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ABSTRACT BOOK



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TURBULENT DIFFUSION ON VERY SMALL SCALES IN THE QUIET PHOTOSPHERE

Abramenko, Valentyna

Big Bear Solar Observatory

Turbulent diffusion is the key mechanism that dominates the magnetic flux dispersal over the solar surface on small spatial and time scales. To explore the nature of the turbulent diffusion (normal or anomalous diffusivity), data of high spatial and time resolution are needed. Modern data from SDO/HMI and from New Solar Telescope (NST) of Big Bear Solar Observatory allow to study diffusivity on scales down to 140 s/1000 km and 10 s/77 km, respectively. We find the regime of anomalous super-diffusivity on all available scales from both data sets. Interestingly, super-diffusivity regime is different for different magnetic environments on the Sun. Thus, super-diffusion, measured via the spectral index, γ , which is the slope of the mean-squared displacement spectrum, increases from the plage area ($\gamma=1.48$) to the quiet sun area ($\gamma=1.53$) to the coronal hole ($\gamma=1.67$). The result is discussed in the framework of the small-scale turbulent dynamo action in various magnetic environments on the solar surface.

SOLVING THE LAPLACIAN VECTOR FOR AXISYMMETRIC FIELDS IN A SPHERICAL SHELL: AN APPROXIMATION TO THE DIFFERENTIAL ROTATION OF THE SOLAR TACHOCLINE.

Acevedo-Arreguin, Luis

University of California Santa Cruz

Gough and McIntyre (1998) suggested that the sharp rotational transition of the solar interior beneath the radiative-convective interface was the result of a primordial magnetic field interacting with large-scale meridional flows generated in the nearby convection zone. An analysis of the balance between Lorentz and Coriolis forces led them to find mathematical expressions to relate the layer structure of the proposed tachopause-tachocline system and its magnetofluid dynamics. This force balance assumed a viscous stress-free tachocline. Under the same assumptions, we obtain solutions for the phi-components of the Laplacian vector and the viscous stress tensor to find mathematical expressions for the angular velocity in the vicinity of the tachocline. [Poster]

2-D NUMERICAL SIMULATIONS OF THE SOLAR TACHOCLINE WITH THE LOWEST POSSIBLE
DIFFUSIVITIES.

Acevedo-Arreguin, Luis, and Garaud, Pascale

University of California Santa Cruz

According to Wood, McCaslin, and Garaud (2011), many numerical simulations of the solar tachocline have failed in getting magnetic field confinement by large-scale meridional flows downwelling from the convection zone because of exploring the wrong parameter space. Here, we present some results from 2-D numerical simulations with the lowest possible diffusivities following the relative order of magnitudes recommended by Wood et al. We found some interactions between a magnetic field induced by a imposed electric current density and fluid in motion within a weakly stratified region below the radiative-convective interface. These interactions seem to generate a layer structure resembling the tachopause-tachocline system described by Gough and McIntyre's (1998) theory. [Poster]

MAGNETIC FIELD MODELING WITH STEREOSCOPY AND MAGNETOGRAMS

Aschwanden, M., Wuelser, Nitta, Schrijver, DeRosa, Malanushenko

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We developed a new code to reconstruct the 3D magnetic field of solar active regions using stereoscopically triangulated loops with STEREO/A+B and magnetogram data from MDI or HMI. We are using potential field models as well as non-potential field models (nonlinear quasi-force-free fields) that can be quickly forward-fitted to observations using parameterizations of analytical approximations of uniformly twisted flux tubes. This method improves the misalignment angles between theoretical models and observed magnetic fields down to 5 degrees.

DIAGNOSTICS OF PRECURSOR PHASE EMISSION IN SOLAR FLARES

Awasthi, Arun K.(1) and Jain Rajmal (2)

Physical Research Laboratory

We study the origin of precursor phase emission in solar flares as well as its relation and influence on the main phase emission. We estimate the flare plasma parameters in multi-wavelength emission during precursor phase of energy release in 13 flare events observed between year 2003 and 2004. We employ X-ray spectral and temporal mode observations from Solar X-ray Spectrometer (SOXS) and RHESSI missions, EUV observations from TRACE mission and H-alpha observations from NAOJ, HUIROU and YUNNAN observatories. The analysis of spectral mode observation of X-ray emission in the precursor phase emission reveal that the plasma temperature (T) and differential emission measure (DEM) vary in the range of 9-12 MK and $0.005 - 0.05 \times 10^{49} \text{cm}^{-3} \text{keV}^{-1}$ respectively. The estimated plasma parameters suggest a low energy and moderate temperature emission in the precursor phase of solar flare. Further, in order to visualize the spatial relation between the precursor phase to the main phase emission, we employ the RHESSI observations. The CLEAN images of precursor and main phase emission in 6-12 keV energy band reveal the co-spatiality of the emission in both the phases. In addition, we note the emission in precursor phase is visible only in low-energy band i.e. between 6-12 keV in contrast to the main phase emission which reaches the value of 20-25 keV energy band. We further employ the EUV emission to visualize the response of the corona in the precursor phase emission. The analysis of EUV emission suggests that the precursor phase emission is originated from low-altitude coronal loops, however, in co-spatial with the main phase energy release site. The origin of this phase of emission is still not very clear and the extensive study of H-alpha emission in view of role of filament dynamics is going on which may clear the clouds.

RING DIAGRAM PARAMETER ESTIMATION AND SPECTRAL MODEL ASSUMPTIONS

Baldner, C.S. (1), Basu, S.(2), Bogart, R.S.(1), Howe, R.(3), Rabello-Soares, M.C.(1)

(1) Stanford University; (2) Yale University; (3) University of Birmingham

Ring diagrams are used to study the structure and dynamics of the near-surface layers of the Sun. The parameters of primary interest are frequencies and velocities in both the zonal and meridional direction as a function of wavenumber and of radial order n . These parameters are recovered by fitting a model of the spectral profile to three-dimensional power spectra of small regions of the Sun. In addition to the spatial frequency and the zonal and meridional velocity components, our spectral model has ten free parameters. Using HMI resolved Doppler data, we explore the systematic trends in these parameters with disk position, as well as the effects that these parameters have on our estimation of the parameters of primary interest.

A STUDY OF CORONAL MASS EJECTIONS AND THE SUBSURFACE STRUCTURE AT THEIR SOURCE
REGIONS

Baldner C. (1), Chen J.(2), Vourlidas A.(3)

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Coronal mass ejection (CME) is one of the most violent phenomena in the solar atmosphere. One of the possible sources to cause such violent eruption could be the magnetic flux and energy from below the photosphere, However, due to the large difference in scales, the subsurface and the atmosphere of the Sun have often been studied separately. In this study, our objective is to combine the studies in both fields in the hope to connect the subsurface magnetic fields to the dynamics in the atmosphere. We selected a system of three active regions, AR10987, AR10988 and AR10989, for this study. These three active regions were located approximately at a same latitude and almost equally separated. Two CMEs were detected from this group during our observation period. We compared the CMEs with different CME models both qualitatively and quantitatively. The best-matched model was then used to deduce the possible driving mechanism of the CMEs. For the study of the subsurface structure, we employed the techniques of local helioseismology to obtain both the thermal and magnetic structural properties. I will discuss our results in this presentation.

A SEARCH FOR PRE-EMERGENCE HELIOSEISMIC SIGNATURES OF ACTIVE REGIONS

Barnes, Graham (1), Birch, Aaron (1), Leka, K.D. (1), Braun, Doug (1), Dunn, Tera (1), Gonzalez Hernandez, I. (2)

(1) NorthWest Research Associates, Boulder, CO, (2) National Solar Observatory, Tucson, AZ

Helioseismology can be an important tool for understanding the formation of active regions. As a first step towards this goal, we have carried out a search for statistically significant helioseismic precursors of active region emergence. We used an automatic method to determine the time of emergence based on the NOAA/NGDC active region catalog and MDI/SOHO 96 minute magnetograms. Using GONG data, we applied helioseismic holography to about 100 pre-emergence active regions and a control sample of about 300 quiet-Sun regions. A variety of quantities were determined from helioseismic holography. Both averages over all the times considered, as well as statistical tests based on discriminant analysis, show different signatures for the pre-emergence active regions compared to the quiet-Sun. However, we do not see a clear signature of emergence when considering individual active regions. We discuss the significance of these results.

APPLYING AUTOMATIC BAYESIAN CLASSIFICATION TO HMI IMAGES

Beck, John(1,2), Ulrich, Roger (1) Parker, Daryl (1)

UCLA Dept of Astronomy and Physics(1), Stanford, HEPL(2)

The Bayesian automatic classification system known as “AutoClass” finds a set of class definitions based on a set of observed data and assigns data to classes without human supervision. It has been applied to Mt Wilson data to improve modeling of total solar irradiance variations (Ulrich, et al, 2010). We apply AutoClass to HMI observables to automatically identify regions of the solar surface. To prevent small instrument artifacts from interfering with class identification, we apply a flat-field correction and a rotationally shifted temporal average to the HMI images prior to processing with AutoClass. Additionally, the sensitivity of AutoClass to instrumental artifacts is investigated.

CAN OVERTURNING MOTIONS IN PENUMBRAL FILAMENTS BE DETECTED?

Bharti, Lokesh, Manfred Schuessler and Matthias Rempel

University College of Science, Mohan Lal Sukhadia University, Udaipur, India

Numerical simulations indicate that the filamentation of sunspot penumbrae and the associated systematic outflow (the Evershed effect) are due to convectively driven fluid motions constrained by the inclined magnetic field. We investigate whether these motions, in particular the upflows in the bright filaments and the downflows at their edges, can be reliably observed with existing instrumentation. We use a snapshot from a sunspot simulation to calculate two-dimensional maps of synthetic line profiles for the spectral lines Fe I 7090.4 and C I 5380.34. The maps are spatially and spectrally degraded according to typical instrument properties. Line-of-sight velocities are determined from line bisector shifts. We find that the detectability of the convective flows is strongly affected by spatial smearing, particularly so for the downflows. Furthermore, the line-of-sight velocities are dominated by the Evershed flow unless the observation is made very near the disk center. These problems may have compromised recent attempts to detect overturning penumbral convection. Lines with a low formation height are best suited for detecting the convective flows.

NEW RESULTS FROM HELIOSEISMIC HOLOGRAPHY

Birch, A.C.

NWRA, CoRA Division

Helioseismic holography is a set of methods for local helioseismology and, like time-distance helioseismology, is based on computing cross-covariance functions. Phase-sensitive holography is used to measure wave travel times and acoustic power holography is used to estimate the locations and strengths of sources of wave power. Some of the problems that have been addressed recently are the emergence of active regions, the subsurface structure of sunspots, wave excitation by flares, and imaging active regions on the far side of the Sun.

SHARP: SPACE-WEATHER HMI ACTIVE REGION PATCHES

Bobra, M.G.; Hoeksema, J. T., Sun, X., and the HMI Magnetic Field Team

Stanford University

We present a new data product called Space Weather HMI Active Region Patches, or SHARPs. SHARPs are created as follows: The HMI pipeline analysis code automatically detects active regions in photospheric line-of-sight magnetograms and photograms. This code identifies a patch on the full-disk imagery that encompasses each active region, and then tracks every active region as it crosses the face of the solar disk. The vector magnetic field is determined for each patch and is available as a time series of FITS files. Over 30 space weather quantities are calculated per patch, including the Gradient-Weighted Neutral Line Length (Mason and Hoeksema, 2010), current helicity (Leka and Barnes 2003, I and II), and neutral-line length (Falconer et al., 2008). Data series and plots of quantities are available in near real time, i.e., with no more than an hour lag, with a 12-minute cadence. All the data are available in the Joint Science Operations Center, or JSOC, at <http://jsoc.stanford.edu/ajax/lookdata.html>.

THE HMI RING-DIAGRAM PIPELINES: A STATUS REPORT

Bogart, R.S.(1), C.S. Baldner(1), S. Basu(2), D.A. Haber(3), R. Howe(4), I. Gonzalez Hernandez(5), F. Hill(5), K. Jain(5), M.C. Rabello-Soares(1), S. Tripathy(5)

(1)Stanford University, Stanford, Calif., (2)Yale University, New Haven, Conn., (3)Univ. of Colorado, Boulder, Colo., (4)National Solar Observatory, T

The HMI analysis pipeline for determination of sub-surface flows has been running for nearly one year, and virtually all HMI Doppler data from the beginning of the mission have been analyzed. Over 3.5 million local-area power spectra of regions of various sizes have been produced and fitted, and inversions for the depth structure of flows have been produced for over 130,000 of the larger regions. The pipeline for determination of the sub-surface thermal structure is still under active development, with test results available for analysis for a number of strong active regions. We describe the ring-diagram pipelines, report on their performance as part of the overall HMI data analysis pipeline, describe the data products available, and discuss outstanding problems and issues for further development.

OBSERVED DIFFERENCE BETWEEN THE VERTICAL AND HORIZONTAL MAGNETIC FIELD
GRADIENTS IN SUNSPOTS

Bommier, Veronique

LESIA, Observatoire de Paris

A difference (larger than the measurements uncertainties) was observed between the vertical and horizontal gradients of the magnetic field in sunspots. This difference was observed with multiline recordings achieved with the THEMIS telescope and the HINODE/SOT/SP instrument. The multiline feature corresponds to a depth probing. This difference was already present in the literature, which will be discussed in details. The method for interpreting the spectropolarimetric data in terms of magnetic field will be also detailed.

MODELS OF SOLAR CYCLE AND PREDICTIONS

Alfio Bonanno

INAF - Catania Astrophysical Observatory

The location of the alpha effect in the Sun has always been a topic of debate. In this talk I will discuss the possibility that current-driven and quasi-interchange instabilities in the tachocline are responsible for a cross-helicity generated alpha-effect. It will be suggested that stable stratification can never suppress current-driven instabilities in the presence of finite thermal conductivity, although the growth rate can be significantly reduced. 3D numerical simulations support the picture that the most dangerous instabilities have an arbitrarily large azimuthal wave number with a resonant character. Mean field solar dynamo models consistent with this picture will then be presented. It will be shown that a meridional circulation with a deep stagnation point plays a key role in determining the properties of the dynamo action, and in particular its parity. Consequences of these results also for the magnetic activity of the exoplanet hosting star i-Hor will also be briefly considered.

