELA's Measurements of Magnetospheric Effects on High Energy Solar Particles

Whether solar energetic particles (SEP) attain energies in excess of a GeV through flare reconnection or through CME-driven shocks is still in debate today. Observations of the properties of SEPs relate both to the acceleration mechanisms at play but also to the influences experienced during transport. The Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics (PAMELA) instrument, provides new observations of SEPs that uniquely set apart the affects of acceleration from those of transport. PAMELA detects the composition and the angular distribution of the particles about the magnetic field, i.e. pitch angle distribution, over a broad energy range (from ~80 MeV to beyond one GeV) -- bridging a critical gap between space-based measurements and ground-based. We report on the observation of high-energy SEP data from PAMELA acquired during the 2012 May 17 ground level enhancement (GLE). These data exhibit differential anisotropies and thus transport features over the instrument rigidity range. SEP protons exhibit two distinct pitch angle distributions; a low-energy population that extends to 90° and a population that is beamed at high energies ($>$ 1 GeV), consistent with neutron monitor measurements. The arrival of SEPs over a broad range in energy at Earth within 20 minutes sets strong constraints on the pitch angle distribution of SEPs originating at the Sun. To explain a low-energy SEP population that exhibits significant scattering or redistribution accompanied by a high-energy population that reaches the Earth relatively unaffected by dispersive transport effects, we postulate that the scattering or redistribution takes place locally. We believe these are the first comprehensive measurements of the effects of solar energetic particle transport in the Earth's magnetosheath.
Author(s): Georgia de Nolfo[5], M. Boezio[4], Ulisse Bravar[6], A. Bruno[7], Eric R. Christian[5], M. Martucci[1], M. Merge[1], E. Mocchiutti[4], R Munini[4], M. Ricci[3], James Michael Ryan[6], Steven Stochaj[2], N. Thakur[5]
Institution(s): *1. Department of Physics, University of Rome ``Tor Vergata'', I-00133, 2. Electrical and Computer Engineering, New Mexico State University, 3. INFN, Laboratori Nazionali di Frascati, Via Enrico Fermi 40, I-00044 , 4. INFN, Sezione di Trieste, 5. NASA/GSFC, 6. Space Science Center, University of New Hampshire, 7. University of Bari, I-70126*

206 – Magnetosphere

206.01 – Instantaneous configuration of the geomagnetic field inferred from the low-altitude isotropic boundaries: modeling and observations

Understanding the interplay between ionospheric, auroral and magnetospheric phenomena requires detailed knowledge of Earth's magnetic field geometry under various solar wind conditions. This geometry is directly relevant to the magnetic field mapping between different regions of near-Earth space.
To evaluate the instantaneous geomagnetic field configuration we probe the isotropic boundaries (IB) of energetic particles measured at low altitudes. Those are interpreted as the boundary between the regions of adiabatic and stochastic particle motion in the equatorial magnetotail and provide information regarding the degree of magnetic field stretching.
We investigate the topology and dynamics of the magnetotail current during active and quiet times as de- pendent on solar wind and IMF parameters based on NOAA/POES MEPED and DMSP SSJ/4 measurements in combination with global magnetospheric simulations using the Space Weather Modeling Framework (SWMF).
The extensive NOAA/POES MEPED low-altitude data sets give the locations of isotropic boundaries, which are used to extract information regarding particle distributions and field structure in the source regions in the magnetosphere.
We present a comparison between the magnetic field lines with the observed IB latitude and those com- puted from the SWMF using the theoretical relation for IB locations in the magnetotail, i.e. where the

ratio between curvature radius and Larmor radius is close to 8. This investigation assesses the accuracy of the model magnetic field and the structure of the magnetotail. The results are examined in relation to the solar wind and IMF conditions to determine the corresponding configuration and dynamics of the magnetotail.
Author(s): Raluca Ilie[1], Natalia Ganushkina[1], Gabor Toth[1], Michael Liemohn[1]
Institution(s): *1. University of Michigan*

206.02 – Dawn-Dusk and Interhemispheric Asymmetries in the Magnetospheric Tail Lobes

Dawn-Dusk asymmetries and inter-hemispheric asymmetries are common throughout the solar wind-magnetosphere-ionosphere system, but to date little research has been conducted on the asymmetries that are present in the magnetotail lobes. Here we investigate the extent to which asymmetries in magnetosperic convection (specifically the rotation of the converection pattern towards the premidnight sector) are reflected in the properties of the magnetotail lobe magnetic field, and the cold ion population in the lobes. We employ data from Cluster, Geotail, Double Star and THEMIS taken during intervals of steady southward IMF so asymmetries resulting from IMF BY are minimised. Initial results are suggestive of a higher lobe magnetic field strength in the premidnight sector, consistent with the asymmetric convection pattern and also a higher magnetic field strength in the winter hemisphere.
Author(s): Andrew Walsh[1], Stein Haaland[2]
Institution(s): *1. European Space Agency, 2. Max Planck Institute for Solar System Research*

206.03 – The Substorm Current Wedge Revisited

Almost 40 years ago the concept of the substorm current wedge was developed to explain the magnetic signatures observed on the ground and in geosynchronous orbit during substorm expansion. In the ensuing decades new observations, including radar and low-altitude spacecraft, MHD simulations, and theoretical considerations have tremendously advanced our understanding of this system. The AMPTE/IRM, THEMIS and Cluster missions have added considerable observational knowledge, especially on the important role of fast flows in producing the stresses that generate the substorm current wedge. Recent detailed, multi-spacecraft, multi-instrument observations both in the magnetosphere and in the ionosphere have brought a wealth of new information about the details of the temporal evolution and structure of the current system. In this paper, we briefly review recent in situ and ground-based observations and theoretical work that have demonstrated a need for an update of the original picture. We present a revised, time-dependent picture of the substorm current wedge that follows its evolution from the initial substorm flows through substorm expansion and recovery, and conclude by identifying open questions.
Author(s): Larry Kepko[2], Robert McPherron[6], Sergey Apatenkov[5], Wolfgang Baumjohann[3], Joachim Birn[4], Mark Lester[7], Rumi Nakamura[3], Tuija Pulkkinen[1], Victor Sergeev[5]
Institution(s): *1. Aalto University, 2. NASA GSFC, 3. Space Research Institute, 4. Space Science Institute, 5. St. Petersburg State University, 6. University of California, Los Angeles, 7. University of Leicester*

206.04 – Statistical analysis of storm-time near-Earth current systems

Currents from the Hot Electron and Ion Drift Integrator (HEIDI) inner magnetospheric hot ion results for all of the intense storms (90 events) from solar cycle 23 (1996 - 2005) are calculated, presented, and analyzed. We have categorized these currents into the various systems that exist in near-Earth space, specifically the eastward and westward symmetric ring current, the partial ring current, the banana current, and the tail current. The current results from each run set are combined by a normalized

superposed epoch analysis technique that scales the timeline of each phase of each storm before summing the results. It is found that there is a systematic ordering to the current systems, with the asymmetric current systems peaking during storm main phase (tail current rising first, then the banana current, followed by the partial ring current) and the symmetric current systems peaking during the early recovery phase (westward and eastward symmetric ring current having simultaneous maxima). The median and mean peak amplitudes for the current systems ranged from 1 to 3 MA, depending on the setup configuration used in HEIDI, except for the eastward symmetric ring current, for which the mean never exceeded 0.3 MA for any HEIDI setup. The self-consistent electric field description in HEIDI yielded larger tail and banana currents than the Volland-Stern electric field, while the partial and symmetric ring currents had similar peak values between the two applied electric field models.
Author(s): Michael Liemohn[1], Roxanne M Katus[2], Raluca Ilie[1]
Institution(s): *1. University of Michigan, 2. West Virginia University*

206.05 –
Statistical examination of the magnetospheric temperature

Plasma temperature is a fundamental parameter. A global picture of the magnetospheric plasma temperature can describe the energy coupling in the magnetosphere. This study quantitatively examines heating and propagation of energetic ions. Specifically, we calculate and validate the temperature throughout the magnetosphere from Two Wide-Angle Imaging Neutral-Atom Spectrometers (TWINS) energetic neutral atom flux data. The magnetospheric temperature data has been calculated using plasma physics methods [*Scime et al.,* 2002;*Keesee et al.,* 2011]. In this study, the previous result is expanded to provide continuous, 10-minute resolution temperature data for large, moderate, and then small geomagnetic storms. We validate the result using error analysis between the two TWINS satellites and between TWINS and in situ measurements from the Time History of Events and Macroscale Interactions during Substorms (THEMIS) satellites. The combination of these two error analyses spatially and temporally test the quality of the result. Statistical techniques are used to examine magnetosphere dynamics under distinctly different solar wind driving conditions. We preform superposed epoch analyses to investigate the change in temperature throughout the magnetosphere as a function of storm time for given types of storms. We anticipate seeing significant changes in the temperature as a function of storm time for each type of solar wind driver. We will quantify these changes and show how the various storm types lead to drastically different configurations during a geomagnetic storm.
Author(s): Roxanne M Katus[2], Amy M Keesee[2], Michael Liemohn[1]
Institution(s): *1. University of Michigan, 2. West Virginia University*

206.06 – Particle acceleration by inductive electric fields in the Earth's magnetosphere

The terrestrial magnetosphere has the capability to rapidly accelerate charged particles up to very high energies over relatively short times and distances, leading to an increase in the near Earth currents. These energetic particles are injected from the magnetotail into the inner magnetosphere through two primary mechanisms. One transport method is the potential-driven convection. This occurs during periods of southward Interplanetary Magnetic Field (IMF), which allows part of the dawn-to-dusk solar wind electric field to effectively map down to the polar ionosphere. The second transport process, substorm activity, involves a sudden reconfiguration of the magnetic field and the creation of transient induced electric fields. The relative contribution of potential and inductive electric field driven convection resulting in the development of the storm-time ring current has remained an unresolved question in Geospace research.
Since the energy of charged particles can be altered only by means of electric fields, knowledge of the

relative contribution of potential versus inductive electric fields at intensifying the hot ion population in the inner magnetosphere is required. However, it is not possible to distinguish the two terms by only measuring the electric field. Therefore assessing the importance of induced electric field is possible by thorough examination of the time varying magnetic field and current systems using global modeling of the entire system.
The induced electric field is calculated as a 3D integration over the entire magnetosphere domain. However, though computationally challenging, the full volume integration approach removes the need to trace independent field lines and lifts the assumption that the magnetic field lines can be treated as frozen in a stationary ionosphere.
In this work, we quantitatively assess the relative contributions on potential and inductive electric fields at driving plasma sheet ions into the inner magnetosphere, as well as the consequence of these injections on the distortion of the near-Earth magnetic field and current systems.
Author(s): Raluca Ilie[2], Lars K.S. Daldorff[1], Natalia Ganushkina[2], Michael Liemohn[2]
Institution(s): *1. Goddard NASA, 2. University of Michigan*

208 – SPD George Ellery Hale Prize: An X-ray-EUV Spectroscopic View of the Solar Atmosphere, George A. Doschek (Naval Research Laboratory)

208.01 – An X-ray-EUV Spectroscopic View of the Solar Atmosphere

Much of our knowledge of physical conditions in the solar chromosphere, transition region, and corona, such as temperature, electron density, element abundances, mass motions and turbulent motions, depends on analysis of high resolution X-ray-EUV spectroscopic data. The analysis of spectroscopic data depends in turn on spectral line identifications, and the atomic processes governing the production of the spectral lines in the solar atmosphere. In terms of astronomy, X-ray and EUV spectroscopy is relatively new and is a product of the space age combined with laboratory programs such as the inertial confinement laser fusion program and spectra obtained from tokamak plasmas. In addition there are parallel developments in the theory of atomic structure and the calculation of essential atomic parameters. This all began in the 1960s and continues even today. The 1960s and 1970s saw the discovery of the cosmic background radiation, the discovery of quasars and pulsars, and the launch of multitudinous spacecraft in almost every area of astronomy. I have been privileged to be a participant in this solar and cosmic adventure to understand plasmas far from home. I will review how we got from very little knowledge of the X-ray and EUV solar spectrum to the excellent data that we have today as well as theoretical tools such as CHIANTI. I will also highlight some of the achievements in the development of high-resolution spectrometers. I will review the major results learned about the solar atmosphere from spectroscopy and how they bear on understanding the fundamental physical processes that heat the corona, drive solar flares, and generate coronal mass ejections.
Author(s): George A. Doschek[1]
Institution(s): *1. Naval Research Laboratory*

209 – MAVEN: Early Results I

209.01 – Early MAVEN Results on the Mars Upper Atmosphere and Atmospheric Loss to Space

The Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft went into orbit around Mars on 21 September 2014. After a commissioning phase that included science observations of Mars and of Comet Siding Spring during its close approach, its primary science phase began on 16 November 2014 and will

run for a full Earth year, until November 2015.
The science objectives of the MAVEN mission are to characterize the upper atmosphere and ionospheric structure and composition, the interactions of the sun and the solar wind with the planet, and the processes driving loss of gas from the atmosphere to space. Our goal is to understand the chain of processes leading to escape today, learn how to extrapolate back in time, and determine the integrated escape of atmosphere over Martian history.
MAVEN has nine instrument sensors collected into eight separate instruments. The first group of instruments measures the properties of the solar wind and of the sun that drive the processes in the upper atmosphere. The second group measures the structure and composition of the upper atmosphere and of the ions in the ionosphere, and also measures isotope ratios that can tell us about the integrated escape to space. In this group, NGIMS measures properties in situ at the location of the spacecraft, and IUVS measures them remotely, providing a powerful combination of local and global measurements. The third group measures the properties of the ionosphere that both drive escape and determine the composition and properties of the escaping ions.
The spacecraft and all science instruments are functioning nominally, and science data is being collected utilizing our planned observing scenarios. The first deep-dip campaign is scheduled for the second week of February 2015.
By the time of the TESS meeting, we expect to have a preliminary understanding of the instrument behavior, operations, and calibrations. We also expect to have sufficient data collected to allow us to reach preliminary conclusions about the state of the upper atmosphere, interactions with the solar wind, escape of atmospheric gas to space at the present epoch, and integrated escape to space over time.
Author(s): Bruce Jakosky[3], Joe Grebowsky[1], Janet Luhmann[2]
Institution(s): *1. NASA/GSFC, 2. University of California, 3. University of Colorado*

209.02 – Early Observations of the Upper Atmosphere and Ionosphere of Mars by MAVEN's Neutral Gas and Ion Mass Spectrometer

The Neutral Gas and Ion Mass Spectrometer (NGIMS) of the Mars Atmosphere and Volatile Evolution (MAVEN) Mission is designed to characterize the source region of escaping atoms in the upper atmosphere and ionosphere of Mars. The NGIMS instrument is a quadrupole analyzer with a mass rang of 2-150 Da. It utilizes a dual ion source in order to measure both surface reactive neutrals (using the Open Source Neutral mode - OSN), inert neutrals (using the Closed Source Neutral mode – CSN), and thermal ions (using the Open Source Ion mode – OSI) at altitudes below 500 km.
In the first few months of the MAVEN mission, NGIMS alternated on sequential orbits between measurement sequences that focus on fully characterizing neutral species (using the CSN/OSN modes) and ions (using the CSN/OSI modes). The collected data revealed the substantial structure present in both neutral and ion densities with spatial scales of hundreds of kilometers along the spacecraft track. The data also brought to light the sharp contrast between the day side and night side atmospheric profiles of neutrals and ions in both total density and relative abundance.
Author(s): Mehdi Benna[1], Paul R Mahaffy[1], Meredith Elrod[1]
Institution(s): *1. NASA GSFC*

209.03 – Trends in Mars Thermospheric Density and Temperature Structure Obtained from MAVEN In-situ Datasets: Interpretation Using Global Models

The Mars thermosphere-ionosphere-exosphere (TIE) system constitutes the atmospheric reservoir (i.e. available cold and hot planetary neutral and thermal ion species) that regulates present day escape

processes from the planet. Without knowledge of the physics and chemistry creating this TIE region and driving its variations (e.g., solar cycle, seasonal), it is not possible to constrain either the short-term or long-term histories of atmosphere escape. The characterization of this upper atmosphere reservoir is one of the major science objectives of the MAVEN mission.
We investigate both in-situ Neutral Gas and Ion Mass Spectrometer (NGIMS) neutral densities/temperatures and Accelerometer Experiment (ACC) reaction wheel (RW) derived mass densities/temperatures obtained over the first ~400 orbits. This sampling occurs when periapsis latitudes ranged from about 32° to 74°N; periapsis local mean solar times (LMST) ranged from about 15:00 to 06:00; and corresponding periapsis altitudes ranged from ~200 km down to ~150 km. This dayside in-situ sampling lasted until about 17-December-2014, after which the periapsis began moving Southward toward nightside Northern mid-latitudes. During this dayside period, monthly mean solar EUV-UV fluxes corresponded to F10.7 ~ 150-160 at Earth (solar moderate conditions) and the Martian season was approaching perihelion (Ls ~ 205 to 254°).
Thermospheric trends (e.g. latitude, local time, diurnal) of extracted densities and inferred temperatures will be compared with corresponding 3-D Mars Global Ionosphere-Thermosphere Model (M-GITM) simulated outputs in order to understand the variations observed, and probe the underlying physical processes responsible. Solar rotation variations in EUV fluxes and their impacts on dayside temperatures will also be examined.
Author(s): Stephen W Bougher[3], Robert H. Tolson[2], Paul R. Mahaffy[1], Timothy E. Johnston[3], Kirk Olsen[3], Jared M. Bell[2]
Institution(s): *1. Goddard Space Flight Center, 2. National Institute of Aerospace, 3. U. of Michigan*

209.04 – Structure of the Martian Ionosphere: MAVEN STATIC First Results

The Suprathermal And Thermal Ion Composition (STATIC) sensor on the MAVEN spacecraft provides the first detailed look at the Martian ionosphere and its interface to the solar wind. STATIC measures ion composition, density, temperature, and flows in the deep ionosphere (<180 km), resolving the cold O_2+ dominated plasma whose temperature is often less than 0.02 eV. The nightside ionosphere has shown a remarkable amount of structure with sharp gradients in both density and composition on horizontal scale sizes of ~10 km. During deep-dip excursions to ~125 km in eclipse, STATIC observed tenuous heavy ions in with M/Q of ~55-60 and ~85-90 amu/e. STATIC has captured the transition to a warmer, mixed ionosphere between 200 and 500 km altitudes where comparable amounts of O_2+, O+, and H+ are observed. STATIC also resolves more tenuous concentrations of CO_2+, H_2+, H_3+, He+, C+, and O++ at these intermediate altitudes. In addition to measuring cold ionospheric plasma, STATIC measures the heating and acceleration of cold ions to escape velocities at the solar wind interface. Counter-streaming ion beams are observed in these heating regions, along with significant convection flows and velocity-dispersed ion signatures. Draped magnetic field capture of cold ionospheric plasma is directly observed as a loss mechanism where dense beams of ions are accelerated down the magnetotail along the current sheet. This talk will focus on the low and intermediate altitude observations by STATIC which reveal a wealth of ionospheric structure and plasma dynamics that play a role in atmospheric loss.
Author(s): James P McFadden[4], Roberto Livi[4], Janet Luhmann[4], Jack Connerney[2], David L. Mitchell[4], Christian Mazelle[1], Laila Andersson[3], Bruce Jakosky[3]
Institution(s): *1. CESR, 2. GSFC, 3. LASP, 4. UC Berkeley*

209.05 – Structure of the Martian Ionosphere: Observations of Suprathermal Electrons by MAVEN SWEA

The Solar Wind Electron Analyzer (SWEA) onboard the MAVEN spacecraft provides detailed observations of suprathermal electrons in the Mars environment. SWEA measures the energy and angular distributions of electrons from 3 eV to 4.6 keV, with a cadence of 2 seconds (~8 km along the orbit at periapsis). During the first months of the mission, periapsis sampled northern latitudes from 30 to 75 degrees and altitudes down to ~150 km, including the dawn and dusk terminators, the day- and night-side ionospheres, and regions with and without significant crustal magnetic sources. The interface between the ionosphere and the overlying magnetosheath is structured and variable. On a given periapsis pass, the spacecraft can pass multiple times between the sheath and the ionosphere, with a pattern that does not repeat from orbit to orbit. When present, crustal magnetic sources can trap ionospheric plasma and significantly influence this structure. During a one-week "deep-dip" period (Feb 11-17), periapsis was lowered to ~125 km altitude. Suprathermal electrons are observed within the night-side ionosphere down to the lowest altitudes reached by the spacecraft on all 37 deep-dip orbits. Above ~200 km altitude, two sources of suprathermal electrons are observed: transport of ionospheric plasma from the day side and precipitation of electrons from the magnetotail. From 200 to 125 km altitude, the suprathermal electron density drops by more than a factor of 1000, as these electrons lose energy to interactions with atmospheric CO2. Corresponding ion density contrasts are typically not observed by STATIC, implying that the bulk of the electron distribution has shifted to energies below SWEA's 3-eV threshold.

Author(s): David L. Mitchell[3], Matthew Fillingim[3], Robert Lillis[3], Christian Mazelle[1], Morgane Steckiewicz[1], James P McFadden[3], Jack Connerney[2], Laila Andersson[4], Janet Luhmann[3], Bruce Jakosky[4]
Institution(s): *1. IRAP, 2. NASA-GSFC, 3. Univ. of California, Berkeley, 4. Univ. of Colorado*

209.06 – Density Structures Within the Martian Ionosphere from the Langmuir Probe and Waves Instrument on the MAVEN Mission

MAVEN is the first mission to Mars that has included a full suite of particles and fields instruments, allowing characterization of the plasma environment from the solar wind down to ~125-150 km altitude. These altitudes are below the exobase, and well into the ionosphere. The ionospheric density had not been measured locally down to these altitudes before MAVEN, and previous spacecraft that did measure the density at higher altitudes did not include full particles and fields suites. The Langmuir Probe and Waves (LPW) instrument on MAVEN provides measurements of the plasma frequency that allow the density to be determined within 5%. Since the plasma line is not always present, the LPW instrument was designed to be able to broadcast white noise to stimulate the plasma. This broadcasting feature has proven very successful and for some orbits the plasma line is observed nearly continuously. The cadence of these measurements within the ionosphere allows the density to be determined with a spatial resolution as small as ~8 to ~16 km. In this paper, observations of electron density structures from the first 6 months of operation are presented. During this time period the orbit precessed, so measurements were made both on the dayside and nightside. Observed density structures include variations of almost 2 orders of magnitude within ~40 km along the orbital track below 300 km. Observations of these density structures are presented with supporting measurements from the other particles and fields instruments.

Author(s): Tess McEnulty[4], David Andrews[2], Laila Andersson[4], Robert E Ergun[4], Greg T Delory[3], Chris M Fowler[4], MIchiko W Morooka[4], Tristan Weber[4], Anders I Eriksson[2], David L. Mitchell[3], James P McFadden[3], Jasper Halekas[5], Davin Larson[3], Jack Connerney[1], Jared Espley[1],Francis G Eparvier[4]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Swedish Institute for Space Physics, 3. University of California, Berkeley, 4. University of Colorado, Boulder, 5. University of Iowa*

210 – Flux Ropes Posters

210.01 – The Plasma Structure of a Long-lasting Sigmoid as Revealed by Hinode and Magnetic Field Modeling

We present multi-thermal observations from Hinode/XRT and EIS plasma diagnostics over a large part of the lifetime of a long-lasting sigmoid observed between Dec 05 and Dec 07, 2007. This region is the best observationally covered sigmoidal region by XRT and EIS simultaneously. We analyze EIS/XRT thermal maps as well EIS Doppler velocity, density and non-thermal width (NTW) maps in conjunction with non-linear force-free field (NLFFF) models constrained by the XRT data. We show that material accumulates in the dips of
twisted flux rope field lines, the temperature is enhanced at the locations of strong current concentrations in the model, and NTWs are enhanced at the outskirts of the region coinciding with large-scale QSLs that envelope the region. We follow the evolution of these plasma parameters and the filed lines from the best-fit NLFFF models in time and space leading to the flare on Dec 07, 2007.
Author(s): Antonia Stefanova Savcheva[1]
Institution(s): *1. Smithsonian Astrophysical Observatory*

210.02 – Analyzing an IRIS Blowout and Standard jets via Magnetofrictional Simulation

The imaging spectrograph, IRIS, offers unprecedented spatial and temporal resolution of small-scale phenomena, which allows the study of their spectral properties in the chromosphere and transition region. This study presents IRIS observations of a blowout and a standard coronal jet, demonstrating the ability of IRIS to detect reconnection effects in the low atmosphere in the available suite of spectral lines. We present Doppler velocity and non-thermal width (NTW) maps of the jet and their evolution in time. We interpret the results using magnetofrictional simulations simulations of jets. We present a data-driven magnetofrictional simulation of the same jet and match the magnetic and current structure of the jets to the observed NTW maps. We infer the height of the null point and the extent of the region showing reconnection effects. We discuss the implications of understanding reconnection effects in conjunction with NTW maps.
Author(s): Antonia Stefanova Savcheva[1]
Institution(s): *1. Smithsonian Astrophysical Observatory*

210.03 – Modeling of magnetic cloud expansion

A model of an expanding elliptic cylindrical force-free flux rope is used to interpret in-situ magnetic cloud observations by spacecraft. Input quantities are measurements of magnetic field components and velocity magnitudes along a spacecraft trajectory inside a magnetic cloud. During the fitting procedure flux-rope geometric parameters and cloud expansion velocity are determined. Observed separate velocity components are not used in the fitting procedure, but in radial (expansion) velocity construction which is compared to model one to test our model more strictly. 24 magnetic clouds with clearly expressed expansion were fitted by the model. Radial velocity profiles qualitatively correspond to model ones in majority of cases (83%), in more than half of them (58%) quantitatively.
Author(s): Marek Vandas[1], Eugene Romashets[2], Athanassios Geranios[3]
Institution(s): *1. Astronomical Institute, Academy of Sciences, 2. IZMIRAN, 3. University of Athens*

210.04 – Earth-directed ICME magnetic field configurations

It is known that the geoeffectiveness of interplanetary coronal mass ejections (ICMEs) depends on their magnetic field configuration. However, it remains unclear how the ICME interactions with the solar wind or other solar transient structures affect their magnetic configuration through, say, distortion of their cross-section, or deformation of their front. Obviously, precise space weather forecasting is depended on precise understanding of the evolution of the ICME internal magnetic topology.
The goal of this study is to identify the ambient solar wind parameters that affect the flux-rope geometry and magnetic field configuration.
Author(s): Teresa Nieves-Chinchilla[1], Angelos Vourlidas[4], Adam Szabo[2], Neel Savani[3], M. Leila Mays[1], Miguel Angel Hidalgo [5], Yu Wenyuan[6]
Institution(s): *1. CUA, 2. GSFC/NASA, 3. Imperial College, 4. JHAPL, 5. UAH, 6. UNH*

210.05 – The Physical Processes of Eruptive Flares Revealed By An Extremely-Long-Duration Event

In this work, we report the physical processes of eruptive flares inferred from an extremely- long-duration event occurred on June 21, 2011. The flare, peaked at C7.5 level, had a two-hour-long rise time in soft X-rays; this rise time is much longer than the usual rise time of solar flares that last for only about ten minutes. Combining the fact that the flare occurred near the disk center as seen by SDO, but near the limbs as seen by STEREO A and B, we are able to track the evolution of the eruption in 3-D as well as in a rare slow-motion manner. The time sequence of temperature maps, constructed from six corona-temperature passbands of AIA, clearly shows process of how the highly-twisted sigmoid structure prior to the eruption is transformed into a near-potential post-eruption loop arcade. The observed sigmoid is likely to be the structure of a twisted magnetic flux rope, which reached a height of about 60 Mm at the onset of the eruption. The onset is likely triggered by the instability (or loss of equilibrium) of the flux rope as indicated by the slow rise motion prior to the impulsive phase. We also find that the complex evolution of footprints of the eruption as seen from AIA transition region images is consistent with the magnetic evolution in the corona, which is the consequence of the combined effects of the expansion of the magnetic flux rope and the magnetic reconnection of surrounding magnetic fields. The 3-D magnetic structure inferred from NLFFF extrapolation will be compared with that inferred from observations.
Author(s): Zhenjun Zhou[2], Jie Zhang[1], Georgios Chintzoglou[1]
Institution(s): *1. george mason university, 2. The University of Science and Technology of China*

211 – Magnetosphere Posters

211.01 – Imaging the Magnetosphere in Soft X-Rays

The charge exchange that occurs when high charge state solar wind ions encounter exospheric neutrals in the Earth's magnetosheath and cusps results in the emission of soft (0.1 to 1 keV) x-rays that have been observed by a number of astrophysics telescopes with narrow fields of view. A global imager would be able to visualize and diagnose the state of the solar wind-magnetosphere interaction, including the characteristics of reconnection on the dayside magnetopause. This talk presents our current efforts to develop such an imager, including both hardware and simulations of the expected signatures.
Author(s): David Sibeck[1], Hyunju K. Connor[1], MIchael Collier[1], Kip Kuntz[2]
Institution(s): *1. GSFC, 2. JHU*

211.02 – Magnetopause standoff position and its time-dependent response to solar wind conditions: Models and Observations

We model changes in the magnetopause position due to different solar wind conditions for several events. The study uses the Run-On-Request capabilities within the MHD models available from the Community Coordinated Modeling Center (CCMC) at NASA Goddard Space Flight Center, specifically BATS-R-US, OpenGGCM, LFM and GUMICS models. The magnetopause standoff position prediction and response time to the solar wind changes will then be compared to results from available empirical models (e.g. Chao et al., 2002), and to Cluster, Geotail, and THEMIS missions magnetopause crossing observations. Rigorous analysis/comparison of observations and empirical models is critical in determining magnetosphere dynamics for model validation. We will identify solar wind conditions that affect the model predictions significantly and lead to differences between the models. Preliminary results show that the modeled magnetopause standoff position takes about 30 min to respond to changes in the dynamic pressure and IMF Bz, and about 80 min to return to its nominal position.
Author(s): Yaireska Marie Collado-Vega[2], David Sibeck[2], Ilja Honkonen[1]
Institution(s): *1. Geospace Physics Laboratory/ORAU, 2. NASA GSFC*

211.03 – Buoyancy Waves in Earth's Magnetosphere

Thin-filament simulations raised the possibility that underpopulated flux tubes moving earthward through the plasma sheet from the distant plasma sheet might oscillate a few times before coming to rest near the inner edge. Such oscillations, called braking or interchange oscillations, have been observed, and their periods agree fairly well with the predictions of the thin-filament model. However, the thin-filament model assumes a highly idealized geometry and so does not provide a fully adequate theory of the oscillations. This paper addresses two questions: (1) How do the thin-filament oscillations relate to linear eigenmodes of the magnetosphere? (2) What do the corresponding eigenfunctions look like? We investigate those questions by focusing on a simple wedge-shaped plasma configuration with circular field lines that resembles the Earth's magnetosphere in that it exhibits interchange oscillations in the thin filament approximation. However, the wedge configuration is also simple enough that linear eigenfunctions can easily be calculated. If we consider wavelengths smaller than the scale length for spatial variations in the wedge and frequencies far below the fast-mode speed, the resulting wave equation has exactly the form of an equation for buoyancy oscillation of the neutral atmosphere. The frequency of the thin-filament oscillation appears in the wave equation in exactly the way that the buoyancy frequency ω_b (also known as the Brunt-Väisälä frequency) appears in the neutral-atmosphere equation. As in the neutral-atmosphere case, the magnetospheric buoyancy wave of frequency ω propagates through the region where the buoyancy frequency exceeds ω, but is evanescent in the region where the buoyancy frequency is less than ω.
Author(s): Richard Alan Wolf[1], Aaron Moore Schutza[1], Frank Rocco Toffoletto[1]
Institution(s): *1. Rice University*

211.04 – Modeling of mesoscale flux-tube interchange motions in the inner magnetosphere

Mesoscale flux-tube interchange motions associated with bursty bulk flows and dipolarization fronts play a significant role in particle transport from the plasma sheet into the inner magnetosphere. One of the challenges is to quantify the relative role of these processes compared to large-scale particle energization as part of global-scale convection. In this paper, we will describe latest progress in attempting quantitative modeling of flux-tube interchange processes using a high-resolution version of the Rice Convection Model (RCM) that includes effects of inertial drifts. Including effects of inertial drifts is necessary to allow oscillatory motion of flux tubes in inner magnetospheric models. We generalized the formulation of the RCM by making three simplifying assumptions: (i) the communication between the equatorial plane and ionosphere occurs either instantaneously or with a given time lag, (ii) the

pressure is isotropic and therefore constant along field lines, and (iii) for purposes of calculating the effect of inertia, all of a flux tube's mass is assumed to be concentrated in the equatorial plane. We will present idealized numerical simulations of a depleted flux tube propagation in the magnetosphere, and quantify particle injection signatures. Our analysis of the simulations will include ionospheric electric fields and particle precipitation signatures of the flow channels associated with propagation of depleted flux tubes, and address the sensitivity of the results to the assumptions made in the inclusion of the inertia effects.
Author(s): Stanislav Sazykin[1], Richard Alan Wolf[1], Jian Yang[1], Frank Rocco Toffoletto[1]
Institution(s): *1. Rice University*

211.05 – The Morphology of Ring Current He-Ions in Earth's Inner Magnetosphere

The Radiation Belt Storm Probe Ion Composition Experiment (RBSPICE) instrument on the Van Allan Probes makes unique measurements of, among other ring current species, He-ions in the ~65-keV to ~520-keV energy range. In this paper we report on the spatial "double belt" structure of ring current He-ions as measured on both spacecraft during quiet and active magnetic conditions. Specifically, we show the 3D structures of both the low L-shell, high energy and high L-shell, low energy populations at all magnetic local times. We also present the first ring current measurements of He-ions above ~520-keV, which were obtained in a modified RBSPICE operation mode. These high energy He-ions appear to be modulated by ionospheric-controlled electric field variability, as was suggested in earlier modeling efforts.
Author(s): Andrew Gerrard[1], Jessie Cusanelli[1], Louis Lanzerotti[1]
Institution(s): *1. New Jersey Institute of Technology*

