Session 4
Morphology of Active Regions and Filaments

4.1 (Invited)

Life and Death of Active Regions

Aad van Ballegooijen[1]

[1] *Harvard-Smithsonian Center for Astrophysics, MS-15,60 Garden Street, Cambridge, MA 02138, USA*

Active regions are thought to consist of weakly twisted, Omega-shaped magnetic loops emerging from a toroidal field located near the base of the Sun's convection zone (CZ). After an Omega loop has fully emerged into the solar atmosphere, the magnetic field continues to evolve under the influence of the solar differential rotation and turbulent flows in the CZ. This causes "diffusion" of the observed surface flux and cancellation of flux at polarity inversion lines (PIL). I discuss the physical processes involved in flux cancellation, and present a 3D model for the coupled evolution of the magnetic field in the corona and CZ. According to this model, magnetic fields submerge below the photosphere at the PIL. However, the axial magnetic field (the component along the PIL) is prevented from submerging as a result of natural physical conditions at the photospheric boundary. Therefore, magnetic shear builds up in the corona above the PIL, producing weakly twisted coronal "flux ropes" with significant magnetic free energy. These flux ropes eventually become unstable, leading to flares and coronal mass ejections. Submerging fields are transported back to the base of the CZ, repairing the toroidal flux ropes. Interactions between neighboring Omega loops can cause changes in the toroidal flux system that may be important for understanding the solar dynamo.

4.2 (Invited)

Observation and Modeling of Solar Active Region Magnetic Helicity: Implications for Subsurface Dynamics and Eruptive Activity

Dibyendu Nandy[1]

[1]*Montana State University, Department of Physics, Montana State University, Bozeman, MT 59717, USA*

Solar active region magnetic fields are generated by a dynamo mechanism in the interior of the Sun, from where they buoyantly rise to erupt through the photosphere as sunspots. During this buoyant rise through the convection zone, the magnetic flux tubes interact with a variety of sub-photospheric physical processes that result in the flux tubes acquiring specific properties such as twist and tilt. In this talk, I will review observations and modeling of these active region properties and discuss their implications for magnetic helicity and flux tube dynamics in the solar convection zone. I will also present a new technique for photospheric active region twist measurement that does not rely on the force-free field equation, and outline a methodology for quantifying the susceptibility of active region flux tubes to the magnetohydrodynamic kink instability mechanism, that may result in large-scale solar eruptions such as CMEs.

4.3

On a Significant Origin of Coronal Helicity

Lirong Tian[1]

[1]*Rice University, 6100 Main Street, Houston, TX 77005, USA*

We select 23 active regions with pronounced sigmoidal structure in *Yohkoh* soft X-ray images to study which one is more important origin of coronal helicity between the emergence of twisted magnetic fields and photospheric horizontal motions. Considering such active regions (ARs) were developing in a mature manner, which should have no strong emergence of magnetic flux, we may study if the horizontal motions play an important role in coronal helicity injection. We calculate positive and negative redial magnetic flux, and estimate total flux of magnetic helicity (ΔH_{lct}) over about five days using *MDI/96m* magnetograms and local correlation tracking technique. It is found that only six (6/14) ARs significantly injected the helicity flux over $1.0 \times 10^{43}\mathrm{Mx}^2$ in fourteen ARs which emerged the magnetic flux smaller than $1.0 \times 10^{22}\mathrm{Mx}$, which displays a little role of the horizontal motions played in coronal helicity injection. While in other nine ARs which emerged magnetic flux larger than $1.0 \times 10^{22}\mathrm{Mx}$, seven (7/9) injected more helicity flux over $1.0 \times 10^{43}\mathrm{Mx}^2$, which signifies a more important role of the significant emergence of the magnetic flux in the coronal helicity. Comparing with the force-free parameter, α_{best} calculated by HSOS vector magnetograms, it is found that 20/23 (87%) ARs have same signs of α_{best} and ΔH_{lct}, and both display a very high linear correlation. 15/20 (75%) ARs have consistent handedness of the helicity and the sigmoidal shape in SXR images, i.e. positive (negative) helicity vs S (Z)-shaped sigmoid. We also estimate contribution of differential rotation to the helicity injection, based on equations of DeVore (2000), which is less important. Furthermore, we have studied the helicity injection of 18 active regions which began to emerge from the eastern disk, and also find an important role of the significant emergence of the magnetic flux. All the results suggest that strong emergence of twisted magnetic fields is most important origin in coronal helicity injection.