ACTIVE REGIONS FROM NEAR-SURFACE DYNAMICS

Axel Brandenburg (1,2), Koen Kemel (1,2), Nathan Kleeorin (1,3), Dhrubaditya Mitra (1), Igor Rogachevskii (1,3)

(1) NORDITA, (2) Stockholm Univ. (3) Ben-Gurion Univ

We present the first numerical demonstration of the negative effective magnetic pressure instability in direct numerical simulations of stably-stratified, externally-forced, isothermal hydromagnetic turbulence in the regime of large plasma beta. By the action of this instability, initially uniform horizontal magnetic field forms flux concentrations whose scale is large compared to the turbulent scale. We further show that the magnetic energy of these large-scale structures is only weakly dependent on the magnetic Reynolds number. Our results support earlier mean-field calculations and analytic work which identified this instability. Applications to the formation of active regions in the Sun are discussed.

VARIATION OF QUIET SUN MAGNETIC ELEMENTS BETWEEN 2006 AND 2011 USING HINODE SOT/SP

Buehler, D. (1), Lagg, A. (2), Solanki, S.K. (3)

Max Planck Institute for Solar System Research

The Hinode satellite has revealed copious amounts of horizontal flux covering the quiet Sun, nurturing the notion of local dynamo action operating close to the solar surface. We sought to investigate the variation in the occurrence as well as the strength of circular and linear polarisation on the quiet Sun during the minimum of cycle 23, covering a period from November 2006 until August 2011. This investigation used Hinode SOT/SP images of the disk centre and a large FOV and focussed on line-integrated linear and circular polarisation signals obtained from the Fe I 6302.5 Å absorption line. The circular polarisation showed an overall linear decline in occurrence from November 2006 until August 2011. By comparing PDFs we found that this decline is associated in particular with network elements. The internetwork on the other hand showed a 10% decrease in occurrence from November 2010 until June 2009, followed by an equal increase until August 2011. The investigation also revealed a reduction of 30% in the occurrence of linear polarisation signals between November 2006 and December 2009. From August 2010 until August 2011 the occurrence of linear polarisation was increasing again. Hence, our results show that the occurrence of the ubiquitous linear polarisation of the internetwork as seen by Hinode is measurably influenced by the solar cycle. This implies that an independent local dynamo process is unlikely to be the sole cause responsible for the generation of this magnetic flux.

METHOD OF CLEANING IMAGES OF THE GONG++ NETWORK

J.C. Buitrago-Casas(1), J.D. Alvarado-Gómez(1), J.C. Martínez-Oliveros(2), C. Lindsey(3), A-C. Donea(4), B. Calvo-Mozo(1)

(1) Observatorio Astronomico Nacional, Universidad Nacional de Colombia.,(2) Space Sciences Laboratory, University of California, Berkeley, CA USA; (3) North West Research Associates, CORA Division, Boulder, CO USA; (4)Centre for Stellar and Planetary Astrophysics, School of Mathematical Sciences, Monash University, Melbourne Australia

The GONG++ network has been widely used in helioseismic analysis. However, because the GONG observatories are ground based, its images are subject to smearing by the terrestrial atmosphere. Temporal variations in atmospheric smearing introduce noise in helioseismic observations of active regions. In this work, we summarize techniques Lindsey and Donea (2008) applied to Postel projections of GONG active-region observations to reduce this noise. We introduce improvements based de-smearing techniques that take a warpage in Postel projections of active regions away from disk center. We have applied the method to GONG++ Doppler observations of seismically active flares and compared the results with Doppler seismic observations by SOHO/MDI and SDO/HMI.

HOW FAR CAN MINIMAL MODELS EXPLAIN THE SOLAR CYCLE?

F. Busse and R. Simev

University of Bayreuth

A physically consistent model of magnetic generation by convection in a rotating spherical shell with a minimum of parameters is applied to the sun. Despite its unrealistic features the model exhibits a number of properties resembling those observed on the sun. The model suggests that the large scale solar dynamo is dominated by a non-axisymmetric $m=1$ component of the magnetic field.

STOKED DYNAMOS: MAGNETIC FEEDING OF DYNAMOS AND NONDYNAMOS

Ben Byington, Jen Stone, Nic Brummell & Douglas Gough

University of California, Santa Cruz

Magnetic diffusion timescales in the sun are long enough that dynamo mechanisms are not required to explain the mere presence of a solar magnetic field. Rather, it is the large scale organization and chaotically modulated oscillations that suggest dynamo activity. However, one could ask what the effects of a fossil field deep in the interior might have on the visible characteristics of the system. In particular, could it be possible to save a failing dynamo in the convective region, by leaking in small amounts of fossil field from deep in the interior? If it were possible, could one tell the difference between this system and a true dynamo? In the present work, we examine the behavior of a number of non-dynamo systems when they are “stoked” through the addition of small amounts of external field. Without stoking, these non-dynamo systems can share many characteristics with dynamos, such as exponential growth in the kinematic regime, yet ultimately fail to sustain magnetic field over many diffusive timescales. For the first system examined (a kinematic dynamo, but nonlinear non-dynamo), the stoking does not affect the non-dynamo properties of the system, yet still sets up a basic sustained equilibrium that may be hard to distinguish from a dynamo for a distant observer, depending on the level of the stoking. Early analysis has also been done on a second different type of system (an essentially nonlinear failing dynamo) where stoking is more likely to result in a system indistinguishable from a true dynamo.

MERIDIONAL CIRCULATION IN THE SOLAR CONVECTION ZONE: DEEP OR SHALLOW?

Chakraborty, Sudepto (1), Duvall, Thomas L., Jr. (2), Hartlep, Thomas (1)

(1) W. W. Hansen Experimental Physics Laboratory, Stanford University, (2) Solar Physics Laboratory, NASA Goddard Space Flight Center

Meridional circulation in the solar convection zone is a key ingredient in flux-transport models of the solar dynamo formulated to explain the 22-year solar magnetic activity cycle. Furthermore, poleward meridional flow has been observed on the surface of the Sun using various techniques, including Doppler velocity measurements and local helioseismology. An equatorward return flow is inferred to exist from a consideration of mass conservation, and is invoked in flux-transport dynamo models to explain the equatorward migration of active region formation during the course of a solar cycle. The depth of this return flow is, however, a point of contention due to lack of any conclusive observational evidence. Theory, simulations and local helioseismic inversions seem to suggest that a reverse flow should exist somewhere in the deep convection zone ($0.80R$), perhaps extending to even below the base of convection zone ($0.60R$), i.e., meridional circulation is deep. But recently, based on inferences made from analysis of latitudinal advection of large supergranules using a cross-correlation tracking technique, Hathaway (2011) has proposed that meridional circulation is shallow with flow reversal occurring at $0.95R$. In this preliminary work we begin a systematic investigation of this disputed issue using time-distance helioseismology. We analyze and compare the meridional travel-time differences of various flow models and simulated data, thus laying the groundwork for consistent interpretation (deep or shallow?) of future work involving time-distance analysis of real solar data obtained from, e.g., the Helioseismic Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO).

MECHANISMS OF SUNSPOT FORMATION

Cheung, M. C. M. (1), Rempel, M. (2)

(1) Lockheed Martin Solar & Astrophysics Laboratory, Palo Alto, CA, USA, (2) High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA.

We present numerical MHD simulations that model the rise of magnetic flux tubes through the upper 16 Mm of the solar convection zone and into the photosphere. Due to the strong stratification (a density contrast of 10^4), the emerging field is initially dispersed over a wide area. Nevertheless, the dispersed flux is eventually able to reorganize into coherent spots with photospheric field strengths of ~ 3 kG. In the models, sunspot formation is weakly sensitive to the initial subsurface field strength and to the presence of magnetic twist. As a consequence sunspots can form from untwisted flux tubes with as little as 5 kG average field strength at 16 Mm depth. The physical mechanisms which enables this robust formation process to occur will be discussed.

REVIEW AND NEW RESULTS OF LOCAL HELIOSEISMOLOGY

Dean-Yi Chou

National Tsing Hua University, Taiwan

We briefly review various methods used in local helioseismology, and discuss our recent results on the acoustic waves scattered by sunspots. We use a deconvolution method to obtain the 2-D wave function of the scattered wave from the cross correlations between the incident wave and the signal at various points on the surface. The wave functions of scattered waves associated with various incident waves could be used to probe the sunspot. The interference fringes between the scattered wave and the incident wave are detected because the coherent time of the incident wave is of the order of wave period. These interference fringes play the same role as a hologram in optics. We demonstrate that these interference fringes (hologram) can be used to reconstruct the 2-D scattered wavefield of the sunspot.

CURRENT STATE OF SDO DATA DISTRIBUTION

Alisdair Davey and the VSO Team

Harvard Smithsonian Center for Astrophysics

We describe the current state of SDO data distribution. This includes the distribution of data to various sites within the United States and in Europe. We describe the various holdings these sites have. We discuss how data can be downloaded from the VSO and describe the VSO IDL client which allows users to localize data download to the nearest cache.

PHOTOSPHERIC SIGNATURES OF SOLAR FLARES

P. Desai, R. Bogart, S. Couvidat and J. Schou

Stanford University

White Light flares (WLF's) are enjoying a renewed interest in the solar community since the recent detections of white light continuum emission of solar flares with TRACE (Hudson et.al, 2006; Fletcher et.al, 2007) and HINODE(Wang, H., 2009). The Helioseismic and Magnetic Imager (HMI) on the Solar Dynamic Observatory (SDO) produces a nearly continuous stream of full disc images of the sun in a set of six narrow wavelength bands around the FeI photospheric absorption line at 6173 Angstrom with filtergrams made at a cadence of one every 1.85 seconds. Preliminary analysis shows that the photospheric signature of Xray flares of sufficient intensity (Martinez Oliveros, J.C. et al, 2011) can be readily detected in the HMI data. Motivated by this finding, we have analyzed the HMI observables (in particular the Line Depth and Continuum Intensity) and the corresponding line core intensity during recent GOES M and X class flares (e.g. M6.6 on 2/13/2011, X2.2 on 2/15/2011, X6.9 on 8/9/11).

VARIABILITY OF FIVE-MINUTE SOLAR OSCILLATIONS IN THE CORONA AS OBSERVED BY THE
EXTREME ULTRAVIOLET SPECTROPHOTOMETER (ESP) ON THE SOLAR DYNAMICS
OBSERVATORY EXTREME ULTRAVIOLET VARIABILITY EXPERIMENT (SDO/EVE)

Leonid Didkovsky (1), Darrell Judge (1), Alexander Kosovichev (2), Seth Wieman (1), and Tom Woods (3)

(1) USC; (2) Stanford University, HEPL; (3) LASP

Solar oscillations in the corona were detected in the frequency range corresponding to five-minute acoustic modes of the Sun. The oscillations have been observed using soft X-ray measurements from the Extreme Ultraviolet Spectrophotometer (ESP) of the Extreme Ultraviolet Variability Experiment (EVE) onboard the Solar Dynamics Observatory (SDO). The ESP zeroth-order channel observes the Sun as a star without spatial resolution in the wavelength range of 0.1 to 7.0 nm (the energy range is 0.18 to 12.4 keV). The amplitude spectrum of the oscillations, calculated from six-day time series, showed a significant increase in the frequency range of 2 to 4 mHz. This increase was interpreted as a response of the corona to solar acoustic (p) modes, and some p-mode frequencies among the strongest peaks were identified. In this work we show how these increases in the 2 to 4 mHz frequency range vary on a daily basis and compare this variability for quiet and intermediate levels of solar activity. We found that the increases do not correlate with the changes of daily mean irradiance or with the standard deviation of the irradiance.

SUBSURFACE SUPERGRANULAR VERTICAL FLOWS AS MEASURED FROM TIME-DISTANCE HELIOSEISMOLOGY

T.L. Duvall Jr. & S.M. Hanasoge

NASA/GSFC (author 1) and Princeton Univ. (author 2)

As large-distance rays approach the solar surface approximately vertically, travel times for large separations are mostly sensitive to vertical flows. Large distances have not been used much to measure supergranular flows, at least in part because of the increased noise for large separations. By measuring only the mean flow over a large number of supergranules, it is possible to circumvent the deleterious effect of the noise with the downside being the sacrifice of measuring the flows of individual cells. We find in the present work that the travel time difference for point-annulus combinations is about 4-5 [s] for the distance range of 5-24 [deg]. This signal is much larger than expected and would imply vertical flow of hundreds of meters per sec. Modeling and simulations are used to study this result. The results are that supergranular subsurface vertical flows are much larger than the measured photospheric value of about 10 [m/s].

THE DYNAMICS OF THE SOLAR RADIATIVE ZONE

Eff-Darwich, A. (1,2), Korzennik, S.G. (3)

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The dynamics of the solar internal radiative zone is still poorly constrained by comparison with the dynamics of the convective zone. This situation gets even worse if we attempt to infer temporal variations of the rotational profile of the radiative interior. Many existing data sets contains small amount of modes that are sensitive to the inner layers of the sun; moreover, the estimations of data uncertainties in these sets are usually wrong. As a result, most existing data sets only support the estimation of relatively few parameters (i.e. rotation rate in depth and latitude) in the radiative zone. A methodological strategy was devised to increase the amount of observed modes that are sensitive to the radiative zone, while special care was taken in the determination of the observational uncertainties. This methodology has been applied to both MDI and GONG data covering the complete solar cycle 23. The numerical inversion of all observational sets obtained for Cycle 23 results in the best inferences of the rotation in the radiative region, to date. These results are presented and the method described, as well as the possible implications for the theory of solar and stellar evolution.

POLARITY INVERSION LINE - SPACE WEATHER IMPLICATIONS

Alexander Engell, Alisdair Davey and the FFT Team

Harvard Smithsonian Center for Astrophysics

We have developed an automated algorithm to detect polarity inversion lines on the entire disk from HMI magnetograms. From the locations of the polarity inversion lines and the magnetic line of sight data we can obtain polarity inversion line "properties" such as the potential transverse field gradient, magnetic gradient, and the amount of shear if vector magnetograms are available. Using bounding boxes called Harps from Stanford that locate areas of high magnetic activity we then are able to focus on polarity inversion that are more likely associated with flaring. The location of flares are determined through the Flare Detective module from the Feature Finding Team. Once a statistical database is put together we hope to identify certain values of the PIL properties that may relate to the locations and magnitudes of flares with a prediction value.