211.06 – Overview of Van Allen Probes - Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE): Science Results and Data Access

The Van Allen Probes Mission includes the Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) energetic particle detectors, one on each of the two spacecraft. These detectors are performing in-situ observations of the Proton spectra (6.7 KeV thru 532 KeV), Helium spectra (33 KeV thru 584 KeV), Oxygen spectra (50 KeV thru 1.25 MeV), generic ion spectra (40 KeV thru 1 MeV), and electron spectra (20 KeV thru 1 MeV). For observations after mid-January 2015 the Helium spectra now goes from 33 KeV thru 1 MeV and the Oxygen spectra now goes from 50 Kev thru 1 MeV. While the primary target of the RBSPICE instruments is the ring current composition, the instruments are operational through all aspects of the orbit of each spacecraft. This poster presents a summary of the major RBSPICE science results as well as an overview of the highest level RBSPICE data products produced, the RBSPICE data visualization and analysis software, and links to access everything online.
Author(s): Jerry Wayne Manweiler[1], Lawrence Brown[2], James Douglas Patterson[1], Matina Gkioulidou[2], Aleksandr Y Ukhorskiy[2], Andrew Gerrard[3], Donald G Mitchell[2], Louis J Lanzerotti[3], A T Y Lui[2]
Institution(s): *1. Fundamental Technologies, LLC, 2. Johns Hopkins Applied Physics Laboratory, 3. New Jersey Institute of Technology*

211.07 – Observations of possible injection of interplanetary oxygen into the inner magnetosphere

With the Advanced Composition Explorer's (ACE) Electron Proton and Alpha Monitor (EPAM) instrument being in a halo orbit about L1 and the Van Allen Probe's Radiation Belt Storm Probes Ion Composition Experiment (RBSPICE) instrument being in an eccentric orbit through the inner magnetosphere, the two instruments are situated perfectly for observing the inner magnetospheric response to energetic

interplanetary particle events. Both instruments are designed to measure electrons and ions with energies between tens of keV and a few MeV, depending upon particle species. Using a new data analysis technique we've developed, the EPAM instrument can provide high energy-resolution, species-resolved energy spectra for a number of ion species including helium and oxygen which RBSPICE is designed to observe. Between May 22nd and 26th of 2013, EPAM observed an energetic particle event with a nearly flat energy spectra and greatly enhanced helium and oxygen composition. RBSPICE measured a strong surge in oxygen flux, but saw no correspondingly strong increase in the helium flux. We present a detailed analysis and comparison of the energetic ion spectra, composition, and timing measured by the ACE and the Van Allen Probes instruments in conjunction with magnetic field and energetic particle measurements from other spacecraft for this event, and provide a discussion on the injection of interplanetary oxygen into the inner magnetosphere.
Author(s): James Douglas Patterson[1], Jerry Wayne Manweiler[1], Andrew Gerrard[3], John Bonnell[4], Scott Bounds[5], Matina Gkioulidou[2], Donald G Mitchell[2], Louis J Lanzerotti[3]
Institution(s): *1. Fundamental Technologies, LLC, 2. Johns Hopkins University, 3. New Jersey Institute of Technology, 4. University of California Berkeley, 5. University of Iowa*

211.08 – MLT Dependent Plasmapause Location Derived from IMAGE EUV

The location of the outer edge of the plasmasphere (the plasmapause) as a function of geomagnetic storm-time is identified and investigated statistically in relation to the solar wind driver. Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) Extreme Ultraviolet (EUV) data are used to create an automated method that locates and extracts the plasmapause. The plasmapause extraction technique searches a set range of possible plasmasphere densities for a maximum gradient. The magnetic local time (MLT) dependent plasmapause results are compared to manual extraction results. The plasmapause results from 39 intense storms are examined along a normalized epoch storm timeline to determine the average plasmapause L-shell as a function of MLT and storm-time. The average extracted plasmapause L-shell follows the expected storm-time plasmapause behavior. The results show that, during the main phase, the plasmapause moves Earthward and a plasmaspheric drainage plume forms near dusk and across the dayside during strong convection. During the recovery phase the plume becomes re-entrained in corotational motion around the Earth, while the average plasmapause location moves further from the Earth. The results are also investigated in terms of the solar wind driver. We find evidence that shows that the inner magnetospheric response to Magnetic Cloud (MC) and Sheath (SH)-driven events is similar but the response is different for CIR-driven events.
Author(s): Roxanne M Katus[3], Dennis Gallagher[1], Michael Liemohn[2], Amy M Keesee[3]
Institution(s): *1. NASA MSFC, 2. University of Michigan, 3. West Virginia University*

212 – Flux Ropes Throughout the Heliosphere

212.01 – What Do EUV Dimmings Tell Us About CME Topology

Large-scale coronal EUV dimmings develop on timescales of hours in association with a flare or filament eruption, and are known to be well correlated with coronal mass ejections (CMEs). However, it is not clear why some CMEs have dimmings and some do not, nor is it clear how these dimmings relate to CME topology. The inner coronal coverage of SDO AIA and STEREO EUVI, combined with the extended field of view of PROBA2's SWAP imager, allow us the opportunity to map the topology of a dimming region in three dimensions into an erupting CME. Although the location and extent of a dimming region appears to be the best indicator of the inner "footprint" of a CME, the correlation is far from perfect. However,

dimmings can provide vital clues about the development and 3D kinematics of CMEs. This is particularly important as we are currently in an extended period where the STEREO coronagraph images are not always available and are increasingly "mirroring" LASCO images, and therefore the 3D properties of a CME will be difficult to deduce. Thus, understanding the inner coronal manifestations of a CME can provide clues to its structure and dynamics, even without multi-viewpoint coronagraph observations. We present the results of this combined analysis effort, along with a discussion of how dimmings can be used to forecast CME trajectories.
Author(s): Barbara J. Thompson[4], Marc L. DeRosa[3], Richard R. Fisher[4], Larisza D. Krista[6], Ryun Young Kwon[2], James P. Mason[7], Mona L. Mays[4], Nariaki V Nitta[3], David F. Webb[1], Matthew J West[5]
Institution(s): *1. Boston College, 2. GMU, 3. LMSAL, 4. NASA GSFC, 5. SIDC, Royal Observatory of Belgium, 6. SWPC/NOAA and CIRES/CU, 7. UC Boulder*

212.02 – Investigations of the Role of Magnetic Twist in Flux Rope Emergence

Simulations of the rise of buoyant magnetic flux ropes through the solar convection zone show that flux ropes break up and cease to be buoyant if their magnetic twist is too weak. Similarly, simulations of the emergence of magnetic flux ropes through the photosphere into the solar atmosphere show that buoyant flux ropes will not emerge if their twist is too weak. Yet observations consistently show that the majority of emerged active regions have twist which is orders of magnitude smaller than the lower limit required by these simulations.
We report on a series of numerical investigations which attempt to resolve this contradiction by searching for mechanisms which can reduce the minimum twist required to successfully emerge flux ropes. We then investigate the magnitude and distribution of alpha, the measure of twist most often observed, at the photosphere in these simulations, and compare these to observed magnitudes and distributions of alpha. We discuss the implications of these results for our current understanding of how active regions rise to the solar surface and emerge into the solar atmosphere.
This work was supported by the NASA Living with a Star program.
Author(s): Mark G Linton[1], James Leake[1]
Institution(s): *1. Naval Research Laboratory*

212.03 – Investigation on Eruptive Prominences Observed by SDO

We will present an investigation of the polar crown prominence that erupted on 2012 March 12. This prominence is observed at the southeast limb by SDO/AIA (end-on view) and displays a quasi vertical-thread structure. Bright U-shape (horn-like) structure is observed surrounding the upper portion of the prominence (171 Angstrom) before the eruption and becomes more prominent during the eruption. When viewed on the disk, STEREO-B shows that this long prominence is composed of a series of vertical threads and displays a half loop-like structure during the eruption. We focus on the magnetic support of the prominence by studying the structure and dynamics of the prominence before and during the eruption using observations from SDO and STEREO. During the eruption, AIA observes dark ribbons seen in absorption at 171 Angstrom in corresponding to the bright ribbons at 304 Angstrom. We construct a series of magnetic field models (including sheared arcade model, twisted flux rope model, and model with HFT), then compare with observations. Various observational characteristics appear to support the twisted flux rope model. Our study suggests that the flux rope supporting the prominence enters the regime of torus instability at the onset of the fast rise phase, and evidence of reconnection (post-eruption arcade, new U-shape Structure, rising blobs) appears about one hour later. We will also present a statistical study on the kinematics of limb eruptive prominences observed by SDO/AIA. A brief introduction on an online catalog of prominence eruptions observed by SDO/AIA will also be presented.

Author(s): Yingna Su[2], Patrick McCauley[1], Adriaan van Ballegooijen[1], Haisheng Ji[2], Katharine Reeves[1], Edward DeLuca[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Purple Mountain Observatory*

212.04 – Magnetic Field-line Twist and Length Distributions inside Interplanetary Magnetic Flux Ropes

We report on the detailed and systematic study of field-line twist and length distributions within magnetic flux ropes embedded in Interplanetary Coronal Mass Ejections (ICMEs). The Grad-Shafranov reconstruction method is utilized together with a constant-twist nonlinear force-free (Gold-Hoyle) flux rope model and the commonly known Lundquist (linear force-free) model to reveal the close relation between the field-line twist and length in cylindrical flux ropes, based on in-situ spacecraft magnetic field and plasma measurements. In particular, we utilize energetic electron burst observations at 1 AU together with associated type III radio emissions detected by the Wind spacecraft to provide unique measurements of magnetic field-line lengths within selected ICME events. These direct measurements are compared with flux-rope model calculations to help assess the fidelity of different models and to provide diagnostics of internal structures. We show that our initial analysis of field-line twist indicates clear deviation from the Lundquist model, but better consistency with the Gold-Hoyle model. By using the different flux-rope models, we conclude that the in-situ direct measurements of field-line lengths are consistent with a flux-rope structure with spiral field lines of constant and low twist, largely different from that of the Lundquist model, especially for relatively large-scale flux ropes. We will also discuss the implications of our analysis of flux-rope structures on the origination and evolution processes in their corresponding solar source regions.
Author(s): Qiang Hu[3], Jiong Qiu[1], Sam Krucker[2]
Institution(s): *1. Montana State University, 2. Space Science Center, UC Berkeley, 3. University of Alabama in Huntsville*

212.05 – Modeling Detached Magnetic Structures in the Inner Heliosphere

Currently, the WSA-ENLIL-Cone modeling system is used by various space weather agencies for operational forecasting of corotating and transient solar wind disturbances in the inner heliosphere. This modeling system provides global context and arrival times of the solar wind streams and coronal mass ejections (CMEs) to Earth, planets, and spacecraft. Such predictions are running continuously and much faster than real time. However, CME-like disturbances are generated by launching hydrodynamic transients and thus it is not possible to predict the southward magnetic field (-Bz). In this presentation, we a 3-D analytic model of the magnetic spheromak, launch it into the background solar wind at 0.1 AU and simulate their evolution in the inner heliosphere as the first step in modeling more realistic transient disturbances. Main advantage above hydrodynamic ejecta is in smaller distortion/comperssion due to magnetic field tension and in more reslistic density profiles. This modeling system would enable routine operational modeling of the heliospheric space weather event-by-event and faster than real-time.
Author(s): Dusan Odstrcil[2], Marek Vandas[1]
Institution(s): *1. Astronomical Institute, 2. GMU & NASA/GSFC*

212.06 – Predicting the Arrival of ICME Signatures at L1 with Stereoscopic Measurement and Drag-Based Modelling

We present a new technique for predicting the arrival of Interplanetary Coronal Mass Ejection (ICME) signatures, including the compression/shock front and the magnetic cloud, at the L1 point using arrival

times obtained from the ACE satellite. The method is based on obtaining accurate height measurements of the CME based on observations from multiple observing points and fitting these measurements into a drag-based model. Unlike previous work with the drag-based model, our technique does not fit the data assuming static model parameters and instead varies the characteristics of aerodynamic drag as a function of distance into the heliosphere, using physical assumptions to simplify the model terms. This correction, as well as a geometric correction based on the propagation direction of the eruption and flux rope geometry allow for an improved prediction at L1. The method is currently dependent on white-light images from the STEREO spacecraft, but demonstrates the great benefit to space weather forecasting that could be derived from a mission to the L5 point. Combining coronagraph and heliospheric imager observations from L5 with SOHO data to allow for stereoscopic imaging of all Earth directed CMEs could greatly improve our forecasting capabilities.
Author(s): Phillip Hess[1], Jie Zhang[1]
Institution(s): *1. George Mason University*

213 – Coronal Heating II

213.01 – The Focusing Optics X-ray Solar Imager: Second Flight and Recent Results

Energy release and particle acceleration on the Sun is a frequent occurrence associated with a number of different solar phenomenon including but not limited to solar flares and coronal mass ejections. The exact mechanism through which particle are accelerated is still not well understood. One of the best ways to gain insight into accelerated particles on the Sun is by observing the Sun in hard X-rays (HXR) which provide one of the most direct diagnostics of energetic electrons. Past and current HXR observations lack the sensitivity and dynamic range necessary to observe the faint signature of accelerated electrons where they are accelerated in the solar corona. However these limitations can be overcome through the use of HXR focusing optics coupled with solid-state pixelated detectors. We present on the second successful launch of the Focusing Optics X-ray Solar Imager, a sounding rocket payload which flew on December 11, 2014. In this flight, the FOXSI optics were upgraded for better sensitivity and new CdTe strip detectors were included to provide increased detection efficiency. During this flight, FOXSI observed thermal emission from at least three active regions (AR#12234, AR#12233, AR#12235). Another observation target for FOXSI was the quiet Sun. In this presentation we summarize the flight as well as the latest observations and analysis.
Author(s): Steven Christe[1], Sam Krucker[4], Lindsay Glesener[4], Brian Ramsey[2], Shin-nosuke Ishikawa[3], Juan Camilo Buitrago Casas[4], Natalie Foster[4], Tadayuki Takahashi[5]
Institution(s): *1. NASA GSFC, 2. NASA MSFC, 3. National Astronomical Observatory, 4. Space Sciences Lab, 5. University of Tokyo*

213.02 – High-sensitivity search for transient solar X-ray emission with NuSTAR

We present the first results of a search for transient X-ray emission in quiet solar regions with the NuSTAR astrophysics satellite. Transient brightenings of 10^{24}-10^{27} ergs, or "nanoflares," have been observed as thermal emission in EUV and soft X-rays, but never in hard X-rays (HXRs) due to lack of sensitivity. Frequent nanoflares could account for a significant fraction of the energy release needed to heat the corona to >1 MK. NuSTAR directly images X-rays from ~2-80 keV, with much higher sensitivity than dedicated solar HXR instruments. More importantly it can point at the Sun without suffering damage, a rare capability for an astrophysics instrument. We have developed an algorithm to search the NuSTAR data in space and time for transient events, while taking into account instrumental and

systematic effects. Preliminary analysis yields a sensitivity to events ~0.001 times as bright as an "typical" RHESSI microflare (Hannah et al. 2008), for linear scaling and event duration of 10 seconds. Future observations at full-Sun flux levels below GOES ~B5 will increase our sensitivity by an order of magnitude or more.
Author(s): Andrew Marsh[7], Iain Hannah[8], Lindsay Glesener[6], David M Smith[7], Brian Grefenstette[2], Kristin Madsen[2], Sam Krucker[6], Hugh Hudson[8], Stephen White[1], Amir Caspi[5], Steven Christe[3], Albert Shih[3], Richard Mewaldt[2], Michael Pivovaroff[4], Julia Vogel[4]
Institution(s): *1. Air Force Research Laboratory, 2. Caltech, 3. GSFC, 4. LLNL, 5. SWRI, 6. UC Berkeley, 7. UC Santa Cruz, 8. University of Glasgow*

213.03 – Nanoflare Heating of the Quiet Sun

How the solar corona is heated to temperatures of over 1 MK, while the photosphere below is only ~ 6000 K remains one of the outstanding problems in all of space science. Solving this problem is crucial for understanding Sun-Earth connections, and will provide new insight into universal processes such as magnetic reconnection and wave-particle interactions. We use a new systematic technique to analyze the properties of coronal heating throughout the solar corona using data taken with the Atmospheric Imaging Assembly onboard the Solar Dynamics Observatory. Our technique computes cooling times of the coronal plasma on a pixel-by-pixel basis and has the advantage that it analyzes all of the coronal emission, including the diffuse emission surrounding distinguishable coronal features. We have already applied this technique to 15 different active regions, and find clear evidence for dynamic heating and cooling cycles that are consistent with the 'impulsive nanoflare' scenario. What about the rest of the Solar corona? Whether the quiet Sun is heated in a similar or distinct manner from active regions is a matter of great debate. In this paper, we apply our coronal heating analysis technique to quiet Sun locations. We find that the majority of the analyzed quiet Sun locations do undergo dynamic heating and cooling cycles, consistent with impulsive nanoflares. However, there are important characteristics that are distinct from those of active regions.
This research was supported by a NASA Guest Investigator grant.
Author(s): Nicholeen M. Viall[1], James A Klimchuk[1]
Institution(s): *1. NASA Goddard Space Flight Center*

213.04 – Coronal Fourier Power Spectra: Implications for Coronal Seismology and Coronal Heating

The dynamics of regions of the solar corona are investigated using Atmospheric Imaging Assembly 171 Å and 193 Å data. The coronal emission from the quiet Sun, coronal loop footprints, coronal moss, and from above a sunspot is studied. It is shown that the mean Fourier power spectra in these regions can be described by a power law at lower frequencies that tails to a flat spectrum at higher frequencies, plus a Gaussian-shaped contribution that varies depending on the region studied. This Fourier spectral shape is in contrast to the commonly held assumption that coronal time series are well described by the sum of a long timescale background trend plus Gaussian-distributed noise, with some specific locations also showing an oscillatory signal. The implications of the observed spectral shape on the fields of coronal seismology and the automated detection of oscillations in the corona are discussed. The power-law contribution to the shape of the Fourier power spectrum is interpreted as being due to the summation of a distribution of exponentially decaying emission events along the line of sight. This is consistent with the idea that the solar atmosphere is heated everywhere by small energy deposition events.
Author(s): Jack Ireland[1], James McAteer[3], Andrew Inglis[2]
Institution(s): *1. ADNET Systems, Inc / NASA GSFC, 2. Catholic University of America, 3. New Mexico State University*

213.05 – Turbulent photospheric drivers of multiscale solar corona

We investigate the collective dynamics of transient photospheric and coronal events detected using high-resolution solar magnetograms and coronal emission images. We focus on statistical, ensemble-averaged properties of the interacting solar regions [Uritsky et al., 2011, 2013, 2014; Uritsky and Davila, 2012], as opposed to case-oriented methodologies recruited in some previous studies. The behavior of solar events is studied in the three-dimensional space-time enabling accurate representation of the event evolution. By applying advanced data analysis methods including feature tracking algorithms, multiscale correlation analysis and scaling analysis techniques, we identify leading physical scenarios of the photosphere - corona coupling in quiet and active solar regions, and strive to identify new statistical precursors of coronal eruptions. We also discuss the possibility of modeling multiscale photosphere - corona interactions using idealized three-dimensional MHD models. The obtained results shed a new light on the origin of multiscale dissipation in the solar corona by enabling quantitative validation of several popular statistical physical scenarios, such as e.g. intermittent turbulence, self-organized criticality, and topological complexity.
Author(s): Vadim M Uritsky[1], Leon Ofman[1], Joseph M. Davila[2]
Institution(s): *1. CUA at NASA/GSFC, 2. NASA/GSFC*

213.06 – Measuring Elemental Abundances in Impulsive Heating Events with EIS

It is well established that elemental abundances vary in the solar atmosphere and that this variation is organized by first ionization potential (FIP). Previous studies have indicated that in the solar corona low FIP elements, such as Fe, Si, and Mg, are enriched relative to high FIP elements, such as H, He, C, N, and O. In this paper we report on measurements of plasma composition made during transient heating events observed at transition region temperatures with the Extreme Ultraviolet Imaging Spectrometer (EIS) on Hinode. During these events the intensities of O IV, V, and VI emission lines are enhanced relative to emission lines from Mg V, VI, and VII and indicate a composition close to that of the photosphere. Differential emission measure calculations show a broad distribution of temperatures in these events. Long-lived coronal structures, in contrast, show an enrichment of low FIP elements and relatively narrow temperature distributions. We conjecture that plasma composition is an important signature of the coronal heating process, with impulsive heating leading to the evaporation of unfractionated material from the lower layers of the solar atmosphere and higher frequency heating leading to the accumulation of low-FIP elements in the corona.
Author(s): Harry Warren[2], George A. Doschek[2], Peter Young[1]
Institution(s): *1. George Mason University, 2. Naval Research Laboratory*

214 – Global Oscillation Network Group (GONG)

214.01 – GONG, Helioseismology, and the Sun's internal dynamics

GONG has made remarkable contributions to the development of helioseismology and our understanding of the solar interior. Even before GONG produced any data, the teams of community scientists formed under the auspices of the GONG project led to significant advances in helioseismology, for example the development of helioseismic inversion techniques. Once the network became operational and the first observations started coming in, GONG data revealed as never before the Sun's

internal dynamics, in particular the solar internal rotation. In this talk I shall review GONG's contribution to helioseismology and the helioseismic results from the project.
Author(s): Michael Thompson[1]
Institution(s): *1. NCAR*

214.02 – The Role of GONG observations in Global MHD Modeling

The solar magnetic field is an essential aspect of any predictive model of the solar corona. For many years, the magnetic field has been measured most reliably in the photosphere. So-called ``synoptic'' maps of the photospheric field (actually built up from magnetograms acquired over the course of the solar rotation) are or have been available from a number of ground- and space-based observatories, including the Global Oscillation Network Group (GONG). MHD models of the solar corona have typically used these maps to develop boundary conditions. GONG data is unique among the ground-based observatories in (1) providing magnetogams at a high-cadence (2) providing 24 hour coverage and (3) supplying helioseismic data that can be used to provide estimates of new active regions that have emerged on the far side of the Sun. These three elements are especially important as MHD models attempt to address the time-dependent nature of the corona. In this talk we describe how the combination of flux transport models driven by GONG data, along with estimates of far side active region emergence, can be used in coronal MHD modeling and the advantages gained from this approach. Work supported by AFOSR, NASA, and NSF.
Author(s): Jon Linker[2], Cooper Downs[2], Roberto Lionello[2], Ronald M Caplan[2], Pete Riley[2], Zoran Mikić[2], Nick Arge[1], Carl Henney[1]
Institution(s): *1. AFRL, 2. Predictive Science Inc.*

214.03 – Brief History of Using GONG for Space Weather Forecasting

In 2006 the National Solar Observatory’s (NSO) Global Oscillation Network Group (GONG) completed the upgrade of their magnetographs with new polarization modulators permitting, for the first time, proper inter-calibration of the magnetic field data from a global network of six different instruments. This development was ground breaking for at least three reasons. First, it allowed the magnetograms from the different magnetographs to be merged together into global maps of the photospheric magnetic field. Second, it was the first ground based system that could monitor the full-disk solar magnetic field 24/7 at moderate spatial resolution (2 arcsec) and high temporal cadence (60 seconds). Third, techniques for merging magnetic field data from the six (technically identical but practically) different instruments were developed, which can now be applied to future ground based networks. Approximately one year after the GONG upgrade, NOAA/SWPC began routinely using the new GONG maps as input to the Wang-Sheeley-Arge (WSA) coronal and solar wind model. Since this time, use of GONG data for space weather applications has grown rapidly. For example, GONG photospheric field maps are now the primary data driving the operational WSA+Enlil model at NOAA/SWPC. In addition, GONG magnetograph and helioseismic farside data are beginning to be used as input to the ADAPT flux transport model to generate synchronic maps and forecast F10.7 and EUV. This talk provides a brief history of the use of GONG for practical space weather forecasting purposes.
Author(s): Nick Arge[1], Carl Henney[1], Frank Hill[2]
Institution(s): *1. AFRL, 2. National Solar Observatory*

214.04 – Investigating a solar influence on cloud cover using the North American Regional Reanalysis data

The controversial connection between cosmic rays, solar activity and cloud cover are investigated using a climatological reconstructed reanalysis product: the North American Regional Reanalysis which provides high resolution, low, mid-level, high, and total cloud cover data over a Lambert conformal conic projection permitting land/ocean discrimination. Pearson's product moment regional correlations were obtained between monthly cloud cover data and solar variability indicators, cosmic ray neutron monitors, and several climatological oscillatory modes for respective cloud layers. Results confirm a previously identified contrast between continental and maritime low level cloud cover forcing response. Additionally, galactic cosmic ray forcing correlations are universally inverse of solar flux correlations. With the exception of low cloud cover, climatological indices exhibit greater correlation than exogenic sources.
Author(s): Daniel S Krahenbuhl[1]
Institution(s): *1. ASU*

214.05 – A comprehensive measurement of deep solar meridional flow

We perform a comprehensive measurement of the deep solar meridional flow using 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 in acoustic waves traveling below the surface. One key problem is how to remove the dominating center-to-limb (CtoL) effect in the travel time. We develop a new measurement strategy, measuring acoustic travel times along all radial directions of the solar disk, for all skip distances and focused at all disk-centric distances. Presuming that the CtoL effect varies only with disk-centric distance and the meridional flow varies only with latitude, we disentangle the CtoL effect and the meridional-flow-induced travel-time shifts by solving a set of linear equations that relate the measurements with those two quantities. We show the isolated CtoL effect and the inverted results for the solar meridional flow, and also discuss the isotropy of the CtoL effect.
Author(s): Ruizhu Chen[1], Junwei Zhao[1]
Institution(s): *1. Stanford University*

214.06 – Solar-cycle variation of subsurface flows during 20 years

We study the solar-cycle variation of the zonal and meridional flow in the near-surface layers of the solar convection zone from the surface to a depth of about 16 Mm. We have analyzed Dopplergrams obtained with the Michelson Doppler Imager (MDI) onboard the Solar and Heliospheric Observatory (SOHO), the Global Oscillation Network Group (GONG),and the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) with a dense-pack ring-diagram analysis. The three data sets combined cover almost two solar cycles. The zonal and meridional flows vary with the solar cycle. Their amplitude variation tracks the mean latitude of activity and appears about three years before magnetic activity is visible in synoptic maps of the solar surface. We focus on the variation of the zonal and meridional flows, including their long-term variation at mid- and low-latitudes using GONG and MDI data and their variation at the high latitudes that are now accessible using HMI data. We will present the latest results.
Author(s): Rudolf Komm[1], Rachel Howe[2], Frank Hill[1]
Institution(s): *1. National Solar Observatory, 2. University of Birmingham*

300 – Plenary Talk: The Heliosphere in Transition, Justin Kasper (University of Michigan)

300.01 – The Heliosphere in Transition

The heliosphere consists of the connective tissue of particles, fields and photons that mediate our interaction with the Sun and with interstellar space. Exploration of the heliosphere yields clues to the nature of environments we cannot reach ourselves, illuminating the composition of the solar interior, or the acceleration of cosmic rays in the galaxy. The heliosphere is also a laboratory for us to understand the fundamental physics of magnetized plasma, from heating and instabilities to coupling with neutral gas and dust. This talk will review some of the most exciting recent results in the heliosphere with a focus on transitions: what we can learn by exploring transitions within the heliosphere, how the heliosphere is responding to the long term transition in solar activity, and how our very view of the heliosphere is in transition with upcoming missions such as Solar Probe Plus, Solar Orbiter and IMAP.

Author(s): Justin Kasper[1]
Institution(s): *1. University of Michigan*

301 – Plenary Talk: A New Paradigm for Ionosphere-Thermosphere-Mesosphere Physics, Tim Fuller-Rowell (Cooperative Institute for Research in Environmental Science)

301.01 – A New Paradigm for Ionosphere-Thermosphere-Mesosphere Physics

The ionosphere-thermosphere-mesosphere system is predominantly a neutral atmosphere domain with a fairly small fraction, less than 1%, that is ionized, similar in some ways to the chromosphere. Neutral dynamics and composition therefore play an important role in influencing and controlling the ionospheric plasma density and creating structure. Neutral thermospheric dynamics is driven from both above and below. Absorption of solar extreme ultraviolet radiation drives a global circulation, and magnetosphere/ionosphere plasma convection can accelerate neutral winds in excess of 1 km/s through collisions, and raise gas temperature by hundreds of degrees Kelvin by frictional dissipation. During extreme events these solar and magnetospheric sources dominate the ITM system, and understanding the plethora of physical processes that ensue has been the focus for more than 50 years. However, the bulk of solar energy reaching Earth penetrates well into the lower atmosphere and to the surface. Even if only a small fraction of this large energy reservoir can reach above 100 km it can have a significant impact on the ITM system and its variability. The main dynamic coupling and transfer of energy from below is largely through atmospheric waves, particularly tides (waves with harmonics of the 24 hour solar day), and gravity waves from the multitude of sources in the lower atmosphere. We now appreciate that dynamical changes and warmings in the stratosphere from changes in planetary wave activity can lead to a 50% change in electron content in the ionosphere, and which can actually be forecast days in advance. Tropospheric convection over continental landmass imprints a longitude structure on the ionosphere. Convective adjustment, extreme weather, wind shear, airflow over mountains, are some of the many sources of gravity waves activity that can grow in amplitude as they propagate into the thermosphere where they modulate and tilt the ionosphere. The ITM system is dynamic and variable even during apparently quiescent times, and understanding this new range of physical processes has created a new paradigm.