References

DeVore, C. R. 2000, ApJ, 539, 944

4.4

Flare Energy Supply and Magnetic Field Variations

Hugh Hudson[1] **and B. T. Welsch**

[1]*SSL/UC Berkeley, 7 Gauss Way, Berkeley CA 94720-7450, USA*

A flare (or CME) results from a restructuring of the coronal magnetic field, and this process has recently been found to produce stepwise changes in the photospheric line-of-sight magnetic field. These changes must be consistent with the requirement that the total coronal magnetic energy diminishes, and we infer that both pre-flare and post-flare field configurations must also meet the force-free condition. It has additionally been proposed by Melrose that the vertical current density not change on the observed flare energy-release time scales of a few minutes. We examine these constraints by various means, including a study of theoretical concepts and vector magnetograms, anticipating that Hinode, SDO, and ATST will make detailed maps of the stepwise changes routinely available in the future.

4.5

Vector Magnetograms and Reconstruction for Determining the Coronal Morphology above Active Regions

Tahar Amari[1]

[1]*Centre de Physique Théorique, Ecole Polytechnique, CNRS, 91128 Palaiseau Cedex, France*

The structure of the low corona depends strongly on its magnetic field because of low plasma beta. Determinations of global quantities such as magnetic energy and helicity, and magnetic topology, as well as local ones such as the electric current distribution, are important to serve as input or constraints to understand, for example, under what conditions a configuration is going to erupt. However the magnetic field is not yet accessible as a 3D vector field in the corona and one must rely on the photospheric measurement of the vector magnetic field by vector magnetographs such as SOLIS, ASP, IVM, THEMIS, and HINODE, as well as models to compute the force free field configuration corresponding to those data. I will describe progress and results on the methods we have developed to determine the vector photospheric magnetic field from vector magnetic data at the active region scale as well as at the full Sun scale since connections between distant active regions exist. The associated use of those models with existing vector magnetograms will be useful to characterize the nature of the pre-CME active region configuration. Some ongoing collaboration using SOLIS current synoptic maps and future use of vector data will be described.

4.6

GONG Magnetic Field Movies – The Director's Cut

Frank Hill,[1] J. Bolding, R. Clark, K. Donaldson-Hanna, J. Harvey, G. Petrie, C. Toner, and T. Wentzel

[1] *National Solar Observatory, 950 N. Cherry Avenue, Tucson, AZ 85719, USA*

In 2006, the Global Oscillation Network Group (GONG) program installed improved polarization modulators at all six sites, thereby lowering the spatially varying background zero-point of the magnetic field images by a factor of 30 to 0.1 G. The resulting data set is unprecedented in terms of cadence and temporal coverage – full-disk 800 × 800 pixel longitudinal magnetograms are obtained every minute continuously around the clock with an average duty cycle of 87%. Ten-minute averaged magnetograms from each site are now being routinely returned, and are available minutes after acquisition on the GONG web site. This data set is freely available for any research use, and should be useful for studies of short time period variations in the structure of active regions. Movies centered on and tracking active regions will be presented

4.7

Filament Substructures and their Interrelation

Yong Lin,[1] **Sara F. Martin, and Oddbjorn Engvold**

[1]*Institute of Theoretical Astrophysics, University of Oslo, Norway, Institute of Theoretical Astrophysics, Postboks 1029 Blindern, 0315 Oslo, Norway*

The main structural components of solar filaments, their spines, barbs and legs at the extreme ends of the spine, will be illustrated from recent high resolution observations. We will show the appearance of these structures in various types of filaments from those in active regions to those in quiescent filaments as well as intermediate examples. The interrelation of the spines, barbs and legs will be discussed. We suggest that only a single physical model is needed to explain this entire spectrum of filaments.