DYNAMIC EVOLUTION OF EMERGING MAGNETIC FLUX TUBES IN THE SOLAR CONVECTIVE ENVELOPE

Y. Fan

HAO

I present recent results on modeling the buoyant rise of active region scale flux tubes in the solar convective envelope based on both a thin flux tube model incorporating the effects of giant-cell convection as well as 3D spherical-shell anelastic MHD simulations. It is found that the dynamic evolution of the flux tube changes from magnetic buoyancy dominated to convection dominated as the initial field strength of the flux tube varies from about 100 kG to 15 kG. Overall, the effect of the convective flow is found to allow mid to weak field strength range flux tubes (15 kG - 50 kG) to develop emerging loops with properties that are more consistent with the observed properties of solar active regions. For these flux tubes, the convective flow is found to reduce the rise time, reduce the latitude of emergence through anchoring by downdrafts, and promote tilt angles that are consistent with the observed mean tilt of solar active regions because of the mean kinetic helicity in the flow. The initial twist of the tube cannot be too high in order for the tilt of the emerging loops to be dominated by the effect of the Coriolis force and be consistent with the mean tilt of solar active regions. I will also discuss the properties of the emerging flux tube as it approaches the top layers of solar convective envelope based on these models.

COUPLING OF CONVECTIVE FLOWS AND EMERGING MAGNETIC FIELDS

Fang, Fang (1), Manchester IV, Ward (2), Abbett, William P., van der Holst, Bart (4)

(1) University of Michigan, Michigan, USA, (2) University of Michigan, Michigan, USA, (3) University of California, Berkeley, California, USA, (4) University of Michigan, Michigan, USA

We carry out radiative MHD simulations on the rising process of a buoyant magnetic flux rope inside the convection zone and its further emergence into the upper atmosphere. Our model takes into account of the radiative cooling, coronal heating and the ionization. The emergence of the flux rope is accompanied by turbulent surrounding plasma flows. Analysis on the magnetic fluxes shows that the convective downflows play an important role in formation of the concentrated polarities in the convection zone. During the rising of the flux rope, the magnetic energy is first injected through the photosphere by the emergence, followed by energy transport by horizontal flows, after which the energy is subducted back to the convection zone by the submerging flows.

STATISTICAL ANALYSIS OF BRIGHTENINGS NEAR CORONAL HOLE BOUNDARIES

Farid, S. (1), Winebarger, A. (2), Lionello, R. (3), Titov, R.(3)

(1) Harvard-Smithsonian Center for Astrophysics (2) NASA Marshall Space Flight Center (3) Predictive Science,Inc.

In this study, we investigate the properties of small-scale brightenings that occur in and near the boundary of an on-disk coronal hole using an automatic detection algorithm. Previously, attempts to explain the quasi-rigid rotation of on-disk CH's by small-scale reconnections at the boundary have been observationally limited. Using SDO/AIA 171,193 and SDO/HMI high cadence observations, we attempt to re-examine the role small-scale brightenings may have in the evolution of on-disk CH's. We examine spatial and temporal evolution, intensity, distribution within the CH, correlation to magnetic activity, and correspondence to the distribution of the 'squashing factor', Q . We present the preliminary results of our study and discuss implications for CH boundary theories.

NUMERICAL SIMULATIONS OF SCATTERING OF F-MODES BY MAGNETIC FLUX TUBES

Felipe, Tobias (1), Birch, Aaron C. (1), Crouch, Ashley D. (1), Braun, Douglas C. (1)

(1) NorthWest Research Associates, Colorado Research Associates, Boulder, CO 80301, USA

The scattering of the f -mode by a magnetic flux tube is analyzed using three-dimensional numerical simulations. An f -mode wave packet is propagated through a realistic solar atmosphere embedded with a flux tube of 200 km radius and 1600 G field strength. A quiet Sun simulation without the tube being present is also performed as a reference. Sausage ($m = 0$) and kink ($m = \pm 1$) modes are excited in the magnetic tube and propagate downward along the field lines, while the resulting scattered wave is mainly an f -mode composed of a mixture of $m = 0$ and $m = \pm 1$ modes. Low power is also scattered into high-order acoustic p -modes. We have evaluated the absorption and phase shift from a Fourier-Hankel decomposition of the vertical velocities.

MOMENTUM BALANCE IN ERUPTIVE SOLAR FLARES: THE LORENTZ FORCE ACTING ON THE SOLAR ATMOSPHERE AND THE SOLAR INTERIOR

George H. Fisher

Space Sciences Lab, UC Berkeley

We compute the change in the Lorentz force integrated over the outer solar atmosphere implied by observed changes in vector magnetograms that occur during large, eruptive solar flares. This force perturbation should be balanced by an equal and opposite force perturbation acting on the solar photosphere and solar interior. The resulting expression for the estimated force change in the solar interior generalizes the earlier expression presented by Hudson, Fisher & Welsch (2008), providing horizontal as well as vertical force components, and provides a more accurate result for the vertical component of the perturbed force. We show that magnetic eruptions should result in the magnetic field at the photosphere becoming more horizontal, and hence should result in a downward (towards the solar interior) force change acting on the photosphere and solar interior, as recently argued from an analysis of magnetogram data by Wang & Liu. We suggest that there should be an observational relationship between the force change computed from changes in the vector magnetograms, the outward momentum carried by the ejecta from the flare, and the amplitude of the helioseismic disturbance driven by the downward force change. We use the impulse driven by the Lorentz force change in the outer solar atmosphere to derive an upper limit to the mass of erupting plasma that can escape from the Sun. Finally, we compare the expected Lorentz force change at the photosphere with simple estimates from flare-driven gasdynamic disturbances and from an estimate of the perturbed pressure from radiative backwarming of the photosphere in flaring conditions.

ON THE MAGNETIC-FIELD DIAGNOSTICS POTENTIAL OF SDO/HMI

Fleck, B. (1), Hayashi, K. (2), Rezaei, R. (3), Vitas, N., (4), Centeno, R. (5), Couvidat, S. (2), Fischer, C. (1), Steiner, O. (3), Straus, T. (6), Viticchie, B. (1)

(1) ESA, (2) Stanford Univ., (3) KIS, (4) SRON, (5) HAO, (6) INAF/OAC

The Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO) is designed to study oscillations and the magnetic field in the solar photosphere. It observes the full solar disk in the Fe I 6173 absorption line. We use the output of two high-resolution 3D, time-dependent, radiative magneto-hydrodynamics simulations (one based on the MURAM code, the other one on the COBOLD code) to calculate Stokes profiles for the Fe I 6173 line for a snapshot of a plage region and a snapshot of an enhanced network region. After spatially degrading the Stokes profiles to HMI resolution, they are multiplied by a representative set of HMI filter response functions and Stokes filtergrams are constructed for the 6 nominal HMI wavelengths. The magnetic field vector and line-of-sight Doppler velocities are determined from these filtergrams using a simplified version of the HMI magnetic field processing pipeline. Finally, the reconstructed magnetic field is compared to the actual magnetic field in the simulation.

THE DEPENDENCE OF CORONAL VELOCITIES ON SUB-PHOTOSPHERIC MAGNETIC AND VELOCITY
FIELDS

Alan Gabriel and Lucia Abbo

(1) Institut d'Astrophysique Spatiale, Orsay, France. (2) Osservatorio Astronomico di Torino, Italy

We examine the relationship between coronal outflow velocities derived from Hinode/EIS spectra and the underlying photospheric supergranular cell structure derived from SDO/HMI and SDO/AIA observations. We show to what extent the spatial distribution of the outflow follows the expected expansion in the corona of the photospheric magnetic field emergence.

RECENT RESULTS FROM HELIOSEISMIC MEASUREMENTS OF THE MERIDIONAL FLOW USING THE
FOURIER-LEGENDRE DECOMPOSITION TECHNIQUE

Glogowski, Kolja (1), Doerr, Hans-Peter (1), Roth, Markus (1)

(1) Kiepenheuer-Institut für Sonnenphysik, Freiburg, Germany

We use the Fourier-Legendre decomposition (FLD) technique to measure the sub-surface meridional flow and present recent results obtained with data from the GONG and HMI instruments. The FLD technique was originally developed by Braun et al. (1988) to study p-mode absorption in sunspots and applied by Braun & Fan (1998) to measure the meridional flow. The time-dependent oscillation signal is decomposed into pole- and equatorward traveling wave fields whose power spectra show a slight frequency shift that is related to the meridional flow in sub-surface layers of the convection zone. We applied the FLD to time series of Doppler velocity maps provided by the GONG and HMI instruments and used the SOLA inversion method (Pijpers & Thompson, 1994) to derive the velocity of the sub-surface meridional flow from the measured frequency shifts and the solar model S of Christensen-Dalsgaard et al. (1996). By averaging over large parts of each solar hemisphere we were able to measure the meridional flow down to a depth of 60 Mm, while smaller patches at different latitudes allowed us to analyze its latitudinal variation at lower depths.

HIGH-RESOLUTION OBSERVATIONS OF THE SOLAR DYNAMICS AND MAGNETISM

Phil Goode, Wenda Cao and Vasyl Yurchyshyn

BBSO/NJIT

The NST is the first facility-class solar telescope built in the US in a generation. Images and movies illustrating the high resolution capabilities of the NST will be shown. In particular, high resolution NST observations reveal vortices in the granular field that are associated with newly discovered, but ubiquitous small-scale jets, which are much smaller-scale than Hinode type-II jets. NST observations have been used to probe the nature of the diffusion of magnetic bright points, which seems consistent with the operation of small-scale dynamos, while seeming to be sufficient on large-scales to support the Wang-Sheeley dynamo picture. Other recent NST results correlated with satellite observations will be shown and discussed.

CORONAL MAGNETIC FIELD MEASUREMENT USING CME-DRIVEN SHOCK OBSERVATIONS

N. Gopalswamy, N. Nitta, S. Yashiro, P. Mäkelä, H. Xie, S. Akiyama

NASA Goddard Space Flight Center

Collisionless shocks form ahead of coronal mass ejections (CMEs) when the CME speed exceeds the Alfvén speed of the ambient plasma in the corona and interplanetary medium. The shock stands at a distance from the CME flux rope that depends on the shock Mach number, the geometry of the driver, and the adiabatic index. While the shock ahead of the CME has been observed for a long time in the in situ data, it has been identified recently near the Sun in the coronagraphic and EUV images. Unlike in situ observations, the imaging observations are two dimensional, so one can better discern the CME-shock relationship near the Sun. Gopalswamy and Yashiro (2011) demonstrated that the coronal magnetic field can be derived from the shock standoff distance measured in coronagraphic images. The method involves measuring the standoff distance, the radius of curvature of the flux rope, and assuming the value of the adiabatic index and deriving the Alfvénic Mach number. The next step is to derive the Alfvénic Mach number from the measured shock speed and an estimate of the local solar wind speed. The final step involves deriving the magnetic field from the Alfvén speed by measuring the local plasma density either from coronagraphic (polarized brightness) images (Gopalswamy and Yashiro 2011) or from the band-splitting of type II radio bursts (Gopalswamy et al., 2011). In this paper, we derive the combined magnetic field profile from near the Sun to the edge of the LASCO field of view (1.5 to 30 solar radii) and compare it with the current model profiles.

WHAT HAVE WE LEARNED, WHAT HAVE WE REALLY LEARNED, AND WHAT DO WE WISH TO
LEARN?

Douglas Gough

University of Cambridge

Helioseismology has been widely acclaimed to have been a great success: it seems to have answered nearly all the questions that we originally asked, some with unexpectedly high precision. So where are we going now? It takes only a brief scrutiny of the equations describing the structure and dynamical evolution of the Sun, together with those governing the low-amplitude seismic modes of oscillation to appreciate what can, at least in principle, be reliably inferred from seismology. Anything further must depend on other criteria, such as general physical argument, traditional astronomical observation, or even prejudice. It is obligatory to be explicit about how such information is used. Our subject has advanced to a new level of sophistication; we are now trying to probe almost inaccessible aspects of the physics, and the techniques for unravelling them are becoming more and more intricate, beyond the point where most scientists wish to tread. There must necessarily be increased trust, and it is our responsibility not to betray it. The broader scientific community want simply to use our results in their research; for that they must know their, and which aspects of them can really be trusted. Much of the emphasis of SDO seismology concerns the workings of the convection zone. We want to know what controls the solar cycle, how magnetic field is amplified, modulated and then suppressed, how sunspots are formed and destroyed – and what determines their lifespan. We want to know the geometry of at least the larger scales of convective motion, and how, beneath the seen superficial layers of the Sun, the processes that control the total radiative output are modulated. At least some of us want to understand how all these matters influence our procedures for inferring the gross properties of the Sun, and how they impinge on our broader ideas of the evolution of the Sun in particular, and of stars in general. Addressing such delicate issues with confidence may now seem an almost impossible task for we who have lived through years of stumbling in the darkness, finally emerging to bathe in the secure light illuminating the minute arena of knowledge that we have been instrumental in uncovering. Now it is incumbent on the young to proceed likewise: to grasp at the edge perception with initially insecure data and ideas, fully appreciating the uncertainty, of course; then moulding and strengthening them into a new body of secure scientific knowledge.

DYNAMO ACTION AND MAGNETIC BUOYANCY IN CONVECTION SIMULATIONS WITH VERTICAL SHEAR

G. Guerrero (1,2), P. Käpylä (3)

(1) Stanford University, CA, USA, (2) Nordita, Stockholm, Sweden, (3) Department of Physics, University of Helsinki, Finland

A hypothesis for sunspot formation is the buoyant emergence of magnetic flux tubes created by the strong radial shear at the tachocline. In this scenario, the magnetic field has to exceed a threshold value before it becomes buoyant and emerges through the whole convection zone. In this work we present the results of direct numerical simulations of compressible turbulent convection that include a vertical shear layer. Like the solar tachocline, the shear is located at the interface between convective and stable layers. We follow the evolution of a random seed magnetic field with the aim of study under what conditions it is possible to excite the dynamo instability and whether the dynamo generated magnetic field becomes buoyantly unstable and emerges to the surface as expected in the flux-tube context. We find that shear and convection are able to amplify the initial magnetic field and form large-scale elongated magnetic structures. The magnetic field strength depends on several parameters such as the shear amplitude, the thickness and location of the shear layer, and the magnetic Reynolds number (R_m). Models with deeper and thicker shear layers allow longer storage and are more favorable for generating a mean magnetic field. Models with higher R_m grow faster but saturate at slightly lower levels. Whenever the toroidal magnetic field reaches amplitudes greater a threshold value which is close to the equipartition value, it becomes buoyant and rises into the convection zone where it expands and forms mushroom shape structures. Some events of emergence, i.e., those with the largest amplitudes of the amplified field, are able to reach the very uppermost layers of the domain. These episodes are able to modify the convective pattern forming either broader convection cells or convective eddies elongated in the direction of the field. However, in none of these events the field preserves its initial structure. The back-reaction of the magnetic field on the fluid is also observed in lower values of the turbulent velocity and in perturbations of approximately three per cent on the shear profile.