Author(s): Tim Fuller-Rowell[1]
Institution(s): *1. Cooperative Institute for Research in Environmental Sciences*

302 – Flares and CMEs Posters

302.01 – Particle energization in a chaotic force-free magnetic field

A force-free field (FFF) is believed to be a reasonable description of the solar corona and in general a good approximation for low-beta plasma. The equations describing the magnetic field of FFF is similar to the ABC fluid equations which has been demonstrated to be chaotic. This implies that charged particles will experience chaotic magnetic field in the corona. Here, we study particle energization in a time-dependent FFF using a test particle approach. An inductive electric field is introduced by turbulent motions of plasma parcels. We find efficient particle acceleration with power-law like particle energy spectra. The power-law indices depend on the amplitude of plasma parcel velocity field and the spatial scales of the magnetic field fluctuation. The spectra are similar for different particle species. This model provide a possible mechanism for seed population generation for particle acceleration by, e.g., CME-driven shocks. Generalization of our results to certain non-force-free-field (NFFF) is straightforward as the sum of two or multiple FFFs naturally yield NFFF.
Author(s): Xiaocan Li[1], Gang Li[1], Brahmananda Dasgupta[1]
Institution(s): *1. The University of Alabama in Huntsville*

302.02 – Energy conversion and particle acceleration during magnetic reconnection in solar flare plasma

Recent solar flare observations have inferred that a large fraction of the electrons in the acceleration site are accelerated into non-thermal energies, and the accelerated electrons form power-law energy spectra. Magnetic reconnection is widely accepted to be the energy source of solar flares and may serve as one of the particle acceleration mechanisms. Here, we use two-dimensional PIC simulations to study energy conversion and particle acceleration during reconnection in a low-beta (~0.01) plasma. In the end of the simulations, up to 50% of the electrons can be accelerated into non-thermal energies, which contains about 90% of the total electron kinetic energy. Power-law energy spectra of electrons develop for sufficiently large simulation domain. We then investigate the detailed particle acceleration process using a drift approximation. Fermi mechanism is found dominant for no/low guide field cases, while parallel heating is dominant for high guide field cases. The energy conversion and particle acceleration process is consistent with that inferred in solar flares.
Author(s): Xiaocan Li[2], Fan Guo[1], Hui Li[1], Gang Li[2]
Institution(s): *1. Los Alamos National Lab, 2. The University of Alabama in Huntsville*

302.03 – Accelerated electron distributions with high- and low-energy cutoffs deduced from the application of a return-current model to solar flare X-ray spectra observed by RHESSI

The X-ray bremsstrahlung emission observed from solar flares requires a high flux, and corresponding high current, of non-thermal electrons. This current is thought to be stabilized by a co-spatial return current, which also resupplies electrons to the acceleration region. In the standard collisional thick-target model (CTTM), electrons accelerated in the corona lose all of their energy through Coulomb collisions when they reach the higher densities in the lower atmosphere of the sun. In the presence of the return current, however, the electrons also lose energy in the corona as they propagate downward. These losses introduce a break into the observed X-ray spectrum if the potential drop associated with the return current is sufficiently high.
We analyzed the temporal evolution of RHESSI (*Ramaty High Energy Solar Spectroscopic Imager*) spectra from a solar flare with strong spectral breaks in terms of a return-current collisional thick-target model (RCCTTM). The presence of strong breaks ensures that albedo and non-uniform ionization are not sufficient to explain the spectral flattening at energies below the break. We find that the model

successfully fits the spectral data. The fits were significantly improved with the inclusion of a high-energy cutoff to the injected electron distribution (better chi-squared values and residuals), providing the time evolution of the highest energy to which electrons were accelerated. A lower limit to the low-energy cutoff to the electron distribution was obtained by restricting the beam density to a value less than the ambient coronal density. The derived plasma resistivity and the drift speed of the return-current electrons both suggest that plasma turbulence might have been important in the corona.
This work was supported by the NASA Heliophysics Guest Investigator Program and the RHESSI Project.
Author(s): Meriem Alaoui[1], Gordon D. Holman[1]
Institution(s): *1. NASA/GSFC*

302.04 – Collisional Diffusion and Thick-Target Energy Losses in Solar Flares -- Death to the "Low-Energy Cufoff"

We extend previous studies of nonthermal electron transport in solar flares by including the effects of collisional diffusion on the energy loss rate of the electron distribution as a whole. We conclude that previous estimates of electron energy loss, particularly at energies E ~ 10kT or less, have been greatly overestimated. Consequently the required number of electrons at the low-energy end of the accelerated electron spectrum, and concomitantly the overall energy content in the accelerated electrons, are significantly reduced. Use of an artificially-imposed ``low-energy cutoff'' in the accelerated spectrum is therefore not only unwarranted, but also unnecessary.
Author(s): Gordon Emslie[2], Nicolas Bian[1], Natasha Jeffrey[1], Eduard Kontar[1]
Institution(s): *1. University of Glasgow, 2. WKU*

302.05 – Electron Acceleration and Radiative Hydrodynamic Simulations of the 29 March 2014 X1.0 flare

The X1.0 flare on 29 March 2014 presents a unique opportunity to use its observations to better understand the origin of the white light emission and the evolution of the spectral line profiles. RHESSI observed the whole flare including the impulsive phase, allowing us to estimate the variation of the spectral parameters of the accelerated electrons using the Stanford acceleration code. Using this as input to the radiative RADYN code, we determine the hydrodynamic response of the solar atmosphere and the spectrum of the continuum and line emission. Using this self consistent results and observations we constrain the characteristics of the acceleration mechanism.
Author(s): Fatima Rubio da Costa[1], Lucia Kleint[2], **Vahe Petrosian[1]**
Institution(s): *1. Stanford University, 2. University of Applied Sciences and Arts Northwestern Switzerland*

302.06 – Study of the Most Harmful Solar Energetic Particle for Shielding next Human Space Flights

Solar energetic particles (SEPs) accelerated by solar events such as flares and coronal mass ejections are radiation risks for humans in space on board the International Space Station (ISS), and will be significant obstacles for future long-duration manned space flight missions. This research supported efforts to improve predictions of large solar storms and aimed for a better understanding of Heliophysics. The main objective was to generate a dated catalog of the highest energy range SEPs measured by the Alpha Magnetic Spectrometer (AMS-02). Using online graphical user interfaces from the satellites, Solar and Heliospeheric Observatory (SOHO) and Geostationary Operational Environmental Satellite (GOES-13, 15), the generated data files from the mounted particle detectors were plotted along a specified energy range. The resulting histograms illustrated the low energy range data from SOHO (4 MeV to 53 MeV) and the low-mid energy range from GOES (0.8 MeV to 500 MeV), which collectively provided a low- to

mid-energy range spectrum of the specific event energy ranges versus the SEP proton flux. The high energy range results of the AMS-02 (125 MeV to a few TeV) will eventually be incorporated with the two alternative space satellites of lower energy ranges for a complete analysis across a full SEP energy range. X-ray flux from GOES-15 were then obtained and plotted with the corresponding time to portray initial phenomena of the solar events. This procedure was reproduced for 5 different events determined energetic enough to be measured by AMS-02. The generated plots showed correlation between the different satellite detectors.
Author(s): Bryan Komei Yamashiro[1]
Institution(s): *1. University of Hawaii at Manoa*

302.07 – A Unified Computational Model for Solar and Stellar Flares

We describe a unified computational framework which can be used to model impulsive flares on the Sun and on dMe stars. The models are constructed assuming that the flare impulsive phase is caused by a beam of charged particles (primarily electrons and protons) that is accelerated in the corona and propagates downward depositing energy and momentum along the way. This rapidly heats the lower stellar atmosphere causing it to explosively expand and emission to dramatically brighten. Our models consist of flux tubes that extend from the sub-photosphere into the corona. We simulate how these flare-accelerated particles propagate down one dimensional flux tubes and heat the stellar atmosphere using Fokker-Planck kinetic theory. Detailed radiative transfer is included so that model predictions can be directly compared with observations. The flux of flare-accelerated particles drives return currents which additionally heat the stellar atmosphere, and these effects are also included in our models. We examine the impact of the flare-accelerated particle beams on model solar and dMe stellar atmospheres and perform parameter studies varying the injected particle energy spectra. We find the atmospheric response is strongly dependent on the accelerated particle cutoff energy and spectral index.
Author(s): Joel Allred[1], Adam Kowalski[2], Mats Carlsson[3]
Institution(s): *1. NASA/GSFC, 2. University of Maryland, 3. University of Oslo*

302.08 – Progress Report on Doppler Shift Results from SDO/EVE

The EUV Variability Experiment (EVE) onboard the Solar Dynamics Observatory (SDO) has been obtaining unprecedented observations of solar variation on times scales of seconds during flares and over the rising phase of Solar Cycle 24 since its start of normal operations in May 2010. Unexpectedly, as first pointed out in Hudson et. al., *Ap. J.* (2011), even with EVE's spectral resolution of 0.1 nm and 'irradiance' measurements, EVE has the ability to very accurately determine Doppler shifts in all emissions during solar flares and coronal mass ejections (CMEs). The technique for deriving these absolute velocities is not straightforward, as the optical and instrumental effects must first be eliminated in order to separate the absolute plasma velocities from the instrument effects. Initial results were first presented at the Solar Dynamics Observatory (SDO) Meeting in Cambridge, MD in March 2013. This presentation will discuss the progress that has been made since then on the efforts to eliminate the instrumental component, as well as show some of the updated results of absolute velocities of multiple emissions at a wide range of temperatures during solar flares.
Author(s): Phillip C Chamberlin[1]
Institution(s): *1. NASA GSFC*

302.09 – The Radiated Energy Budget Of Chromospheric Plasma In A Major Solar Flare Deduced From Multi-Wavelength Observations

The response of the lower solar atmosphere is an important diagnostic tool for understanding energy transport during solar flares. The 15 February 2011 X-class flare was fortuitously observed by a host of space-based instruments that sampled the chromospheric response over a range of lines and continua at <20s cadence. These include the free-bound EUV continua of H I (Lyman), He I, and He II, plus the emission lines of He II at 304Å and H I (Lyα) at 1216Å by SDO/EVE, the UV continua at 1600Å and 1700Å by SDO/AIA, and the white light continuum at 4504Å, 5550Å, and 6684Å, along with the Ca II H line at 3968Å using Hinode/SOT. RHESSI also observed the entire event at energies up to ~100keV, making it possible to determine the properties of the nonthermal electrons deemed to be responsible for driving the enhanced chromospheric emission under the assumption of thick-target collisions. Integrating over the duration of the impulsive phase, the total energy contained in the nonthermal electrons was found to be $>2\times10^{31}$ erg. By comparison, the summed energy detected by instruments onboard SDO and Hinode amounted to $\sim3\times10^{30}$ erg; about 15% of the total nonthermal energy. The Lyα line was found to dominate the measured radiative losses in contrast to the predictions of numerical simulations. Parameters of both the driving electron distribution and the resulting chromospheric response are presented in detail to encourage the numerical modeling of flare heating for this event to determine the depth of the solar atmosphere at which these line and continuum processes originate, and the mechanism(s) responsible for their generation.
Author(s): Ryan Milligan[2], Graham Stewart Kerr[3], Brian Dennis[1], Hugh Hudson[3], Lyndsay Fletcher[3], Joel Allred[1], Phillip Chamberlin[1], Jack Ireland[1], Mihalis Mathioudakis[2], Francis Keenan[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Queen's University Belfast, 3. University of Glasgow*

302.10 – The Multi-Instrument (EVE-RHESSI) DEM for Solar Flares, and Implications for Residual Non-Thermal Soft X-Ray Emission

In the soft X-ray energy range, solar flare spectra are typically dominated by thermal emission. The low energy extent of non-thermal emission can only be loosely quantified using currently available X-ray data. To address this issue, we combine observations from the EUV Variability Experiment (EVE) on-board the Solar Dynamics Observatory (SDO) with X-ray data from the Reuven Ramaty High Energy Spectroscopic Imager (RHESSI). The improvement over the isothermal approximation is intended to resolve the ambiguity in the range where the thermal and non-thermal components may have similar photon fluxes. This "crossover" range can extend up to 30 keV for medium to large solar flares. Previous work (Caspi et.al. 2014ApJ...788L..31C) has concentrated on obtaining DEM models that fit both instruments' observations well. Now we are interested in any breaks and cutoffs in the "residual" non-thermal spectrum; i.e., the RHESSI spectrum that is left over after the DEM has accounted for the bulk of the soft X-ray emission. Thermal emission is again modeled using a DEM that is parametrized as multiple gaussians in temperature; the non-thermal emission is modeled as a photon spectrum obtained using a thin-target emission model ('thin2' from the SolarSoft Xray IDL package). Spectra for both instruments are fit simultaneously in a self-consistent manner. The results for non-thermal parameters then are compared with those found using RHESSI data alone, with isothermal and double-thermal models.
Author(s): James M McTiernan[3], Amir Caspi[2], Harry Warren[1]
Institution(s): *1. Naval Research Laboratory, 2. Southwest Research Institute, 3. Univ California Berkeley*

302.11 – An Investigation of Flare Footpoint DEMs using AIA Diffraction Patterns

The heating of flare footpoints by accelerated electrons is a well-established component of the standard flare model. However, limitations of current instruments make it challenging to obtain high cadence,

high resolution observations of the brightest footpoint regions, predominantly due to low cadence, or pixel saturation.
In moderate and large flares observed by the Solar Dynamics Observatory's Atmospheric Imaging Assembly, CCD pixels in the footpoint regions are frequently saturated despite the automatic exposure control. Using the method of Schwartz et al. (2014), we reconstruct saturated footpoint kernels in the brightest flaring regions and investigate the evolving footpoint differential emission measure at the full 12 second AIA cadence. This is compared to the changing electron fluxes observed with the Reuven Ramaty Solar Spectroscopic Imager (RHESSI) to investigate the relationship between the non-thermal electron energy flux and the footpoint thermal response.
(Schwartz, R. A., Torre, G., & Piana, M. (2014), Astrophysical Journal Letters, 793, LL23)
Author(s): Claire Raftery[2], Hazel Bain[2], Richard Schwartz[1], Gabriele Torre[3], Sam Krucker[2]
Institution(s): *1. Catholic Univeristy/GSFC, 2. UC Berkeley, 3. Universit́a di Genova*

302.12 – How gas-dynamic flare models powered by Petschek reconnection differ from those with ad hoc energy sources

Many aspects of solar flare dynamics including chromospheric evaporation have been, for more than thirty years, studied using one-dimensional models of static flaring loops. These models solve one-dimensional gas-dynamic equations for the dynamics of plasma inside a static loop, subjected to energy input through either non-thermal particles or heating. While they have been extremely successful at explaining the characteristics of emission observed in flares, none so far have been developed in which the energy input is derived self-consistently from the loop's dynamics. Instead the energy input is specified ad hoc. According to another line of theoretical investigation, flares derive their energy from magnetic energy released through fast magnetic reconnection. In the model due originally to Petschek reconnection occurring in a small diffusion region produces a bent flux tube whose retraction generates fast flows (an outflow jet) and shocks where flow energy is thermalized. In a recent line of work this scenario has been generalized so it may be incorporated into a one-dimensional loop model of the kind used so successfully in flare modeling. In this new model the flaring loop itself undergoes the retraction and shock formation, and thereby introduces the flare energy self-consistently. Here we compare the gas dynamics driven by retraction and shocking to those from more conventional static loop models. We find significant differences during the first minute, when retraction produces high densities at the loop top, while ad hoc heating tends to rarify the loop top.
Author(s): Dana Longcope[1], James A Klimchuk[2]
Institution(s): *1. Montana State University, 2. NASA/GSFC*

302.13 – Bright EUV knots on post-flare loops: Are we seeing slow shocks?

Post flare loops imaged in the EUV sometimes show bright knots of emission at their apices. Knots from the loops in an arcade often line up to form a bar of coronal emission parallel to the polarity inversion line. These features have been variously interpreted as the results of colliding evaporation flows or volume enhancement at the point of weakest magnetic field. Here we consider the possibility that the features are produced through density enhancement resulting from shock compression during the reconnection process. We present simulations of thin flux tube dynamics following reconnection, which capture the essential physics of Petschek's fast reconnection model. The slow shock present during reconnection and subsequent retraction produce a high density region which persists even after the loop has achieved its ultimate equilibrium configuration. This high density produces enhanced emission at the bottom of the current sheet. Evaporation flows impinge on the high density region resulting in further enhancement to the density and the emission at the same position: the bottom of the current

sheet. We compare these results to those from more conventional simulation where ad hoc heating drives evaporation from both feet.
Author(s): John Unverferth[1], Dana Longcope[1], Katharine Reeves[2]
Institution(s): *1. Montana State University, 2. Smithsonian Astrophysical Observatory*

302.14 – The Myth of Long Duration Flare Emission: Slow Heating or Slow Cooling?

Long duration flare emissions lasting for a few hours are likely governed by magnetic reconnection that continuously heats flare plasmas in continuously formed flare loops. In this study, we confirm that this process leads to the long-duration total emission for up to four hours in a C2.9 flare on 2011 September 13. Observed by AIA, the flare exhibits an ordered spread of flare UV ribbons along the polarity inversion line, followed by the sequential formation of post-flare loops in EUV emissions. We infer heating rates of thousands of flare loops from the UV light curves at the flare foot-points, and model the flare total emission with the 0d EBTEL model, which reproduces the global evolution pattern of the long-duration flare EUV emissions as the result of superposition of continuously formed and heated flare loops. However, observations at single loop pixels also show long duration EUV emission at 10 MK, long cooling time from 10 MK to 3 MK, and later on very short duration of EUV emission at 1-2 MK. All of these signatures cannot be produced by superposition of multiple impulsive heating events. Our experiments, with both the 0d EBTEL model and a 1d hydrodynamic model, have demonstrated that a heating profile in a single loop consisting of two parts, an intense impulsive heating followed by a low-rate heating 1-2 orders of magnitude smaller that is attenuated over 20-30 minutes, is required to produce the observed time evolution signatures in a single loop. The total energy in the gradual heating phase is comparable with that in the impulsive heating phase in a flare loop. We discuss viable physical mechanisms for such two-phase heating in a post-reconnection flare loop.
Author(s): Jiong Qiu[1], Dana Longcope[1], James A Klimchuk[2]
Institution(s): *1. Montana State University, 2. NASA Goddard Space Flight Center*

302.15 – Multi-thermal Energies of Solar Flares

Measuring energy partition in solar eruptions is key to understanding how different processes affect their evolution. In order to improve our knowledge on this topic, we are participating in a multi-study project to measure the energy partition of 400 M- and X-class flares and associated coronal mass ejections (CMEs). In this study we focus on the flare thermal energies of 391 of these events. We improve upon previous studies in the following ways: 1) We determine thermal energy using spatially resolved multi-thermal differential emission measures (DEMs) determined from AIA (Atmospheric Imaging Assembly) rather than relying on the isothermal assumption; 2) We determine flare volumes by thresholding these DEM maps rather than relying on single passband observations which may not show the full flare volume; 3) We analyze a greater number of events than previous similar studies to increase the statistical reliability of our results. We find that the thermal energies of these flares lie in the range 10^26.8—10^32 erg. These results are compared to those of Aschwanden et al. (2014) who examined a subset of these events. They determined the dissipated non-potential magnetic energy which is thought to be the total energy available to drive solar eruptions. For the 171 events common to both studies, we find that the ratio of flare thermal energy to dissipated magnetic energy ranges from 2%—40%. This is an order of magnitude higher than previously found by Emslie et al. (2012). This may be because Emslie et al. (2012) had to assume the amount of non-potential magnetic energy, or that they relied on the isothermal assumption to determine flare thermal energies. The improved results found here will help us better understand the role played by flare thermal processes in dissipating the overall energy of solar eruptions.

Author(s): Daniel Ryan[3], Markus Aschwanden[1], Paul Boerner[1], Amir Caspi[4], James McTiernan[5], Harry Warren[2]
Institution(s): *1. Lockheed Martin Solar and Astrophysics Laboratory, 2. Naval Research Laboratory, 3. Royal Observatory of Belgium, 4. Southwest Research Institution, 5. University of California*

302.16 – Towards Predicting Solar Flares

We present a statistical study of solar X-ray flares observed using GOES X-ray observations of the ~50,000 fares that occurred from 1986 - mid-2014. Observed X-ray parameters are computed for each of the flares, including the 24-hour non-flare X-ray background in the 1-8 A band and the maximum ratio of the short (0.5 – 4 A) to long band (1-8 A) during flares. These parameters, which are linked to the amount of active coronal heating and maximum flare temperature, reveal a separation between the X-, M-, C-, and B- class fares. The separation was quantified and verified through machine-learning algorithms (k nearest neighbor; nearest centroid). Using the solar flare parameters learned from solar cycles 22-23, we apply the models to predict flare categories of solar cycle 24. Skill scores are then used to assess the success of our models, yielding correct predictions for ~80% of M-, C-, and B-class flares and 100% correct predictions for X-flares. We present details of the analysis along with the potential uses of our model in flare forecasting.
Author(s): Lisa Winter[1], Karatholuvu S. Balasubramaniam[2]
Institution(s): *1. AER, 2. AFRL*

302.17 – Investigation of a failed Filament Eruption During the VAULT2.0 Campaign Observations

We report the first results from an observing campaign in support of the VAULT2.0 sounding rocket launch on September 30, 2014. VAULT2.0 is a Lya (1216Å) spectroheliograph capable of 0.4" (~300 km) spatial resolution. The objective of the VAULT2.0 project is the study of the chromosphere-corona interface. VAULT2.0 observations probe temperatures between 10000 and 50000 K, a regime not accessible by Hinode or SDO. Lyα observations are, therefore, ideal, for filling in this gap. The observing campaign was closely coordinated with the Hinode and IRIS missions. Several ground-based observatories also provided important observations (IBIS, BBSO, SOLIS). Taking advantage of this simultaneous multi-wavelength coverage of target AR 12172 we are able to perform a detailed investigation on a failed eruption of a Magnetic Flux Rope-like structure that was recorded in the joint observations, starting before VAULT2.0's flight.
Author(s): Georgios Chintzoglou[1], Angelos Vourlidas[2], Samuel Tun-Beltran[3], Guillermo Stenborg[3]
Institution(s): *1. George Mason University, 2. Johns Hopkins University, 3. Naval Research Laboratory*

302.18 – Dependence of Sunspot Properties on Flare Occurrence and Flare-CME Association

Previous studies showed that the intense flares tend to erupt from the large sunspot region with complex magnetic configuration and strong magnetic field. However, note that not all the active regions (ARs) classified as $\beta\gamma\delta$ would produce X-class flares. To clarify the significance of sunspot properties on solar explosive events, we reexamine the dependence of flare magnitude on sunspot size and magnetic type during 1996-2014 based on the report of NOAA Solar Region Summary and the measurements of GOES soft X-ray flux. In particular, we focus on the $\beta\gamma\delta$-type ARs to relate the flare productivity to the sunspot area and magnetic field strength by means of the line-of-sight magnetograms from SOHO/MDI and SDO/HMI. Two flare-productive ARs, 10486 and 12192, with $\beta\gamma\delta$ magnetic configuration during most periods of their disk passages are further investigated to characterize the sunspots and flare-CME association.

Author(s): Ya-Hui Yang[1]
Institution(s): *1. Institute of Space Science, National Central University*

302.19 – On the Relationship between Solar Magnetic Forces and CME Momenta

Free magnetic energy is the energy source of solar flares and CMEs. At the initiation of a CME, the free magnetic energy converts to kinetic energy and few other types of energy. Observable magnetic field sudden changes have been found at the onset of flares. The Lorentz force around the onset of a flare have been formulated in recent studies and can be estimated using photospheric vector magnetic field data. It is proposed that outward Lorentz force impulses could be related to CME momenta. We analyze about 30 CMEs and their source region magnetic fields. The best vector magnetic field data are observed for active regions near the center of the solar disk. We first select CMEs that appear to be halo or partial halo CMEs in the LASCO images, and then we use STEREO SECCHI COR2 white light images to estimate CME mass and speed. We then estimate the Lorentz forces in the source active regions at the flare onset using SDO HMI photosheric vector magnetic field data. We report our studies and describe our analyses.

This study is under the support of NSF grants.
Author(s): Yan Li[2], **Ben Lynch**[2], Xudong Sun[1], Brian T Welsch[2], David J Bercik[2], George H Fisher[2]
Institution(s): *1. Stanford University, 2. University of California*

302.21 – Comparison of the X-ray Emission from Two Quiescent Filament Eruptions

Quiescent filament eruptions, solar eruptive events occurring outside of active regions, have yet to be studied in detail in the high-energy regime. Though similar to active region flares, quiescent filament eruptions typically occur in extended regions of relatively weak magnetic field strength and on longer time scales, allowing in-depth analyses to probe possible causes of the eruption. A previous study on a quiescent filament eruption on 2013 September 29 demonstrated the significance of emerging magnetic flux, which can perturb the magnetic structures that support the filament. We present a new solar eruptive event that occurred on 2014 November 1 on the southeast limb. This two-ribbon event occurred outside of any active regions and produced a coronal mass ejection with a velocity ~ 1800 km/s. Soft X-ray emission is observed by both GOES and RHESSI during the eruption, and the spatially resolved RHESSI data shows 3 - 9 keV emission correlated only with the eastward-expanding ribbon. Interaction between a compact, strong magnetic region and the eastern ribbon appears to be a likely catalyst of the X-ray flare. A similar interaction between magnetic structures appears to be responsible for the compact RHESSI X-ray source seen in the 2013 September 29 event. Our multiwavelength analyses of these quiescent filament eruptions and associated C-class flares will further our understanding of solar eruptive events.
Author(s): Adi Foord[1], Gordon D. Holman[1]
Institution(s): *1. NASA Goddard Space Flight Center*

302.22 – Twisting, Rolling Motions, and Helicity in Prominence Eruptions

Panasenco et al. [1] report observations of several CMEs that display a rolling motion about the axis of the erupting prominence. Murphy et al. [2] present simulations of line-tied asymmetric magnetic reconnection that make a falsifiable prediction regarding the handedness of rolling motions of flux ropes during solar eruptions. Mass motions in prominence eruptions tend to be complicated and characterizing these motions is a challenge. We use the AIA filament eruption catalog [3] as a source for

finding events. If rolling motions are detected then we will investigate the handedness prediction. We use magnetograms from HMI to determine the strength and asymmetric properties of the photospheric magnetic field in the regions of interest and will use AIA observations to determine the handedness of the rolling motions. We then compare the photospheric magnetic information with the handedness to determine if there is a relationship between the two. We also determine the chirality of the prominences to see if there is any interesting relationship to the twist, rolling motion and/or handedness of the roll.
[1] O. Panasenco, S. Martin, A. D. Joshi, & N. Srivastava, J. Atmos. Sol.-Terr. Phys., 73, 1129 (2011)
[2] N. A. Murphy, M. P. Miralles, C. L. Pope, J. C. Raymond, H. D. Winter, K. K. Reeves, D. B. Seaton, A. A. van Ballegooijen, & J. Lin, ApJ, 751, 56 (2012)
[3] http://aia.cfa.harvard.edu/filament/
Author(s): Sean McKillop[2], Mari Paz Miralles[1], Nicholas A Murphy[2], Patrick McCauley[2], Yingna Su[2]
Institution(s): *1. Harvard - Smithsonian CfA, 2. Smithsonian Astrophysical Observatory*

302.23 – The Blob Connection: From EUV to white light

Coronal Mass Ejections (CMEs) are frequently followed by a newly formed current sheet in their wake, as observed in LASCO white light data. In a subset of these post-CME ray structures, relatively bright "blobs" are seen moving outward along these rays. These blobs have been interpreted as consequences of plasmoid instability in the current sheet. We examine several instances, taken from the SOHO/LASCO CME-Rays Catalog we are currently developing, where these blobs are clearly visible. Using several different techniques to visually inspect AIA and SWAP data in multiple wavelengths, we look for traces of material being ejected corresponding to the later appearance of the blobs in the LASCO coronagraph. While definitive links are difficult to establish due to the gap in data between the outermost EUV field of view and the innermost LASCO C2 data, we piece together evidence that supports their connection in several cases. In this poster, we present a select few of these events in greater detail. This work funded by SP02H1701R from Lockheed-Martin to SAO and NASA grant NNX13AG54G.
Author(s): Nicole Schanche[2], Katharine Reeves[2], David F Webb[1]
Institution(s): *1. Boston College, 2. Smithsonian Astrophysical Observatory (SAO)*

303 – Waves and Turbulence Throughout the Heliosphere

303.01 – Helioseismology with Seismometers: I Seismic Evidence

Since the discovery of seismic ``hum'' in 1998 unexpected lines have been observed in terrestrial seismology. In this talk we give evidence that these lines cannot have a terrestrial source but must originate as normal modes of the Sun. Power spectra of good seismic data at times that are free of major earthquakes have numerous unusual properties, including:
1) There are strong periodic signals at frequencies below that of $_0S_2$, the lowest terrestrial seismic mode and down to ~30 uHz.
2) These modes have high Q's, much higher than that of terrestrial seismic modes.
3) We have been able to match many of the frequencies in seismic spectra with those measured by optical helioseismology. With P_{2,7} all five singlets are observed.
This study gives further evidence that solar modes propagate through interplanetary space and are sufficiently strong to literally shake the Earth.
Author(s): Frank Vernon[2], David J. Thomson[1]
Institution(s): *1. Queens University, 2. Univ California San Diego*

303.02 – Helioseismology with Seismometers: II Coherence with the Interplanetary Magnetic Field

Since the discovery of seismic "hum'' in 1998 unexpected lines have been observed in terrestrial seismology.
In this talk we give further evidence that these lines originate as normal modes of the Sun. Frequencies observed in terrestrial seismic and geomagnetic data are often split by multiples of a cycle/day and, unexpectedly, by multiples of one-half cycle per sidereal day.
There is coherence between the interplanetary magnetic field (IMF) at ACE (located at L_1) and terrestrial geomagnetic and seismic data. There are slight frequency offsets between colocated geomagnetic and seismic data similar to those observed in normal modes excited by earthquakes. These have been attributed to dispersion from large-scale structure in the Earth.
Both the splitting and coherence with the IMF give further confirmation that solar modes propagate through interplanetary space and are sufficiently strong to literally shake the Earth. This gives another method to detect and possibly identify solar gravity and low--frequency P-modes.
Author(s): David J. Thomson[1], Frank L Vernon[2]
Institution(s): *1. Queen's University, 2. UCSD*

303.03 – Electromagnetic cyclotron waves near the proton cyclotron frequency in the solar wind

Strong narrow-band electromagnetic waves around the proton cyclotron frequency (fpc) have been found sporadically in the solar wind from 0.3 to 0.7 AU during MESSENGER spacecraft's cruise phase. These waves are transverse and circularly polarized, and they propagate in directions quasi-parallel to the magnetic field. The wave power decreases quadratically with heliocentric distance, faster than the trend if assuming the conservation of Poynting flux for wave packets, suggesting there is energy dissipation from the waves, which could contribute to the heating and acceleration of solar wind plasma. Although the wave frequency is a few times of fpc in the spacecraft frame, it is a fraction of fpc in the solar wind plasma frame after removing the Doppler shift effect. In this frequency range, the waves can be left-hand (LH) polarized ion cyclotron waves or right-hand (RH) polarized magnetosonic waves. Because the waves are LH or RH polarized in the spacecraft frame with otherwise nearly identical characteristics, they could be due to Doppler shift of a same type of waves or a mixture of waves with intrinsically different polarizations. Through the assistance of audification, we have studied the long-lasting wave events in 2005 using high-cadence magnetic field data from the Wind mission. Statistically, in contrast with general solar wind, the protons at these waves are distributed closer to the proton instability thresholds, while the alpha particles at these waves are distributed further away from the alpha instability thresholds. For selected events of extensive waves, the ion distribution is analyzed in detail. A mixture of temperature anisotropies for core protons, beam protons, and alpha particles, as well as proton beam drift are often found in such events. We conduct linear wave dispersion analysis using these ion moments to examine whether these waves can be explained by the local generation of kinetic instabilities such as the LH ion cyclotron, the RH firehose, and the RH ion beam instability.
Author(s): Lan K Jian[5], Scott Boardsen[4], Pablo Moya[1], Michael Stevens[2], Robert Alexander[6], Adolfo Vinas[3]
Institution(s): *1. Catholic University of America, 2. Harvard Smithsonian Center for Astrophysics, 3. NASA Goddard Space Flight Center, 4. University of Maryland, Baltimore County, 5. University of Maryland, College Park, 6. University of Michigan*

303.04 – A Novel Analysis of Acoustic Oscillations in Chromospheric Active Regions

A helioseismic analysis of the chromosphere is employed in H-alpha to study how solar flares around active regions affect the behavior of acoustic oscillations. Our analysis deals with flares directly over sunspots, where the region is highly magnetized. In our current study of analyzing these oscillations in the chromosphere we study the temporal evolution of the oscillatory behavior from data taken from the Global Oscillation Network Group (GONG) H-alpha detectors. We investigate the wave behavior across different frequency bands ($1 < \nu < 8.33$ mHz). In order to analyze the frequency bands of the oscillations, our analysis utilizes time series data to create Fourier power spectra of individual pixels spatially resolved and temporally evolved around the flare region; thereby creating a movie of each frequency band. This study entails three active regions, directly over sunspots, in which flaring activity is taking place from two solar flares, which occurred on June 13th and July 12th, 2012. We found that the intensity of the flare has an effect on the oscillations within different frequency bands. A suppression of power was observed in *dark anomalous structures* across the total frequency bands and in other regions there was an observed boost in power due to flaring activity. We find that, in the heart of all three regions, the low-frequency power (∼1–2 mHz) is substantially enhanced immediately prior to and after the flare, and that power at all frequencies up to 8 mHz is depleted at flare maximum. This depletion is both frequency and time dependent, which probably reflects the changing depths visible during the flare in the bandpass of the filter. These variations are not observed outside the flaring region. The depletion may indicate that acoustic energy is being converted into thermal energy at flare maximum, while the low-frequency enhancement may arise from an instability in the chromosphere and provide an early warning of the flare onset.
Author(s): Teresa Monsue[2], Frank Hill[1], Keivan G. Stassun[2]
Institution(s): *1. National Solar Observatory, 2. Vanderbilt University*

303.05 – Spectral Analysis of Velocities in Quiescent Prominences Observed with Hinode

High-resolution observations of solar prominences, especially with the Solar Optical Telescope (SOT) on Hinode, reveal the presence of upward and downward flows consistent with convection, at length scales that were not accessible with previous telescopes. Since prominences are magnetic structures, the strength and arrangement of their magnetic fields are crucial for determining whether a given prominence will erupt into a coronal mass ejection. Convective flows can twist and tangle those magnetic fields. However, the magnetic fields within the prominences are extremely difficult to measure; therefore measurements of the dynamics of the magnetized plasma in prominences, and the balance between magnetic and gas-pressure forces, are valuable for understanding how these apparently stable structures can evolve to become suddenly eruptive. We will show our findings from analysis of the dynamics in a few solar prominences using local correlation tracking, and make estimates of the kinetic energy, diffusivity, and vorticity.
This work is supported by NASA under contract NNM07AB07C with the Smithsonian Astrophysical Observatory.
Author(s): David McKenzie[1], Michael Freed[1]
Institution(s): *1. Montana State University*

303.06 – Some Candidates for Solar Gravity Modes

Since the accidental discovery of solar modes in space (Thomson,Maclennan, and Lanzerotti, Nature, 1995) work has continued and there are now a few candidates for identified solar gravity modes using charged particles and interplanetary magnetic field data. Contrary to initial expectations, there is a preference for higher-*l* modes, typically *l* = 2 to 5.
Second, different frequencies are expected at ACE (at L_1) and Ulysses, in an almost sidereal solar-polar

orbit. Given a candidate detection at ACE where signal-to-noise ratios are higher, one can then shift frequencies by ±32m nHz and test for agreement at Ulysses.
Third, the 7.5 degree inclination of the ecliptic on the solar equator splits odd-parity modes at ACE by 32 nHz. The two sub-singlets have a defined phase relation that can be used as a further check on parity. Two such modes are $G_{2,-1}$ at 296.195 uHz and $G_{3,-2}$ at 296.887 uHz. Both have all $2l+1$ singlets detected on both ACE and Ulysses.
The 11 singlets of the $G_{5,-1}$ mode are also all detected above the 99% level. The mode has a center frequency of 383.812 uHz with $a_1 \approx 918$ nHz.
Author(s): David J. Thomson[1]
Institution(s): *1. Queen's University*

304 – CMEs: The Eruption

304.01 – Connecting the evolution and properties of CMEs to their low coronal signatures. A modeling case study of the 'simple' Feb 13 2009 event

The early onset and and evolution of a CME is a process that features an intimate coupling between the erupting flux-system and the ambient corona. For this reason low coronal signatures that we often observe in the EUV can be used to infer information on the physical nature and evolution of CMEs. In this presentation we will discuss a 3D thermodynamic MHD simulation of the Feb 13 2009 eruption, which occurred from an isolated region during solar minimum and produced well characterized EUV wave and transient coronal dimming features. Using observations as a guide, we simulate the entire evolution of the eruption and global corona, starting from the initial stable configuration through onset and evolution to the post-eruptive reconfiguration. With a particular focus on coronal dimmings, we track how the connectivity of the erupting flux-rope evolves with time and how this relates to corresponding dimmings in synthetic EUV observables. We find that the appearance of the core dimming regions and their migration over time can be related to when and where the erupting rope reconnects with itself and the adjacent arcade. Other aspects related to CME evolution, such as the generation of an EUV wave and quasi-periodic fast-propagating waves are also discussed.
Author(s): Cooper Downs[1], Tibor Török[1], Viacheslav Titov[1], Wei Liu[2], Jon Linker[1], Zoran Mikić[1]
Institution(s): *1. Predictive Science Inc., 2. Stanford University*

304.02 – Observation and Modeling of a Termination Shock in a Solar Eruption as a Possible Particle Accelerator