4.8

Topological Analyses of Eruptive Filaments

Olya Panasenco[1] **and Sara F. Martin**

[1]*Helio Research, 5212 Maryland Ave., La Crescenta, CA 91214, USA*

Erupting filaments (prominences) that we have analyzed from Hα Doppler data at Helio Research and from SOHO/EIT 304 Å show several different motions along the main axis and legs. Our simple geometrical analyses of these motions reveal strong coherency in some filaments between their chirality, and the direction of the vertical motions of the top of the filaments, and the directions of twisting of their legs. Viewed from the positive network side, dextral filaments develop rolling motion toward the observer along with right-hand helicity in the left leg (clockwise streaming for downward motion) and left-hand helicity in the right leg. Sinistral filaments, also viewed from the positive network field side, have the opposite pattern: rolling motion at the top away from the observer, left-hand helical twist in the left leg (counterclockwise for downward motion) and right-hand twist in the right leg. We find consistency between our analyses of these motions and forms determined from our Hα Doppler observations and twists or bending deduced from the properties of erupting filaments observed in EIT images at 304Å. We cannot reconcile these findings with filaments modeled as magnetic flux ropes that by definition only have one sign of helicity. In addition, the popular hypothetical configuration of an eruptive filament as a twisted flux rope does not account for the complete range of observed shapes in the erupting filaments. However, we find that a simple flat ribbon or sheet satisfactorily reproduces nearly all of the observed forms. The flat ribbon is the most logical beginning topology because filament spines already have this topology prior to eruption and an initial long flat sheet with parallel, non twisted threads, as a basic form, can be bent into many more and different geometrical forms than a flux rope. To date, we have been able to identify three common patterns of motion. All are consistent with the ribbon topology and characterize the helicity of many erupting filaments: (1) Roll of the top of the filament with horizontal and vertical components, (2) Twist of the legs consistent in sign with the rolling motion along the top of the filament, and (3) Rotation (writhe) of the whole filament as it moves and expands outward. Considering that erupting filament dynamics have large-scale coherency and always occur beneath CMEs, we suggest that it is reasonable for the top of an erupting filament to be first in responding to relatively unknown, changing, coronal forces in its environment.

For morphological analyses of eruptive filaments we used the ratio h/l, where h is the height of filament, l is distance between its legs, and also α, the angle in degrees of twist or roll during increments of time, t. We consider three general cases: 1) $h/l \sim 0$; 2) $h/l > 1$, legs close together; 3) $h/l \leq 1$, legs far apart. We also describe the relationship between the direction of twists in the legs and the roll direction at the top of the filament using the geometrical terms: l, h, and α. Starting with our finding that filaments are thin sheets after their eruption, as known before their eruption, we apply our geometrical analyses to determine the sign of magnetic helicity and estimate the degree of twisting or bending in different parts of the top and legs of erupting filaments.

4.9

Limits to the Radiative Asymmetry of the Quiet Solar Disk

William Livingston[1] **and N. R. Sheeley Jr. (NRL)**

[1]*National Solar Observatory, 950 N. Cherry Avenue, Tucson, AZ 85719, USA*

Precise data on the uniformity of photospheric radiation over the solar disk seems not to exist. Such may be needed for the future detection of planets crossing solar-like stellar disks, for example. To obtain this information we have made monochromatic scans along the central meridian of the quiet Sun using single element detectors which do not require ‘flat fielding’. The scans were in continua and selected Fraunhofer lines ranging from 3129 to 46880 Å; the observational epoch was near solar minimum: Oct 2006 to Feb 2007. The meridian was chosen to avoid rotational doppler shifts. We extract the asymmetry between the N and S hemispheres and this is our main product. In the near IR and visible continuum, averaging over granulation and discounting sunspots, such asymmetry is as low as 0.01%; 0.005% at 34168 Å on 8 Feb 2007. In the violet and UV this increases to 1%. In the cores of medium strength photospheric lines and in chromospheric lines the asymmetry is up to 15%. Faculae are the probable source of our measured quiet disk asymmetries, and the continuum at 34168 Å is favorable for this reason. Line core scans are in general flatter than continuum scans because they sample thinner, higher layers of the atmosphere, where the temperature gradient is less. Obviously it would be desirable to expand on the temporal coverage.

4.10

Application of Data Assimilation Methods to Non-Linear Solar Dynamo Models

Irina Kitiashvili[1]

[1] *Kazan State University, Dept. of Astronomy, Kazan University, Kremlevskaya Str., 18, Kazan, Russia, 420008*

Prediction of parameters of the 11-year solar cycles is one the most interesting problems of solar physics, in which helioseismology observations play an important role. However, the knowledge of the underlying processes is incomplete, and this makes predictions of the solar cycles difficult. The data assimilation approach developed in meteorology and Earth sciences makes possible efficient and accurate estimations of physical properties, which cannot be observed directly. In a first approximation, the solar dynamo models can be described in terms of simple, Lorenz-type, dynamical systems. The application of data assimilation to this type of models and the initial results are discussed in this presentation.

4.11

Measuring the Photospheric Activity: Spectral Diagnostics

Jose Carlos del Toro Iniesta,[1] **D. Orozco Suárez, D. Cabrera Solana, and L. R. Bellot Rubio**

[1]*Instituto de Astrofísica de Andalucia (CSIC), Apdo. de Correos 3004, E-18080 Granada, Spain*

Our knowledge of the photospheric activity depends to a high degree on our ability to extract the physical information encoded in the Stokes profiles of spectral lines. Simplified models as well as analytical solutions of the radiative transfer equation help us to decipher the diagnostic capabilities of the various spectral lines and can be used to decide the target spectral lines of new instrumentation.