THEORETICAL COMPARISON OF PLASMA FLOW AND MAGNETIC FEATURE TRACKING SPEEDS IN THE SUN

G. Guerrero (1,2), M. Rheinhardt (2), A. Brandenburg (2), M. Dikpati (3)

(1) Stanford University, CA, USA, (2) Nordita, Stockholm, Sweden, (3) HAO Boulder, CO, USA

Doppler measurements of the poleward flow speed at the solar surface reveal a systematic difference from the speed inferred from magnetic feature-tracking (MFT). In order to understand the reason for this difference we simulate the magnetic feature tracking (MFT) speed using advective-diffusive transport models in both one and two dimensions. By depositing magnetic bipolar regions at different latitudes at the Sun's surface and following their evolution for a prescribed meridional circulation and magnetic diffusivity profiles, we derive the MFT speed as a function of latitude. We find that in a one dimensional surface-transport model the simulated MFT speed at the surface is always the same as the meridional flow-speed used as input to the model, but is different in a two-dimensional transport model in the meridional (r , θ) plane. The difference depends on the value of the magnetic diffusivity and on the radial gradient of the latitudinal velocity. We have confirmed our results with two different codes in spherical and Cartesian coordinates.

BOUNDARY DRIVEN DYNAMOS AND ROLE OF THE MAGNETIC BOUNDARY CONDITIONS

Celine Guervilly, Nic Brummell, Gary Glatzmaier, Katelyn White

UC Santa Cruz

In 2007, the Von Karman Sodium (VKS) dynamo experiment in Cadarache, France, produced a large-scale self-sustained magnetic field from a highly turbulent flow of liquid sodium driven by the mechanical forcing exerted by two counter-rotating impellers (Monchaux et al. 2007 PRL). However, this achievement is overshadowed by the fact that, even for the strongest mechanical forcing achievable in the experiment, dynamo action only occurs when the impellers are made of soft iron - a material of high magnetic permeability, which allows a discontinuity in the magnetic field between the fluid and the impellers. Elucidating the effects of magnetic boundary conditions on the dynamo is critical to understanding how the dynamo mechanism operates in shear driven systems, such as the VKS dynamo experiment, the plasma Couette experiment in Madison, Wisconsin (Spence et al. 2009 ApJ), and the spherical Couette experiment in College Park, Maryland (Kelley et al. 2007 GAFD). We have numerically investigated this problem using a self-consistent three-dimensional MHD model of the flow between concentric spheres. The two hemispheres of the outer wall counter-rotate, exerting an azimuthal viscous force that drives the mean flow. The magnetic permeability and electrical conductivity of the finite-thickness wall (which mimics the role of the experimental impellers) can be varied independently. For sufficiently strong forcing, the mean flow is unstable to non-axisymmetric shear instabilities, which generate time-dependent small-scale motions. Mean large-scale and fluctuating small-scale motions can act as a dynamo mechanism, amplifying an initial weak magnetic field and ultimately sustaining a strong, large-scale magnetic field. We will describe how the coherent organization of the flow and magnetic field on various spatial scales leads to dynamo action, despite the turbulent nature of the flow. We will discuss the role of the wall properties (electrical conductivity, magnetic permeability, and thickness) on this process.

LATEST RESULTS FOUND WITH RING-DIAGRAM ANALYSIS

D. A. Haber (1), C. Baldner (2), S. Basu (3), R.S. Bogart (2), I. González-Hernández (4), F. Hill (4), R. Howe (4), K. Jain (4), R. Komm (4), C. Rabello-Soares (2), S. Pinkerton (5), S. Tripathy (4)

(1) JILA/University of Colorado, (2) HEPL-CSSA/Stanford University, (3) Yale University (4) National Solar Observatory, (5) University of Southern California

This talk will mainly be a preview of the posters generated by the HMI Rings Team on large-scale (meridional and zonal) flows; characterizations of active regions at various stages of evolution using data from AIA as well as from HMI; systematic changes in frequencies, flows, and other fitted parameters as a function of disk placement, underlying magnetism, B angle, etc.; and the status of the Rings pipeline. It will also include any new ring-diagram results from GONG and MDI.

PROGRESS REPORT ON THE TESTING OF HELIOSEISMIC TECHNIQUES FOR MEASURING THE
SOLAR MERIDIONAL FLOW USING ARTIFICIAL DATA

Hartlep, Thomas

Stanford University, CA, USA

The meridional flow is of fundamental importance for understanding magnetic flux transport in the solar interior. Reliable measurements of the flow could provide important constraints for dynamo theories. The actual shape and strength of the meridional flow, in particular its return flow in the deep interior, remain unknown. Numerical simulations of helioseismic wave propagation provide means for testing and calibrating measurement techniques, and may increase our confidence in the inferences obtained from helioseismic inversions. The numerical simulations compute the time evolution of the helioseismic wave field in the full solar interior in the presence of a prescribed meridional flow. I will report on the progress of the simulations and the efforts of using various helioseismic techniques to measure the meridional flow from artificial data produced by the simulations.

THE SYNOPTIC MAPS OF BR FROM HMI OBSERVATIONS: BETTER INPUT FOR THE GLOBAL
CORONAL MODELS.

Keiji Hayashi, Yang Liu, Xudong Sun, J. Todd Hoeksema (1), Rebecca Centeno Elliott (2), Graham
Barnes and K.D. Leka (3)

(1) Stanford, (2) HAO, (3) CoRA/NWRA

The vector magnetic field measurement can, in principal, give the “true” radial component of the magnetic field. We prepare a few types of synoptic maps of the radial photospheric magnetic field, such as a test map from the vector magnetic field data disambiguated under the assumption that the field direction is close to radial. These are compared with the “standard” radial map derived from line-of-sight magnetograms. The field strength in high latitude regions derived from the vector data is generally weaker than the standard map. Although the structures of the global corona derived using MHD and PFSS modeling applied to different types of maps are quite similar, noticeable differences are found, especially in the high latitude regions. We will show details of these test maps and discuss the issues in determining the radial component of the photospheric magnetic field near the poles.

SOLAR CYCLE VARIATIONS OF THE INTERIOR

Frank Hill

NSO

It has been known for some time that the properties of the solar oscillations evolve in parallel with the activity cycle. Today, these properties can be used to infer how the solar interior changes as the cycle waxes and wanes. The subsurface behavior of both the meridional flow, which is thought to set the amplitude of the solar cycle in flux-transport dynamos, and the zonal flow or torsional oscillation that appears to be tightly correlated with the timing of the cycle have now been followed Using 16 years of data from GONG, SOHO, and SDO. The flows have been observed over all of cycle 23, and the start of the peculiar cycle 24. In addition, changes in the frequencies have recently exhibited an unusual double minimum that may reflect the progression of the cycle from deep to shallow layers. These results will be reviewed and possible future avenues of future research will be presented.

SOURCES OF EUV IRRADIANCE VARIATIONS

Hock, Rachel A.

Laboratory for Atmospheric and Space Physics, Univ. of Colorado Boulder

The Extreme ultraviolet Variability Experiment (EVE) onboard Solar Dynamic Observatory (SDO), part of NASA's Living With the Star (LWS) program launched on 11 February 2010. Normal science operations began 1 May 2010 and have continued uninterrupted since then. The EVE instruments measure the solar extreme ultraviolet (EUV) irradiance from 0.1 to 105 nm with unprecedented spectral resolution (0.1 nm), temporal cadence (10 sec minimum), and accuracy (20% or better). Here, I will discuss how new observations from EVE have expanded our understanding of how and why the EUV irradiance varies. While much of the initial science from EVE has focused on the changes in the EUV irradiance due to solar flares, non-flaring active region evolution has been observed to cause significant changes as well.

HMI MAGNETIC FIELD OBSERVATIONS

Hoeksema, J. Todd (1); HMI Magnetic Field Team, The (2)

Stanford University, CA USA

The Helioseismic and Magnetic Imager (HMI) on NASA's Solar Dynamics Observatory (SDO) constantly produces a wide variety of magnetic field data products including 45-second line-of sight magnetograms, 12-minute vector field times series in both full disk and HMI Active Region Patches (HARPs), synoptic maps and synchronic frames, model calculations of the coronal field and solar wind, and near-real-time parameters for space weather. Other products, such as surface flow maps, can be produced on demand or on request. We present examples of data products and compare some of these with measurements from other observatories, including MDI. Quick-look data are available within a few minutes of observation. A more complete set of definitive science data products is offered within a few days and comes in three types. "Pipeline products", such as full disk vector magnetograms, will be computed for all data on an appropriate cadence. A larger menu of "On Demand" products, such as Non-Linear Force Free Field snapshots of an evolving active region, will be produced whenever a user wants them. Less commonly needed "On Request" products that require significant project resources, such as a high resolution MHD simulation of the global corona, will be created subject to availability of resources. Further information can be found at the SDO Joint Science Operations Center web page, jsoc.stanford.edu.

MULTI-WAVELENGTH ACOUSTIC POWER MAPS AND 3-D POWER SPECTRA FROM SDO

Howe, R.(1), Baldner, C.(2), Bogart, R. S. (2), Haber, D. A. (3), Jain, K. (4)

(1) University of Birmingham, UK (2) Stanford University, Stanford, CA (3) University of Colorado, Boulder, CO (4) National Solar Observatory, Tucson AZ

The 1600 and 1700 Angstrom bands of AIA are sensitive to the five-minute oscillations used in helioseismology. We investigate the acoustic response of these bands and the HMI velocity and continuum intensity to various kinds of local magnetic activity, including a current active region, a decayed active region, and quiet Sun. We will present maps of the acoustic power at various frequencies as a function of position and of spatial wavelength, for the AIA bands and for the HMI velocity and continuum intensity, and also maps of the relative phase and coherence of these observables. We will also consider the results of small-area local helioseismology for the HMI velocity in corresponding regions, and show that even weak fields can have distinct effects on the behavior of acoustic waves near the surface.

CO-EVOLUTION OF LONG-LIVED CORONAL STRUCTURES AND PHOTOSPHERIC FLOW FIELDS

Neal Hurlburt

Lockheed Martin ATC

Large-scale flows in the vicinity of filaments, coronal holes and active regions are investigated. We identify sets of each over the year of past year using the Heliophysics Events Knowledgebase (HEK). Surface velocities are extracted from a set of HMI data cubes using a spectral optical flow method that sample the structures disk passage. We then investigate the co-evolution of the flow patterns and coronal structures as seen by AIA.

DETECTING SUBSURFACE SIGNATURES OF EMERGING MAGNETIC FLUX

Stathis Itonidis

Stanford University

Investigations of emerging magnetic flux are important for the studies of solar magnetism as well as for improving space weather forecasts. Local helioseismology provides tools for detecting emerging active regions before they appear on the surface. Using Doppler observations from SOHO/MDI and SDO/HMI instruments and a modified deep-focus time-distance measurement scheme, it is demonstrated that strong emerging flux events can be detected as deep as 65,000 km below the surface and 1-2 days before the magnetic flux becomes visible in the photosphere. These events cause travel-time shifts of the order of 12-16 seconds and rise to the surface with an average speed of 0.3-0.6 km/s. I compare the helioseismic measurements with theoretical predictions, discuss implications of these results for sunspot studies, and suggest potential applications to space weather forecast.

MULTI-SPECTRAL ANALYSIS OF HELIOSEISMIC ACOUSTIC MODE PARAMETERS

Kiran Jain (1), S. Tripathy (1), S. Basu (2), R. Bogart(3), I. Gonzalez Hernandez (1), F. Hill (1), R. Howe (4), S. Kholikov (1), R. Komm (1)

(1) National Solar Observatory, USA, (2) Yale University, USA (3) Stanford University, USA, (4) University of Birmingham, UK

Simultaneous measurements at different wavelengths from SDO offer the prospect of studying the sensitivity of helioseismic inferences to the choice of observing height both in quiet-Sun and magnetically active regions. In this poster, we present comparison of mode parameters obtained with different observables, quantify differences, and interpret results in the context of the formation height and the anticipated phase relationships between the oscillations at those heights. This work is expected to enhance our understanding of the excitation and damping of the oscillations and the uncertainties in helioseismic inferences.

A COMPARISON OF SOLAR CYCLE VARIATIONS IN THE EQUATORIAL ROTATION RATES OF THE SUN'S SURFACE AND SUNSPOT GROUPS

J. Javaraiah

Indian Institute of Astrophysics, Bangalore-560034, India

The solar equatorial rotation determined from the sunspot group data is shown to be varying on several times scales, including the 11-year solar cycle time scale, whereas the variations found in the Sun's surface equatorial rotation determined from the Mt. Wilson Doppler-velocity measurements are so far doubted and attributed to the inconsistency in the data due to the frequent changes in the Mt. Wilson spectrograph instrumentation. We analysed the Solar Optical Observatory sunspot group data and the Mt. Wilson Doppler-velocity measurements during the period 1986-2007 and determined the variations in the annual mean values of the equatorial rotation rates (the intercept term, 'A', in the equations of the traditional laws of the solar differential rotation) of the sunspot groups and the Sun's surface. We find that the solar cycle variation in 'A' determined from the Mt. Wilson Doppler velocity data substantially differs with the corresponding variation in 'A' determined from the sunspot group data that did not include the values of the abnormal angular motions of the spot groups, whereas closely resembles to the corresponding variation in 'A' determined from the spot group data that included the values of the abnormal angular motions. The comparison of the mean values of 'A' derived from these three data sets with the radial variation in the equatorial rotation rate determined from helioseismic measurements suggest that a reason for the above discrepancy could be the solar rotation rates determined from the spot group data with and without the contributions of the abnormal angular motions of the spot groups may represent the rotation rates of the shallower layers and the relatively deeper layers of the Sun, respectively. This strongly suggest that the solar cycle variation in the surface 'A' determined from the Doppler-velocity measurements is of the solar origin rather than it is caused by the inconsistency and uncertainties in the data.