Solar eruptions and their associated solar flares are the most energetic particle accelerators in our solar system. Yet the acceleration mechanism remains uncertain. A possible candidate often invoked in the standard picture of solar eruptions is a termination shock, produced by fast reconnection outflows impinging upon dense, closed loops in a helmet-type geometry. However, the importance of termination shocks in solar particle acceleration remains controversial, mainly because there has been no direct detection of such shocks. Here we report direct imaging of the location and evolution of a termination shock during the rise phase of a solar eruption. The shock appears at radio wavelengths as a narrow surface sandwiched between multitudes of downward-moving plasma blobs and the underlying, newly-reconnected flaring loops, and evolves coherently with a loop-top hard X-ray source in the shock downstream region. The shock produces many short-lived, point-like radio sources, each interpreted as emission from a turbulence cell interacting with fast (nonthermal) electrons. These point-like radio sources clearly outline the termination shock front and their positions change in reaction to the arrival

of the fast plasma blobs, which are well-reproduced by our numerical simulations based on a resistive magnetohydrodynamics reconnection model in a standard two-ribbon flare geometry. We further show that a temporary disruption of the shock coincides with a reduction of radio and hard X-ray emission associated with the energetic electron population. Our observations strongly favor a scenario in which the termination shock is responsible for accelerating electrons to high energies.
Author(s): Dale E. Gary[2], Bin Chen[1], Timothy S Bastian[3], Chengcai Shen[1], Sam Krucker[4]
Institution(s): *1. Harvard/Smithsonian, 2. New Jersey Institute of Technology, 3. NRAO, 4. UC/Berkeley*

304.03 – Multi-stage filament eruption and the decay index distribution, A case study

The general consensus of solar eruptions is the release of magnetic free energy. However, it is still a big challenge to our understanding of the initiation of such events. From the observing perspective, the erupting material, basically filaments or magnetic flux ropes, usually keep either their original shape or become more twisted. The former case can be explained by torus instability and the latter represents the scenario of eruptions caused by kink instability. The model of torus instability requires a fast decay of the overlaying magnetic field, quantitatively defined as the vertical magnetic gradient in the log space. A specific range (1.1 to 2.0) of the decay index has been identified by previous studies and can be used to distinguish eruptive and confined eruptions. On the other hand, two phases of filament eruptions, i.e., a slow rising motion followed by a fast escape, were frequently observed. We present such a filament eruption occurred on 2007 May 19, in which the deprojected heights of the filament are measured by the stereoscopic reconstruction with STEREO observations. During the slow rising phase, the filament remained below 40 Mm. The decay indices are calculated using the extrapolated SOHO/MDI magnetograms. We found that the decay indices increase as a function of height and reaches the special range (1.1 to 2.0) around 30 to 50 Mm. This result reveals a picture of the two-stage filament eruption, in which a small perturbation breaks the equilibrium and leads the filament to lift up slowly. Once the filament reaches the critical height, the overlying field drops significantly leading to an acceleration of the filament eruption.
Author(s): Yan Xu[1], Chang Liu[1], Ju Jing[1], Haimin Wang[1]
Institution(s): *1. New Jersey Institute of Technology*

304.04 – Large-scale and Long-duration Simulation of a Multi-stage Eruptive Solar Event

We employ a data-driven 3D MHD active region evolution model by using the Conservation Element and Solution Element (CESE) numerical method. This newly developed model retains the full MHD effects, allowing time-dependent boundary conditions and time evolution studies. The time-dependent simulation is driven by measured vector magnetograms and the method of MHD characteristics on the bottom boundary. We have applied the model to investigate the coronal magnetic field evolution of AR11283 which was characterized by a pre-existing sigmoid structure in the core region and multiple eruptions, both in relatively small and large scales. We have succeeded in producing the core magnetic field structure and the subsequent eruptions of flux-rope structures (see https://dl.dropboxusercontent.com/u/96898685/large.mp4 for an animation) as the measured vector magnetograms on the bottom boundary evolve in time with constant flux emergence. The whole process, lasting for about an hour in real time, compares well with the corresponding SDO/AIA and coronagraph imaging observations. From these results, we show the capability of the model, largely data-driven, that is able to simulate complex, topological, and highly dynamic active region evolutions. (We acknowledge partial support of NSF grants AGS 1153323 and AGS 1062050, and data support from SDO/HMI and AIA teams).
Author(s): chaowei Jiang[1], Qiang Hu[1], S. T. Wu[1]

Institution(s): *1. University of Alabama in Huntsville*

304.05D – Laboratory identification of storage-and-release eruption regimes in the solar corona

Ideal magnetohydrodynamic (MHD) instabilities such as the kink and torus instabilities are believed to play an important role in driving long-lived solar magnetic flux ropes to erupt. In this paper, we report the findings of a laboratory flux rope experiment that is specifically designed to explore the parameter space for these two eruptive instabilities. In particular, we scan the twist in the flux rope for the kink instability and the decay index of the potential field for the torus instability. Using *in situ* magnetic probes, we identify four distinct stability regimes in the experiment: (1) stable; (2) eruptive; (3) failed kink; and (4) failed torus. The identification of the failed kink regime validates the importance of the torus instability in driving flux rope eruptions. The identification of the failed torus regime, on the other hand, constitutes an entirely new finding. By directly measuring the forces acting on the flux rope plasma, we show that a strong magnetic tension force that is derived from the toroidal magnetic field in the flux rope suppresses eruptions in the failed torus regime.
This research is supported by DoE Contract Number DE-AC02-09CH11466 and by the NSF/DoE Center for Magnetic Self-Organization (CMSO).
Author(s): Clayton E Myers[1], Masaaki Yamada[1], Hantao Ji[1], Jongsoo Yoo[1], Will Fox[1], Jon Jara-Almonte[1]
Institution(s): *1. Princeton Plasma Physics Laboratory*

304.06 – Initial Results from Mingantu Ultrawide Spectral Radioheliograph

Radio imaging spectroscopy over wide range wavelength in dm/cm-bands will open new windows on solar flares and coronal mass ejections by tracing the radio emissions from accelerated electrons. The Chinese Spectral Radioheliograph (CSRH) with two arrays in 400MHz-2GHz /2-15GHz ranges with 64/520 frequency channels have just been established in Mingantu Observing Staion, National Astronomical Observatories, Chinese Academy of Sciences in Inner Mongolia of China. CSRH is re-named as Mingantu Ultralwide Spectral Radioheliograph (MUSER) after its accomplishment. We will introduce the progress and current status of MUSER. Some preliminary results of MUSER will be presented.
On 11 Nov. 2014, a burst event was registered by MUSER-I array at 400MHz-2GHz waveband. According to SGD event list there was a C-class flare event at 04:49UT in the disk center and the radio bursts during 04:22-04:24UT was attributed to this flare. However, MUSER-I image observations of the bursts indicate that the radio burst peaked around 04:22UT was due to another eruptive event at the east limb of the Sun, which may be related a CME event afterwards.
Author(s): Yihua Yan[1], Linjie Chen[1], Sijie Yu[1], CSRH TEAM[1]
Institution(s): *1. National Astronomical Observatoires, Chinese Academy ofSciences*

305 – MAVEN: Early Results II

305.01 – Early Results From the MAVEN Magnetometer

The MAVEN spacecraft arrived at Mars on Sept. 21, 2014 and the magnetometer -- part of the overall particle and fields instrument suite -- has been collecting data since that time. The MAVEN mission is designed to characterize the solar wind's interaction with the induced martian magnetosphere and the magnetometer plays a key role in that characterization. We will discuss early results from these observations including: 1) the role of magnetic topology in allowing solar wind access to the martian ionosphere, 2) the role of reconnection between the IMF and the induced ionospheric fields and/or the

crustal fields, 3) the role of plasma waves in redistributing energy across the system and 4) the unique set of observations taken during the time period when Mars was enveloped by the coma and ion tail of Comet Siding Spring. We will further discuss these observations in the context of the other particle and fields instruments onboard MAVEN and comment on how these observations can inform the hypothesis that the solar wind has eroded the martian atmosphere over billions of years.
Author(s): Jared Espley[1], Jack Connerney[1], Gina DiBraccio[1], D. A. Brain[2], Ron Oliversen[1]
Institution(s): *1. NASA Goddard, 2. University of Colorado*

305.02 – Plasma and wave properties downstream of Martian bow shock: Hybrid simulations and MAVEN observations

Two-dimensional hybrid simulation codes are employed to investigate the kinetic properties of plasmas and waves downstream of the Martian bow shock. The simulations are two-dimensional in space but three dimensional in field and velocity components. Simulations show that ion cyclotron waves are generated by temperature anisotropy resulting from the reflected protons around the Martian bow shock. These proton cyclotron waves could propagate downward into the Martian ionosphere and are expected to heat the O^+ layer peaked from 250 to 300 km due to the wave-particle interaction. The proton cyclotron wave heating is anticipated to be a significant source of energy into the thermosphere, which impacts atmospheric escape rates. The simulation results show that the specific dayside heating altitude depends on the Martian crustal field orientations, solar cycles and seasonal variations since both the cyclotron resonance condition and the non/sub-resonant stochastic heating threshold depend on the ambient magnetic field strength. The dayside magnetic field profiles for different crustal field orientation, solar cycle and seasonal variations are adopted from the BATS-R-US Mars multi-fluid MHD model. The simulation results, however, show that the heating of O^+ via proton cyclotron wave resonant interaction is not likely in the relatively weak crustal field region, based on our simplified model. This indicates that either the drift motion resulted from the transport of ionospheric O^+, or the non/sub-resonant stochastic heating mechanism are important to explain the heating of Martian O^+ layer. We will investigate this further by comparing the simulation results with the available MAVEN data. These simulated ion cyclotron waves are important to explain the heating of Martian O^+ layer and have significant implications for future observations.
Author(s): Chuanfei Dong[6], Dan Winske[3], Misa Cowee[3], Stephen W Bougher[6], Laila Andersson[2], Jack Connerney[1], Jared Epley[1], Robert Ergun[2], James P McFadden[4], Yingjuan Ma[5], Gabor Toth[6], Shannon Curry[4], Andrew Nagy[6], Bruce Jakosky[2]
Institution(s): *1. Goddard Space Flight Center, NASA, 2. LASP, University of Colorado, 3. Los Alamos National Lab, 4. SSL, University of California, 5. University of California, 6. University of Michigan*

305.03 – Using Space Weather Forecast Tools for Understanding Planetary Magnetospheres: MESSENGER Experience Applied to MAVEN Studies

The Wang-Sheeley-Arge (WSA)-ENLIL solar wind modeling tool has been used to calculate the values of interplanetary magnetic field (IMF) strength (B), solar wind speed (V), density (n), ram pressure ($\sim nV^2$), cross-magnetosphere electric field (**VxB**), Alfvén Mach number (M_A), and other derived quantities of relevance for space weather purposes at Earth. Such parameters as solar wind dynamic pressure can be key for estimating the magnetopause standoff distance, as just one example. The interplanetary electric field drives many magnetospheric dynamical processes and can be compared with general magnetic activity indices and with the occurrence of energetic particle bursts within the Earth's magnetosphere. Such parameters also serve as input to the global magnetohydrodynamic and kinetic magnetosphere models that are used to forecast magnetospheric and ionospheric processes. Such modeling done for

Earth space weather forecasting has helped assess near-real-time magnetospheric behavior for MESSENGER at Mercury (as well as other mission analysis and Mercury ground-based observational campaigns). This solar-wind forcing knowledge has provided a crucial continuing step toward bringing heliospheric science expertise to bear on solar-planetary interaction studies. The experience gained from MESSENGER at Mercury is now being applied to the new observations from the MAVEN (Mars Atmosphere and Volatile Evolution) mission at Mars. We compare the continuous WSA-ENLIL results derived from modeling to the MAVEN SWIA and MAG data from mid-December 2014 to the present time. This provides a broader contextual view of solar wind forcing at Mars and also allows a broader validation of the ENLIL model results throughout the inner heliosphere.
Author(s): Daniel N. Baker[3], R. M. Dewey[3], D. A. Brain[3], Bruce Jakosky[3], Jasper Halekas[4], Jack Connerney[1], Dusan Odstrcil[1], M. Leila Mays[1], Janet Luhmann[2]
Institution(s): *1. NASA, 2. University of California, 3. University of Colorado Boulder, 4. University of Iowa*

305.04 – MAVEN Observations of Flux Transport on the Dayside Martian Magnetosphere

The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission offers a new opportunity to investigate the complex solar wind-planetary interaction at Mars. In this environment, the interplanetary magnetic field (IMF) drapes around the planet's ionosphere and localized crustal magnetic fields to form an induced magnetosphere. The Martian magnetosphere is often described in a steady-state depiction; however, dynamic processes are responsible for the transport of flux throughout the system, as the IMF continually drapes around the ionosphere. One of these processes is magnetic reconnection, a ubiquitous phenomenon in space plasmas that is responsible for the conversion of magnetic energy into kinetic energy. Understanding the occurrence of reconnection, and its ability to remove flux from Mars' dayside magnetosphere, may have implications for particle transport mechanisms leading to atmospheric escape. Here we infer the occurrence of magnetic reconnection on the dayside magnetosphere of Mars using MAVEN's Particles and Fields Package. Magnetic reconnection can occur at any location where a magnetic shear is present and is observed on the dayside Martian magnetosphere in several ways: 1) in the form of a non-zero magnetic field component normal to the obstacle; 2) as magnetic flux ropes formed by reconnection in the draped IMF near the induced magnetopause; and 3) as flux ropes resulting from the detachment of crustal fields. Constraining these characteristics will enhance our understanding of the Mars-solar wind interaction and, more specifically, how plasma and magnetic flux is transported away from the dayside magnetosphere.
Author(s): Gina A DiBraccio[1], Jared Espley[1], D. A. Brain[3], Jack Connerney[1], Jasper Halekas[4], David L. Mitchell[2], James P McFadden[2], Yuki Harada[2], Takuya Hara[2]
Institution(s): *1. NASA GSFC, 2. University of California, Berkeley, 3. University of Colorado, 4. University of Iowa*

305.05 – MAVEN Observations of Escaping Planetary Ions from the Martian Atmosphere: Mass, Velocity, and Spatial Distributions

The Mars-solar wind interaction accelerates and transports planetary ions away from the Martian atmosphere through a number of processes, including 'pick-up' by electromagnetic fields. The MAVEN spacecraft has made routine observations of escaping planetary ions since its arrival at Mars in September 2014. The SupraThermal And Thermal Ion Composition (STATIC) instrument measures the ion energy, mass, and angular spectra. It has detected energetic planetary ions during most of the spacecraft orbits, which are attributed to the pick-up process. We found significant variations in the escaping ion mass and velocity distributions from the STATIC data, which can be explained by factors such as varying solar wind conditions, contributions of particles from different source locations and

different phases during the pick-up process. We also study the spatial distributions of different planetary ion species, which can provide insight into the physics of ion escaping process and enhance our understanding of atmospheric erosion by the solar wind. Our results will be further interpreted within the context of the upstream solar wind conditions measured by the MAVEN Solar Wind Ion Analyzer (SWIA) instrument and the magnetic field environment measured by the Magnetometer (MAG) instrument. Our study shows that the ion spatial distribution in the Mars-Sun-Electric-Field (MSE) coordinate system and the velocity space distribution with respect to the local magnetic field line can be used to distinguish the ions escaping through the polar plume and those through the tail region. The contribution of the polar plume ion escape to the total escape rate will also be discussed.
Author(s): Yaxue Dong[3], Xiaohua Fang[3], D. A. Brain[3], James P McFadden[2], Jasper Halekas[4], Jack Connerney[1]
Institution(s): *1. Goddard Space Flight Center, 2. University of California Berkeley, 3. University of Colorado, 4. University of Iowa*

305.06 – The Solar Energetic Particle experiment on MAVEN: First Results

The Solar Energetic Particle (SEP) instrument arrived at Mars onboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) Mission on September 22, 2014. In order for MAVEN to determine the role that loss of volatiles to space has played through time, solar energy input to the Martian system must be characterized. An important (if infrequent and episodic) portion of this input is in the form of solar energetic particle (SEP) events. Understanding the relationship between SEP events and atmospheric escape is crucial to understanding the climate history of Mars. The SEP instrument characterizes such events at Mars by measuring energetic protons and electrons in the energy range absorbed by the upper atmosphere. Additionally, under certain conditions, SEP directly measures the flux of escaping Oxygen that has been picked up by the Solar Wind and can provide limits on this important escape mechanism [1]. The implications of the model comparison with SEP data for the escape of neutral oxygen from Mars will be discussed. SEP takes much of its heritage from the Solid State Telescope (SST) on the THEMIS mission, consisting of 2 orthogonal dual double-ended solid-state telescopes. Proton spectra from 25 keV to 6 MeV and electron spectra from 25 keV to 1 MeV will be collected in 4 look directions at 3 measurement cadences over MAVEN's 4.5-hour elliptical orbit: 32s far from the planet, 8s between 300 and 800 km altitude and 2s below 300 km. SEP measures particle fluxes from ~20 to ~107 cm-2 s -1 sr-1. We will present results from the first 5 months of the MAVEN science mission.
References: [1] Rahmati A. et al. (2014) GRL 41(14) , 4812-481
Author(s): Davin Larsen[2], **Robert J Lillis[2]**, Ali Rahmati[5], Patrick Dunn[2], Tom Cravens[5], David Curtis[2], Ken Hatch[2], Miles Robinson[2], David Glaser[2], Jasper Halekas[4], Bruce Jakosky[3], Janet Luhmann[2], James P McFadden[2], Jack Connerney[1]
Institution(s): *1. NASA Goddard Space Flight Center, 2. UC Berkeley, 3. University of Colorado, 4. University of Iowa, 5. University of Kansas*

307 – Observing Flares Across the Spectrum

307.01 – The Temporal Behaviour of Lyman-alpha During Solar Flares Using SDO/EVE

The Lyα line of hydrogen at 1216Å is the strongest emission line in the solar spectrum. It is formed in the mid-to-upper chromosphere and is a primary driver of changes in terrestrial ionospheric density. It has also recently been shown to dominate the radiative losses during an X-class solar flare (Milligan et al. 2014). Despite the diagnostic potential of Lyα there are relatively few papers in the literature that

discuss changes in Lyα emission during solar flares. The MEGS-P broadband (100Å) diode on SDO/EVE measures full-disk Lyα emission at 10s cadence making it ideal for studying such variations. Although formed in the chromosphere, the temporal variations in Lyα appear more gradual in nature, with rise times of tens of minutes, compared to just a few minutes in other chromospheric features, such as Hα, He II, Lyman continuum, C III, etc. In fact, in many large events, emission detected by MEGS-P appears to obey the Neupert Effect; i.e. the time derivate of Lyα closely matches that of impulsive chromospheric emission. Here I will discuss a number of conditions, both solar and instrumental, that may explain why this relationship seems to exist. I shall also compare MEGS-P observations with spectrally and temporally resolved Lyα measurements from SORCE/SOLSTICE.
Author(s): Ryan Milligan[1]
Institution(s): *1. Queen's University Belfast*

307.02 – IRIS Observations of the Mg II h & k Lines During a Solar Flare

The bulk of the radiative output of a solar flare is radiated from the chromosphere. We have, until very recently, lacked routine observations of one of the strongest chromospheric lines: the MgII h&k resonance lines. These optically thick lines sample the atmosphere from the upper photosphere to the upper chromosphere and have been shown to be important diagnostics of the atmosphere in the non flaring features (quiet Sun, plage, network, sunspots, and prominences). However, only one flare observation of these lines has been reported (Lemaire et al 1984). With the launch of the IRIS solar telescope we are in a position to routinely observe the MgII h&k lines during flares, and we present a detailed study of the response of these lines to a solar flare. The spatial and temporal behaviour of the integrated intensities, k/h line ratios, line of sight velocities, line widths and line asymmetries were investigated during an M class flare, using a nonparametric quartiles approach. Redshifts of ~20km/s and line broadenings are observed at times of significant intensity enhancements, at the outer edge of the flare ribbons. The lines show blue asymmetry in only the most intense sources. Interestingly the characteristic central reversal feature that is ubiquitous in quiet Sun observations is absent in flaring profiles. Subordinate lines in the MgII passband are observed to be in emission within flaring sources, brightening and cooling in sync with the resonance lines. Additionally, we present the results of initial experiments with advanced numerical models to aid in the physical interpretation of these observed properties. This was achieved using the radiation hydrodynamic code RADYN that simulates the response of the solar atmosphere to flare energy input (we used a range of beam parameters to investigate energy injection to the atmosphere). RADYN provides both the hydrodynamic response of the atmosphere and the radiative response in energetically important lines and continua. The hydrodynamic output from RADYN was used as input to the radiative transfer code RH that solves the MgII resonance lines using partial redistributon.
Author(s): Graham Stewart Kerr[2], Paulo J. A Simões[2], Jiong Qiu[1], Lyndsay Fletcher[2]
Institution(s): *1. Montana State University, 2. University of Glasgow*

307.03 – Energy partitions and evolution in a purely thermal solar flare

A conventional way of producing a hot plasma in the flaring loops is via the impact of the nonthermal particles accelerated in flares due to release of the excessive magnetic energy, which has come to be known as the Neupert effect. We know, however, that in many events the heating starts clearly before the particle acceleration, which implies that no accelerated particles may be required for this heating. To this end, we present here a flare whose microwave emission is consistent with a purely thermal distribution of electrons, based on the gyro- and free-free emission it produced. An advantage of analyzing thermal gyro emission is its unique ability to precisely yield the magnetic field in the radiating

volume. When combined with observationally-deduced plasma density and temperature, these magnetic field measurements offer a straightforward way of tracking evolution of the magnetic and thermal energies in the flare. For the event described here, the magnetic energy density in the radio-emitting volume declines over the flare rise phase, then stays roughly constant during the extended peak phase, but recovers to the original level over the decay phase. At the stage where the magnetic energy density decreases, the thermal energy density increases; however, this increase is insufficient, by roughly an order of magnitude, to compensate for the magnetic energy decrease. We conclude that the apparent decrease of the magnetic field in the radio source over the rise phase of the flare requires an upward propagating magnetic reconnection/plasma heating process, such as in the standard flare scenario, but with one remarkable difference: the absence of any significant nonthermal electron generation. We expect that the study of these rare thermal flares will better clarify the origin of such purely thermal events, characterized by significant energy release observed through the plasma heating, but without any measurable acceleration of the charged particles.
This work was partially supported by NSF grants AGS-1250374 and AGS-1262772, and NASA grant NNX14AC87G.
Author(s): Gregory Fleishman[1], Gelu M Nita[1], Dale E. Gary[1]
Institution(s): *1. NJIT*

307.04 – Infrared Flare Observations at 5 and 10 Microns

New observations from the McMath-Pierce Solar Facility at Kitt Peak have been made showing infrared continuum emission in solar flares. Using a NASA/GSFC two-color Quantum Well Infrared Photodetector array, observations of several flares have been made in continuum channels centered near 5 and 10 microns. The evolution of the continuum emission in time, and the spatial changes seen in the flares will be presented, as well as an analysis of the ratio of the emission observed and the applications to models of the lower atmosphere of solar flares.
Author(s): Matt Penn[2], Donald Jennings[1], Murzy Jhabvala[1], Allen Lunsford[1]
Institution(s): *1. NASA/GSFC, 2. National Solar Observatory*

307.05 – Numerical and Observational Examination of the Spectral Variation of Extended Coronal Hard X-Ray Sources

The presence of extended coronal hard X-ray sources, for example the 2005 Aug 23 flare, has opened up opportunities for probing the electrons accelerated by solar flares. The loop morphology of the source enables, through the use of RHESSI imaging spectroscopy, detailed analysis of changes in the electron flux spectrum along the spatial extent of the emission. We present a realistic one-dimensional model of the corona subject to coulomb collisions and localised stochastic acceleration akin to a looptop acceleration region. Both ballistic and diffusive transport are examined and the variation of the density weighted mean electron flux, $\langle nVF \rangle$, along our numerical loop will be compared with RHESSI observations to determine the dominant processes in the corona. We will also comment on the validity of the leaky-box Fokker-Planck approximation.
Author(s): Duncan James Stackhouse[1], Eduard Kontar[1]
Institution(s): *1. University of Glasgow*

307.06 – Initial Observations of Solar Bursts with the Expanded Owens Valley Solar Array

The Expanded Owens Valley Solar Array (EOVSA) is a newly expanded and upgraded, solar-dedicated radio array consisting of 13 antennas equipped with receivers designed to cover the 1-18 GHz frequency range. Beginning in the fall of 2014, it began taking data on four antennas in total power mode, and observed a number of solar flares ranging from the X3.1 flare of 2014 Oct 24 to small events of low C-class, with 1-s time resolution at more than 300 frequencies in the range 2.5-18 GHz. The array is now (Feb. 2015) operating with 8 antennas in both total power and interferometry mode, and is rapidly being commissioned for full operation with all 13 antennas. Here we present some initial observations with the array, emphasizing the remarkable temporal and spectral resolution of the instrument, together with joint RHESSI hard X-ray and SDO EUV observations.
Author(s): Dale E. Gary[2], Natsuha Kuroda[2], Gregory Fleishman[2], Gelu M Nita[2], Stephen White[1], Gordon Hurford[3], James McTiernan[3]
Institution(s): *1. AFRL, 2. New Jersey Institute of Technology, 3. UC/Berkeley*

308 – Solar Cycle and Shorter-Duration Variations and Their Consequences in the Heliosphere

308.01 – North south asymmetry in the photospheric and coronal magnetic fields observed by different instruments

Several recent studies have shown that the solar and heliospheric magnetic fields are north-south asymmetric. The southward shift of the Heliospheric current sheet (HCS) (the so-called bashful ballerina phenomenon) is a persistent pattern, which occurs typically for about three years during the late declining phase of solar cycle. We study here the hemispherical asymmetry in the photospheric and coronal magnetic fields using Wilcox Solar Observatory (WSO), Mount Wilson, Kitt Peak, Solis, SOHO/MDI and SDO/HMI measurements of the photospheric magnetic field since the 1970s and the potential field source surface (PFSS) model.
Multipole analysis of the photospheric magnetic field has shown that the bashful ballerina phenomenon is a consequence of g_2^0 quadrupole term, which is oppositely signed to the dipole moment. We find that, at least during the four recent solar cycles, the g_2^0 reflects the larger magnitude of the southern polar field during a few years in the declining phase of the cycle. Although the overall magnetic activity during the full solar cycle is not very different in the two hemispheres, the temporal distribution of activity is different, contributing to the asymmetry. The used data sets are in general in a good agreement with each other, but there are some significant deviations, especially in WSO data. Also, the data from Kitt Peak 512 channel magnetograph is known to suffer from zero level errors.
We also note that the lowest harmonic coefficients do not scale with the overall magnitude in photospheric synoptic magnetic maps. Scaling factors based on histogram techniques can be as large as 10 (from Wilcox to HMI), but the corresponding difference in dipole strength is typically less than two. This is because the polar field has a dominant contribution to the dipole and quadrupole components. This should be noted, e.g., when using synoptic maps as input for coronal models.
Author(s): Ilpo Virtanen[1], Kalevi Mursula[1]
Institution(s): *1. University of Oulu*

308.02 – Trends Of The Void: Solar Cycles Observed Through Polar Coronal Holes

Coronal holes are defined by their open magnetic field configuration and lack of emitting plasma. Holes that cap the northern and southern solar poles are the longest-lived features observed on the Sun – persisting for nearly an entire solar cycle. Polar holes disappear briefly at solar maximum for about a

year before returning. The size and evolution of the polar holes are also strongly anti-correlated with the solar activity cycle. Their longevity combined with this solar activity relationship makes polar coronal holes an ideal proxy for measuring the long-term evolution of the solar magnetic field. We use a perimeter tracking technique to measure the size and location of the polar coronal holes for 19 years starting in 1996. Utilizing the SOHO EIT archive and current SDO AIA images, we present a comprehensive look at how polar coronal holes evolve and what they can tell us about our current and unusual solar cycle.
Author(s): Michael S Kirk[2], Shea Hess Webber[1], W. Dean Pesnell[2]
Institution(s): *1. George Mason University, 2. NASA Goddard Space Flight Center*

308.03 – The Minimum of Solar Cycle 23: As Deep as It Could Be?

After a lull lasting more than 60 years of seemly uniform solar minima, the solar minimum of solar cycle 23 came as a great surprise due to its depth, duration, and record lows in a wide variety of solar activity indices and solar wind properties. One of the consequence of such an event is the revival of the interest in extreme minima, grand minima, and the identification of a solar basal state of minimum magnetic activity.
In this presentation we will discuss a new way of binning sunspot group data, with the purpose of better understanding the impact of the solar cycle on sunspot properties, and how this defined the characteristics of the extended minimum of cycle 23. Our main result is centered around the fact that the sunspot size distribution is composed of two populations, a population of groups and active regions, and second of pores and ephemeral regions. We find that only the properties of the former population, the active regions, is found to vary with the solar cycle, while the propeties of pores and ephemeral regions does not.
Taking advantage of our statistical characterization we probe the question of the solar baseline magnetism. We find that, when hemispheres are treated separately, almost every one of the past 12 solar minima reaches such a point. However, due to asymmetries in cycle phase, the basal state is very rarely reached by both hemispheres at the same time. From this we infer that, even though each hemisphere did reach the magnetic baseline, from a heliospheric point of view the minimum of cycle 23 was not as deep as it could have been.
Author(s): Andres Munoz-Jaramillo[4], Ryan Senkpeil[6], Dana Longcope[4], Andrey Tlatov[3], Alexei A. Pevtsov[5], Laura Balmaceda[2], Edward E. DeLuca[7], Petrus C Martens[1]
Institution(s): *1. Georgia State University, 2. Institute for Astronomical, Terrestrial and Space Sciences (ICATE-CONICET), 3. Kislovodsk Mountain Astronomical Station of the Pulkovo Observatory, 4. Montana State University, 5. National Solar Observatory, 6. Purdue University, 7. Smithsonian Astrophysical Observatory*

308.04 – Solar Cycle 24 up to Now: Flying Over Peaks and Through Streams

Solar Cycle 24 has been a below-average sunspot cycle. There were peaks in the daily and monthly-averaged sunspot number in the Northern hemisphere in 2011 and in the Southern hemisphere in 2014. Now that sunspot activity appears to be on the decline, another part of the solar cycle becomes important. Energetic events from high-speed streams flowing from the Sun can produce crippling radiation storms in the magnetosphere. Predicting those events that will affect our assets in space requires a different kind of solar prediction and some idea of how the radiation will propagate through the solar system. With the rapid increase in solar data and capability of numerical models of the solar convection zone we are developing the ability to forecast the level of the next solar cycle. But no prediction based only on sunspot number will be usable for predicting the variation of the decline of a sunspot cycle. I will describe the status of Solar Cycle 24, our need for solar activity predictions at all phases of the solar cycle, and anticipate how those predictions could be made more accurate in the future.

Author(s): W. Dean Pesnell[1]
Institution(s): *1. Goddard Space Flight Center*

308.05 – Fe XIV Synoptic Observations as a Predictor for the Time of Solar Maximum in Cycle 24

In 2012 (Am. Geophys. Union Fall Meeting, Abstract SH12A-05) and 2013 (*Solar Phys*. Online First, DOI 10.1007/s11207-012-0216-1) Altrock discussed the status of Cycle 24 relative to synoptic observations of
Fe XIV from Sacramento Peak (http://nsosp.nso.edu/corona). He found that using earlier cycles, in which solar maximum occurred when Fe XIV emission features associated with the classic "Rush to the Poles" reached latitudes 76 ± 2 degrees, the *northern hemisphere* Fe XIV features predicted a maximum in the north at 2011.6 ± 0.3. This was confirmed by hemispheric sunspot numbers from SIDC (http://www.sidc.be/silso/) and sunspot areas from NASA MSFC http://solarscience.msfc.nasa.gov/greenwch.shtml). The earlier papers
also noted that southern high-latitude Fe XIV emission indicated the possibility of a southern maximum early in 2014. At low latitudes, earlier cycles reached solar maximum when Fe XIV emission features reached latitudes 20 ± 1.7 degrees. In 2013, these features were at 21 and 15 degrees in the north, again indicating that northern maximum had already occurred. In the south, the Fe XIV features were at 24 degrees. Gopalswamy et al. (2012, *Ap. J. Let*. **750**:L42) come to similar conclusions from a study of microwave brightness and prominence eruptions. This paper will extend the previous studies up to 2014 to include the recent extraordinary surge of activity in the southern hemisphere. In particular we will examine in more detail the relationship between hemispheric Fe XIV emission features and both global and hemispheric sunspot numbers to see (i) if the previous studies correctly predicted the times of hemispheric solar maxima and (ii) what we can learn from the inclusion of two more years of data. The observations used herein are the result of a cooperative program of the Air Force Research Laboratory and the National Solar Observatory.