EXCITATION OF SOLAR ACOUSTIC WAVES AND VORTEX TUBE DYNAMICS

Kitiashvili I.N. (1), Kosovichev A.G. (1), Lele S.K. (1), Mansour N.N. (2), Wray A.A. (2)

(1) Stanford University, CA, USA, (2) NASA Ames Research Center, CA, USA

Oscillatory behavior is one of the basic properties of the solar surface. Therefore understanding the mechanism of acoustic waves excitation in the turbulent near-surface layer is very important for the interpretation of helioseismology data and development of new methods of helioseismic diagnostics of the solar interior, as well as for understanding of the role of the acoustic flux in the energy transport. Observations of individual impulsive events generating acoustic waves have been mostly detected in the intergranular lanes and are associated with local strong cooling of fluid elements. Also, the modern high-resolution observations revealed a process of dragging of small-scale magnetic concentrations toward the center of a convective vortex motion in the photosphere. A substantial progress is being made from the analysis of high-resolution observational data, particularly from Hinode, Sunrise, NST, and SDO/HMI, and also from high-resolution realistic numerical simulations. The simulations take into account all essential turbulent and other physical properties of the solar plasma, and allow us to look at the scales that cannot be resolved in observations, and also compare the data and models. We present new results of 3D radiative MHD simulations of the upper convection zone and atmosphere, and show that one of the possible mechanisms of the acoustic waves generation is a result of interaction two and more vortex tubes in the intergranular lanes. The process of a vortex annihilation, which produces acoustic waves, the properties of these waves and vortices, magnetic influence on the efficiency of acoustic emission, and comparison with the available observational data will be discussed.

SUBSURFACE KINETIC HELICITY OF FLOWS NEAR ACTIVE REGIONS

Komm R., Jain K., Petrie G., Pevtsov A., González Hernández I., Hill F.

National Solar Observatory

We study the temporal variation of subsurface flows associated with emerging and decaying active regions on the Sun. We measure the subsurface flows analyzing GONG high-resolution Doppler data with ring-diagram analysis. We can detect the emergence of magnetic flux in these flows when averaging over a sufficiently large sample. In a previous study, we have found that emerging flux has a faster rotation than the ambient fluid and pushes it up, as indicated by enhanced vertical velocity and faster-than-average zonal flow. Here, we show that the kinetic helicity density of subsurface flows increases when new flux emerges and decreases when flux decays.

LARGE-SCALE FLOWS FROM HMI USING THE RING-DIAGRAM PIPELINE

Komm R. (1), González Hernández I. (1), Hill F. (1), Bogart R.S. (2), Rabello-Soares, M.C. (2)

(1) National Solar Observatory, (2) HEPL Stanford University

We determine the zonal and meridional flows in subsurface layers derived from HMI Doppler data processed with the HMI ring-diagram pipeline. We analyze subsurface flow measurements obtained during Carrington rotation 2097 to 2113. We are especially interested in flows at latitudes of 60 degree and higher, since previous observations have been limited to lower latitudes (using local helioseismic techniques). Systematic effects, such as B0-angle variations, have to be taken into account to lead to reliable flow estimates at high latitudes. We will present the latest results.

A DETERMINATION OF HIGH DEGREE MODE PARAMETERS BASED ON MDI OBSERVATIONS

S.G. Korzennik(1), M.C. Rabello-Soares(2), J. Schou(2) & T. Larson(2)

(1) Harvard-Smithsonian Center for Astrophysics, (2) Stanford

We present the best to date determination of high degree mode parameters obtained from the longest full-disk high-resolution data set available over the 13 years of MDI operations. A ninety day long time series of full-disk two arc-second per pixel resolution dopplergrams were acquired in 2001, thanks to the high rate telemetry provided by the deep space network. These dopplergrams were decomposed using our best estimate of the image scale and the known components of MDI's image distortion. The spherical harmonics decomposition was carried out up to $l=1000$, and a sine multi-taper power spectrum estimator was used to generate power spectra for all degrees and all azimuthal orders up to $l=1000$. We used a large number of tapers to reduce the realization noise. Since at high degrees the individual modes blend into ridges, there is no reason to preserve a high spectral resolution. These power spectra were fitted for all degrees and all azimuthal orders, between $l=100$ and $l=1000$, and for all orders with substantial amplitude, generating in excess of 6 million individual estimate of frequencies, line-widths amplitudes and asymmetries, corresponding to some 6,000 singlets. Fitting at high degrees generates characteristics of the blended ridges, characteristics that do not correspond to the underlying mode characteristics. We used a sophisticated forward modeling of the mode to ridge blending to recover the best possible estimate of the underlying mode characteristics for the mode frequency, as well as the line-width, amplitude and asymmetry. We describe this modeling, as it has been recently fine tuned, and the iterative process used to refine its input parameters. Finally not only did we generate corrected mode characteristics and their uncertainties, but we computed the sensitivity of the model to its input set to best estimate the precision of the ridge to mode correction itself. This was carried out to assess the magnitude of any residual systematic errors in the final estimates of the mode characteristics.

RESULTS FROM FITTING 13+ YEARS OF GONG AND MDI DATA AT LOW AND INTERMEDIATE DEGREES

S.G. Korzennik

Harvard-Smithsonian Center for Astrophysics

I present the latest results from fitting modes at low and intermediate degrees (up to $l=300$ for the f-mode, $l=200$ for p-modes), using my state of the art fitting methodology. Time series of various lengths have been fitted, from a single 4608-day long epoch (64 times 72 day or 12.6 yr) down to 64 separate segments for the “traditional” 72-day long epochs, and including 32x, 16x, 8x, 4x and 2x 72-day long overlapping epochs. We used MDI time series of spherical harmonic coefficients computed using an improved spatial decomposition. This decomposition now includes our best estimate of the image plate scale and of the MDI instrumental image distortion. We used the GONG time series of spherical harmonic coefficients as generated by the GONG pipe-line (available up to $l=200$ only). The leakage matrices used for the fitting includes the distortion of the eigenfunctions by the solar differential rotation. The undistorted leakage matrices were carefully reviewed and independently recomputed. The effect of the leakage matrix (and its residual inadequacy) can be readily observed when using longer time series than the traditional 72 or 108-day long ones. We compare in details results from fitting GONG and MDI, using for the first time the same fitting code, although a different leakage matrix, and the exact same time span.

STRONG PHOTOSPHERIC IMPACT OF M-CLASS FLARE: HELIOSEISMIC RESPONSE, WHITE LIGHT
EMISSION AND MAGNETIC RESTRUCTURING

Alexander Kosovichev, Priya Desai, Keiji Hayashi

Stanford University

Solar flare of July 30, 2011, had a modest X-ray class (M9), but made a very strong photospheric impact, observed by the Helioseismic and Magnetic Imager (HMI) on Solar Dynamics Observatory. The flare generated helioseismic waves, (also observed with the SDO/AIA instrument), caused a large expanding area of white-light emission, and was accompanied by substantial restructuring of magnetic fields in the flare region. There was no significant hard X-ray emission and no coronal mass ejection. This indicates that the flare energy release was probably confined in the lower atmosphere. We present results of initial analysis of the SDO data.

SUBPHOTOSPHERIC FLOWS AND EVOLUTION OF ACTIVE REGIONS

A.G. Kosovichev and J.Zhao

Stanford University

The HMI instrument on SDO has provided unprecedented opportunities for studying the subsurface dynamics of active regions during their emergence and various stages of the evolution. We analyzed maps of subsurface flows, obtained by using the HMI time-distance helioseismology pipeline, in order to investigate links between the subsurface properties and surface magnetic structures, and also their relationships to flaring and CME activity for several interesting regions. The results reveal strong shearing and twisting flows during high-activity periods. We discuss how properties of the subphotospheric flows, such as divergence, vorticity and helicity, can characterize the evolution and activity of magnetic regions.

EVOLUTION OF AN ACTIVE REGION FILAMENT AS OBSERVED IN THE PHOTOSPHERE AND
CHROMOSPHERE SIMULTANEOUSLY

Kuckein, Christoph (1,2), Martinez Pillet, Valentin (1), Centeno, Rebeca (3)

(1) Instituto de Astrofísica de Canarias, Tenerife, Spain, (2) Departamento de Astrofísica, Universidad de La Laguna, Tenerife, Spain, (3) High Altitude Observatory (NCAR), Boulder, CO

A multiwavelength study and comparison of the vector magnetic field in a compact active region filament (NOAA 10781) for 2005 July 3rd and 5th is presented. Different inversion codes were used to analyze the full Stokes vectors acquired with the Tenerife Infrared Polarimeter (TIP-II) in a spectral range which comprises the chromospheric He I 10830 Å multiplet and the photospheric Si I 10827 Å line. Other data from ground- and space-based telescopes has been used to have a complete view of the evolution of the active region (AR). We found that the filament was clearly observed for the first time, on July 3rd, after a “sliding-door” effect a-la Okamoto et al. (2008) of the polarity inversion line (PIL). The chromospheric vector magnetic field in the filament was strongly sheared (parallel to the filament axis) whereas the photospheric field lines had an inverse polarity configuration. For July 5th we had a different field of view but still half of it remained the same. We now observed pores and orphan-penumbral features that emerged along the PIL. A normal polarity configuration is inferred in the filament above these features and strongly sheared field lines along the PIL are found below, in the photosphere. The inferred vector magnetic fields of the filament suggest a flux rope topology. Furthermore, the observations indicate that the filament is divided in two parts, one of it seems to be trapped in the photosphere. Inferred magnetic field strengths and velocity measurements inside and below the filament will be presented. An evolutionary scenario for this AR filament is suggested.

DOES THE SUN CHANGE ITS SHAPE?

Kuhn, J.R., Bush, R. I., Emilio, M., Scholl, I.

Institute for Astronomy, UH

Its not easy to change the radius or the shape of the Sun. It must come with a large energy cost and will be difficult to disentangle from the complicated physics at the boundary between the radiatively opaque and transparent solar atmosphere. HMI offers great advantages for measuring the limb physics which we're using to look for solar cycle variations that could be clues to how the interior changes. This talk will update the ongoing effort to understand the solar limb better.

OBSERVATIONS OF EMERGING FLUX REGIONS WITH SWAMIS-EF

Lamb, Derek A. (1), DeForest, Craig E. (1), Davey, Alisdair R. (2), Timmons, Ryan P. (3)

(1) Southwest Research Institute, Boulder, CO, (2) Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, (3) Lockheed Martin Solar & Astrophysics Lab, Palo Alto, CA

The SWAMIS magnetic feature tracking algorithm is working in the SDO pipeline to detect emerging flux regions from the size of active regions down to ephemeral regions. We will present a brief overview of the emerging flux detection algorithm, show a sample of events as one would see them in the HEK, and show some examples illustrating the underlying performance of the algorithm in more detail than is available in the HEK. Finally, we will present some measurements of the amount of magnetic flux emergence detected by the algorithm over a month-long time period and compare that with previously-published estimates of the magnetic flux emergence rate. SWAMIS-EF enables such previously-difficult measurements to now be routinely made.

COMPARING LEAKAGE MATRICES

Larson, T.P. (1), Schou, J. (2), Korzennik, S.G. (3)

(1) and (2) Stanford University, Stanford, CA, (3) Harvard-Smithsonian Center for Astrophysics,
Cambridge, MA

The standard leakage matrix for global mode helioseismology is calculated assuming a value of zero for the P-angle, B-angle, and CCD offsets, and value of 1 AU for the observer distance. Since image center is not constant we vary this parameter so see what effect it has on the leaks and explore the possibility of using a leakage matrix averaged over pixel offsets. Since the B-angle and observer distance vary in a known way with time, we recompute the leakage matrix for realistic values of these parameters and repeat the fits to find out how the mode parameters are affected. Since previous studies have indicated certain systematic errors are associated with the apodization, we also compute leakage matrices for different apodizations, repeat the spherical harmonic decomposition with those apodizations, and fit these to see the effect on mode parameters. Lastly, we compare the leakage matrix computed at Stanford with a completely independent calculation in order to both verify our results and discover the source of any discrepancy.

SUPERGRANULATION SUPER-ROTATION

Lee, Shannon(1) and Beck, John(2)

Stanford University^{1&2}, San Francisco State University⁽¹⁾, UCLA⁽²⁾

Supergranulation is a long studied feature of solar convection. The cellular pattern and horizontal outflows are consistent with a convective phenomenon, but the details of supergranulation can not be explained by a simple convective model. One such aspect is its apparent super-rotation. Supergranulation appears to rotate a few percent faster than the solar surface plasma which some try to explain using rooting-depth. However, this rotation can be better explained as wavelike properties of supergranulation. Using dopplergrams from the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO) as well as from the MDI instrument aboard SOHO we have obtained evidence of wavelike properties of supergranulation.

INTERPRETING VECTOR MAGNETIC FIELD DATA IN THE CONTEXT OF MODELING RESULTS
(AND VICE-VERSA)

KD Leka

NWRA

The magnetic field structures of solar phenomena as inferred from polarimetric measurements of the solar atmosphere are invaluable to understanding the physical reasons for the morphology and dynamics observed. In a complementary manner, numerical models of the solar atmosphere allow an exploration of the physics, guided by the observables. Context, however, can be key. In this talk I will remark on approaches, and limitations of direct comparisons between numerical models of the solar atmosphere and remote-observations of the same, especially in the context of HMI vector magnetic field data.

COMPARISON OF STEREO'S FAR-SIDE OBSERVATIONS OF SOLAR ACTIVITY AND
PREDICTIONS FROM THE GLOBAL OSCILLATIONS NETWORK GROUP (GONG)

Liewer, P. C. (1), Hall, J. R.(1), Gonzalez Hernandez, I. (2), Hill, F. (2), Thompson, W. T. (3), Misrak, A.
(1), De Jong, E. M. (1)

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Beginning February 18, 2011, the STEREO mission in conjunction with SDO, for the first time, gave us an “All Sun” view of the entire corona in extreme ultraviolet (EUV) light. Here, we compare STEREO/EUVI views of solar activity on the far side to predictions of far-side strong magnetic field regions from helioseismology using National Solar Observatory/ Global Oscillation Network Group (GONG) observations (see <http://gong.nso.edu/data/farside/>). The GONG project produces “All Sun” Carrington maps of strong magnetic field regions; far side regions with a probability of 70% or higher are labeled. We have produced “All Sun” EUV Carrington maps of coronal magnetic activity by combining nearly simultaneous STEREO A & B EUVI data and SDO AIA data at each of the four EUVI wavelengths. We then visually determine whether or not magnetic activity is seen in the corona (as evidenced by brightening in EUV) at the locations predicted by GONG. We have analyzed all GONG far-side predictions from February through June 2011. For 139 of 157 comparisons (89%), activity is observed in the corona by STEREO A or B. For 18 predictions, no activity was seen at the predicted region. We have also analyzed GONG’s success at predicting 15 large active regions that appear on the East limb (as viewed from Earth) during this time period. For those not predicted, we use STEREO B EUVI data to determine whether or not the regions had significant activity during the time when GONG should have been able to predict them.