Author(s): Richard Altrock[1]
Institution(s): *1. Air Force Research Laboratory*

308.06 – The Quasi-Annual Forcing of The Sun's Eruptive, Radiative, and Particulate Output: Pervasive Throughout The Heliosphere

The eruptive, radiative, and particulate output of the Sun are modulated by our star's enigmatic 11-year sunspot cycle. Over the past year we have identified observational signatures which illustrate the ebb and flow of the 11-year cycle – arising from the temporal overlap of migrating activity bands which belong to the 22-year magnetic activity cycle. (At the 2012 Fall AGU Meeting, Leamon & McIntosh presented a prediction of minimum conditions developing in 2017 and Cycle 25 sunspots first appearing in late 2019.) As a consequence of this work we have deduced that the latitudinal interaction of the oppositely signed magnetic activity bands in each hemisphere (and across the equator near solar minimum) dramatically impacts the production of Space Weather events such as flares and Coronal Mass Ejections (CMEs). The same set of observations also permits us to identify a quasi-annual variability in the rotating convecting system which results in a significant local modulation of solar surface magnetism. That modulation, in turn, forces prolonged periods of significantly increased flare and CME production, as well as significant changes in the Sun's ultraviolet (UV), extreme ultraviolet (EUV), and X-Ray irradiance. These fluctuations manifest themselves throughout the Heliosphere

(throughout Heliophysics) and can be inferred in variations of such wide-ranging phenomena as the South Atlantic Anomaly, the thermosphere, the radiation belts, and the can address "Has Voyager left the Heliosphere?"
Author(s): Robert J Leamon[1], Scott W McIntosh[2]
Institution(s): *1. Montana State University, 2. NCAR/HAO*

309 – Image Processing, Computing & Data Management PLUS Instrumentation I

309.01 – The CoMP Instrument and Data Processing

We present an overview of the Coronal Multichannel Polarimeter (CoMP) coronagraph instrument, which observes infrared lines sensitive to the magnetic field in the solar corona. The overview covers the general properties of the instrument, its sensitivity to solar phenomena of interest, and sources of error and uncertainty in its data. We also show some updated results and processing of the data, which include improved coalignment and updated calibration (flat-fielding, dark subtraction, and polarization cross-talk). The ultimate goal of this processing is more clearly resolving the linear polarization signal (especially of the weaker 10798 Angstrom line) in the data and eventually resolving the Stokes V signal as well.
Author(s): Joseph E Plowman[1], Giuliana de Toma[1], Steven Tomczyk[1]
Institution(s): *1. High Altitude Observatory*

309.02 – Description and primary results of Total Solar Irradiance Monitor, a solar-pointing instrument on an Earth observing satellite

Solar driving mechanism for Earth climate has been a controversial problem for centuries. Long-time data of solar activity is required by the investigations of the solar driving mechanism, such as Total Solar Irradiance (TSI) record. Three Total Solar Irradiance Monitors (TSIM) have been developed by Changchun Institute of Optics, Fine Mechanics and Physics for China Meteorological Administration to maintain continuities of TSI data series which lasted for nearly 4 decades.
The newest TSIM has recorded TSI daily with accurate solar pointing on the FY-3C meteorological satellite since Oct 2013. TSIM/FY-3C has a pointing system for automatic solar tracking, onboard the satellite designed mainly for Earth observing. Most payloads of FY-3C are developed for observation of land, ocean and atmosphere. Consequently, the FY-3C satellite is a nadir-pointing spacecraft with its z axis to be pointed at the center of the Earth. Previous TSIMs onboard the FY-3A and FY-3B satellites had no pointing system, solar observations were only performed when the sun swept through field-of-view of the instruments. And TSI measurements are influenced inevitably by the solar pointing errors. Corrections of the solar pointing errors were complex. The problem is now removed by TSIM/FY-3C. TSIM/FY-3C follows the sun accurately by itself using its pointing system based on scheme of visual servo control. The pointing system is consisted of a radiometer package, two motors for solar tracking, a sun sensor and etc. TSIM/FY-3C has made daily observations of TSI for more than one year, with nearly zero solar pointing errors. Short time-scale variations in TSI detected by TSIM/FY-3C are nearly the same with VIRGO/SOHO and TIM/SORCE.
Instrument details, primary results of solar pointing control, solar observations and etc will be given in the presentation.
Author(s): Hongrui Wang[1], Wei Fang[2], Huiduan Li[3]

Institution(s): *1. Changchun Institute of Optics, Fine Mechanics and Physics, 2. Changchun Institute of Optics,Fine Mechanies and Physics, 3. Chuxiong Normal University*

309.03 – Upcoming long-duration balloon flight of the Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS)

We present the status of preparations for the upcoming Antarctic long-duration balloon flight of the balloon-borne Gamma-Ray Imager/Polarimeter for Solar flares (GRIPS) instrument in December 2015. GRIPS will provide a near-optimal combination of high-resolution imaging, spectroscopy, and polarimetry of solar-flare gamma-ray/hard X-ray emissions from ~20 keV to >~10 MeV. GRIPS will address questions raised by recent solar flare observations regarding particle acceleration and energy release, such as: What causes the spatial separation between energetic electrons producing hard X-rays and energetic ions producing gamma-ray lines? How anisotropic are the relativistic electrons, and why can they dominate in the corona? How do the compositions of accelerated and ambient material vary with space and time, and why? The spectrometer/polarimeter consists of sixteen 3D position-sensitive germanium detectors (3D-GeDs), where each energy deposition is individually recorded with an energy resolution of a few keV FWHM and a spatial resolution of $<0.1\ mm^3$. Imaging is accomplished by a single multi-pitch rotating modulator (MPRM), a 2.5-cm thick tungsten-alloy slit/slat grid with pitches that range quasi-continuously from 1 to 13 mm. The MPRM is situated 8 meters from the spectrometer to provide excellent image quality and unparalleled angular resolution at gamma-ray energies (12.5 arcsec FWHM), sufficient to separate 2.2 MeV footpoint sources for almost all flares. Polarimetry is accomplished by analyzing the anisotropy of reconstructed Compton scattering in the 3D-GeDs (i.e., as an active scatterer), with an estimated minimum detectable polarization of a few percent at 150-650 keV in an X-class flare.
Author(s): Albert Y. Shih[4], Pascal Saint Hilaire[5], Nicole A. Duncan[5], Gordon J. Hurford[1], Hazel Bain[5], Bennett A. Maruca[5], Steven E. Boggs[5], Andreas C. Zoglauer[5], David Smith[6], Hiroyasu Tajima[3], Mark S. Amman[2]
Institution(s): *1. FHNW, 2. LBNL, 3. Nagoya University, 4. NASA/GSFC, 5. SSL/UC Berkeley, 6. UC Santa Cruz*

309.04 – SDO/HMI – RHESSI White-Light Flare Catalog: First Results

In recent years several observation of white-light flare features in the low corona using data from the Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory have been reported. We present the first results of a white-light flare catalog based on SDO/HMI 6173A Intensity observations and the RHESSI flare catalog. We selected flares during 2011 and 2012 with GOES classification above M1.0 that were fully or partially observed by RHESSI as reported in the RHESSI flare catalog. We found that at least one third of the flares present white-light enhancement in the 6173A line and at least one fifth of the events show above the limb white-light sources. We will also discuss the physical implications of these observations.
Author(s): Juan Carlos Martinez Oliveros[1], Hugh Hudson[1], Pascal Saint Hilaire[1]
Institution(s): *1. Space Sciences Laboratory, UC Berkeley*

309.05 – Data Realities : Citation Equals Funding

Solar physics has a problem with tracking the impact of solar data's use in scientific literature. Data collected by solar-observing missions is used in many other fields, but we do not have good information about who is using our data. Solar data is useful not only in solar physics, but also general astronomy,

planetery, space weather, space physics and earth science.
The sun is the only star that we can see in high detail; solar data is used to erase moonlight from night-time images; coronagraphs have found more comets than night-observing telescopes; space weather affects life on earth, communications, air traffic, and manned space-flight.
As our missions' continued funding is justified through use of our data, missing too many of these uses could decrease our future funding or lead to cancellation. As our current methods of finding data use is through human review of the literature, we are much more likely to miss usage in fields outside of solar physics.
To better deal with tracking cross-discipline data usage, a number of groups have come up with guidelines and principles for data citation.[1,2,3] We provide an update on the efforts of multiple groups working on standards to implement both data and software citation.
[1] National Research Council, 2012. http://www.nap.edu/catalog.php?record_id=13564
[2] CODATA, 2013. http://dx.doi.org/10.2481/dsj.OSOM13-043
[3] 2014. http://www.force11.org/datacitation
Author(s): Joseph Hourclé[1]
Institution(s): *1. NASA/GSFC*

310 – Heliosphere Posters

310.01 – Forthcoming Coronal Mass Ejection Observations with the Very Large Array (VLA)

It is widely recognized that measurement of Faraday rotation through a coronal mass ejection (CME) provides unique information on the internal plasma structure of the CME, particularly the form of the magnetic field. The Faraday rotation measure is proportional to the path integral through the CME of the electron density and the line-of-sight component of the magnetic field. In spite of this importance, there are relatively few measurements of Faraday rotation produced by a CME. The Very Large Array (VLA) of the National Radio Astronomy Observatory is an outstanding instrument for measurement of Faraday rotation, and its capabilities have been greatly improved by an upgrade over the past decade. In the case of VLA observations, the trans-coronal sources of radio waves are radio galaxies and quasars. A difficulty in measuring Faraday rotation of a CME is the unpredictability of the CME phenomenon. It is difficult to predict whether a given line of sight to a background source will be occulted by a CME on a given day. We have received approval to carry out ``triggered'' CME observations with the VLA in the summer of 2015. In these observations, we will rely on coronagraph detections of a CME to initiate VLA observations of select background sources. This observing mode will improve on one previously used, in which a decision to observe had to be made a day or more in advance. The goal of these observations will be to secure Faraday rotation measurements on one or more lines of sight that pass through critical parts of a CME. In this paper, we will describe our planned triggering scheme, the selection of background sources, choice of observing frequency and selection of lines of sight that can best determine the plasma structure of a CME. Our planning also depends on prior experience in measurement of coronal Faraday rotation, and Faraday rotation ``transients'' associated with CMEs. This work was supported at the University of Iowa by grant ATM09-56901 from the National Science Foundation.
Author(s): Steven R Spangler[1], Jason E Kooi[1], Joseph R Sink[1]
Institution(s): *1. University of Iowa*

310.02 – Radial and Azimuthal Oscillations in Halo Coronal Mass Ejections

We present the first observational detection of radial and azimuthal oscillations in full halo coronal mass ejections (HCMEs). We analyse nine HCMEs well-observed by the Large Angle and Spectrometric Coronagraph (LASCO) from February to June, 2011. Using the LASCO C3 running difference images, we estimated the instantaneous apparent speeds of the HCMEs in different radial directions from the solar disk centre. We find that the development of all these HCMEs is accompanied with quasi-periodic variations of the instantaneous radial velocity with the periods ranging from 24 to 48 minutes. The amplitudes of the instant speed variations reach about a half of the projected speeds. The amplitudes are found to anti-correlate with the periods and correlate with the HCME speed, indicating the nonlinear nature of the process. The oscillations have a clear azimuthal structure in the heliocentric polar coordinate system. The oscillations in seven events are found to be associated with distinct azimuthal wave modes with the azimuthal wave number m=1 for six events and m=2 for one event. The polarisation of the oscillations in these seven HCMEs is broadly consistent with those of their position angles with the mean difference of 42.5 degree. The oscillations may be connected with natural oscillations of the plasmoids around a dynamical equilibrium, or self-oscillatory processes, e.g. the periodic shedding of Alfv\'enic vortices. Our results indicate the need for advanced theory of oscillatory processes in CMEs.
Author(s): Harim Lee[1], Yong-Jae Moon[1], Valery Nakariakov[2]
Institution(s): *1. Kyung Hee University, 2. University of Warwick*

310.03 – Development of a full ice-cream cone model for halo CME structures

The determination of three dimensional parameters (e.g., radial speed, angular width, source location) of Coronal Mass Ejections (CMEs) is very important for space weather forecast. To estimate these parameters, several cone models based on a flat cone or a shallow ice-cream cone with spherical front have been suggested. In this study, we investigate which cone model is proper for halo CME morphology using 33 CMEs which are identified as halo CMEs by one spacecraft (SOHO or STEREO-A or B) and as limb CMEs by the other ones. From geometrical parameters of these CMEs such as their front curvature, we find that near full ice-cream cone CMEs (28 events) are dominant over shallow ice-cream cone CMEs (5 events). So we develop a new full ice-cream cone model by assuming that a full ice-cream cone consists of many flat cones with different heights and angular widths. This model is carried out by the following steps: (1) construct a cone for given height and angular width, (2) project the cone onto the sky plane, (3) select points comprising the outer boundary, (4) minimize the difference between the estimated projection points with the observed ones. We apply this model to several halo CMEs and compare the results with those from other methods such as a Graduated Cylindrical Shell model and a geometrical triangulation method.
Author(s): Hyeonock Na[1], Yong-Jae Moon[1]
Institution(s): *1. Kyung Hee University*

310.04 – Global MHD modeling of an ICME focused on the physics involved in an ICME interacting with a solar wind

We developed a three-dimensional (3D) magnetohydrodynamic (MHD) code to investigate the structure of a solar wind, the properties of a coronal mass ejection (CME) and the interaction between them. This MHD code is based on the finite volume method incorporating total variation diminishing (TVD) scheme with an unstructured grid system. In particular, this grid system can avoid the singularity at the north and south poles and relax tight CFL conditions around the poles, both of which would arise in a spherical coordinate system (Tanaka 1994). In this model, we first apply an MHD tomographic method (Hayashi et al. 2003) to interplanetary scintillation (IPS) observational data and derive a solar wind from the physical

values obtained at 50 solar radii away from the Sun. By comparing the properties of this solar wind to observational data obtained near the Earth orbit, we confirmed that our model captures the velocity, temperature and density profiles of a solar wind near the Earth orbit. We then insert a spheromak-type CME (Kataoka et al. 2009) into the solar wind to reproduce an actual CME event occurred on 29 September 2013. This has been done by introducing a time-dependent boundary condition to the inner boundary of our simulation domain (50rs < r < 300rs). On the basis of a comparison between the properties of a simulated CME and observations near the Earth, we discuss the physics involved in an ICME interacting with a solar wind.
Author(s): Jun-Mo An[2], Tetsuya Magara[2], Satoshi Inoue[4], Keiji Hayashi[1], Takashi Tanaka[3]
Institution(s): *1. Chinese Academy of Sciences, 2. Kyung Hee University, 3. Kyushu University, 4. Nagoya University*

310.05 – Time-dependent modeling of solar wind acceleration from turbulent heating in open flux tubes

The acceleration of the solar wind, particularly from open flux tubes, remains an open question in solar physics. Countless physical processes have been suggested to explain all or parts of the coupled problem of coronal heating and wind acceleration, but the current generation of observations have been so far unable to distinguish which mechanism(s) dominates. In this project, we consider heating by Alfvén waves in a three-dimensional, time-dependent reduced magnetohydrodynamics model. This model solves for the heating rate as a function of time due to the twisting and braiding of magnetic field lines within a flux tube, which is caused by Alfvén waves generated at the single footpoint of the flux tube. We investigate three specific structures commonly found in the corona: 1) an open flux tube in a coronal hole, 2) an open flux tube on the edge of an equatorial streamer, and 3) an open flux tube directly neighboring an active region. We present the time-dependent heating rate, power spectra of fluctuations, and the time-averaged properties of the solar wind arising from each magnetic structure. We compare the time-averaged properties from the present modeling with previous results from a one-dimensional, time-steady code (Cranmer et al. 2007) to better calibrate the physics in the lower-dimensional code and get a better understanding of the intricate role that bursty, transient heating from Alfvén-wave-driven turbulence plays in the acceleration of the solar wind from different magnetic structures.
Author(s): Lauren Nicole Woolsey[1], Steven R. Cranmer[2]
Institution(s): *1. Harvard University, 2. University of Colorado*

310.06 – Case Studies of Extreme Solar Wind in the Current Solar Cycle

We examine solar wind ion characteristics and solar origins for typical and extreme solar wind speed cases, utilizing near-Earth (OMNI) and STEREO data. Sources of the solar wind are known to be linked to the phase of the solar cycle and include coronal holes, coronal mass ejections, and multiple cycle-dependent sources for the so-called “slow” solar wind. This past solar minimum was characterized by weak transients and sustained periods of slow solar wind, and included cases of “slow” and “slower” solar wind stream interactions. In contrast, intervals around solar maximum have included extremely fast interplanetary coronal mass ejections, with one such ICME observed in situ by STEREO A exceeding 2000 km/s at 1 AU. We will compare extreme cases of slow and fast solar wind observed in situ by STEREO to general solar wind ion parameters, particularly for proton and iron ions.
Author(s): Antoinette Galvin[2], Kristin Simunac[1]
Institution(s): *1. St. Petersburg College, 2. University of New Hampshire*

310.07 – Solar and heliospheric signatures of an unusual jet event on 20 November 2012

We describe the solar and heliospheric signatures of an unusual jet event seen on the Sun on 20 November 2012. The jet itself is formed very suddenly in a piece of apparently quiet Sun distant from large opposite polarity sources such as active regions. The jet event is associated with a low energy (6-12 keV) flare observed by RHESSI. Higher hard x-ray energies are not observed, indicating only low energy electrons were produced. Several hours later, a dispersive helium-3 rich event is seen in ACE/ULEIS data, which is not associated with electron-SEPs or a Type III radio burst. High resolution ACE/ULEIS ion data suggest an onset time close to the time of the jet. We discuss the heliospheric connectivity of this event using data from STEREO, ACE, WIND and estimates of the open magnetic flux arising from the solar surface around the jet. Although this event is studied in detail, we have found five other similar events in the data, and we discuss these briefly.
Author(s): Jack Ireland[1], Georgia de Nolfo[2], James Michael Ryan[3]
Institution(s): *1. ADNET Systems, Inc / NASA GSFC, 2. NASA GSFC, 3. University of New Hampshire*

310.08 – Determining Coronal Magnetic Field Connections for Sources of Solar Energetic Particle Events

The transport of solar energetic (E > 10 MeV) particles (SEPs) from their solar sources to 1 AU is governed by the topology of the heliospheric magnetic fields connecting the two regions. The standard means of determining the coronal source for an SEP event is to assume a Parker spiral field connection to the source region through a model potential field source surface (PFSS). Using a solar wind forecast model such as the Wang-Sheeley-Arge (WSA) model, which includes interplanetary wind dynamics, together with a 1 AU spacecraft observational validation should provide a significant improvement over the spiral field approximation. The actual SEP source regions are unknown, but we can test the variance of the WSA source regions calculated in different model realizations for a given SEP event. The variance may be of little importance if the SEPs are injected at high coronal sources, but it may be crucial if the sources lie in the low corona and the source region squashing factor Q is high. To explore these factors we selected 12 SEP events for which coronal magnetic source regions were identified with the standard Parker spiral and PFSS model. We then ran WSA using different realizations of the global magnetic field input maps generated by the Air Force Data Assimilative Photospheric Flux Transport (ADAPT) model to see how the calculated source regions differed among the realizations and in contrast to the simple Parker/PFSS source regions. The WSA model results were tested with 1 AU solar wind data and compared with the background solar wind types as an additional validation factor. Various effects such as field-line meandering and the presence of closed or disconnected fields are briefly considered in the context of attempts to establish the coronal field connections.
Author(s): Stephen Kahler[1], Nick Arge[1], Carl Henney[1]
Institution(s): *1. Air Force Research Laboratory*

310.09 – Solar and Galactic Cosmic Rays Observed by SOHO

Both the Cosmic Ray Flux (CRF) and Solar Energetic Particles (SEPs) have left an imprint on SOHO technical systems. While the solar array efficiency degraded irreversibly down to 75% of its original level over 1 ½ solar cycles, Single Event Upsets (SEUs) in the solid state recorder (SSR) have been reversed by the memory protection mechanism. We compare the daily CRF observed by the Oulu station with the daily SOHO SEU rate and with the degradation curve of the solar arrays. The Oulu CRF and the SOHO SSR SEU rate are both modulated by the solar cycle and are highly correlated, except for sharp spikes in the SEU rate, caused by isolated SEP events, which also show up as discontinuities in the otherwise slowly

decreasing solar ray efficiency. This allows to discriminate between effects with solar and non-solar origin and to compare the relative strength of both. We find that the total number of SSR SEUs with solar origin over the 17 ½ years from January 1996 through June 2013 is of the same order as those generated by cosmic ray hits. 49% of the total solar array degradation during that time can be attributed to proton events, i.e. the effect of a series of short-lived, violent events (SEPs) is comparable to the cycle-integrated damage by cosmic rays.
Author(s): Bernhard Fleck[2], Werner Curdt[3], Jean-Philippe Olive[1], Ton van Overbeek[2]
Institution(s): *1. Airbus Defence & Space , 2. ESA, 3. MPS*

310.10 – Voyager Observations in the Distant Heliosheath – an Analogy With ISEE-3 Observations in the Deep Geomagnetic Tail

We suggest an analogy between energetic particle and magnetic field observations made by the Voyager 1 spacecraft in the distant heliosheath at 122 AU in August 2012 and those made in the distant geomagnetic tail by the Energetic Particle Anisotropy Spectrometer (EPAS) on the ISEE 3 spacecraft in 1982-1983, including remarkable similarities in the behavior of the energetic particle intensities and anisotropies despite large differences in the time and distance scales.
The analogy suggests that Voyager 1 may have moved not into the interstellar medium from heliosheath but instead into a region equivalent to the "lobes" of the geomagnetic tail. This region may be composed of heliospheric field lines which have reconnected with the interstellar medium beyond the spacecraft and so are open to the entry of cosmic rays, while heliospheric particles (e.g., Anomalous Cosmic Rays) are free to escape, leaving only a weak population of large pitch-angle ACRs with "pancake" distributions similar to those also seen by ISEE 3 in the lobes of the tail. If this is the case, the actual heliopause (equivalent to the magnetopause), where the ambient interstellar medium is entered, lies beyond the current distance of Voyager 1.
Temporary variations in the energetic particle and magnetic field intensities at Voyager over a period of around 27 days prior to the final boundary crossing are interpreted as the boundary twice approaching Voyager 1 and then retreating Sunward before the final crossing occurred. Similar features were frequently observed in the deep tail due to tail dynamics and "flapping" in the solar wind. The 27 day interval suggests that rotation of the heliosphere may have contributed to this boundary motion. Energetic particles in the tail are accelerated by reconnection in the plasma sheet which can lead to the formation of plasmoids. Both are elements of some recent models of the heliopause.
Author(s): Ian Richardson[1]
Institution(s): *1. University of Maryland*

311 – Space Weather III

311.01 – A Phase Diagram for Solar Flares

Using the data from the NOAA/GOES X-ray observations of ~50,000 flares, we develop a Phase Diagram for solar flares. Such a Solar Flare Phase Diagram helps to trace the underlying energy structure of solar flares, and provides a prediction framework. The temperature (maximum ratio of short (0.5 – 4 A) to long band (1-8 A) band) and background solar x-ray radiation (at 1-8 A band) forms the basis of the phase diagram. Using the phase diagram and relevant statistical analysis, we derive insights into the eruptive nature of flares during the solar-cycle ramp (ramp up to and ramp down from solar maximum) phases and peak phase of the solar cycle.

Author(s): K S Balasubramaniam[2], Lisa Winter[1], Rick Pernak[1]
Institution(s): *1. AER, 2. USAF*

311.02 – Forecasting flares and Coronal Mass Ejections by the evolution of Active Regions

We present newly discovered pre-flare behaviour of the evolution of sunspot groups by analysing the SOHO/MDI-Debrecen Data (SDD) catalogue. Our method employes the horizontal gradient of magnetic field (G_M) defined between two spots with opposite polarities at the polarity inversion line of ARs. The G_M is a n excellent proxy measure of magnetic non-potentiality at the photosphere, derived from the observed line-of-sight component of the magnetic field. The value and temporal variation of this proxy is found to possess important diagnostic information about the intensity of expected flares.

Next, we address the benefits of introducing the generalisation of this proxy, i.e. the weighted horizontal magnetic gradient, WG_M. This new approach does not limit anymore the analysis to two spots having the largest horizontal magnetic gradient value. Instead, all spots are now taken into account within an appropriately defined small region in the AR.

This new tool greatly enhances the capability of forecast, including (i) the accuracy of onset time prediction, (ii) CME risk assessment, (iii) whether a flare, stronger than M5 in terms of the GOES classification, is followed by another event within 18 hours. We argue that our method is currently one of the bests to forecast these eruptive events. Finally, we discuss the limitations of our approach and propose how to potentially mitigate these shortcomings.
Author(s): Marianna Brigitta Korsos[1]
Institution(s): *1. University of Sheffield*

311.03 – Solar Flare Forecasting Using Time Series of SDO/HMI Vector Magnetic Field Data and Machine Learning Methods

This project is motivated by the need to understand the physical mechanisms that generate solar flares, and assess whether reliable data-driven flare forecasts are possible. We build a flare forecasting model that takes into account the temporal evolution of the active regions and provides improved forecasts for the next 24 hours. We use SDO/HMI vector magnetic field data for all the flaring regions with magnitude M1.0 or higher that have been observed with HMI and several thousand non-flaring regions. Each region is characterized by hundreds of features, including physical properties, such as the current helicity and the Lorentz force, as well as parameters that describe the temporal evolution of these properties over a two-day interval, starting 3 days and ending 1 day before the flare eruption. All of these features were used to train a Support Vector Machine (SVM), which is a supervised machine learning method used in classification problems. The results show that the SVM algorithm can achieve a True Skill Statistic of 0.91, an accuracy of 0.985, and a Heidke skill score of 0.861, improving the results of Bobra and Couvidat (2015).
Author(s): Stathis Ilonidis[2], Monica G Bobra[1], Sebastien Couvidat[1]
Institution(s): *1. Stanford University, 2. University Corporation for Atmospheric Research*

311.04 – Characterization of Solar Eruptions reported by EruptionPatrol

Observation of the solar atmosphere reveals a wide range of real and apparent motions, from small scale jets and spicules to global-scale coronal mass ejections. Identifying and characterizing these motions are essential to advance our understanding the drivers of space weather. A method for automatically identifying eruptions near the solar surface (either from filaments or otherwise) has recently been developed and integrated into the Heliophysics Events Knowledgebase. Here we report on the EruptionPatrol module for identifying eruptions in data collected by the SDO/AIA instrument and on the characterization and analysis of its output. A cluster analysis on the time periods reported by EruptionPatrol demarcates several large-scale events spanning significant portions of the solar disk with lifetimes of up to six hours.

Author(s): Neal Hurlburt[1]
Institution(s): *1. LMATC*

311.05 – The Sources of $F_{10.7}$ Emission

The solar radio flux at a wavelength of 10.7 cm, $F_{10.7}$, serves as a proxy for the Sun's ionizing flux striking the Earth and is a heavily used index for space weather studies. In principal both the coronal sources of ionizing flux and strong coronal magnetic fields contribute to $F_{10.7}$via the bremsstrahlung and gyroresonance mechanisms respectively. Recently the Karl G. Jansky Very Large Array (JVLA) has added the capability to make high-spatial-resolution images of the Sun at 10.7 cm. We present the results of a trial study comparing an $F_{10.7}$ image from the JVLA with the bremsstrahlung emission predicted to be present. The predicted bremsstrahlung image is calculated with spatially resolved differential emission measures derived from extreme ultra-violet images of the Sun acquired by the Atmospheric Imaging Assembly. Photospheric magnetograms are used to identify likely regions of strong coronal magnetic field, and the circular polarization measured by the JVLA is used as a tracer of gyroresonance contributions. We find that only a small fraction of the variable $F_{10.7}$ flux can be attributed to gyroresonance emission.

Author(s): Samuel Schonfeld[2], Stephen White[1], Carl Henney[1], Nick Arge[1], James McAteer[2]
Institution(s): *1. Air Force Research Laboratory, 2. New Mexico State University*

311.06 – The Coronal Global Evolutionary Model (CGEM): Toward Routine, Time-Dependent, Data-Driven Modeling of the Active Corona

The Coronal Global Evolutionary Model (CGEM) is a model for the evolution of the magnetic field in the solar corona, driven using photospheric vector magnetic field and Doppler measurements by the HMI instrument on NASA's Solar Dynamics Observatory. Over days-long time scales, the coronal magnetic field configuration is determined quasi-statically using magnetofrictional relaxation. For a configuration that becomes unstable and erupts or undergoes rapid evolution, we can use the magnetofrictional configuration as the initial state for MHD simulations. The model will be run in both global configurations, covering the entire Sun, and local configurations, designed to model the evolution of the corona above active regions. The model uses spherical coordinates to realistically treat the large-scale coronal geometry. The CGEM project also includes the dissemination of other information derivable from HMI magnetogram data, such as (i) vertical and horizontal Lorentz forces computed over active region domains, to facilitate easier comparisons of flare/CME behavior and observed changes of the photospheric magnetic field, and (ii) estimates of the photospheric electric field and Poynting flux. We describe progress that we have made in development of both the coronal model and its input data, and discuss magnetic evolution in (i) the well-studied NOAA AR 11158 around the time of the 2011 February 15 X2.2 flare, and (ii) AR 11944 around the time of the 2014 January 7 X1.2 flare.

Author(s): Brian T Welsch[3], Mark CM Cheung[1], George H Fisher[3], Maria D Kazachenko[3], Xudong Sun[2]
Institution(s): *1. LMSAL, 2. Stanford University, 3. University of California, Berkeley*

312 – Chromosphere-Transition Region-Corona

312.01 – Three Dimensional Chromospheric Thermal Structure of Sunspot

We have observed sunspots using the Spectropolarimeter for infrared and optical wavelength ranges at the Dunn Solar Telescope during 29 July to 4 August 2013. The data consists of full Stokes profiles in the Ca II 854.2 nm and Fe I 1.56 micron lines. The inversion of these Stokes spectra provides the magnetic, thermal and velocity structure at photospheric and chromospheric heights of sunspots. In this contribution, we present the results on the 3D thermal structure in the super-penumbral canopy of a well rounded sunspot, derived by a novel approach for the inversion of Ca II IR spectra. Tracing individual fibrils in the super-penumbral canopy, we find that about half of them form only short loops of a a few Mm length that return to the photosphere in the close surroundings of the sunspot instead of connecting to more remote magnetic network at the outer end of the moat flow.
Author(s): Debi Prasad Choudhary[1], Christian Beck[3], R Rezaei[2]
Institution(s): *1. California State University Northridge, 2. Kiepenuer-Institute for Solarphysics, 3. National Solar Observatory*

312.02 – The Chromosphere above the sunspot umbra as seen in the New Solar Telescope and Interface Region Imaging Spectrograph

Recent observations of sunspot's umbra suggested that it may be finely structured at a sub-arcsecond scale representing a mix of hot and cool plasma elements. In this study we report observations from the New Solar Telescope (NST) of the umbral spikes, which are cool jet-like structures seen in the chromosphere of an umbra. Our analysis indicates that the spikes are not associated with photospheric umbral dots and they tend to occur above darkest parts of the umbra, where magnetic fields are strongest. The spikes exhibit up and down oscillatory motions and their spectral evolution suggests that they might be driven by upward propagating shocks generated by photospheric oscillations.
We analyze sunspot oscillations using Interface Region Imaging Spectrograph (IRIS) data and narrow-band NST images and found long term variations in the intensity of chromospheric shocks. Also, sunspot umbral flashes (UFs) appear as narrow bright lanes running along the light bridges (LBs) and clusters of umbral dots (UDs). Time series suggested that UFs preferred to appear on the sunspot-center side of LBs, which may indicate the existence of a compact sub-photospheric driver of sunspot oscillations. We find that the sunspot's umbra appears bright in IRIS images above LBs and UDs. Co-spatial and co-temporal SDO/AIA data showed that these locations were associated with bright footpoints of umbral loops suggesting that LBs may play an important role in heating these loops. The power spectra analysis showed that the intensity of umbral oscillations significantly varies across the umbra and with height, suggesting that umbral non-uniformities and the structure of sunspot magnetic fields may play a role in wave propagation and heating of umbral loops.
Author(s): Vasyl Yurchyshyn[2], Phil Goode[2], Valentyna Abramenko[3], Ali Kilcik[1]
Institution(s): *1. Akdeniz University, 2. New Jersey Institute of Technology, 3. Pulkovo Observatory-Russian Academy of Sciences*

312.03 – Chromospheres of Various Cool Stars from Models of the UV

One important clue to the physical mechanism of chromospheric heating in the Sun is provided by the well-known widespread presence of chromospheres in most cool stars. Recent UV observations are shedding more light into the characteristics of these chromospheres and transition-regions. The physical

modeling of these, combined with the older, observations provides much less ambiguous constraints than the Ca II line and other visible data could provide. We are building this new generation of models that are providing interesting trends that give clues on the atmospheric parameters where physical mechanisms of chromospheric and coronal heating operate.
We will present some of the current results and will point to some of the trends that are starting to emerge. This is of course an ongoing topic and much remains to be learnt.
Author(s): John Fontenla[2], Kevin France[3], Jeff Linsky[3], Mariela Vieytes[1], Jeese Witbrod[3]
Institution(s): *1. CONICET, 2. NWRA, 3. University of Colorado*

312.04 – Synthetic 3D modeling of active regions and simulation of their multi-wavelength emission

To facilitate the study of solar active regions, we have created a synthetic modeling framework that combines 3D magnetic structures obtained from magnetic extrapolations with simplified 1D thermal models of the chromosphere, transition region, and corona. To handle, visualize, and use such synthetic data cubes to compute multi-wavelength emission maps and compare them with observations, we have undertaken a major enhancement of our simulation tools, GX_Simulator (ftp://sohoftp.nascom.nasa.gov/solarsoft/packages/gx_simulator/), developed earlier for modeling emission from flaring loops. The greatly enhanced, object-based architecture, which now runs on Windows, Mac, and UNIX platform, offers important new capabilities that include the ability to either import 3D density and temperature distribution models, or to assign to each individual voxel numerically defined coronal or chromospheric temperature and densities, or coronal Differential Emission Measure distributions. Due to these new capabilities, the GX_Simulator can now apply parametric heating models involving average properties of the magnetic field lines crossing a given voxel volume, as well as compute and investigate the spatial and spectral properties of radio (to be compared with VLA or EOVSA data), (sub-)millimeter (ALMA), EUV (AIA/SDO), and X-ray (RHESSI) emission calculated from the model. The application integrates shared-object libraries containing fast free-free, gyrosynchrotron, and gyroresonance emission codes developed in FORTRAN and C++, and soft and hard X-ray and EUV codes developed in IDL. We use this tool to model and analyze an active region and compare the synthetic emission maps obtained in different wavelengths with observations.
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Author(s): Gelu M Nita[3], Gregory Fleishman[3], Alexey A Kuznetsov[1], Maria A Loukitcheva[4], Nicholeen M. Viall[2], James A Klimchuk[2], Dale E. Gary[3]
Institution(s): *1. Institute of Solar-Terrestrial Physics, 2. NASA Goddard Space Flight Center, 3. New Jersey Institute of Technology, 4. Saint-Petersburg State University*

312.05 – The structure of current layers and degree of field line braiding in coronal loops

One proposed resolution to the long-standing problem of solar coronal heating involves the buildup of magnetic energy in the corona due to turbulent motions at the photosphere that braid the coronal field, and the subsequent release of this energy via magnetic reconnection. We examine the ideal relaxation of braided magnetic fields modelling solar coronal loops. It is demonstrated that the ideally accessible force-free equilibria for these braided fields contain current layers of finite thickness. It is further shown that for any such braided field, if a force-free equilibrium exists then it should contain current layers whose thickness is determined by length scales in the field line mapping. The thickness and intensity of the current layers follow scaling laws, and this allows us to extrapolate beyond the numerically accessible parameter regime and to place an upper bound on the braid complexity possible at coronal

plasma parameters. At this threshold level the braided loop contains 10^{26}–10^{28}ergs of available free magnetic energy, more than sufficient for a large nanoflare.
Author(s): David I Pontin[1], Gunnar Hornig[1]
Institution(s): *1. University of Dundee, UK*

312.06 – Re-interpreting Prominences Classified as Tornadoes

Some papers in the recent literature identify tornado prominences with barbs of quiescent prominences while papers in the much older historic literature include a second category of tornado prominence that does not correspond to a barb of a quiescent prominence. The latter are described as prominence mass rotating around a nearly vertical axis prior to its eruption and the rotation was verified by spectral measurements. From H alpha Doppler-shifted mass motions recorded at Helio Research or the Dutch Open Telescope, we illustrate how the apparent tornado-like motions, identified with barbs, are illusions in our mind's eye resulting from poorly resolved counterstreaming threads of mass in the barbs of quiescent prominences. In contrast, we confirm the second category of rotational motion in prominences shortly before and during eruption. In addition, we identify this second category as part of the late phase of a phenomenon called the roll effect in erupting prominences. In these cases, the eruption begins with the sideways rolling of the top of a prominence. As the eruption proceeds the rolling motion propagates down one leg or both legs of the prominence depending on whether the eruption is asymmetric or symmetric respectively. As an asymmetric eruption continues, the longer lasting leg becomes nearly vertical and its rotational motion also continues. If only this phase of the eruption was observed, as in some historic cases, it was called a tornado prominence. However, when we now observe entire eruptions in time-lapse sequences, the similarity to terrestrial tornadoes is lost. We conclude that neither prominence barbs, that give the illusion of rotation, nor the cases of true rotational motion, in the legs of erupting prominences, are usefully described as tornado prominences when the complete prominence structure or complete erupting event is observed.
Author(s): Sara F. Martin[1], Aparna Venkataramanasastry[2]
Institution(s): *1. Helio Research, 2. Inter-University Centre for Astronomy and Astrophysics*

313 – MAVEN: Early Results III

313.01 – Characterizing low frequency plasma waves at Mars with MAVEN

We use the measurements from the Solar Wind Ion Analyzer (SWIA) and the magnetometer (MAG) instruments aboard the MAVEN spacecraft to characterize plasma waves in the Martian magnetosphere. SWIA is a toroidal energy analyzer that measures 3-d ion velocity distributions, and we use it for measuring ion moment fluctuations. MAG instrument, on the other hand, is a fluxgate magnetometer, and we use it for measuring magnetic field fluctuations. Mars is unique in the solar system because of two characteristics: it only has an induced magnetosphere with strong crustal fields at low altitudes, and it has an extended atmosphere due to its lower gravity. Due to these two characteristics, Mars presents a unique environment to study the interaction of a planetary magnetosphere and an exosphere with the solar wind. One consequence of this interaction is the excitation of low frequency plasma waves which have highest power near and below the proton gyrofrequency. Studying these waves is of interest because they can play a vital role in the mass and energy transport in the Martian magnetosphere. In this investigation, we use both ion moment fluctuations (density and velocity) and the magnetic field fluctuations to characterize these low frequency plasma waves.