FLARE SEISMOLOGY FROM SDO OBSERVATIONS

Charles Lindsey, Juan Carlos Martinez Oliveros & Hugh Hudson

Northwest Research Associates

Some flares release intense seismic transients into the solar interior. These transients are the sole instance we know of in which the Sun's corona exerts a conspicuous influence on the solar interior through flares. The desire to understand this phenomenon has led to ambitious efforts to model the mechanisms by which energy stored in coronal magnetic fields drives acoustic waves that penetrate deep into the Sun's interior. These mechanisms potentially involve the hydrodynamic response of the chromosphere to thick-target heating by high-energy particles, radiative exchange in the chromosphere and photosphere, and Lorentz-force transients to account for acoustic energies estimated up to at 5×10^{27} erg and momenta of order 6×10^{19} dyne sec. An understanding of these components of flare mechanics promises more than a powerful diagnostic for local helioseismology. It could give us fundamental new insight into flare mechanics themselves. The key is appropriate observations to match the models. Helioseismic observations have identified the compact sources of transient seismic emission at the foot points of flares. The Solar Dynamics Observatory is now giving us high quality continuum-brightness and Doppler observations of acoustically active flares from HMI concurrent with high-resolution EUV observations from AIA. Supported by HXR observations from RHESSI and a broad variety of other observational resources, the SDO promises a leading role in flare research in solar cycle 24.

MEASURING THE MAGNETIC ENERGY AND HELICITY IN THE EMERGING ACTIVE REGIONS
WITH HMI VECTOR MAGNETOGRAMS.

Yang Liu, HMI vector field team

Stanford University, and Others

Magnetic energy flux and helicity flux across the photosphere are calculated using HMI vector magnetic field data and DAVE4VM (Schuck 2008) technique. The active regions studied in the paper, from simple to complex, are AR11072, AR11117 and AR11158. The results are following. (1) Helicity flux from surface flows is dominant. Its variation is consistent with flux emergence but has a phase lag. Helicity flux from vertical flows is small. This implies that the emerged field is initially close to potential. Both fluxes have the same sign during flux emergence. (2) Energy flux from surface flows is consistent in phase with flux emergence. It approaches to zero after emergence stops. Energy flux from vertical flows shows an outstanding delay in phase with the flux emergence, and it keeps fairly high level after emergence stops. Upflows surrounding sunspots contributes substantially energy. (3) The horizontal velocity derived by tracking the photospheric footpoints of magnetic tubes is close to the horizontal plasma velocity.

THEORIES OF MAGNETIC ENERGY RELEASE AND CONVERSION IN SOLAR FLARES: POSSIBLE
ROLES FOR MAGNETIC RECONNECTION

Dana Longcope

Montana State University

Solar flares are now generally believed to occur through the rapid release of magnetic energy through reconnection. The basic scenario for this process was outlined more than 50 years ago, but only in the past decade have theoretical models been able to explain the generation of large parallel electric fields previously pre-supposed. The upshot of these theories is that reconnection electric fields must be localized within a current sheet in order to change magnetic field line topology at observed rates. The apparent resolution of this long-standing puzzle (Petschek mode vs. Sweet-Parker mode) raises a host of new questions concerning how reconnection can result in the conversion of magnetic field energy to other forms. If it is in fact localized, the reconnection electric field cannot be directly responsible for plasma heating or particle acceleration. The magnetic energy is stored over a large coronal volume whose plasma which will never be exposed to the reconnection electric field. Energy conversion must therefore occur away from the reconnection site, as an indirect consequence. In spite of its secondary place in the chain of events, this energy conversion is the main effect we typically ascribe to solar flares. I will review the current theoretical understanding of how magnetic reconnection might lead to a release and the conversion of magnetic energy. This work supported by a joint grant from NSF and DOE

ORIGINS OF ROLLING, TWISTING AND NON-RADIAL PROPAGATION OF ERUPTIVE SOLAR EVENTS

Sara F. Martin and Olga Panasenco

Helio Research

We demonstrate that major asymmetries in erupting filaments and CMEs are not only related to each other but that major twists and non-radial motions typically are related to the larger, more global environment around eruptive events. This overarching result grew out of a number of earlier studies that we now encapsulate within the bigger picture. If a filament erupts non-radially, as frequently happens, the top of its spine first bends to one side and evolves into a sideways rolling motion. As shown by 304 Angstrom observations from SOHO and STEREO and earlier H alpha Doppler observations, the rolling motion propagates down the legs of erupting filaments resulting in the large scale twists commonly observed in them. The initial rolling initiates twist of opposite chirality in the two legs. In addition to the observed absence of twist in the pre-eruptive state, further evidence that the energy creating the twist comes from above was found in Doppler shifts; the rotational motions in the legs of erupting filaments are not only opposite in sign to each other but the twists in both legs are opposite in sign to that required if the observed sense of twist were generated at the feet or in the legs of the erupting filament. We next demonstrate that the combined ascent and initial bending is non-radial in the same general direction as for the surrounding CME. However, the non-radial motion of the filament is greater than that of the CME. In considering the global environment around CMEs, as can be approximated by the Potential Field Source Surface (PFSS) Model, we found that both erupting filaments and their surrounding CMEs are non-radial only in the direction away from a nearby coronal hole and toward local and global null points. Due to the presence of the coronal hole, the global forces on the CME are asymmetric. The CME propagates non-radially in the direction of least resistance and that is always away from the coronal hole as we demonstrate by comparing low latitude and high latitude examples. Through modeling and comparison with observed events, we anticipate that major twists and non-radial motions in erupting prominences and CMEs will become predictable to the extent that their environments are well-defined and measurable.

SUNSPOTS AND ACTIVE REGION FILAMENTS: WHAT DO THEY HAVE IN COMMON?

V. Martinez Pillet

Instituto de Astrofísica de Canarias

Sunspots are preceded by a well documented and spectacular phase of magnetic flux emergence, easy to identify in almost any spectral range. This phase is followed by a more subtle process of flux disappearance that includes diffusion and magnetic cancelation. The decay phase coincides with the development of an active region filament at the Neutral Line that slowly evolves and often gets spelled in CME events. These Active Region filaments harbor field strengths of several hundredths of Gauss which represent the strongest field concentrations second only to the sunspots themselves. However, no link between the sunspots and the Active Region filaments are known to exist. The conditions under which these two ingredients of Active Regions can indeed be related to each other will be reviewed in the light of recent observations made in the He 10830 Å spectral region.

SUB-SURFACE STRUCTURE AND DYNAMICS OF THE ACTIVE REGION NOAA 11158

Ram Ajoy Maurya

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Solar active region NOAA 11158 appeared near the disk center in the rising phase of the current solar cycle 24 at location S19W03 on 2011 February 12. It evolved very rapidly during the disk passage in the period 2011 February 12-21 after its birth on February 12th. It developed from a simple beta- to a complex beta-gamma-delta configuration by 2011 February 15-16. It was very energetic during its disc passes and produced the first X-class flare (X2.2) of the current solar cycle 24. It is expected that characteristically this active region should be distinct as compared to other less flare-productive active regions. In order to identify any distinguishing features in the internal structure and dynamics of this active region, we have studied the surface and sub-surface characteristics using high resolution observations obtained from Helioseismic and Magnetic Imager (HMI) on board Solar Dynamics Observatory. To investigate these characteristic properties, we have also derived the vorticity vector and the kinetic helicity density of subsurface flows using ring diagrams. The detailed results will be presented in this paper.

RECOVERING JOY'S LAW, TILT ANGLE AS A FUNCTION OF LONGITUDE, AND TILT ANGLE CHANGE DURING EMERGENCE

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Bipolar active regions in both hemispheres tend to be tilted with respect to the East-West equator of the Sun in accordance with Joy's law which describes the tilt angle as a function of latitude. Joy's law can be generalized as: average tilt angle = $2^\circ \pm 0.2^\circ$ latitude. Mt Wilson Observatory (MWO) data from 1917-1985 are used to analyze the active region tilt angle as a function of hemisphere and longitude, in addition to the more common dependence on latitude. We determine the minimum number of sunspot groups needed to recover Joy's law in any given amount of time. We present hemispheric differences in Joy's law for cycles 17-21. Sunspot cycle 17 and 19 show a small but significant dependence of tilt angle on longitude over portions of the solar cycle. This implies that toroidal fields at the base of the convection zone are tipped with respect to the solar equatorial plane, affecting the initial angle at which magnetic field ropes begin their rise. Finally, we use SDO/HMI data to record the change of tilt angle over time as a sunspot group emerges.

THE SOLAR DIFFERENTIAL ROTATION AND MERIDIONAL CIRCULATION: A STATUS BRIEFING FROM THE FRONT LINES

Mark Miesch

HAO/NCAR

Much progress has been made in the past decade in our understanding of how mean flows in the solar convection zone are established. Although researchers have long attributed the solar differential rotation to the convective Reynolds stress, new numerical models and theoretical paradigms have clarified how Reynolds stresses operate in conjunction with baroclinic forcing and meridional circulations. New insights include thermal coupling to the tachocline, the alignment of isorotation and isentropic surfaces, and the role of the surface boundary layer in regulating the Rossby number of the convection zone. Moreover, recent application of the concept of gyroscopic pumping has clarified how the differential rotation and the meridional circulation are linked through their mutual inertia. This is particularly relevant for the Near-Surface Shear Layer (NSSL), where global and local helioseismic inversions can be used to probe mean flow dynamics in detail. In this talk I will review these recent insights and discuss how they may be used to construct improved models of solar internal dynamics.

PROPAGATION AND IMPACT OF MULTIPLE CORONAL MASS EJECTIONS EVENTS ON AUGUST 1
2010 IN THE HELIOSPHERE

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On August 1 2010 a large region of the solar northern hemisphere displayed major activity involving a complex set of central meridian and remote active regions, and two large prominence channels (Schrijver and Title, JGR, 2011). We witnessed the eruption of four coronal mass ejections (CMEs) which partly impacted Earth and lead to one of the first geomagnetic storms of the new solar cycle. We present an overview of the results of several analyses exploiting the extraordinary completeness of the imaging data (SDO/STEREO/SOHO) in combination with numerical simulations (ENLIL) and in situ observations. The imprints of the CMEs, including a prior event on July 30, were observed in situ in an almost laboratory-like configuration at 4 widely separated locations spanning over 120 degrees of heliospheric longitude (STEREO-B, Venus Express, ACE/Wind, ARTEMIS, and MESSENGER). The CME density enhancements could be followed with the STEREO-A/HI and Coriolis/SMEI instruments continuously from the Sun to 1 AU. Evidences of CME-CME interactions and resulting overlapping tracks in Jmaps make the analysis complex, but nevertheless we find robust interpretations for linking two magnetic flux ropes at Earth, one of them geo-effective and including elevated alpha particles related to possible filament material, to their solar counterparts. Additionally, we discuss the relationship between the in situ observations and the global picture given by the ENLIL model.

MULTI-WAVELENGTH TIME-DISTANCE HELIOSEISMOLOGY ANALYSES

Nagashima, Kaori (1), Zhao, Junwei (1), Duvall, Thomas, Jr. (2), Kosovichev, Alexander G., (1),
Parchevsky, Konstantin (1), Sekii, Takashi (3)

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Travel times of the acoustic waves in the Sun tell us the structure and the dynamics of the Sun. This information have been used to probe the solar interior. If we exploit multi-layer observation datasets, however, it will provide us with means to study the wave propagation between the layers as well (Nagashima et al. 2009). In this study, using multi-wavelength datasets obtained by Hinode/SOT, SDO/HMI, and SDO/AIA we calculate the cross-correlation function of the wavefield and carry out time-distance helioseismology analyses. Our preliminary results show that when we cross-correlate the wavefields of two different layers the cross-correlation functions between these layers are different from the cross-correlation functions of both single layers, and this provides us with an insight of wave propagation properties. We also use numerical simulations of solar oscillations to help interpret our observational results.

SUNSPOT GROUPS SIMULTANEOUSLY OBSERVED WITH HMI AND MDI

A.A. Norton (1), J. Schou (2), Y. Liu (2), J.T. Hoeksema (2)

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Simultaneous data from HMI and MDI is analyzed for active regions 11084 and 11087. We showcase the improved quality of HMI 45-second magnetogram data over MDI magnetogram data due to higher spectral and spatial sampling as well as better optical alignment and a magnetically more sensitive spectral line. Specifically, HMI magnetogram data contains less leakage of p-mode signal, umbrae do not show saturation at low intensities, and HMI flux values are consistent with vector data. We show comparisons of magnetic time series and power spectra observed by HMI and MDI for sunspot, plage and quiet-Sun.

TAHOMAG - VECTOR-MAGNETOGRAPH FOR INTERHELIOPROBE

I.E.Kozhevator, V.N.Obridko, E.A.Rudenchik

IZMIRAN

Presented is the design of TAHOMAG - a vector-magnetograph for the INTERHELIOPROBE space mission. Since the instrument is supposed to conduct measurements under the conditions of strongly changing spacecraft velocity with respect to the Sun, we have chosen the scheme of a magnetograph with a spectrograph. A part of the spectrum of length 6 \AA is fixed in the vicinity of the FeI 6302 \AA line. The contours of the Stokes parameters are recorded with a high spectral resolution. The polarization analyzer does not have mobile parts. The spatial resolution in the vicinity of the perihelion (0.3 a.u.) is expected to be 50-75 km.