Author(s): Suranga Ruhunusiri[2], Jasper Halekas[2], Jack Connerney[1], Jared Espley[1], Davin Larson[3], David L. Mitchell[3]
Institution(s): *1. NASA/GSFC, 2. The University of Iowa, 3. University of California*

313.02 – Observation of ICME Interaction with the Martian Ionosphere

Using preliminary data from the MAVEN plasma and magnetic field instruments we observe the interaction between an Interplanetary Coronal Mass Ejection (ICME) event and Mars' ionospheric environment. The ICME onset is observed on October 17th 2014 at 23:00, closely coinciding with the arrival of Comet Siding Spring, and is followed by a compression of the magnetosheath and ionosphere. After the apparent passage of the ICME, on October 18th at 09:00 the magnetosheath drastically expands relative to nominal conditions prior to the ICME arrival. Data availability is only limited during the expansion phase of Mars' ionospheric environment. These phenomena have been previously observed using MEX data (e.g. Opgenoorth et al., 2013 and Dubini et al., 2009), which also show an increase of ion outflow from the upper atmosphere. We will use MAVEN data, together with its high resolution and magnetic field measurements, to expand upon these results.
Author(s): Roberto Livi[2], James P McFadden[2], Janet Luhmann[2], David L. Mitchell[2], Bruce Jakosky[3], Jasper Halekas[4], Jack Connerney[1]
Institution(s): *1. Goddard Space Flight Center, 2. University of California, Berkeley, 3. University of Colorado, Boulder, 4. University of Iowa*

313.03 – Preliminary Results on Mars and the Siding Spring Meteor Shower from MAVEN's Imaging UV Spectrograph

The MAVEN mission to Mars is designed to study the upper atmosphere and its response to external drivers, searching for clues to the cause of long-term atmospheric loss. MAVEN carries the Imaging UV Spectrograph (IUVS) for remote sensing studies of the atmosphere through vertical scans from the limb through the corona, UV imaging of the planet and stellar occultations. Each observational mode has successfully observed the spectral features and spatial distributions as intended, confirming and expanding our understanding of the Mars upper atmosphere as observed by the Mariner spacecraft and Mars Express. Furthermore, IUVS witnessed the aftermath of an intense meteor shower on Mars caused by Comet Siding Spring. For a period of many hours, the planet's UV spectrum was dominated by emission from ionized magnesium deposited by meteor ablation in the upper atmosphere. Initial results from the originally-planned Mars observations include:
• Significant persistent structures in the thermospheric day glow emissions, dependent primarily on solar zenith angle, along with significant variability on daily timescales;
• Nitric oxide nightglow and low-level auroral emissions of substantially greater nightside extent than previously seen;
• The first vertical profiles of the D/H ratio in the atmosphere and their evolution with Mars season;
• The most complete maps and vertical profiles of H, C and O in the Mars corona;
• The first global snapshot of the middle atmosphere obtained by a day-long stellar occultation campaign;
Other results from the missions's preliminary phases will be included.
Author(s): Justin Deighan[1], Nicholas Schneider[1]
Institution(s): *1. Laboratory for Atmospheric and Space Physics*

313.04 – Oxygen Pickup Ions at Mars: Model Comparisons with MAVEN Data and Implications for Oxygen Escape

A major source of atmospheric escape on Mars is the dissociative recombination of O2+ in the ionosphere, which creates oxygen atoms with energies exceeding the escape energy. These atoms are the source of the hot oxygen exosphere of Mars, which extends to tens of Martian radii. Direct measurement of the distant oxygen exosphere, which is mainly populated with escaping neutral oxygen atoms, is difficult due to the very low densities at these distances. However, ionization of these atoms creates pickup ions that are accelerated by the solar wind convective electric field to high energies, allowing them to be measured by the SEP (Solar Energetic Particle) instrument onboard the MAVEN (Mars Atmosphere and Volatile EvolutioN) spacecraft.
We modeled the hot oxygen at Mars and its interaction with the solar wind using Monte Carlo and test particle methods and using densities and temperatures from the MTGCM (Mars Thermospheric General Circulation Model). The distribution function of hot oxygen atoms at 300 km is calculated using a two-stream method, and the Liouville theorem extends this distribution for the gravitationally bound and escaping parts to high altitudes. We determined the O+ flux upstream of Mars as a function of energy, and separate it into parts due both the gravitationally bound and the escaping oxygen. Significant fluxes of O+ ions are predicted for energies greater than 60 keV and have been observed by the SEP instrument, even when MAVEN was several Martian radii away from the planet. These data-model comparisons will be presented and then interpreted in terms of the escape of oxygen from Mars.

Author(s): Tom Cravens[5], Ali Rahmati[5], Davin Larsen[2], Rob Lillis[2], Jack Connerney[1], Jasper Halekas[3], Stephen W Bougher[4]
Institution(s): *1. NASA Goddard SpaceFlight Center, 2. Univ. of California, 3. Univ. of Iowa, 4. Univ. of Michigan, 5. University of Kansas*

400 – Plasma-Neutral Coupling

400.01 – Basic Properties of Plasma-Neutral Coupling in the Solar Atmosphere

Plasma-neutral coupling (PNC) in the solar atmosphere concerns the effects of collisions between charged and neutral species'. It is most important in the chromosphere, which is the weakly ionized, strongly magnetized region between the weakly ionized, weakly magnetized photosphere and the strongly ionized, strongly magnetized corona. The charged species' are mainly electrons, protons, and singly charged heavy ions. The neutral species' are mainly hydrogen and helium. The resistivity due to PNC can be several orders of magnitude larger than the Spitzer resistivity. This enhanced resistivity is confined to the chromosphere, and provides a highly efficient dissipation mechanism unique to the chromosphere. PNC may play an important role in many processes such as heating and acceleration of plasma; wave generation, propagation, and dissipation; magnetic reconnection; maintaining the near force-free state of the corona; and limiting mass flux into the corona. It might play a major role in chromospheric heating, and be responsible for the existence of the chromosphere as a relatively thin layer of plasma that emits a net radiative flux 10-100 times greater than that of the overlying corona. The required heating rate might be generated by Pedersen current dissipation triggered by the rapid increase of magnetization with height in the lower chromosphere, where most of the net radiative flux is emitted. Relatively cool regions of the chromosphere might be regions of minimal Pedersen current dissipation due to smaller magnetic field strength or perpendicular current density. This talk will discuss PNC from an MHD point of view, and focus on the basic parameters that determine its effectiveness. These parameters are ionization fraction, magnetization, and the electric field that drives current perpendicular to the magnetic field. By influencing this current and the electric field that drives it, PNC directly influences the rate at which energy is exchanged between the electromagnetic field and particles. In this way, PNC can have a strong influence on the energetics of a process that involves the conversion of magnetic energy into particle energy, which subsequently appears as radiation, waves, bulk flow, and heating.

Author(s): Michael Goodman[1]
Institution(s): *1. West Virginia High Technology Consortium Foundation*

400.02 – X-Ray Emission in the Heliosphere: Ion-Neutral Collisions as a Plasma Diagnostic

The solar corona is the most powerful source of x-rays in the solar system but x-ray emission has also been observed from planets, including the Earth and Jupiter, from the Moon, from comets, and from interstellar gas entering the heliosphere. Astrophysical x-ray emission primarily comes from hot plasmas, such as in the million degree solar corona. The gas and plasma in planetary atmospheres are rather cold and the x-ray emission is driven by solar radiation and/or the solar wind. For example, x-rays from Venus come from the scattering and K-shell fluorescence of solar x-rays from the neutral atmosphere. Auroral x-ray emission at Earth and Jupiter is produced by energetic electron and ion precipitation from the magnetospheres into the atmospheres. Cometary and heliospheric x-ray emission is caused by charge transfer of high charge state solar wind ions (e.g., O^{7+}, C^{6+},…) with neutral hydrogen and helium.
An important source of solar system x-rays is the solar wind charge exchange (SWCX) mechanism. The solar wind originates in the hot solar corona and species heavier than helium (comprising about 0.1% of the gas) are highly-charged (e.g., O^{7+}, C^{6+}, Fe^{12+},….). Such ions undergo charge transfer collisions when they encounter neutral gas (e.g., cometary or interstellar gas or the Earth's geocoronal hydrogen). The product ions are in highly-excited states and, subsequently, emit soft x-ray photons. The SWCX mechanism can explain the observed cometary x-ray emission and can also explain part of the soft x-ray background (the other part of which originates in the hot interstellar medium).
The Earth has an extensive hot hydrogen exosphere, or geocorona, that is visible in scattered solar Lyman alpha. X-ray emission is produced in the magnetosheath due to the SWCX mechanism as the solar wind interacts with the exospheric gas. The most intense x-ray emission comes from the subsolar sheath region and from the cusp regions. Imaging of this emission by a spacecraft located outside the magnetosphere would provide a global view of the solar wind interaction with Earth including dayside magnetic reconnection processes.

Author(s): Tom Cravens[2], David Sibeck[1], MIchael Collier[1]
Institution(s): *1. NASA Goddard SpaceFlight Center, 2. University of Kansas*

400.03 – Global ENA Imaging of Earth's Dynamic Magnetosphere

The interaction between singly charged ions of Earth's magnetosphere and its neutral exosphere and upper atmosphere gives rise to Energetic Neutral Atoms (ENAs). This has enabled several missions to remotely image the global injection dynamics of the ring current and plasma sheet, the outflow of ions from Earth's polar regions, and the location of the sub-solar magnetopause. In this presentation we review ENA observations by the Astrid, IMAGE, TWINS and IBEX missions. We focus on results from the IMAGE/HENA Camera including observations of proton and oxygen ion injections in to the ring current and their impact on the force-balance and ionospheric coupling in the inner magnetosphere. We report also on the status of inversion techniques for retrieving the ion spatial and pitch-angle distributions from ENA images. The presentation concludes with a discussion of future next steps in ENA instrumentation and analysis capabilities required to deliver the science as recommended by the Heliophysics Decadal Survey.

Author(s): Pontus Brandt[1]

Institution(s): *1. The Johns Hopkins University Applied Physics Laboratory*

400.04 – Earth's Interaction Region: Plasma-Neutral Interactions in the Weakly Ionized gas of Earth's High Latitude Upper Atmosphere

The high-latitude regions of Earth's upper atmosphere are strongly influenced by plasma-neutral interactions. These interactions couple electrodynamic processes of the ionosphere with hydrodynamic processes of the more abundant thermosphere neutral gas, consequently connecting the high-latitude upper atmosphere to distant regions of the geoplasma environment. This produces a complex spatial and temporal interplay of competing processes that results in a myriad of physical and chemical responses and a rich array of neutral and plasma morphologies that constitute the high-latitude thermosphere and ionosphere. The altitude extent from the lower thermosphere to the upper ionosphere (90km – 1000km) can be considered Earth's space-atmosphere interaction region - likened to the solar chromosphere's interaction region where radiative processes and hydrodynamic waves from the dense lower atmosphere produce a cold lower boundary that quickly transitions over a few 100 kilometers to neutral and plasma temperatures that are five times hotter. A thousand or more kilometers further in altitude, Earth's upper atmosphere becomes a hot, collisionless, geomagnetically controlled protonosphere whose neutral and plasma population originates from the thermosphere and ionosphere. A grand challenge in the study of Earth's interaction region is how the collision-dominated thermosphere/ionosphere system exchanges energy, mass and momentum with the collisionless magnetosphere. This talk will focus primarily on collision-dominated processes of the high-latitude ionosphere and the electromagnetic energy transfer processes that lead to frictional heating of ions and neutrals, and plasma instability phenomenon that leads to extreme electron heating. Observations of the ionosphere response to these processes will be illustrated using incoherent scatter radar measurements. Relevance to the solar chromosphere will be identified where appropriate and outstanding issues in Earth's interaction region will be discussed.
Author(s): Jeffrey Thayer[1], Vicki Hsu[1]
Institution(s): *1. University of Colorado at Boulder*

401 – Solar Energetic Particles in Cycles 23 and 24

401.01 – Solar Sources of 3He-rich Solar Energetic Particle Events in Solar Cycle 24

We still do not understand the origin of impulsive SEP events enriched in 3He and heavy ions. A major impediment may be the difficulty to observe them in the corona, apart from the common knowledge that 3He-rich SEP events are correlated with longer-than-metric type III radio bursts and <100 keV electron events. This is because their X-ray and EUV signatures tend to be tiny and short-lived. Using high-cadence and high-sensitivity EUV images obtained by SDO/AIA, we investigate the solar sources of 26 3He-rich SEP events during solar cycle 24 that were well-observed by ACE. The source locations are further confirmed in data from STEREO/EUVI, which capture solar activities in the regions inaccessible from the Earth. We confirm that 3He-rich events have a broad longitudinal distribution (including locations well behind the west limb) and that a frequent association with coronal jets and narrow CMEs. Some events were seen in association with eruptions of closed structures and large-scale coronal propagating fronts (LCPFs, aka EUV waves). While these LCPFs may account for the occasional mismatching polarities at the source region and L1 in such a way that the particles are transported to and released at a region that has the opposite polarity, their associated CMEs may not be fast enough to drive shock waves for particle acceleration. Moreover, open field lines from PFSS models may not be correct for the entire Sun although they often look reasonable in discrete locations. We also discuss the apparent lack of correlation between the solar sources and the basic properties of 3He-rich SEP events.

Author(s): Nariaki V Nitta[5], Glenn M Mason[1], Linghua Wang[3], Christina Cohen[2], Mark E Wiedenbeck[4]
Institution(s): *1. Applied Physics Laboratory, Johns Hopkins University, 2. California Institute of Technology, 3. Institute of Space Physics and Applied Technology, Peking University, 4. Jet Propulsion Laboratory, 5. Lockheed Martin Solar and Astrophysics Laboratory*

401.02 – Examining Particle Transport in Multi-Spacecraft ^{3}He-Rich SEP Events

One of the surprising outcomes of recent multi-spacecraft studies of solar energetic particle (SEP) events is that small ^{3}He-rich events can have large longitudinal spans. Although their solar source region is typically quite small, individual ^{3}He-rich SEP events have been detected by near-1AU spacecraft separated by as much as 136 degrees. Although bundles of magnetic field lines can expand from small areas (5-10 degrees) at the photosphere to larger (~60 degrees) regions at 2.5 R_S, this is not sufficient to explain the wide ^{3}He-rich events observed by well-separated spacecraft. One possible explanation of these events involves a combination of particle diffusion in the inner heliosphere and field line co-rotation with the Sun. We have examined the onsets of the elevated ^{3}He intensities at ACE and both STEREO spacecraft for several wide ^{3}He-rich SEP events. The timing of these onsets has been compared to that predicted by a diffusive transport model for particle propagation. These results and their implications for the conditions conducive to creating wide ^{3}He-rich SEP events are discussed.
Author(s): Christina Cohen[1], Joe Giacalone[4], Mark E Wiedenbeck[3], Glenn Mason[2]
Institution(s): *1. California Institute of Technology, 2. JHUAPL, 3. JPL/Caltech, 4. University of Arizona*

401.03 – Scatter-free Impulsive SEP Events Observed at Multiple Spacecraft

Impulsive solar energetic particle (ISEP) events are thought to result from particle acceleration associated with magnetic reconnection in relatively compact regions in the solar corona and subsequent escape of accelerated particles along open field lines involved in the reconnection. In some cases, ISEP events measured at 1 AU are observed to have clear velocity dispersion, strongly anisotropic outward flows, and/or flux drop-outs, which indicate that minimal particle scattering has occurred between the Sun and the observer. We have investigated several such "scatter-free" ISEP events that were observed using the energetic particle instruments of the IMPACT suite on NASA's two STEREO spacecraft in April-May 2014 when the spacecraft separation was 38 degrees in heliographic longitude. We will report on the event characteristics and on the solar and heliospheric context in which they occurred and will argue that these events having scatter-free characteristics at two separated spacecraft are providing evidence either for longitudinal transport occurring close to the Sun or for random walk of magnetic field lines that extends over a wide range of longitudes.
Author(s): Mark E Wiedenbeck[3], Christina Cohen[1], Andreas Klassen[5], Richard Leske[1], Paulett C Liewer[3], Glenn Mason[2], Nariaki Nitta[4]
Institution(s): *1. Caltech, 2. JHU/APL, 3. JPL/Caltech, 4. LMSAL, 5. U. Kiel*

401.04 – STEREO/LET Observations of Solar Energetic Particle Pitch Angle Distributions

As solar energetic particles (SEPs) travel through interplanetary space, the shape of their pitch angle distributions is determined by magnetic focusing and scattering. Measurements of SEP anisotropies therefore probe interplanetary conditions far from the observer and can provide insight into particle transport. Bidirectional flows of SEPs are often seen within interplanetary coronal mass ejections

(ICMEs), resulting from injection of particles at both footpoints of the CME or from mirroring of a unidirectional beam. Mirroring is clearly implicated in those cases that show a loss cone distribution, in which particles with large pitch angles are reflected but the magnetic field enhancement at the mirror point is too weak to turn around particles with the smallest pitch angles. The width of the loss cone indicates the magnetic field strength at the mirror point far from the spacecraft, while if timing differences are detectable between outgoing and mirrored particles they may help constrain the location of the reflecting boundary.

The Low Energy Telescopes (LETs) onboard both STEREO spacecraft measure energetic particle anisotropies for protons through iron at energies of about 2-12 MeV/nucleon. With these instruments we have observed loss cone distributions in several SEP events, as well as other interesting anisotropies, such as unusual oscillations in the widths of the pitch angle distributions on a timescale of several minutes during the 23 July 2012 SEP event and sunward-flowing particles when the spacecraft was magnetically connected to the back side of a distant shock well beyond 1 AU. We present the STEREO/LET anisotropy observations and discuss their implications for SEP transport. In particular, we find that the shapes of the pitch angle distributions generally vary with energy and particle species, possibly providing a signature of the rigidity dependence of the pitch angle diffusion coefficient.
Author(s): Richard Leske[1], Alan Cummings[1], Christina Cohen[1], Richard Mewaldt[1], Allan Labrador[1], Edward Stone[1], Mark Wiedenbeck[2], Eric Christian[3], Tycho von Rosenvinge[3]
Institution(s): *1. California Institute of Technology, 2. Jet Propulsion Laboratory, California Institute of Technology, 3. NASA/Goddard Space Flight Center*

401.05 – The Longitudinal Propagation of Solar Energetic Particles

Using observations from the High Energy Telescopes (HETs) on STEREO A and B and similar observations from SoHO, near-Earth, we have identified ~250 individual solar energetic particle events that include >14 MeV protons since the beginning of the STEREO mission (Richardson, et al., *Solar Physics*, 2014). Between the end of December 2009, when the STEREO A and B spacecraft were, respectively, ahead and behind Earth by ~ 65° in ecliptic longitude, and the end of December 2013, 43 different events were clearly detected at all three locations. We have fit Gaussians to the peak intensities observed simultaneously at three spacecraft as a function of observer longitude. The Gaussian peak intensity is poorly correlated with the corresponding CME speed and the full width at half maximum (FWHM) is uncorrelated with the CME speed. Nonetheless, there appear to be distinctly non-random variations of the FWHM values with respect to event time. This is a new and unexpected result. We will investigate possible causes of this effect.
Author(s): Tycho von Rosenvinge[3], Ian Richardson[3], Hilary Cane[4], Eric R. Christian[3], Christina Cohen[1], Alan Cummings[1], Allan Labrador[1], Richard Leske[1], Richard Mewaldt[1], Edward Stone[1], Mark E Wiedenbeck[2]
Institution(s): *1. California Institute of Technology, 2. JPL/Caltech, 3. NASA/Goddard Space Flight Center, 4. U of Tasmania*

401.06 – Investigating the Causes of Solar-Cycle Variations in Solar Energetic Particle Fluences and Composition

Measurements with ACE, STEREO, and GOES show that the number of large Solar Energetic Particle (SEP) events in solar cycle 24 is reduced by a factor of ~2 compared to this point of cycle 23, while the fluences of >10 MeV/nuc ions from H to Fe are reduced by factors ranging from ~4 to ~10. We investigate the origin of these cycle-to-cycle differences by evaluating possible factors that include

properties of the associated CMEs, seed particle densities, and the interplanetary magnetic field strength and turbulence levels. These properties will be evaluated in the context of existing SEP acceleration models.
Author(s): Richard Mewaldt[1], Christina Cohen[1], Glenn M Mason[2], Tycho von Rosenvinge[3], Gang Li[4], Charles Smith[5], Angelos Vourlidas[2]
Institution(s): *1. Caltech, 2. JHUAPL, 3. NASA/Goddard Space Flight Center, 4. University of Alabama/Huntsville, 5. University of New Hampshire*

402 – Image Processing, Computing & Data Management PLUS Instrumentation II

402.01 – The DKIST Data Center: Challenges and Opportunities Ahead

The four-meter Daniel K. Inouye Solar Telescope is currently under construction on Haleakalā, Hawaiʻi, with completion planned in 2019. When fully operational, DKIST will routinely generate 10-20 TB of data and 10^8 metadata elements per day. These data will be transported to the DKIST Data Center at NSO headquarters in Boulder for storage, processing, and distribution.
The initial output from the Data Center is expected to be high-quality calibrated data sets, with corrections applied to the level achievable for each acquired dataset (with variations due to seeing conditions and experiment design, among others). The processed data, along with the software code and full data description, will be made openly available to investigators and interested users.
A key aspect of the design of the DKIST Data Center is its scalability, flexibility, and extensibility. Within an overview of the status of the Data Center development and plans, we will comment on lessons learned thus far in conceiving, designing, and prototyping a petascale informatics facility dedicated to generating high-quality calibrated data sets.
Author(s): Steven Berukoff[1], Kevin Reardon[1], Tony Hays[1], DJ Spiess[1]
Institution(s): *1. National Solar Observatory*

402.02 – Solar Coronal UV Spectroscopy for Solar Wind and SEP Acceleration Investigations

Of all the new areas of solar physics opened by the landmark SOHO mission, the scientific discoveries of the Ultraviolet Coronagraph Spectrometer (UVCS) are unique in both the importance of the new questions raised by these observations and the lack of subsequent investigations to resolve these questions. For example, the first direct evidence of wave-particle coupling as an acceleration mechanism for the solar wind was obtained from UVCS spectro-coronagraphic observations, yet the real limits on the ratio of the parallel to perpendicular ion temperatures (with respect to the magnetic field) in coronal holes and streamers is still unresolved. Another unresolved issue is the role of suprathermal seed particles in rapid diffusive shock acceleration of SEPs. Although the theory has been placed on firmer theoretical ground by recent *in situ* investigations, observations of these suprathermal particles in the corona was never conclusively obtained with UVCS.
Any follow-on UV Spectro-coronagraph must possess two improvements over UVCS in order to address the questions raised during the SOHO mission: 1) increased effective aperture and 2) improved spectrographic contrast (i.e. reduced scattered light). Technological developments in optics, optical design, UV detectors, composite structures, cleanliness control and electronics make it possible to achieve the requisite improvements in a next-generation UV spectro-coronagraph within the constraints of an affordable mission. We discuss specific instrument and mission approaches developed over the last 5 years and the feasibility of implementing them within the next 5 years.

Author(s): John Daniel Moses[1], Yuan-Kuen Ko[1], John (Martin) Laming[1], Leonard Strachan[1], Samuel Tun Beltran[1]
Institution(s): *1. Naval Research Laboratory*

402.03 – RAISE (Rapid Acquisition Imaging Spectrograph Experiment): Results and Instrument Status

We present initial results from the successful November 2014 launch of the RAISE (Rapid Acquisition Imaging Spectrograph Experiment) sounding rocket program, including intensity maps, high-speed spectroheliograms and dopplergrams, as well as an update on instrument status. The RAISE sounding rocket payload is the fastest high-speed scanning-slit imaging spectrograph flown to date and is designed to observe the dynamics and heating of the solar chromosphere and corona on time scales as short as 100-200ms, with arcsecond spatial resolution and a velocity sensitivity of 1-2 km/s. The instrument is based on a class of UV/EUV imaging spectrometers that use only two reflections to provide quasi-stigmatic performance simultaneously over multiple wavelengths and spatial fields. The design uses an off-axis parabolic telescope mirror to form a real image of the sun on the spectrometer entrance aperture. A slit then selects a portion of the solar image, passing its light onto a near-normal incidence toroidal grating, which re-images the spectrally dispersed radiation onto two array detectors. Two full spectral passbands over the same one-dimensional spatial field are recorded simultaneously with no scanning of the detectors or grating. The two different spectral bands (1st-order 1205-1243Å and 1526-1564Å) are imaged onto two intensified Active Pixel Sensor (APS) detectors whose focal planes are individually adjusted for optimized performance. RAISE reads out the full field of both detectors at 5-10 Hz, allowing us to record over 1,500 complete spectral observations in a single 5-minute rocket flight, opening up a new domain of high time resolution spectral imaging and spectroscopy. RAISE is designed to study small-scale multithermal dynamics in active region (AR) loops, explore the strength, spectrum and location of high frequency waves in the solar atmosphere, and investigate the nature of transient brightenings in the chromospheric network.
Author(s): Glenn T. Laurent[4], Donald Hassler[4], Craig DeForest[4], Tom Ayres[6], Michael Davis[5], Bart DePontieu[1], Jed Diller[4], Roy Graham[5], Udo Schule[2], Harry Warren[3]
Institution(s): *1. LMSAL, 2. Max Planck Institute, 3. NRL, 4. Southwest Research Institute, 5. Southwest Research Institute, 6. University of Colorado*

402.04 – Center-to-Limb Variation of Deprojection Errors in SDO/HMI Vector Magnetograms

For use in investigating the magnetic causes of coronal heating in active regions and for use in forecasting an active region's productivity of major CME/flare eruptions, we have evaluated various sunspot-active-region magnetic measures (e.g., total magnetic flux, free-magnetic-energy proxies, magnetic twist measures) from HMI Active Region Patches (HARPs) after the HARP has been deprojected to disk center. From a few tens of thousand HARP vector magnetograms (of a few hundred sunspot active regions) that have been deprojected to disk center, we have determined that the errors in the whole-HARP magnetic measures from deprojection are negligibly small for HARPS deprojected from distances out to 45 heliocentric degrees. For some purposes the errors from deprojection are tolerable out to 60 degrees. We obtained this result by the following process. For each whole-HARP magnetic measure: 1) for each HARP disk passage, normalize the measured values by the measured value for that HARP at central meridian; 2) then for each 0.05 R_s annulus, average the values from all the HARPs in the annulus. This results in an average normalized value as a function of radius for each measure. Assuming no deprojection errors and that, among a large set of HARPs, the measure is as likely to decrease as to increase with HARP distance from disk center, the average of each annulus is expected to be unity, and, for a statistically large sample, the amount of deviation of the average from unity

estimates the error from deprojection effects. The deprojection errors arise from 1) errors in the transverse field being deprojected into the vertical field for HARPs observed at large distances from disk center, 2) increasingly larger foreshortening at larger distances from disk center, and 3) possible errors in transverse-field-direction ambiguity resolution.

From the compiled set of measured vales of whole-HARP magnetic nonpotentiality parameters measured from deprojected HARPs, we have examined the relation between each nonpotentiality parameter and the speed of CMEs from the measured active regions. For several different nonpotentiality parameters we find there is an upper limit to the CME speed, the limit increasing as the value of the parameter increases.

Author(s): David Falconer[2], Ronald Moore[2], Nasser Barghouty[1], Sanjiv K. Tiwari[1], Igor Khazanov[2]
Institution(s): *1. NASA/MSFC, 2. UAHuntsville*

402.05 – Current STEREO Status on the Far Side of the Sun

The current positions of the two STEREO spacecraft on the opposite side of the Sun from Earth (superior solar conjunction) has forced some significant changes in the spacecraft and instrument operations. No communications are possible when the spacecraft is within 2 degrees of the Sun, requiring that the spacecraft be put into safe mode until communications can be restored. Unfortunately, communications were lost with the STEREO Behind spacecraft on October 1, 2014, during testing for superior solar conjunction operations. We will discuss what is known about the causes of loss of contact, the steps being taken to try to recover the Behind spacecraft, and what has been done to prevent a similar occurrence on STEREO Ahead.

We will also discuss the effect of being on the far side of the Sun on the science operations of STEREO Ahead. Starting on August 20, 2014, the telemetry rate from the STEREO Ahead spacecraft has been tremendously reduced due to the need to keep the temperature of the feed horn on the high gain antenna below acceptable limits. However, the amount of telemetry that can be brought down has been highly reduced. Even so, significant science is still possible from STEREO's unique position on the solar far side. We will discuss the science and space weather products that are, or will be, available from each STEREO instrument, when those products will be available, and how they will be used. Some data, including the regular space weather beacon products, are brought down for an average of a few hours each day during the daily real-time passes, while the in situ and radio beacon data are being stored on the onboard recorder to provide a continuous 24-hour coverage for eventual downlink once the spacecraft is back to normal operations.

Author(s): William T Thompson[1], Joseph Gurman[4], Daniel Ossing[3], Janet Luhmann[7], David Curtis[7], Peter Schroeder[7], Richard Mewaldt[2], Andrew Davis[2], Kristin Wortman[3], Christopher Russell[8], Antoinette Galvin[10], Lynn Kistler[10], Lorna Ellis[10], Russell Howard[5], Angelos Vourlidas[3], Nathan Rich[5], Lynn Hutting[5], Milan Maksimovic[6], **Stuart D Bale[7]**, Keith Goetz[9]
Institution(s): *1. ADNET Systems, Inc., 2. California Institute of Technology, 3. Johns Hopkins University Applied Physics Laboratory, 4. NASA Goddard Space Flight Center, 5. Naval Research Laboratory, 6. Observatoire de Paris, 7. University of California Berkeley, 8. University of California Los Angeles, 9. University of Minnesota, 10. University of New Hampshire*

402.06 – Data Citation in Solar Physics: 2015 Update & Recommendations

Last year's Joint Declaration of Data Citation Principles has triggered much discussion about the best ways to handle citation of data across research disciplines. Many communities have gotten together to design solutions to the issues of giving proper credit and attribution, although many fields, including solar physics, have yet to implement them. Issues still exist regarding data citation as a record for

scientific reproducability.
Solar physics data is particularly difficult to cite due to the nature of our collection methods and the method in which our data are used. Other than sounding rocket or balloon flights, our data collection from a given instrument spans years or decades but observing modes, cadence and field of view may vary daily. Researchers may only analyze a short timespan of the data, only given observing modes, at a slower cadence, and/or only a portion of each image; this reduction should be described to ensure that the analysis is reproducible.
Many archives keep only the current, best calibrated data, making updates in place. It can be difficult to determine if the data used in a publication is the same as the currently available data.
We discuss the current progress by the Research Data Alliance's Dynamic Data Citation Working Group, and tools and services that would be useful to identify when data may have been changed by an archive. As it may be some time before standards can be developed, we include a checklist for authors to improve reproducibility of their published articles.
Author(s): Joseph Hourclé[1]
Institution(s): *1. NASA/GSFC*

403 – Image Processing and Instrumentation Posters

403.01 – The Miniature X-ray Spectrograph (MiXS)

The Miniature X-ray Spectrograph (MiXS) is an innovative, small, and fully functional solar X-ray observatory concept designed to fit within a 6U CubeSat platform. MiXS will provide the community with X-ray spectroscopy up to 100 keV of solar flares at a small fraction of the cost of a conventional mission. It includes layered Si/CdTe detectors, providing routine observations of both soft and hard X-ray emission with low background. If selected for funding, MiXS will provide hard X-ray (HXR) spectroscopy throughout the declining phase of this solar cycle allowing continuous solar observations while new generation HXR instrumentation put in orbit. MiXS is the first stage of a much ambitious cube design the Miniature Xray Imager (MiXI), which can provide to the community X-ray imaging up to 40 – 50 keV. In the next solar cycle, coordinated observations between Solar Orbiter's STIX instrument and future MiXS or MiXI iterations will enable solar flare observation from two vantage points, while new observatories will be commissioned. This will provide new insight into the directivity of flare HXR emission and will allow detailed study of both coronal and footpoint sources within the same flare. These results may have profound implications for theories of flare acceleration processes. We describe here the MiXS concept and its usefulness to the solar and heliophysics communities.
Author(s): Juan Carlos Martinez Oliveros[1], Lindsay Glesener[1], Pascal Saint Hilaire[1], David Sundkvist[1], Gordon Hurford[1], Hazel Bain[1], Stuart D Bale[1], Sam Krucker[1]
Institution(s): *1. Space Sciences Laboratory, UC Berkeley*

403.02 – Update of the Photometric Calibration of the LASCO-C2 Coronagraph Using Stars

We present an update to the photometric calibration of the LASCO-C2 coronagraph onboard the SOHO spacecraft. We obtained the new calibration using data from the beginning of the mission in 1996 until 2013. We re-examined the LASCO-C2 photometric calibration by comparing the past three calibrations and the present calibration with the goal of validating an in-flight calibration. We find a photometric calibration factor (PCF) that is very similar to the factor recently published in Gardès, Lamy, and Llebaria (*Solar Phys.* **283**, 667, 2013), which calculated a calibration between 1996 and 2009. The average of our PCF between 1999 and 2009 is the same, within our margin of error, as the average given by Gardès,

Lamy, and Llebaria (*Solar Phys.* **283**, 667, 2013) during the same time period. However, we find a different evolution of the calibration over the lifetime of the LASCO-C2 instrument compared with past results. We find that the sensitivity of the instrument is decreasing by a constant 0.20 [±0.03] % per year. We also find no significant difference in the signal degradation before and after the SOHO interruption. We discuss the effects of this new PCF on the calibrated data set and the potential impact on scientific results derived from the previous calibration.
Author(s): Robin Colaninno[1], Russell Howard[1]
Institution(s): *1. Naval Research Laboratory*

403.03 – SDO/HMI Highlights After Five Years

The SDO five year Prime Mission ends during thisTESS meeting. The HMI isntrument has operated as designed for these five years and has produced data used in more than 600 refereed articles. Some of the highlights from these articles and some not yet published are discussed. The SDO JSOC-SDP (Joint Science Operations Center - Science Data Processing) facility at Stanford status is also reviewed with hints to help with access to SDO HMI and AIA data.
Author(s): Philip H Scherrer[1]
Institution(s): *1. Stanford Univ*

403.04 – The Helioviewer Project: Solar and Heliospheric Data Visualization

Helioviewer.org enables the simultaneous exploration of multiple heterogeneous solar and heliospheric data sets. The latest iteration of this open-source web application brings significant visual and functional enhancements to the user interface. Long overdue from a usability perspective, these changes also pave the way for significant new capabilities planned for the future. Emphasis is placed on the solar imagery, which is now always displayed full-screen. Controls for selecting image layers, feature and event annotations, and observation date and time are presented in a light-weight overlay with individually collapsible sub-sections. Secondary functions such as movie and screenshot generation, link and image sharing, news and community videos are now intuitively grouped and kept out of the way until needed. Tight integration with external services such as the Virtual Solar Observatory and SDO Cut-out Service allows scientists to issue precisely defined requests to download science data sets via the web, SolarSoft/IDL, and SunPy/Python after definining and previewing them visually. Finally, documentation of the Helioviewer Public API has been enhanced and expanded, making it simpler to integrate Helioviewer data into scientific workflows.
Author(s): Jeffrey E Stys[1], Jack Ireland[1], Daniel Müller[2]
Institution(s): *1. ADNET Systems, Inc / NASA GSFC, 2. European Space Agency*

403.05 – FOXSI: Properties of optics and detectors for hard-X rays

The Focusing Optics X-ray Solar Imager (FOXSI) is a state-of-the-art direct focusing X-ray telescope designed to observe the Sun. This experiment completed its second flight onboard a sounding rocket last December 11, 2014 from the White Sands Missile Range in New Mexico. The optics use a set of iridium-coated nickel/cobalt mirrors made using a replication technique based on an electroformed perfect polished surface. Since this technique creates full shells that no need to be co-aligned with other segments, an angular resolution of up to ~5 arcsec is gotten. The FOXSI focal plane consists of seven double-sided strip detectors. Five Silicon and 2 CdTe detectors were used during the second flight.
We present on various properties of Wolter-I optics that are applicable to solar HXR observation, including ray-tracing simulations of the single-bounce ("ghost ray") patterns from sources outside the

field of view and angular resolution for different source angles and effective area measurements of the FOXSI optics. We also present the detectors calibration results, paying attention to energy resolution (~0.5 keV), energy thresholds (~4-15 keV for Silicon and ~4-20 keV for CdTe detectors), and spatial coherence of these values over the entire detector.
Author(s): Juan Camilo Buitrago-Casas[3], Lindsay Glesener[3], Steven Christe[1], Sam Krucker[3], Shin-nosuke Ishikawa[2], Natalie Foster[4]
Institution(s): *1. NASA Goddard Space Flight Center, 2. National Astronomical Observatory of Japan, 3. University of California Berkeley, 4. University of Florida*

403.06 – PSF-Corrected Inversion of MOSES Images: Validation With IRIS Data

The Multi-Order Solar EUV Spectrograph (MOSES) forms three Helium 304 images taken at the m=-1,0,+1 spectral orders. Subtle differences between images encode line profile information. However, differences in instrument point spread function (PSF) in the three orders lead to non-negligible systematic errors in the retrieved profiles. The PSF-corrected SMART 2 algorithm is designed to equalize the PSFs and extract the spectral and doppler information. We apply the algorithm to IRIS raster images to demonstrate the technique's effectiveness.
Author(s): Shane Atwood[1], Charles Kankelborg[1]
Institution(s): *1. Montana State University*

403.07 – SunPy: Solar Physics in Python

SunPy is a community-developed open-source software library for solar physics. It is written in Python, a free, cross-platform, general-purpose, high-level programming language which is being increasingly adopted throughout the scientific community as well as further afield. This has resulted in a wide array of software packages useful for scientific computing, from numerical computation (NumPy, SciPy, etc.), to machine learning (scifitlearn), to visualization and plotting (matplotlib). SunPy aims to provide required specialised software for analysing solar and heliospheric datasets in Python. The current version is 0.5 with 0.6 expected to be released later this year. SunPy provides solar data access through integration with the Virtual Solar Observatory (VSO), the Heliophysics Event Knowledgebase (HEK), and the HELiophysics Integrated Observatory (HELIO) webservices. It supports common data types from major solar missions such as images (SDO/AIA, STEREO, PROBA2/SWAP etc.), time series (GOES/XRS, SDO/EVE, PROBA2/LYRA), and radio spectra (e-Callisto, STEREO/WAVES). SunPy's code base is publicly available through github.com and can be contributed to by anyone. In this poster we demonstrate SunPy's functionality and future goals of the project. We also encourage interested users to become involved in further developing SunPy.
Author(s): Daniel Ryan[6], Steven Christe[5], Stuart Mumford[8], David Perez Suarez[4], Jack Ireland[1], Albert Y. Shih[5], Andrew Inglis[2], Simon Liedtke[7], Russel Hewett[3]
Institution(s): *1. ADNET Systems Inc., 2. Catholic University of America, 3. MIT, 4. Mullard Space Science Laboratory, 5. NASA GSFC, 6. Royal Observatory of Belgium, 7. University of Bremen, 8. University of Sheffield*

403.08 – Status of the SWAMIS Emerging Flux Detection and Feature Tracking Codes

We describe recent improvements to the SWAMIS magnetic feature tracking code for SDO/HMI data. In particular, we detail recent substantial improvements in the detection of emerging flux regions in near-real-time magnetograms, show detailed examples of the detected events, and report on the status of the code in the HMI analysis pipeline. In addition, we describe some recent improvements in efficiently

analyzing full-resolution, full disk HMI magnetograms, and describe our plans for future code development.
Author(s): Derek A Lamb[2], Craig DeForest[2], Alisdair R Davey[1]
Institution(s): *1. Harvard Smithsonian Center for Astrophysics, 2. Southwest Research Institute*

403.09 – SolarSoft Desat Package for the Recovery of Saturated AIA Flare Images

The dynamic range of EUV images has been limited by the problem of CCD saturation as seen countless times in movies of solare flares made using the Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO AIA). Concurrent with the saturation are the eight rays emanating from the saturation locus which are the result of diffraction off the wire meshes that support the EUV passband filters. This is the problem and its solution in a nutshell. By utilizing techniques similar to those used for making images from the rotating modulation collimators on the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) we have developed a software package that can be used to make images of the EUV flare kernels in a highly automated way as described in Schwartz et al. (2014). Starting from cutouts centered around a flaring region, the software uses the point-spread-function (PSF) of the diffraction pattern to identify and reconstruct the region of the primary saturation. The software also uses the best information available to reconstruct the general scene obscured from overflow saturation and subtracts away the diffraction fringes. It is not a total correction for the PSF but is meant to provide the flare images above all. The software is freely available and distributed within the DESAT package of Solar Software.
(Schwartz, R. A., Torre, G., & Piana, M. (2014), Astrophysical Journal Letters, 793, LL23)
Author(s): Richard Alan Schwartz[2], Gabriele Torre[3], Michele Piana[3], AnnaMaria Massone[1]
Institution(s): *1. CNR - SPIN, 2. GSFC, 3. University of Genova*

403.10 – The High Energy X-ray Imager Technology (HEXITEC) for Solar Hard X-ray Observations

High angular resolution HXR optics require detectors with a large number of fine pixels in order to adequately sample the telescope point spread function (PSF) over the entire field of view. Excessively over-sampling the PSF will increase readout noise and require more processing with no appreciable increase in image quality. An appropriate level of over-sampling is to have 3 pixels within the HPD. For current high resolution X-ray mirrors, the HPD is about 25 arcsec. Over a 6-m focal length this converts to 750 µm, the optimum pixel size is around 250 µm. Annother requirement are that the detectors must also have high efficiency in the HXR region, good energy resolution, low background, low power requirements, and low sensitivity to radiation damage. For solar observations, the ability to handle high counting rates is also extremely desirable. The Rutherford Appleton Laboratory (RAL) in the UK has been developing the electronics for such a detector. Dubbed HEXITEC, for High Energy X-Ray Imaging Technology, this Application Specific Integrated Circuit (ASIC), can be bonded to 1- or 2- mm-thick Cadmium Telluride (CdTe) or Cadmium-Zinc-Telluride (CZT), to create a fine (250 µm pitch) HXR detector. The NASA Marshall Space Flight CenterMSFC and the Goddard Space Flight Center (GSFC) has been working with RAL over the past few years to develop these detectors to be used with HXR focusing telescopes. We present on recent results and capabilities as applied to solar observations.
Author(s): Steven Christe[1], Albert Y. Shih[1], Jessica Gaskin[2], Colleen Wilson-Hodge[2], Paul Seller[3], Matthew Wilson[3]
Institution(s): *1. NASA GSFC, 2. NASA MSFC, 3. Rutherford Appleton Laboratory*

403.11 – The Diagnostic Value of Photospheric Fraunhofer Lines in Sun-as-a-Star Observations

The distinctive sensitivity of photospheric Fraunhofer lines to variations in the thermodynamic and magnetic structures of the solar atmosphere provides an excellent tool to investigate these variations at different time scales.
We used daily Sun-as-a-star spectra taken with the Integrated Sunlight Spectrometer (ISS) and longitudinal magnetograms from the Vector SpectroMagnetograph (VSM) to study the correlation between the global magnetic flux and changes in the line shape of several photospheric spectral lines during different phases of the solar cycle. ISS and VSM are two of three instruments comprising the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility operated by the National Solar Observatory. We find a clear signature of temporal global magnetic flux variations in several of these photospheric spectral lines, suggesting that the results of our analysis can be used to develop a better understanding of the magnetic cycle of activity in other solar-type stars.
Author(s): Luca Bertello[1], Alexei A. Pevtsov[1], Andrew R. Marble[1]
Institution(s): *1. National Solar Observatory*

403.12 – A Neutron Spectrometer for Small Satellite Opportunities

The detection of fast neutrons has important implications in such diverse fields as geospace physics, solar physics, and applications within Defense and Security programs. In particular, neutrons provide key observations that complement gamma-ray observations in understanding the magnetic topology and particle acceleration processes at the Sun. Solar neutrons have been observed by space-based missions such as CGRO/COMPTEL and ground-based neutron monitors with energies > 20 MeV. Below 20 MeV, given the neutron half-life of ~15min, the detection of neutrons must take place close to the Sun. The challenge is to build instrumentation that conforms to small satellite platforms making inner heliospheric observations possible as well as Earth-orbiting CubeSats. Scintillator-based technologies have a proven track record for the detection of fast neutrons with high stopping power, good energy resolution, and fast timing. Modern organic scintillators such as stilbene and p-terphenyl, offer improved light output and pulse shape discrimination — the ability to distinguish gamma from neutron-induced signals. Modern readout devices such as silicon photomultipliers (SiPMs) offer an ideal alternative to photomultiplier tubes given their inherently compact size and the very low operating voltages required. The combination of modern scintillators and silicon photomultipliers enables new designs for instruments that conform to small satellite platforms such as CubeSats. We discuss the performance of a double scatter neutron spectrometer based on p-terphenyl coupled to arrays of silicon photomultipliers for readout. In addition, we present preliminary results for pulse shape discrimination using advanced waveform digitization techniques.
Author(s): Georgia de Nolfo[1], Peter Bloser[2], J. Dumonthier[1], A. Garcia-Burgos[1], James Michael Ryan[2], G. Suarez[1], G.E. Winkert[1]
Institution(s): *1. NASA/GSFC, 2. University of New Hampshire*

403.13 – Automated Wave Analysis and Reduction in EUV (AWARE): a tool for the detection and characterization of EUV waves.

Extreme ultraviolet (EUV) waves are large-scale and faint 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 are developing AWARE - the Automated Wave Analysis and REduction algorithm for the detection of EUV waves over the full Sun. AWARE is a Python-based, open-source algorithm that utilizes the SunPy

data analysis package and general purpose signal processing libraries. The core detection algorithm is based on a novel image processing approach to isolating the bright wavefront of the EUV as it propagates across the confounding background emission of the complex structured solar corona. The location, speed and acceleration of the wavefront as a function of direction from the source events are calculated. We describe the core image processing steps of the AWARE algorithm, and demonstrate its application to observational data from SDO/AIA and STEREO/EUVI.
Author(s): Andrew Inglis[1], Jack Ireland[1], Steven Christe[1], Albert Shih[1], Laura Hayes[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Trinity College Dublin*

403.14 – Advanced Scintillator-Based Compton Telescope for Solar Flare Gamma-Ray Measurements

A major goal of future Solar and Heliospheric Physics missions is the understanding of the particle acceleration processes taking place on the Sun. Achieving this understanding will require detailed study of the gamma-ray emission lines generated by accelerated ions in solar flares. Specifically, it will be necessary to study gamma-ray line ratios over a wide range of flare intensities, down to small C-class flares. Making such measurements over such a wide dynamic range, however, is a serious challenge to gamma-ray instrumentation, which must deal with large backgrounds for faint flares and huge counting rates for bright flares. A fast scintillator-based Compton telescope is a promising solution to this instrumentation challenge. The sensitivity of Compton telescopes to solar flare gamma rays has already been demonstrated by COMPTEL, which was able to detect nuclear emission from a C4 flare, the faintest such detection to date. Modern fast scintillators, such as LaBr3, and CeBr3, are efficient at stopping MeV gamma rays, have sufficient energy resolution (4% or better above 0.5 MeV) to resolve nuclear lines, and are fast enough (~15 ns decay times) to record at very high rates. When configured as a Compton telescope in combination with a modern organic scintillator, such as p-terphenyl, sub-nanosecond coincidence resolving time allows dramatic suppression of background via time-of-flight (ToF) measurements, allowing both faint and bright gamma-ray line flares to be measured. The use of modern light readout devices, such as silicon photomultipliers (SiPMs), eliminates passive mass and permits a more compact, efficient instrument. We have flown a prototype Compton telescope using modern fast scintillators with SiPM readouts on a balloon test flight, achieving good ToF and spectroscopy performance. A larger balloon-borne instrument is currently in development. We present our test results and estimates of the solar flare sensitivity of a possible full-scale instrument suitable for flight on long-duration balloon flights or on an Explorer satellite platform.
Author(s): James Michael Ryan[3], Peter Bloser[3], Mark McConnell[3], Jason Legere[3], Christopher Bancroft[3], Ronald Murphy[2], Georgia de Nolfo[1]
Institution(s): *1. Goddard Space Flight Center/NASA, 2. Naval Research Lab, 3. University of New Hampshire*

403.15 – Using Correlation Tracking to Disentangle Spatial and Spectral Data in a Slitless Spectrograph

In a typical slit style spectrograph, the limited field of view afforded by the entrance slit is overcome by rastering the slit across a feature of interest to build a composite image. While it is trivial to separate spatial and spectral data in such an instrument, the cadence of the raster results in a loss of temporal data when attempting to image a feature that is much larger than the entrance slit. The *Multi-Order Solar EUV Spectrograph* (MOSES) is a slitless spectrograph that collects co-temporal spatial and spectral images in He II 304 Å over a 10’ x 20’ field of view through the use of a spherical diffraction grating. Local correlation tracking routines are used to disentangle the spatial and spectral data from images formed by the zero and both first orders of the *MOSES* instrument. The opposing dispersion direction of the

outboard orders allows a diagnostic of the viability of the method when analyzing images obtained from the February 2006 *MOSES* sounding rocket flight.
Author(s): Hans Courrier[1], Charles Kankelborg[1]
Institution(s): *1. Montana State University*

403.16 – Results of a Survey of Long-Term Archiving Implementations

NASA's Heliophysics Data Management Policy calls for discipline-specific "final archives," which will be responsible for the long-term archiving and service of Heliophysics mission data. Long-term archival functions, such as periodic revalidation of the data and migration to newer storage media when appropriate, have never been part of the Solar Data Analysis Center core capabilities. We also recognize that the largest space solar physics data set, the SDO AIA and HMI data at the Stanford Joint Science and Operations Center (JSOC), will eventually need preservation and long-term access, as will the potentially much larger data archive of DKIST observations. We have carried out a study of data archiving best practices in other disciplines and organizations, including NASA's Space Physics Data Facility (SPDF), the National Institute of Standards and Technology (NIST), and private industry, and report on the lessons learned and possible cost models. We seek input from the broader solar physics community on the relative value of various levels of preservation effort.
Author(s): Joseph B Gurman[1], Jennifer L Spencer[1]
Institution(s): *1. NASA Goddard SFC*

403.17 – Eigen-Frequencies of MHD Wave Equations in the Presence of Longitudinal Stratification Density

Coronal Loops oscillations and MHD waves propagating in solar corona and transition region has been observed from TRACE telescope in 1999. In this paper, the MHD mode oscillations of the coronal plasma are studied. The aim is to identify the effect of structuring such as density on the frequencies of oscillations. We modelled the coronal medium as a low- plasma with longitudinally density stratifications. Magnetic flux tube oscillations are categorized to sausage, kink and torsion modes. The MHD equations are reduced and the governing equation are solved numerically using Finite Element Method. Eigenfrequencies and eigenfunctions are extracted. The torsional mode is analyzed. By changing the stratification parameter the antinodes move towards the footpoints and we also concluded that in the thin tube approximation, leakage modes are propagated.
Author(s): shahriar esmaeili[1], Mojtaba Nasiri[1], Neda Dadashi[1], Hossein Safari[1]
Institution(s): *1. university of zanjan*

403.18 – MorePITA - an automated Moreton wave detector

Globally-propagating waves in the solar chromosphere (commonly called Moreton waves) have been observed for more than 50 years, but are typically identified and characterised by eye, leading to significant user bias. The Moreton Pulse Identification and Tracking Algorithm (MorePITA) is a new technique based on the Coronal Pulse Identification and Tracking Algorithm (CorPITA) but tuned to detect Moreton waves using ground based H-alpha observations. We present a preliminary analysis of two events observed by two different Hα telescopes (ISOON and GONG) and compare the results with the equivalent detections made by CorPITA applied to SDO/AIA observations.
Author(s): David Pérez-Suárez[2], David Long[2], Karatholuvu S. Balasubramaniam[1]
Institution(s): *1. Air Force Research Laboratory, 2. Mullard Space Science Laboratory (University College London)*

403.19 – Testing Ionospheric Faraday Rotation Corrections in CASA

The Earth's ionosphere introduces direction- and time-dependent effects over a range of physical and temporal scales and so is a major source for unmodeled phase offsets for low frequency radioastronomical observations. Ionospheric effects are often the limiting factor to making sensitive radioastronomical measurements to probe the solar corona or coronal mass ejections at low frequencies (< 5 GHz). It has become common practice to use global ionospheric models derived from the Global Positioning System (GPS) to provide a means of externally calibrating low frequency data. We have developed a new calibration algorithm in the Common Astronomy Software Applications (CASA) package. CASA, which was developed to meet the data post-processing needs of next generation telescopes such as the Karl G. Jansky Very Large Array (VLA), did not previously have the capability to mitigate ionospheric effects. This algorithm uses GPS-based global ionosphere maps to mitigate the first and second order ionospheric effects (dispersion delay and Faraday rotation, respectively). We investigated several data centers as potential sources for global ionospheric models and chose the International Global Navigation Satellite System Service data product because data from other sources are generally too sparse to use without additional interpolation schemes. This implementation of ionospheric corrections in CASA has been tested on several sets of VLA observations and all of them showed a significant reduction of the dispersion delay. In order to rigorously test CASA's ability to mitigate ionospheric Faraday rotation, we made VLA full-polarization observations of the standard VLA phase calibrators J0359+5057 and J0423+4150 in August 2014, using L band (1 − 2 GHz), S band (2 − 4 GHz), and C band (4 − 6 GHz) frequencies in the D array configuration. The observations were 4 hours in duration, beginning near local sunrise. In this paper, we give a general description of how these corrections are implemented as well as discussion of the code's ability to mitigate the ionospheric effects present in these test observations over a range of times and elevation angles. This work was supported at the University of Iowa by grant ATM09-56901.

Author(s): Jason E Kooi[2], George Moellenbrock[1]
Institution(s): *1. National Radio Astronomy Observatory, 2. University of Iowa*

403.20 – Measurements Verifying the Optics of the Electron Drift Instrument

Magnetic reconnection is the process of breaking and reconnecting of opposing magnetic field lines, and is often associated with tremendous energy transfer. The energy transferred by reconnection directly affects people through its influence on geospace weather and technological systems - such as telecommunication networks, GPS, and power grids. However, the mechanisms that cause magnetic reconnection are not well understood. The Magnetospheric Multi-Scale Mission (MMS) will use four spacecraft in a pyramid formation to make three-dimensional measurements of the structures in magnetic reconnection occurring in the Earth's magnetosphere.The spacecraft will repeatedly sample these regions for a prolonged period of time to gather data in more detail than has been previously possible. MMS is scheduled to be launched in March of 2015. The Electron Drift Instrument (EDI) will be used on MMS to measure the electric fields associated with magnetic reconnection. The EDI is a device used on spacecraft to measure electric fields by emitting an electron beam and measuring the **E** x **B** drift of the returning electrons after one gyration. This paper concentrates on measurements of the EDI's optics system. The testing process includes measuring the optics response to a uni-directional electron beam. These measurements are used to verify the response of the EDI's optics and to allow for the optimization of the desired optics state. The measurements agree well with simulations and we are confident in the performance of the EDI instrument.

Author(s): Vanessa Kooi[1], Craig Kletzing[1], Scott Bounds[1], Kristine M Sigsbee[1]
Institution(s): *1. University of Iowa*

403.21 – High resolution compact Fabry-Perot spectrometer for spaceborne applications

We are developing a robust compact spectrometer for observations of the diffuse objects where large field of view and high spectral resolving power is required. The instrument is based on solid Fabry-Perot etalons that are controlled thermally. The use of higher refractive index glass allows proportionally increase the acceptance angle of the instrument, thus increasing its throughput. The thermal tuning of the etalons makes it simple in operation and robust, which is particularly important in spaceborne applications. This instrument may find its use in the in the spectroscopy and velocity field measurements of the coronal outflows, interplanetary dust studies, Earth atmosphere and large scale diffuse objects of low surface brightness.
Author(s): Alexander Kutyrev[1]
Institution(s): *1. NASA GSFC/UMCP*

404 – SPD Karen Harvey Prize: Advances in the Understanding of Coronal Energy Release Mechanisms, Jonathan W. Cirtain (NASA Marshall Space Flight Center)

404.01 – Advances in the understanding of coronal energy release mechanisms

Conversion of the free energy stored in the solar atmospheric magnetic field has been proposed as the fundamental process maintaining the high temperature corona as well as acting as the energy source for explosive energetic events like flares and Coronal Mass Ejections. One prevailing theory for the energy release mechanism is magnetic reconnection, the process where magnetic field topology is rearranged converting the stored energy into thermal and kinetic energy and used to accelerate particles. Due to the range of spatial and temporal scales involved in these processes, direct observations of magnetic reconnection remain elusive. We will discuss the theory of magnetic reconnection and provide examples from recent observatories and instrumentation that demonstrate clear evidence of reconnection in process.
Author(s): Jonathan W. Cirtain[1]
Institution(s): *1. NASA Marshall Space Flight Center*

405 – The Heliosphere and Beyond

405.01 – Of the consequences of the inferred constitutive nature of state of matter possibly characteristic of a class of strongly magnetized plasma in astrophysics

We conjecture that the structure of a class of solar transients (magnetic cloud, MC) is constituted by matter coalescent to a super strong magnetic field, which high temperature manifests itself through the presence of a hot electron gas, possibly constituted by the halo-part of the e-distribution. We identify the presence of this state of matter in strongly magnetized transients in the solar wind beyond a few solar radii from the Sun and extending well beyond 1 AU[a]. We present a few constitutive properties resulting of a recent thermodynamic study identifying this state of matter. These main outcomes are evaluated for a case study, the June 2, 1998 MC observed with SC Wind. In our view the most relevant outcome is the estimation of its magnetic permeability, two orders of magnitude smaller than that of the vacuum. This implies a highly diamagnetic material. Other properties to be discussed are the anomalous adiabatic behavior of this conjectured e-gas. In addition, and with the help of a simple MHD 3-D evolutionary model of the structure[b], we present estimate values to its: (a) acoustic speed, (b) free current density, (c) and low limit to the electrical permittivity.

[a]Berdichevsky, D. B., and K. Schefers, under review (ApJ, 2014).
[b]Berdichevsky, D. B., Sol Phys, 284, 245-259, 2013.
Author(s): Daniel Benjamin Berdichevsky[1]
Institution(s): *1. BERDICHEVSKY, DANIEL B*

405.02 – Enhanced Spectral Analysis of SEP Reservoir Events by OMNIWeb Multi-Source Browse Services of the Space Physics Data Facility and the Virtual Energetic Particle Observatory

The NASA Space Physics Data Facility and Virtual Energetic Particle Observatory (VEPO) have jointly upgraded the highly used OMNIWeb services for heliospheric solar wind data to also include energetic electron, proton, and heavier ion data in a variety of graphical browse formats. The underlying OMNI and VEPO data now span just over a half century from 1963 to the present. The new services include overlay of differential flux spectra from multiple instruments and spacecraft, scatter plots of fluxes from two user-selected energy channels, distribution function histograms of selected parameters, and spectrograms of flux vs. energy and time. Users can also overlay directional flux spectra from different angular channels. Data from most current and some past (Helios 1&2, Pioneer 10&11) heliospheric spacecraft and instruments are wholly or partially covered by these evolving new services. The traditional OMNI service of correlating magnetic field and plasma data from L1 to 1 AU solar wind sources is also being extended for other spacecraft, e.g. Voyager 1 and 2, to correlations with energetic particle channels. The user capability is, for example, demonstrated to rapidly scan through particle flux spectra from consecutive time periods for so-called “reservoir” events, in which solar energetic particle flux spectra converge in shape and amplitude from multiple spacecraft sources within the inner heliosphere. Such events are important for understanding spectral evolution of global heliospheric events and for intercalibration of flux data from multiple instruments of the same and different spacecraft. These services are accessible at http://omniweb.gsfc.nasa.gov/. SPDF and VEPO are separately accessible at http://spdf.gsfc.nasa.gov/ and http://vepo.gsfc.nasa.gov/.In the future we will propose to extend OMNIWeb particle flux data coverage to the plasma and suprathermal energy range.
Author(s): John F. Cooper[1], Natalia E. Papitashvili[1], Rita C. Johnson[1], Robert McGuire[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. NASA Goddard Space Flight Center*

405.03 – The magnetic flux excess effect as a consequence of non-Parker radial evolution of interplanetary magnetic field

The “magnetic flux excess” effect is exceeding of magnetic flux $F_s=4\pi|B_r|r^2$ measured by distant spacecraft over the values obtained through measurements at the Earth’s orbit (Owens et al., JGR, 2008). Theoretically, its conservation should take place at any heliocentric distance r further than 10 solar radii, which means that the difference between the flux measured at 1 AU and F_s observed in another point in the heliosphere should be zero. However, the difference is negative closer to the Sun and increasingly positive at larger heliocentric distances. Possible explanations of this effect are continuously discussed, but the consensus is yet not reached.
It is shown that a possible source of this effect is the solar wind expansion not accordingly with the Parker solution at least at low heliolatitudes. The difference between the experimentally found ($r^{-5/3}$) and commonly used (r^{-2}) radial dependence of the radial component of the IMF B_r may lead to mistakes in the IMF point-to-point recalculations (Khabarova & Obridko, ApJ, 2012; Khabarova, Astronomy Reports, 2013). Using the observed $B_r(r)$ dependence, it is easy to find the variation of difference between the magnetic flux $F_s(r)$ at certain heliocentric distance r and F_{s_1AU} at 1 AU, which can be calculated as $F_s(r)\text{-}F_{s\_1AU}=4\pi\cdot(B_{1AU}/[1AU]^{-5/3})\ (r^{2-5/3}-[1AU]^{2-5/3})$ (Khabarova, Astronomy Reports, 2013).
The possible influence of presence of the heliospheric current sheet near the ecliptic plane on the

picture of magnetic field lines and consequent deviation from the Parker's model is discussed.
- Khabarova Olga, and Obridko Vladimir, Puzzles of the Interplanetary Magnetic Field in the Inner Heliosphere, 2012, Astrophysical Journal, 761, 2, 82, doi:10.1088/0004-637X/761/2/82, http://arxiv.org/pdf/1204.6672v2.pdf
- Olga V. Khabarova, The interplanetary magnetic field: radial and latitudinal dependences. Astronomy Reports, 2013, Vol. 57, No. 11, pp. 844–859, http://arxiv.org/ftp/arxiv/papers/1305/1305.1204.pdf

Author(s): Olga Khabarova[1]
Institution(s): *1. IZMIRAN*

405.04 – Investigating the heliospheric ion suprathermal tail with *Voyager* LECP/LEMPA/alpha data: Instrument modeling and preliminary results

Using publicly available data from the *Voyager* Low Energy Charged Particle (LECP) instruments, we investigate the form of the solar wind ion suprathermal tail in the outer heliosphere inside the termination shock. This tail has a commonly observed form in the inner heliosphere, that is, a power law with a particular spectral index. The *Voyager* spacecraft have taken data beyond 100 AU, farther than any other spacecraft. However, during extended periods of time, the data appears to be mostly background. We have developed a technique to self-consistently estimate the background seen by LECP due to cosmic rays using data from the *Voyager* cosmic ray instruments and a simple, semi-analytical model of the LECP instruments. In this presentation, we present initial results of applying the simple model to solar wind, heliosheath, and interstellar medium data. The results are the following: 1) the basic shape and overall magnitude of the model spectra is consistent with the data, implying that the source of the omnipresent background is indeed cosmic rays; however, the exact shape is not quite matched, 2) the data taken in the heliosheath, when the signal-to-background ratio is significantly higher, is not inconsistent with the “common” spectrum of Fisk and Gloeckler (j~E^-1.5 with an exponential roll-over), a result which is not obvious from the uncorrected data. An estimate of future improvements to the model will also be discussed.

Author(s): Brent Randol[1], Eric R. Christian[1]
Institution(s): *1. NASA Goddard*

405.05 – Ion-Neutral Coupling in the Outer Heliosphere and Beyond

Charge-exchange between solar wind (SW) ions and interstellar neutral atoms is one of the major physical processes that affect the properties of the colliding media. It decelerates and heats up both the SW and the local interstellar medium (LISM), creates pickup ions (PUI) as a nonthermal ion population, produces energetic neutral atoms (ENAs), and destabilizes the heliopause (HP). The geometrical scale of the heliospheric interface is also strongly influenced by charge exchange. In this presentation, we address the following issues: (1) the filtration of the LISM hydrogen (H) atoms at the heliospheric interface and their deflection from the original direction as they penetrate deep into the heliosphere; (2) the asymmetries of the heliospheric termination shock (TS) and HP due to the combined action of charge exchange and magnetic field pressure; (3) the role of charge exchange in the production of PUIs and related turbulent heating of the SW; (4) the role of secondary (born during primary charge exchange events) neutral atoms on the LISM plasma heating and deceleration, and kinetic effects responsible for the presence (or absence) of a bow shock in front of the HP; (5) the importance of charge exchange at the HP in the destabilization of its nose and flanks and X-ray emission which is expected to highlight those regions; and (6) the role of ENAs, measured by the IBEX and Cassini spacecraft in the analysis of the topology of the heliosphere. Theoretical and numerical results are compared with in situ and remote observations.