PROPAGATION AND TRANSFORMATION OF MHD WAVES IN SUNSPOTS

K.V. Parchevsky, A.G. Kosovichev

Stanford University

It has long been suggested that the fast MHD waves (which are analog of the acoustic waves in non-magnetized regions) can convert into other types of MHD waves (slow MHD and/or Alfvén waves) inside sunspots due to the interaction with the magnetic field. Transformed waves propagate in the deeper layers of the sunspot along the magnetic field lines, removing the energy from the observed wave field. Such mode conversion (if exists) will contribute to the suppression of the acoustic power inside the sunspots. Results of numerical simulations of interaction of MHD waves with magnetized areas show that the mode conversion occurs near the sunspot axis in regions where the wavefront of the fast MHD wave crosses the level where the plasma parameter β is of order of unity. The transformed wave is primarily transverse. Detailed simulations show, that the transformed wave exists even in case where the source is located completely outside of the magnetic region, so the wave, which enters the model of the sunspot, is pure acoustic. To compare simulations of MHD waves in sunspots and observations we need to know at what geometrical depth this comparison has to be done. We propose a method of the wave amplitude and travel-time shortening corrections. Our method is based on the combination of three-dimensional numerical simulations of propagation of MHD waves with 1D LTE radiation transfer simulations of the Stokes profiles of the HMI line. For measuring the Doppler shift we use the same set of 6 narrow-band filters which is used by the HMI instrument. Such simulations will provide the artificial HMI level 1 data (if necessary, non-simultaneity of frames for different polarization channels can be simulated) which can test the whole Time-Distance Pipeline.

PERTURBATIONS IN THE WAVE PARAMETERS NEAR ACTIVE REGIONS

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Stanford University, Stanford, CA

The wave characteristics in magnetically quiet regions with a nearby active region are compared with those of quiet regions at the same solar disk positions, but with no nearby active regions. We search for perturbations in the wave characteristics as the solar acoustic oscillations are affected as they propagate inside the nearby sunspot. The wave parameters were derived from ring-diagram analysis of HMI/SDO data. We find perturbations in several parameters, specially in the amplitude, width and frequency. The frequency observed in a five-degree quiet tile seems to be smaller if there is an active region nearby than if there is not by as much as 6%. We also describe the level of anisotropy in these perturbations in relation to direction of the nearby sunspot.

A STUDY OF ACOUSTIC POWER MAPS OVER SUNSPOT REGIONS USING HMI AND AIA (1600 Å AND 1700 Å) DATA

S.P. Rajaguru (1) and S. Couvidat (2)

(1) Indian Institute of Astrophysics, Bangalore, India. (2) HEPL, Stanford University, Stanford CA, USA

The wavelength channels 1600 Å and 1700 Å from the Atmospheric Imaging Assembly (AIA) onboard SDO are now known to capture clear oscillation signals due to helioseismic p modes. Here we study in detail, in comparison with HMI Doppler data, properties of acoustic power maps over several active regions as a function of p mode frequencies, line-of-sight magnetic field (from HMI) and observation height. We discuss the implications for theories of p mode absorption, conversions and high-frequency acoustic halos.

EFFECTS OF OBSERVATION HEIGHTS AND ATMOSPHERIC WAVE EVOLUTION IN SUNSPOT
SEISMOLOGY: A STUDY USING HMI AND AIA (1600 Å AND 1700 Å) DATA

S.P. Rajaguru (1) and S. Couvidat (2)

(1) Indian Institute of Astrophysics, Bangalore, India. (2) HEPL, Stanford University, Stanford CA, USA

In achieving a high cadence and whole Sun coverage required of them, Doppler imagers such as HMI/SDO and MDI/SOHO necessarily forgo certain intricacies associated with magnetic and velocity field interactions, which require high (spectral) resolution spectropolarimetry for their accurate measurements with straightforward derivation of physical quantities (or observables). Magnetic field modified wave evolution, due to much reduced acoustic cut-off frequencies, in inclined field regions is one such situation. We first show, using a high cadence imaging spectropolarimetric observations made with IBIS instrument at NSO/Sac Peak, that significant contributions to seismically measured travel times arise from the line formation layers. We then present a comparative study of time-distance helioseismic measurements made over three sunspot regions using HMI and AIA (1600 Å and 1700 Å) data, which provide oscillation signals from three different heights. We bring out clear signals of height dependent wave phases and hence height dependent travel times. We further show that such signatures, from their differing contributions in one way travel times (in- or out-going wave travel times), could explain a significant part of the discrepancies between time-distance and other local helioseismic measurements and inferences.

SOLAR CYCLE FINE STRUCTURE AND SURFACE ROTATION FROM CA II K-LINE TIME SERIES DATA

Jeff Scargle, Steve Keil, and Pete Worden

NASA Ames Research Center/NSO

Analysis of three and a half decades of data from the NSO/AFRL/Sac Peak K-line monitoring program yields evidence for four components to the variation: (a) the solar cycle, with considerable fine structure and a quasi-periodicity of 122.4 days; (b) a stochastic process, faster than (a) and largely independent of it, (c) a quasi-periodic signal due to rotational modulation, and of course (d) observational errors (shown to be quite small). Correlation and power spectrum analyses elucidate periodic and aperiodic variation of these chromospheric parameters. Time-frequency analysis is especially useful for extracting information about differential rotation, and in particular elucidates the connection between its behavior and fine structure of the solar cycle on approximately one-year time scales. These results further suggest that similar analyses will be useful at detecting and characterizing differential rotation in stars from stellar light-curves such as those being produced by NASA's Kepler observatory. Component (b) consists of variations over a range of timescales, in the manner of a "1/f" random process. A time-dependent Wilson-Bappu effect appears to be present in the solar cycle variations (a), but not in the stochastic process (b). The data can be found at the National Solar Observatory web site http://nsosp.nso.edu/data/cak_mon.html, or by file transfer protocol at <ftp://ftp.nso.edu/idl/cak.parameters>.

HELIOSEISMIC FRECHET TRAVELTIME KERNELS IN SPHERICAL COORDINATES

Schlottmann, R. B. (1), Kosovichev, A. G. (1)

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Seismic travel time measurements are a crucial tool in the investigation of the solar interior, particularly in the examination of fine-scale structure. Traditional analysis of travel times relies on a geometrical ray picture of acoustic wave propagation, which assumes high frequencies. However, it is well-known that travel times obtained from finite-frequency waves are sensitive to variations of medium parameters in a wide Fresnel zone around the ray path. To address this problem, Frechet travel time sensitivity kernels have previously been developed. These kernels use a more realistic approximation of the wave propagation to obtain a linear relationship between travel times and variations in medium parameters. Frechet kernels take into account the actual frequency content of the measured waves and, thus, reproduce the Fresnel zone. Kernel theory has been well-developed in previous work on plane-parallel models of the Sun for use in local helioseismology. Our primary purpose is to apply kernel theory to much larger scales and in a spherical geometry. We also present kernel theory in a different way, using basic functional analytic methods, in the hope that this approach provides an even clearer understanding of the theory, as well as a set of tools for calculating kernels. Our results are very general and can be used to develop kernels for sensitivity to sound speed, density, magnetic fields, fluid flows, and any other medium parameter which can affect wave propagation.

A METHOD FOR THE CALCULATION OF ACOUSTIC GREEN'S FUNCTIONS FOR USE IN COMPUTING FRECHET TRAVELTIME SENSITIVITY KERNELS

Schlottmann, R. B. (1), Kosovichev, A. G. (1)

(1) Stanford University, Stanford, CA

We have modified a semi-analytical approach, originally intended for the calculation of stellar acoustic normal modes, for use in the efficient calculation of Green's functions. The primary purpose of this code is to provide necessary acoustic responses in the calculation of Frechet traveltime sensitivity kernels. Assuming a spherically symmetric star in hydrostatic equilibrium and the Cowling approximation, we perform the usual spherical harmonic decomposition on the linearized acoustic wave equation, resulting in two coupled first-order ODEs in the radial displacement and Eulerian pressure. Following Gabriel & Noels (1976), we break the radial domain into a finite number of non-uniformly spaced intervals within which we assume that the coefficients of the equations are constant. For each interval, we obtain a sum of two analytical solutions with unknown coefficients. Continuity of the fields yields a system of equations for the coefficients. However, instead of using this system to obtain eigenfunctions and eigenfrequencies, we instead solve it assuming a point source, yielding Green's functions for each frequency and degree, eliminating the usual need to sum a truncated series over mode order. We have made a couple of other modifications to the method to improve efficiency. First, the original system of equations is pentadiagonal, but these can be reduced analytically to a tridiagonal system, which is solved approximately 10 times faster. Next, using a technique from complex analysis, we are able to calculate, in the frequency domain, Green's functions that are windowed in time. This naturally spreads out the linewidths of the mode resonance peaks present in the Green's functions, allowing us to fully capture modes with very small linewidths without resorting to excessively fine sampling in frequency.

MEASURING MERIDIONAL FLOW USING GLOBAL MODES

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In the past the meridional flow has been determined near the photosphere by direct observations and below the solar surface using local helioseismic methods. To first order normal mode frequencies are not sensitive to the meridional flow, and so they are not useful for this purpose. However, the eigenfunctions are sensitive to the meridional flow to first order. Here we describe our progress on a project to measure the eigenfunction perturbations and infer the meridional flow with depth.

TRACKING VECTOR MAGNETOGRAMS FROM THE SOLAR DYNAMICS OBSERVATORY,

P.W. Schuck, X. Sun, K. Muglach, J.T. Hoeksema, and the HMI Vector Field Team

NASA/GSFC, Stanford University, Artep, Inc.

The differential affine velocity estimator for vector magnetograms (DAVE4VM) has been developed for estimating photospheric velocities. The accuracy of this technique has been demonstrated on synthetic magnetograms from MHD simulations. The algorithm was initially formulated in Cartesian coordinates. Thus, for best results, solar vector magnetograms must be transformed from the image plane into a Mercator map or some other Cartesian-like projection before applying DAVE4VM. Recently, DAVE4VM has been modified to incorporate directly the projected spherical geometry of Helioprojective-Cartesian coordinates, thus permitting direct application of the method to image plane vector magnetograms. We will discuss the new algorithm and tests of the modified method and present first results of DAVE4VM applied to Solar Dynamics Observatory vector magnetograms.

LOCAL HELIOSEISMOLOGY AMID SURFACE MAGNETIC FIELDS

Schunker, H.

Max Planck Institute for Solar System Research

One goal of local helioseismology is to elicit three-dimensional information about the sub-surface structure and dynamics of active regions. The physical quantities of interest include flows, sound-speed deviations and magnetic fields. The strong surface magnetic fields associated with these regions induce large perturbations to the waves making inversions difficult to interpret. This talk will highlight the recent efforts towards characterising the perturbations and imaging the interior in the presence of strong magnetic fields.

GLOBAL HELIOSEISMOLOGY

Takashi Sekii

NAOJ

Global helioseismology has been extremely successful in probing the solar interior. Unlike local helioseismology, which was more recently developed, global helioseismology relies on precise determination of eigenfrequencies and their inversions, which renders the global approach suited for measuring long-term averages of symmetric structures in the sun. Strengths and limitations of global helioseismology are discussed, as well as its main results and their impacts on our understanding of the sun.

REALISTIC MHD SIMULATIONS OF MAGNETO-CONVECTION

Robert F. Stein

Michigan State University

We review recent progress in magneto-convection simulations, especially magnetic flux emergence. Very different simulations have shown that flux first emerges in a random, mixed polarity, “pepper-and-salt” pattern and then collects into unipolar regions due to the underlying larger scale field topology. Convection predominantly drags the magnetic field downward, but upflows and buoyancy bring some flux to the surface in the form of serpentine small Ω - and U- loops riding piggy back on the larger loops rising from the deeper convection zone. Flux concentrations first develop close to the surface and then extend downward. In our simulations, we find that strong flux concentrations develop pores. They have a filamentary structure near the surface and extend down through the entire 20 Mm depth of the simulation domain. As expected, the magnetic field is nearly vertical in pore interiors and becomes nearly horizontal at the pore boundaries.

EVOLUTION OF MAGNETIC FIELD AND ENERGY IN A MAJOR ERUPTIVE ACTIVE REGION BASED ON SDO/HMI OBSERVATION

Sun, Xudong (1,2); Hoeksema, Todd (1); Liu, Yang (1); Wiegmann, Thomas (3); Hayashi, Keiji (1);
Chen, Qingrong (2); Thalmann, Julia (3)

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We report the evolution of magnetic field and its energy in NOAA AR 11158 based on a vector magnetogram series from the Helioseismic and Magnetic Imager (HMI). Fast flux emergence and strong shearing motion created a quadrupolar sunspot complex that produced several major eruptions, including the first X-class flare of solar cycle 24. Extrapolated non-linear force-free coronal field shows substantial electric current and free energy increase during early flux emergence along a newly-formed, low-lying filament with a typical 1000 G field strength and 0.45 Mm^{-1} alpha-parameter at its center. The computed magnetic free energy reaches a maximum of $2.62\text{E}32$ erg, about 50% stored below 6 Mm. This free energy decreases by $0.33\text{E}32$ erg within 1 hour of the X-class flare, which is likely an underestimation of the actual energy loss. During the flare, photospheric field changed rapidly: the horizontal field was enhanced by 28% in the AR core region. Such change is consistent with the conjectured coronal field “implosion”, and is in line with both the reconnection signatures and the coronal loop retraction observed by the Atmospheric Image Assembly (AIA). Extrapolation indicates that the coronal field relaxes more rapidly with height after the flare and becomes overall less energetic. These preliminary results demonstrate the capability to quantitatively study the AR field topology and energetics using SDO data— although difficulties still abound.

DYNAMICS OF AN ERUPTING ARCHED MAGNETIC FLUX ROPE IN A LABORATORY PLASMA
EXPERIMENT

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A laboratory plasma experiment has been built at UCLA to study the eruption of arched magnetic flux ropes (AMFRs) in presence of a large magnetized plasma. Arched magnetic flux ropes (AMFRs) are arched-shaped, current-carrying, magnetized plasma structures that ubiquitously exist in the solar atmosphere. Coronal loops and prominences are the main examples of solar AMFRs that frequently erupt and evolve into more energetic events such as jets, flares, and CMEs. Simulation of solar AMFR eruptions in the laboratory plasma experiment involves two essential steps: (i) production of an AMFR ($n \approx 10^{19} \text{ m}^{-3}$, $T_e \approx 10 \text{ eV}$, $B \approx 1 \text{ kG}$, $L \approx 0.5 \text{ m}$) with a persistent appearance (lasting more than hundred Alfvén-transit-times) using a LaB6 plasma source, and (ii) generation of controlled plasma flows from the foot-points of the AMFR using two laser beams (1064 nm, 1 J/pulse) that ablate carbon target placed behind the AMFR foot-points. An additional LaB6 plasma source generates a large magnetized plasma in the background. The laser generated flows can mimic a variety of plasma flow conditions that exist on the sun and they can trigger the AMFR eruption by injecting dense plasma and magnetic flux in the AMFR. Since the experiment is highly reproducible and runs continuously with a 0.5 Hz repetition rate, several thousands of identical loop eruptions are routinely generated and their spatiotemporal evolution is recorded using computer-controlled movable probes. The AMFR images recorded using a high-speed CCD camera and measurement of plasma parameters using three-axis magnetic loop and Langmuir probes demonstrate striking similarities between erupting laboratory AMFRs and solar flare loops. Reference: S. K. P. Tripathi and W. Gekelman, Phys. Rev. Lett. 105, 075005 (2010)*Work supported by US DOE and NSF and performed at the Basic Plasma Science Facility, UCLA

EVOLUTION OF THE SOLAR MAGNETIC ACTIVITY DURING THE HOLOCENE

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The variability of the magnetic features observed in the outer layers of the solar atmosphere is determined by the energetic coupling between the circulation in the convection zone and the solar magnetic field. The 11-year cycle variability is remarkable and was identified few cycles after systematic telescopic observations of sunspots became available. These quasi-periodic oscillations are registered in several parameters such as the total solar irradiance, which is the main external source of energy of the highly coupled Earth's atmospheric/oceanic system. The long-term evolution of the solar activity is also clearly observed in direct and indirect proxies of the solar activity. Periods of low (grand minima) and high (grand maxima) solar activity occurred during the Holocene. However, the precise mechanism that drives the long-term evolution of the solar activity is unknown. Here we show that large storms at the bottom of the convection zone can drive the long-term evolution of the solar activity. We found that the exchange of energy between the zonal flow and perturbations of the velocity fields imposed by large cyclonic/anti-cyclonic activity at the bottom of the convection zone is mapped to the outer layers of the solar atmosphere. The relationships found allowed us to model the long-term evolution of the solar activity through the Holocene. We point out that this mechanism requires much less energy than the one based on changes of the meridional circulation. This approach will help us to constrain the long-term evolution of key solar cycle parameters that are employed to model the long-term evolution of the total and spectral solar irradiance, which are needed to untangle the natural and anthropogenic drivers of the present climate change.

SHORT-TERM FORECAST OF THE SOLAR IRRADIANCE BASED ON SDO/HMI SOLAR DISK
MAGNETOGRAMS AND INTENSITY IMAGES

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The conditions of the upper atmosphere can change rapidly in response to the solar and geomagnetic activity. In particular, the evolution of the thermosphere in response to space weather conditions is necessary to evaluate precisely the air drag, which is a key parameter for survey and precise tracking of space objects in Low Earth Orbit. Among several heliophysical and geophysical quantities, the accurate evolution of the solar irradiance is fundamental to forecast the evolution of the thermosphere. We have recently developed an artificial neural network model to reconstruct in near real-time the evolution of the solar irradiance based on SDO/HMI solar disk magnetograms and intensity images. The model is based on the assumption that that great part of the solar irradiance variability is due to the evolution of the structure of the solar magnetic field. Here we describe the extension of the model needed to provide a short-term forecast of the solar irradiance. We employ a surface flux transport model to infer the evolution of the magnetic bipolar structures, which is then employed to compute the solar irradiance. An online prototype of the near real-time spectral reconstruction is available at <http://lpc2e.cnrs-orleans.fr/soteria/>. This study received funding from the European Community Seventh Framework Programme (FP7/2007-2013, FP7-SPACE-2010-1) under the grant agreement nrs. 218816 (SOTERIA project, www.soteria-space.eu) and 261948 (ATMOP,www.atmop.eu). We also gratefully thank the instrument teams for making their data available.

CORONAL SEISMOLOGY IN THE SDO ERA: AIA OBSERVATIONS OF VARIOUS CORONAL WAVES ASSOCIATED WITH CMEs/FLARES

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MHD waves, as critical diagnostic tools of coronal seismology, can be used to decipher otherwise elusive physical parameters of the solar corona, such as the magnetic field strength and plasma density. They are analogous to acoustic waves used in helioseismology. Recent high cadence, high resolution, full-disk imaging observations from SDO/AIA have opened a new chapter in understanding these waves. Various types of waves associated with flares and/or CMEs have been discovered. In this presentation, we will review such new AIA observations, focusing on the following topics: (1) fine structures in CME-related global EUV waves (so-called EIT waves), including a diffuse pulse superimposed with multiple sharp fronts or “ripples” (Liu et al. 2010, ApJL); (2) quasi-periodic fast waves traveling in coronal funnels at speeds up to 2000 km/s and associated with flares pulsating at similar frequencies (Liu et al. 2011, ApJL); (3) interaction of global EUV waves with local coronal structures on their paths, such as flux-rope coronal cavities (triggered kink oscillations, Liu et al. in preparation) and coronal holes/active regions (deflection). We will discuss the implications of these observations on coronal seismology and on understanding their associated flares and CMEs. We also anticipate to exchange ideas with helioseismologists at this workshop, in a hope to bring together coronal seismology and helioseismology techniques to advance our understanding of solar oscillations from the interior to the upper atmosphere.

UNDERSTANDING LINKS BETWEEN THE INTERIOR AND ATMOSPHERE

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Space Sciences Lab, UC-Berkeley

Magnetic coupling between the solar interior and atmosphere is responsible for many phenomena that interest solar physicists, including atmospheric heating, solar flares, and coronal mass ejections (CMEs). While all these processes release magnetic energy stored in the atmosphere, that energy originated within the solar interior, and the magnetic fields involved are also tethered to the interior. The precise mechanisms by which magnetic energy passes from the interior into the atmosphere to drive such phenomena, however, remain poorly understood. For instance, statistical relationships have been reported between solar flares and the structure and evolution of subsurface flows, inferred from ring diagram analysis; but we can only speculate about the physics underlying such relationships. In addition, we cannot yet say if or how processes in the atmosphere feed back into the interior. For instance, does most active region magnetic flux submerge back into the interior? Or does it escape outward into the atmosphere? I will discuss some open questions regarding magnetic coupling between the interior and atmosphere, and consider ways that the HMI and AIA instruments aboard SDO might be used to address such questions — with input from the audience welcomed!

NUMERICAL SIMULATIONS OF THE VON KARMAN SODIUM EXPERIMENT

Katelyn White, Prof. Nic Brummell, and Prof. Gary Glatzmaier

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A leading topic of physics research is how magnetic fields are generated and maintained in the many astrophysical bodies where they are ubiquitously observed. Of particular interest, are the regenerating magnetic fields of planets and stars, and especially, of course, those of the Earth and the Sun. Dynamo theory suggests that the motion of electrically-conducting fluids could, under certain circumstances, maintain a magnetic field against Ohmic dissipation. Thermal and compositional buoyancy of the Earth's outer core drives the liquid iron-nickel flows, and the outer third of the Sun is a convective plasma, and such flows could potentially sustain dynamo action. While the equations which govern these systems are relatively well known, the observed behaviors can be very diverse and are not well understood due to the extreme parameter ranges in which the equations operate. For the Earth, the magnetic field reverses polarity chaotically with a rough timescale of about 200,000 years, whereas in the Sun they still reverse but with a much more regular period of about 11 years. Currently, there are no theoretical, computational or statistical models that can predict with any accuracy when future reversals will occur. A better knowledge of dynamos is essential to understanding the variability of cosmic objects like the Earth and the Sun, with obvious consequences for human society. For poster session

TRANSPORT OF ANGULAR MOMENTUM AND MAGNETIC FLUX ACROSS THE SOLAR TACHOCLINE

Toby Wood, Nic Brummell, Pascale Garaud

UCSC

The Sun's interior rotation and magnetic activity cycle are both critically dependent on the dynamics of the tachocline, the thin shear layer at the bottom of the Sun's convection zone. We will present recent and ongoing numerical simulations on the transport of angular momentum and magnetic flux by overshooting convection and meridional circulations, which are pumped by the differential rotation of the convection zone. In particular, we argue that a combination of magnetic pumping by turbulent compressible convection and advection by meridional flows is able to confine a global-scale magnetic field to the solar radiation zone, explaining the uniform rotation of that region, as suggested by Gough & McIntyre (1998).

EFFECTS OF TURBULENCE MODELS ON SELF-ORGANIZATION PROCESSES IN SOLAR CONVECTION

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Realistic MHD numerical simulations of subsurface flows and magnetic structures have become achievable because of the development of fast supercomputer systems and efficient parallel computer codes. The dynamics of the subsurface layer is particularly critical for understanding the self-organization processes of magnetoconvection on different scales. Realistic simulations of solar convection in the presence of magnetic fields reveal very interesting dynamics and reproduce several phenomena observed in solar active regions. “SolarBox”, a 3-D real-gas radiative MHD code developed at NASA Ames, was used for our simulations. Because both the Reynolds and magnetic Reynolds numbers are extremely high, research into subgrid modeling of MHD in the solar context is essential, and an important feature of this code is the implementation of various subgrid-scale LES turbulence models. We present a comparison of two such models: a Smagorinskii-type subgrid resistivity model and the Turbulent Effective Lorentz Force model (TELF) and discuss the role of LES models for studying the process of magnetic flux tube formation and the turbulent properties of magnetoconvection.

CYCLIC VARIATIONS OF TOTAL SOLAR ACOUSTIC POWER

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Solar total irradiance tends to increase with solar activity, since faculae's positive effect on irradiance is larger than the sunspots' negative effect on it. Total acoustic power of the Sun is another quantity that can be measured and may vary with solar activity. While acoustic absorption in sunspot areas decreases the total acoustic power, acoustic halos around the sunspots increases the power in higher frequencies. We analyze MDI 15-year observations and current HMI observations to see how the total acoustic power, as well as the acoustic power at different frequency bands, varies with the solar activity. We plot the total acoustic power against daily sunspot numbers and discuss how acoustic power behaves differently at different frequencies.

PROPERTIES OF UMBRAL DOTS AS MEASURED FROM THE NEW SOLAR TELESCOPE DATA AND MHD SIMULATIONS

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Big Bear Solar Observatory

We studied bright umbral dots (UDs) detected in the main sunspot of AR NOAA 11108 and compare their statistical properties to a state-of-the-art MHD model of a sunspot. The study is based on high resolution data recorded on September 20, 2010 by the New Solar Telescope (NST) at Big Bear Solar Observatory and 3D MHD simulations of sunspots. The 46 min data set included photospheric (0.3nm TiO filter centered at 705.7 nm) and chromospheric (0.025nm H-alpha Lyot filter) adaptive optics corrected and speckle reconstructed images. Bright UD, living longer than 150 s, were detected and tracked using an automatic UD detection code. Total 1553 (620) UD were detected in the photospheric (chromospheric) data. Our main findings are: i) none of the analyzed UD is of an exact circular shape, ii) the diameter-intensity relationship only works for bright umbral areas, and iii) UD velocities inversely related to their life time. Comparison of photospheric and chromospheric data showed that nearly all photospheric UD can be identified in the chromospheric images. However, it appears that some small closely spaced UD appear in the chromospheric images as a single cluster, which may lead to the underestimation of the total number of detected chromospheric UD. Also, while slow moving and long living UD seem to exist in both chromosphere and photosphere, fast moving and short living ones are detected mainly in the photospheric images. Comparison of model and observed data shows that both types of UD display very similar statistical characteristics. The main difference between parameters of model and observed UD is that i) the average number of observed UD per unit area is smaller than that of the model UD, and ii) on average, the diameter of model UD is slightly larger than that of observed ones.

NEW RESULTS OF TIME-DISTANCE HELIOSEISMOLOGY FROM SDO/HMI OBSERVATIONS

Junwei Zhao

HEPL, Stanford University

The Helioseismic and Magnetic Imager onboard Solar Dynamics Observatory (SDO/HMI) gives continuous Doppler observations of the solar photosphere with high spatial resolution and temporal cadence. The time-distance data analysis pipeline, developed and implemented at the SDO Joint Science Operations Center (JSOC), provides nearly-full-disk subsurface flow fields and wave-speed perturbation maps every eight hours in nearly real time. I present an overview of the new results obtained from the pipeline analysis, including flow dynamics beneath active regions, large-scale convective flows, and global-scale dynamics. Moreover, a deeper interior analysis code is also developed to derive solar rotational rate and meridional flows in areas up to 200 Mm in depth. I present the profiles of inverted rotational and meridional flow velocities, and give limits on detecting equator-ward meridional flows in the deep interior.

RECENT SUNQUAKES: NEW IMPLICATIONS FOR ENERGY TRANSPORT IN SOLAR FLARES

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It is well established that solar flares are initiated by magnetic reconnection in the solar atmosphere/chromosphere and extend to solar corona with unconnected magnetic helical field and the material that it contains sometimes violently expanding outwards forming a coronal mass ejection. However, the flare energy transport to the underlying photosphere is less understood. Sunquakes are tsunami-like acoustic waves induced in the solar interior by solar flares. The theoretical prediction that flares can excite acoustic waves in the underlying photosphere was made in Wolff 1972, with first observations of the phenomena reported in Kosovichev & Zharkova, 1998. Yet only a limited number of M and X-class flares are known to have produced seismic signatures in the form of ripples or egression sources, with many of the most powerful flares being acoustically quiet. Furthermore, some of the most powerful signatures were recorded from an M-class flares. This raises important questions about how the flare energy and momentum are transported to the solar surface and interior in order to produce sun-quakes. Observations of ripples associated with the first few sun-quakes suggested that hydrodynamic shocks arising from a hydrodynamic response of the ambient plasma to precipitation of energetic particles (electrons or protons) are plausible sources of the seismic emission. Later, noting that sun-quakes are often co-spatial with hard X-ray and white light, another source of seismic emission was proposed related to back-warming of the photosphere by the enhanced chromospheric and coronal radiation caused by physical processes in flares. A third mechanism proposed to account for sun-quakes is related to possible Lorentz force transients that occur as a result of the coronal restructuring of the magnetic field in flares. Recent work comparing samples of white-light flares with and without sun-quakes, and new observations with GONG, Hinode and SDO of seismic emission associated with the X-class flares of 14 December 2006 and 15 February 2011 demonstrate inconsistencies with some existing models. In this work these inconsistencies are explored and possible alternative scenarios are discussed.

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