Author(s): Nikolai Pogorelov[2], Jacob Heerikhuisen[2], Igor Kryukov[1], Gary Zank[2]
Institution(s): *1. Institute for Problems in Mechanics, Russian Academy of Sciences, 2. University of Alabama in Huntsville*

405.06 – Space Physics of Close-in Exoplanets and its Implications for Planet Habitability

The search for habitable exoplanets is currently focused on planets orbiting M-dwarf stars, due to the close proximity of the habitable zone to the star. However, the traditional habitability definition does not account for the physical space environment near the planets, which can be extreme at close-in orbits, and can lead to erosion of te planetary atmosphere. In order to sustain their atmosphers, M-dwarf planets need to have either an intrinsic magnetic field, or a thick atmosphere. Here we present a set of numerical magnetohydrodynamic simulations of the interaction of an Earth-like magnetized planet and a Venus-like non-magnetized planet with the stellar wind of M-dwarf star. We study space physics aspects of these interactions and their implications for planet habitability
Author(s): Ofer Cohen[1]
Institution(s): *1. Harvard-Smithsonian CfA*

406 – The Statistical Flare

406.01 – Hard X-ray imaging spectroscopy of FOXSI microflares

The ability to investigate particle acceleration and hot thermal plasma in solar flares relies on hard X-ray imaging spectroscopy using bremsstrahlung emission from high-energy electrons. Direct focusing of hard X-rays (HXRs) offers the ability to perform cleaner imaging spectroscopy of this emission than has previously been possible. Using direct focusing, spectra for different sources within the same field of view can be obtained easily since each detector segment (pixel or strip) measures the energy of each photon interacting within that segment. The Focusing Optics X-ray Solar Imager (FOXSI) sounding rocket payload has successfully completed two flights, observing microflares each time. Flare images demonstrate an instrument imaging dynamic range far superior to the indirect methods of previous instruments like the RHESSI spacecraft.
In this work, we present imaging spectroscopy of microflares observed by FOXSI in its two flights. Imaging spectroscopy performed on raw FOXSI images reveals the temperature structure of flaring loops, while more advanced techniques such as deconvolution of the point spread function produce even more detailed images.
Author(s): Lindsay Glesener[3], Sam Krucker[3], Steven Christe[1], Juan Camilo Buitrago-Casas[3], Shin-nosuke Ishikawa[2], Natalie Foster[4]
Institution(s): *1. NASA/Goddard Space Flight Center, 2. National Astronomical Observatory of Japan, 3. University of California, Berkeley, 4. University of Florida*

406.02 – Flare Clustering

In this study we tested for groups of flares (flare clusters) in which successive flares occur within a fixed time - the linking window. The data set used is the flare waiting times provided by the X-ray flare detectors on the Geostationary Operational Environmental Satellites (GOES). The study was limited to flares of magnitude C5 and greater obtained during cycle 23. While many flares in a cluster may come from the same active region, the larger clusters often have origins in multiple regions. The longest cluster of the last cycle lasted more than 42 days with an average time separation between successive

flares of 5 hours, where no two flares were separated by more than 36 hours. The flare rate in clusters is 4 to 6 time greater than the rate in solar maximum outside of flares. The are indications that flare clustering is associated with periods of multiple sunspot nests, but they are much rarer.
Author(s): Alan M Title[1]
Institution(s): *1. Lockheed Martin*

406.03 – Magnetic and Hydrodynamic Energy Scaling Laws in Solar Flares

We determine the dissipated non-potential magnetic energy and measure the multi-thermal energy in a sample of about 400 M and X-class flares observed with AIA and HMI during the first 4 years of the SDO mission. The free energy is determined with two nonlinear force-free field (NLFFF) models, one is based on the 3D vector
photospheric magnetic field and the other uses forward-fitting of a vertical-current model to automatically traced coronal loops.The multi-thermal energy is measured with a spatial-synthesis differential emission measure (DEM) code, which yields a more comprehensive multi-thermal energy (being larger by an average
factor of 14) than iso-thermal estimates. We show how the correlations and powerlaw-like size distributions of energies and other geometrical and physical parameters reveal magnetic and hydrodynamic scaling laws
that are in agreement with recent statistical models of nonlinear dissipative systems governed by self-organized criticality.
Author(s): Markus Aschwanden[1], Paul Boerner[1], Yan Xu[3], Jing Ju[3], Dan Ryan[2], Amir Caspi[5], James McTiernan[6], Harry Warren[4]
Institution(s): *1. Lockheed Martin, 2. NASA Goddad Space Flight Center, 3. NJIT, 4. NRL, 5. Southwest Research Institute, 6. University of Berkeley*

406.04 – X-class Flares at the Maximum of Solar Cycle 24

17 instruments on 7 spacecraft were used to examine NOAA GOES X-class solar flares. This data set has unique spatial and temporal coverage of solar activity occurring from 15 February 2011 to 10 September 2014 and includes 32 X-class flare events.
In 32 of 32 cases EUV running difference sequences of Fe XII disk images show the initiation of an LCPF (Nitta et al., 2013) at or near the time of flare onset. These features are generally seen moving upward and away from the X-flare site. In 28 of 32 cases the SWAVES instruments on the STEREO A & B spacecraft detected Type III radio bursts coincident in time with the flare initiation. The four flares that are exceptions are characterized as brief peaks in integrated X-ray flux.
In 31 of 32 of the X-class flare events Cor1 imagers (1.04-4.0 R_o) initially show a rising arch followed by a cavity. In 27of 32 cases at increased heights from three vantage points STEREO and SOHO time sequences follow the development of the outward expansion of structure from 4.0-20 R_o.
It is concluded from the imagery that the LCPF is a shock front (likely MHD fast mode) that surrounds CME and prominence material as structures rise and expand. Using measurements from the CME on 20110307, X5.4, mach number estimates of the shock strength range from 1.7-3.2 over the combined fields of view.
For 25 of 32 events the CMEs detected were either characterized as halo events or demonstrated latitudinal and longitudinal expansion characteristics that would have created a halo for an observer located along the axis between the flare and the nose of the expanding shock. This configuration of a CME can be characterized as a bubble. It is concluded that bubble CMEs were associated with 78% of X-class flares during the maximum of solar cycle 24.

In 6 of 32 cases all NASA proton detectors located at 1 AU distance from the sun were impacted by flare generated protons.

Nitta, N. V., C. J. Schrijver, A. M. Title, W. Liu (2013) Large-scale Coronal Propagating Fronts in Solar Eruptions as Observed by the Atmospheric Imaging Assembly on Board the Solar Dynamics Observatory--an Ensemble Study, *ApJ*, 776:58 (13pp).

Author(s): Richard R. Fisher[1], Kristine A. Rock[2]
Institution(s): *1. NASA GSFC, 2. Retired*

406.05 – How can we interpret and understand pulsations in solar flare emission? A Bayesian model comparison approach.

Recent work has shown that power-law-like Fourier power spectra are an intrinsic property of solar and stellar flare signals, similarly to other astrophysical objects such as gamma-ray bursts and magnetars. It is therefore critical to account for this in order to understand the nature and significance of short-timescale fluctuations in flares.

We present the results of a Bayesian model comparison method for investigating flare time series, fully considering these Fourier power-law properties. Using data from the PROBA2/Large Yield Radiometer, Fermi/Gamma-ray Burst Monitor, Nobeyama Radioheliograph, and Yohkoh/HXT instruments, we study a selection of flares from the literature identified as 'quasi-periodic puslation (QPP)' events. While emphasising that the observed fluctuations are real and of solar origin, we find that, for all but one event tested, an explicit oscillation is not required to explain the observations. Instead, the observed flare signals are adequately described as a manifestation of a power law in the Fourier power spectrum. This evaluation of the QPP phenomenon is markedly different from much of the prior literature.

We conclude that the prevalence of oscillatory signatures in solar and stellar flares may be less than previously believed. Furthermore, studying the slope of the observed Fourier power spectrum as a function of energy may provide us with a diagnostic window into the fundamental nature of solar flares.
Author(s): Andrew Inglis[1], Jack Ireland[1], Marie Dominique[2]
Institution(s): *1. NASA Goddard Space Flight Center, 2. Royal Observatory of Belgium*

406.06 – Characteristics of Four SPE Classes According to Onset Timing and Proton Acceleration Patterns

In our previous work (Kim et al., 2015), we suggested a new classification scheme, which categorizes the SPEs into four groups based on association with flare or CME inferred from onset timings as well as proton acceleration patterns using multienergy observations. In this study, we have tried to find whether there are any typical characteristics of associated events and acceleration sites in each group using 42 SPEs from 1997 to 2012. We find: (i) if the proton acceleration starts from a lower energy, a SPE has a higher chance to be a strong event (> 5000 pfu) even if the associated flare and CME are not so strong. The only difference between the SPEs associated with flare and CME is the location of the acceleration site. For the former, the sites are very low (~1 Rs) and close to the western limb, while the latter has a relatively higher (mean=6.05 Rs) and wider acceleration sites. (ii) When the proton acceleration starts from the higher energy, a SPE tends to be a relatively weak event (< 1000 pfu), in spite of its associated CME is relatively stronger than previous group. (iii) The SPEs categorized by the simultaneous proton acceleration in whole energy range within 10 minutes, tend to show the weakest proton flux (mean=327 pfu) in spite of strong related eruptions. Their acceleration heights are very close to the locations of type II radio bursts. Based on those results, we suggest that the different

characteristics of the four groups are mainly due to the different mechanisms governing the acceleration pattern and interval, and different condition such as the acceleration location.
Author(s): Roksoon Kim[1]
Institution(s): *1. Korea Astronomy and Space Science Institute*

407 – Jets and Supra-Arcade Downflows

407.01 – Small-Scale Filament Eruptions Leading to Solar X-Ray Jets

We investigate the onset of ~10 random X-ray jets observed by Hinode/XRT. Each jet was near the limb in a polar coronal hole, and showed a ``bright point'' in an edge of the base of the jet, as is typical for previously-observed X-ray jets. We examined SDO/AIA EUV images of each of the jets over multiple AIA channels, including 304 Å, which detects chromospheric emissions, and 171, 193, and 211 Å, which detect cooler-coronal emissions. We find the jets to result from eruptions of miniature (size <~10 arcsec) filaments from the bases of the jets. Much of the erupting-filament material forms a chromospheric-temperature jet. In the cool-coronal channels, often the filament appears in absorption and the hotter EUV component of the jet appears in emission. The jet bright point forms at the location from which the miniature filament erupts, analogous to the formation of a standard solar flare arcade in the wake of the eruption of a typical larger-scale
chromospheric filament. The spire of the jet forms on open field lines that presumably have undergone interchange reconnection with the erupting field that envelops and carries the miniature filament. Thus these X-ray jets and their bright points are made by miniature filament eruptions via ``internal'' and ``external'' reconnection of the erupting field. This is consistent with what we found for the onset of an on-disk coronal jet we examined in Adams et al. (2014). This work was supported by funding from NASA/LWS, Hinode, and ISSI.
Author(s): Alphonse Sterling[1], Ronald Moore[2], David Falconer[2]
Institution(s): *1. NASA/MSFC, 2. UAH*

407.02 – Reconnection and Spire Drift in Coronal Jets

It is observed that there are two morphologically-different kinds of X-ray/EUV jets in coronal holes: standard jets and blowout jets. In both kinds: (1) in the base of the jet there is closed magnetic field that has one foot in flux of polarity opposite that of the ambient open field of the coronal hole, and (2) in coronal X-ray/EUV images of the jet there is typically a bright nodule at the edge of the base. In the conventional scenario for jets of either kind, the bright nodule is a compact flare arcade, the downward product of interchange reconnection of closed field in the base with impacted ambient open field, and the upper product of this reconnection is the jet-outflow spire. It is also observed that in most jets of either kind the spire drifts sideways away from the bright nodule. We present the observed bright nodule and spire drift in an example standard jet and in two example blowout jets. With cartoons of the magnetic field and its reconnection in jets, we point out: (1) if the bright nodule is a compact flare arcade made by interchange reconnection, then the spire should drift toward the bright nodule, and (2) if the bright nodule is instead a compact flare arcade made, as in a filament-eruption flare, by internal reconnection of the legs of the erupting sheared-field core of a lobe of the closed field in the base, then the spire, made by the interchange reconnection that is driven on the outside of that lobe by the lobe's internal convulsion, should drift away from the bright nodule. Therefore, from the observation that the spire usually drifts away from the bright nodule, we infer: (1) in X-ray/EUV jets of either kind in coronal holes the interchange reconnection that generates the jet-outflow spire usually does not make the

bright nodule; instead, the bright nodule is made by reconnection inside erupting closed field in the base, as in a filament eruption, the eruption being either a confined eruption for a standard jet or a blowout eruption (as in a CME) for a blowout jet, and (2) in this respect, the conventional reconnection picture for the bright nodule in coronal jets is usually wrong for observed coronal jets of either kind.
Author(s): Ronald Moore[1], Alphonse Sterling[1], David Falconer[1]
Institution(s): *1. NASA/Marshall Space Flight Center*

407.03 – Coronal Jets in Closed Magnetic Regions on the Sun

Coronal jets are dynamic, collimated structures observed in solar EUV and X-ray emission. They appear predominantly in the open field of coronal holes, but are also observed in areas of closed field, especially active regions. A common feature of coronal jets is that they originate from the field above a parasitic polarity of opposite sign to the surrounding field. Some process – such as instability onset or flux emergence – induces explosive reconnection between the closed "anemone" field and the surrounding open field that generates the jet. The lesser number of coronal jets in closed-field regions suggests a possible stabilizing effect of the closed configuration with respect to coronal jet formation. If the scale of the jet region is small compared with the background loop length, as in for example type II spicules, the nearby magnetic field may be treated as locally open. As such, one would expect that if a stabilizing effect exists it becomes most apparent as the scale of the anemone region approaches that of the background coronal loops.
To investigate if coronal jets are indeed suppressed along shorter coronal loops, we performed a number of simulations of jets driven by a rotation of the parasitic polarity (as in the previous open-jet calculations by Pariat et. al 2009, 2010, 2015) embedded in a large-scale closed bipolar field. The simulations were performed with the state of the art Adaptively Refined Magnetohydrodynamics Solver. We will report here how the magnetic configuration above the anemone region determines the nature of the jet, when it is triggered, and how much of the stored magnetic energy is released. We show that regions in which the background field and the parasitic polarity region are of comparable scale naturally suppress explosive energy release. We will also show how in the post-jet relaxation phase a combination of confined MHD waves and weak current layers are generated by the jet along the background coronal loops, both of which may have implications for coronal heating.
This work was supported by an appointment to the NASA Postdoctoral Program (P.F.W.) and by NASA's Living With a Star Targeted Research and Technology program (C.R.D.).
Author(s): Peter Fraser Wyper[1], C R DeVore[1]
Institution(s): *1. Goddard Space Flight Center*

407.04D – Dynamical Thermal Structure of Super-arcade Downflows in Solar Flares

Super-arcade downflows (SADs) have been frequently observed during the gradual phase of flares near the limb. In coronal emission lines sensitive to flaring plasmas, they appear as tadpole-like dark voids against the bright fan-shape "haze" above the well-defined flare arcade and flow toward the arcade. We carefully studied several selected SADs from two flare events using data observed by *Solar Dynamic Observatory / Atmospheric Imaging Assembly* and calculated their differential emission measures (DEMs) as well as the DEM-weighted temperature. Our analysis shows that SADs are associated with a substantially decreased DEMs, by 1~3 order of magnitude, compared with the surrounding plasma. None of the SADs indicate DEM solutions above 20 MK, which implies that SADs are indeed density depletion rather than very hot plasma. This depression in DEMs rapidly recovers as SADs pass through, generally in a few minutes. In addition, we found that SADs in one event appear spatio-temporally

associated with the formation of postflare loops. These results are examined against models and numerical simulations.
Author(s): Xin Chen[1], Rui Liu[2], Na Deng[1], Haimin Wang[1]
Institution(s): *1. New Jersey Institute of Technology, 2. University of Science and Technology of China*

407.05 – On the Magnetohydrodynamics of Supra-Arcade Fan Structures

Supra-Arcade Fan Structures are highly dynamic regions that form above post-reconnection arcades. In these regions, the plasma density and thermal structure evolve on the scale of a few seconds, despite the much slower dynamics of the underlying arcade. Further, the motion of supra-arcade plasma plumes appears to be inconsistent with the low-beta conditions that many authors assume to exist in the solar corona. In order to understand the nature of these highly debated structures it is, therefore, important to investigate the interplay of the magnetic field with the plasma. Here we present a technique for inferring the underlying MagnetoHydroDynamic processes that might lead to the types of motions seen in supra-arcade structures. We begin with EUV observations and develop a time dependent velocity field that is consistent with both mass conservation and local correlation tracking. We then assimilate this velocity field into a simplified MHD code, which deals simultaneously with regions of high and low SNR, thereby allowing the magnetic field to evolve self-consistently with the fluid. Ultimately, we extract the missing contributions from the underlying momentum equation in order to estimate the relative strength of forcing terms. In this way we are able to make estimates of the plasma beta as well as predicting the spectral character of radiated Alfvén waves. It is our hope that this work will help to improve our understanding of the energy balance in these complex regions and, thereby, contribute to our knowledge of the solar corona as a whole. This work is supported by NASA under contract NNM07AB07C with the Smithsonian Astrophysical Observatory, and by grant NNX14AD43G.
Author(s): Roger B. Scott[1], David McKenzie[1], Dana Longcope[1]
Institution(s): *1. Montana State University*

407.06 – The energetics of a global shock wave in the low solar corona

As the most energetic eruptions in the solar system, coronal mass ejections (CMEs) can produce shock waves at both their front and flanks as they erupt from the Sun into the heliosphere. However, the amount of energy produced in these eruptions, and the proportion of their energy required to produce the waves, is not well characterised. Here we use observations of a solar eruption from 2014 February 25 to estimate the energy budget of an erupting CME and the globally-propagating "EIT wave" produced by the rapid expansion of the CME flanks in the low solar corona. The "EIT wave" is shown using a combination of radio spectra and extreme ultraviolet images to be a shock front with a Mach number greater than one. Its initial energy is then calculated using the Sedov-Taylor blast-wave approximation, which provides an approximation for a shock front propagating through a region of variable density. This approach provides an initial energy estimate of ~2.8 x 10^31 ergs to produce the "EIT wave", which is approximately 10% the kinetic energy of the associated CME (shown to be ~2.5 x 10^32 ergs). These results indicate that the energy of the "EIT wave" may be significant and must be considered when estimating the total energy budget of solar eruptions.
Author(s): David Long[2], Deborah Baker[2], David Williams[2], Eoin Carley[1], Peter Gallagher[1], Pietro Zucca[1]
Institution(s): *1. Trinity College Dublin, 2. University College London*

408 – Flares with few-or-no CMEs

408.01 – A Tale of Two Super-Active Active Regions: On the Magnetic Origin of Flares and CMEs

From a comparative study of two super-active active regions, we find that the magnetic origin of CMEs is different from that of flares. NOAA AR 12192 is one of the largest active regions in the recorded history with a sunspot number of 66 and area of 2410 millonths. During its passage through the front disk from Oct. 14-30, 2014, the active region produced 93 C-class, 30 M-class and 6 X-class flares. However, all six X-class flares are confined; in other words, none of them are associated with CMEs; most other flares are also confined. This behavior of low-CME production rate for such as a super active region is rather peculiar, given the usual hand-on-hand occurrence of CMEs with flares. To further strengthen this point, we also investigated the super-active NOAA AR 11429, which had a sunspot number of 28 and area of 1270 millionths. During its passage from March 02-17, 2012, the active region produced 47 C-class, 15 M-class and 3 X-class flares. In this active region, all three X-class flares were accompanied by CMEs, and the same for most M-class flares. Given the relative sizes of the two active regions, the production rates of flares are comparable. But the CME production rates are not. Through a careful study of the magnetic configuration on the surface and the extrapolated magnetic field in the corona, we argue that the generation of flares largely depends on the amount of free energy in the active region. On the other hand, the generation of CMEs largely depends on the complexity, such as measured by magnetic helicity. In particular, we argue that the high CME generation rate in the smaller active region is caused by the emergence and continuous generation of magnetic flux ropes in the region.
Author(s): Jie Zhang[1], Suman Dhakal[1], Georgios Chintzoglou[1]
Institution(s): *1. George Mason University*

408.02 – Why Is the Great Solar Active Region 12192 CME-Poor?

Solar active region (AR) 12192 of October 2014 hosts the largest sunspot group in 24 years. It is the most prolific flaring site of Cycle 24, but surprisingly produced no coronal mass ejection (CME) from the core region during its disk passage. Here, we study the magnetic conditions that prevented eruption and the consequences that ensued. We find AR 12192 to be "big but mild"; its core region exhibits weaker non-potentiality, stronger overlying field, and smaller flare-related field changes compared to two other major flare-CME-productive ARs (11429 and 11158). These differences are present in the intensive-type indices (e.g., means) but generally not the extensive ones (e.g., totals). AR 12192's large amount of magnetic free energy does not translate into CME productivity. The unexpected behavior suggests that AR eruptiveness is limited by some relative measure of magnetic non-potentiality over the restriction of background field, and that confined flares may leave weaker photospheric and coronal imprints compared to their eruptive counterparts.
Author(s): Xudong Sun[1], Monica G Bobra[1], Todd Hoeksema[1], Yang Liu[1], Yan Li[2], Chenglong Shen[3], Sebastien Couvidat[1], Aimee A Norton[1], George H Fisher[2]
Institution(s): *1. Stanford University, 2. UC Berkeley, 3. University of Science and Technology of China*

408.03 – Radio Observations of the CME-poor region AR2192: a type II burst with no CME driver

The remarkable sunspot group NOAA AR 2192 (October 2014) produced X-class flares without CMEs, and in general was large and powerful but with little heliospheric interaction. We discuss radio perspectives on the development of this region. In particular there were decametric type II bursts observed in association with jet-like flares SOL2014-10-21T12:28 (C4.4) and SOL2014-10-21T13:38 (M1.2), as first noted in the Glasgow Callisto observatory and confirmed via the Meudon decametric array. In cases such as this, the global coronal wave responsible for the type II emission seems to

originate from an ejection of material flowing along a previously established field structure, rather than perpendicular to it as in a CME.
Author(s): Hugh Hudson[2], Nicole Vilmer[1], Peter Wakeford[3]
Institution(s): *1. Paris Observatory, 2. UC Berkeley, 3. University of Glasgow*

408.04 – PROBA2/SWAP Observations of the Unusual Activity of AR12192

AR 12192 was the most productive active region of the present solar cycle in terms of flares, but it exhibited many unusual properties. It announced its presence on 14 October 2014 with an eruption that led to the formation of perhaps the largest post-eruptive loop system seen in the solar corona in solar cycle 24. Later this region produced a series of large M- and X-class flares, most of which were essentially confined flares, not associated with any coronal mass ejection. During its second passage across the solar disk, it was associated with a huge region of open field that was observed extending to heights as great as 3 solar-radii in the EUV, some of the largest heights at which any EUV structure has been observed. We discuss our observations of this region with the SWAP EUV imager on board the PROBA2 spacecraft and the implications of the many unusual events and structures associated with this region on our understanding of the mechanisms, such as magnetic reconnection, that drive coronal dynamics, in particular those involved in the onset of flares and eruptions.
Author(s): Daniel B Seaton[1], Matthew J West[1]
Institution(s): *1. Royal Observatory of Belgium*

408.05 – A Prominence/filament eruption triggered by eight homologous flares

Eight homologous flares occurred in active region NOAA 11237 over 16 - 17 June 2011. A prominence system with a surrounding coronal cavity was adjacent to, but still magnetically connected to the active region. The eight eruptions expelled hot material from the active region into the prominence/filament cavity system (PFCS) where the ejecta became confined. We mainly aim to diagnose the 3D dynamics of the PFCS during the series of eight homologous eruptions by using data from two instruments: SDO/AIA and STEREO/EUVI-B, covering the Sun from two directions. The field containing the ejected hot material interacts with the PFCS and causes it to inflate, resulting in a discontinuous rise of the prominence/filament approximately in steps with the homologous eruptions. The eighth eruption triggers the PFCS to move outward slowly, accompanied by a weak coronal dimming. Subsequently the prominence/filament material drains to the solar surface. This PFCS eruption evidently slowly opens field overlying the active region, which results in a final 'ejective' eruption from the core of the active region. A strong dimming appears adjacent to the final eruption's flare loops in the EUVI-B images, followed by a CME. We propose that the eight homologous flares gradually disrupted the PFCS and removed the overlying field above the active region, leading to the CME via the 'lid removal' mechanism.
Author(s): Navdeep K Panesar[1], Alphonse Sterling[3], Davina Innes[2], Ronald Moore[1]
Institution(s): *1. Center for Space Plasma and Aeronomic Research, 2. Max Planck Institute for Solar System Research, 3. NASA/MSFC*

408.06 – Study of a dense, coronal thick target source with the microwave data and 3D modeling

We present a detailed 3D modeling of a dense, coronal thick target X-ray flare using the GX Simulator tool, photospheric magnetic measurements, and microwave data. The developed model offers a remarkable agreement between the synthesized and observed spectra and images in both X-ray and microwave domains, which validates the entire model. The flaring loop parameters validated via the

modeling are fully consistent with those derived from the X-ray spectral fit, but do not easily agree with those derived from the fit of the X-ray image sizes computed at various energies. Specifically, the plasma density obtained in the modeling is noticeably smaller than that derived from the size fit. The performed modeling suggests that the accelerated electrons are trapped at the coronal part of the flaring loop by a turbulence, while proves that the data are clearly inconsistent with the electron magnetic trapping in the weak diffusion regime mediated by the Coulomb collisions. Thus, the modeling confirms the interpretation of the coronal thick-target sources as the sites of electron acceleration in flares.
This work was supported in part by NSF grants AGS-1250374, AGS-1262772, AGS-1153424, AGS-1348513, and AGS-1408703 and NASA grants NNX14AC87G and NNX-13AG13G to New Jersey Institute of Technology.
Author(s): Gregory Fleishman[1], Yan Xu[1]
Institution(s): *1. NJIT*

409 – Large-Scale Corona

409.01 – PROBA2/SWAP EUV images of the large-scale EUV corona up to 3 solar radii: Can we close the gap in coronal magnetic field structure between 1.3 and 2.5 solar radii?

The EUV telescope PROBA2/SWAP has been observing the solar corona in a bandpass near 17.4 nm since February 2010. SWAP's wide field-of-view provides a unique and continuous view of the extended EUV corona up to 2-3 solar radii. By carefully processing and combining multiple SWAP images, low-noise composites were produced that reveal large-scale, EUV-emitting, coronal structures. These extended structures appear mainly above or at the edges of active regions and typically curve towards the poles. As they persist for multiple Carrington rotations and cannot easily be related to white-light features, they give an interesting view on how the coronal magnetic field is structured between 1.3 and 2-3 solar radii, in the gap between SDO/AIA's FOV and typical lower boundaries of coronagraph FOVs. With the help of magnetic field models, we analyse the geometry of the extended EUV structures in more detail and compare with sporadic EUV coronagraph measurements up to as close as 1.5Rs. The opportunities that Solar Orbiter's future observations will bring are explored.
Author(s): Anik De Groof[1], Daniel B Seaton[2], Laurel Rachmeler[2], David Berghmans[2]
Institution(s): *1. European Space Agency/ESAC, 2. Royal Observatory of Belgium*

409.02 – Plasma Properties of Pseudostreamers and Their Solar Wind Streams

We study pseudostreamers (i.e., open-field extensions of plasma from unipolar footpoints in the corona; distinct from classical helmet streamers that have opposite-polarity footpoints) that are believed to be sources of slow to intermediate speed wind streams. We make use of multi-spacecraft and ground-based observations that extend from the solar corona to the solar wind at 1 AU. We compare the physical properties of selected pseudostreamers and helmet streamers to characterize how the differences in magnetic topology affect the plasma properties of the coronal structures and their wind.
Author(s): Mari Paz Miralles[1], Lorraine A. Allen[2]
Institution(s): *1. Harvard-Smithsonian CfA, 2. USCGA, Department of Science, Physics*

409.03 – Non-equilibrium Ionization Modeling of Simulated Pseudostreamers in a Solar Corona Model

Time-dependent ionization is important for diagnostics of coronal streamers, where the thermodynamic time scale could be shorter than the ionization or recombination time scales, and ions are therefor in

non-equilibrium ionization states. In this work, we perform post-processing time-dependent ionization calculations for a three dimensional solar corona and inner heliosphere model from Predictive Sciences Inc. (Mikić & Linker 1999) to analyze the influence of non-equilibrium ionization on emission from coronal streamers. Using the plasma temperature, density, velocity and magnetic field distributions provided by the 3D MHD simulation covering the Whole Sun Month (Carrington rotation CR1913, 1996 August 22 to September 18), we calculate non-equilibrium ionization states in the region around a pseudostreamer. We then obtain the synthetic emissivities with the non-equilibrium ion populations. Under the assumption that the corona is optically thin, we also obtain intensity profiles of several emission lines. We compare our calculations with intensities of Lyman-alpha lines and OVI lines from SOHO/Ultraviolet Coronagraph Spectrometer (UVCS) observations at 14 different heights. The results show that intensity profiles of both Lyman-alpha and OVI lines match well UVCS observations at low heights. At large heights, OVI intensites are higher for non-equilibrium ionization than equilibrium ionization inside this pseudostreamer. The assumption of ionization equilibrium would lead to a underestimate of the OVI intensity by about ten percent at a height of 2 solar radii, and the difference between these two ionization cases increases with height. The intensity ratio of OVI 1032 line to OVI 1037 lines is also obtained for non-equilibrium ionization modeling.
Author(s): Chengcai Shen[1], John C. Raymond[1], Zoran Mikić[2], Jon Linker[2], Katharine K. Reeves[1], Nicholas A. Murphy[1]
Institution(s): *1. Harvard-Smithsonian Center for Astrophysics, 2. Predictive Sciences Inc.*

409.04D – Connecting Coronal Holes and Open Magnetic Field via Numerical Modeling and Observations

Coronal holes are regions of the Sun's surface that map the footprints of open magnetic field lines traced down from the corona and heliosphere beyond. Without the ability to directly and easily observe coronal magnetic field line structure, mapping their footprint 'dance' throughout the solar cycle is crucial for understanding this open field contribution to space weather. Coronal holes provide just this proxy.
Using a combination of SOHO:EIT, SDO:AIA, and STEREO:EUVI A/B extreme ultraviolet (EUV) observations from 1996-2014, coronal holes are automatically detected and characterized throughout this span, enabling long-term solar-cycle-timescale study. In particular, the combination of SDO:AIA and STEREO:EUVI A/B data provides a new viewpoint on understanding coronal hole evolution. As the two STEREO spacecraft drift ahead and behind of the Earth in their orbit, respectively, they are able to peek around the corner and closer to the poles, providing the ability to image nearly the entire solar surface in EUV wavelengths, using SDO data in conjunction. A flux transport model driven by observed bipole data allows for the study and comparison of far-side magnetic field evolution. By combining our numerical models of solar open magnetic field evolution with coronal hole observations, comparison of far-side and polar dynamics becomes possible. Model constraints and boundary conditions are more easily fine-tuned with these global observations. Understanding the dynamics of boundary changes and distribution throughout the solar cycle yields important insight into connecting models of open magnetic field.
Author(s): Chris Lowder[1]
Institution(s): *1. Montana State University*

409.05D – Statistical Studies of Coronal Cavities Since the Launch of SDO

We present a survey of 409 coronal prominence cavities found between May 2010− Sep 2014 using SDO/AIA limb synoptic maps. We examined correlations between cavity’s height, width and length. Our

finding showed that around 50% of cavities were taller than wider, 40% wider and 10% circular in shape. The length of the cavity ranged from 0.09−2.9 $R_\odot$. When the cavity length is greater than 1.5 $R_\odot$, cavity had a narrow height range (0.1–0.3 $R_\odot$), whereas when the cavity length was smaller than 1.5 $R_\odot$, cavity had wider height range (0.07−0.5 $R_\odot$). We find that the overall 3-D topology of the long stable cavities can be characterized as a long tube with an elliptical cross section. We also studied the physical mechanisms behind the cavity drift towards the pole and found it to be tied to the polar reversal. Finally, by observing the evolution of the cavity region using SDO/HMI surface magnetic field observations, we found that cavities formed a belt between the polar coronal hole boundary and the active region belt; we call this new belt the cavity belt. Results showed that the cavity belt migrated towards higher and higher latitude with time and the cavity belt disappeared after the polar magnetic field reversal. This result shows that cavity evolution provides another dimension of knowledge of studying the solar cycle.
Author(s): Nishu Karna[1], Jie Zhang[1], W. Dean Pesnell[2]
Institution(s): *1. George Mason University, 2. Goddard Space Flight Center- NASA*

409.06 – Dynamics and Thermodynamics of the Solar Corona as Inferred from Total Solar Eclipse Observations

Imaging the solar corona during total solar eclipses in broadband white light and in a number of forbidden emission lines in the visible continues to yield unique insights into the dynamics and thermodynamics of the coronal plasma. An overview of recent multiwavelength eclipse observations, spanning almost a solar cycle, will be presented. Particular emphasis will be placed on the thermodynamics of dynamic events such prominence eruptions, plasmoids and CMEs, that are captured in the eclipse images either as they occurred, or from the trails they left behind in the corona.
Author(s): Shadia Habbal[3], Miloslav Druckmuller[2], Huw Morgan[1], Adalbert Ding[4]
Institution(s): *1. Aberystwyth University, 2. Brno University of Technology, 3. Institute for Astronomy, University of Hawaii, 4. Technische Universitaet Berlin*

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