

Session 2
Flux Emergence and Cancellation

2.1 (Invited)

Local Helioseismology and Magnetic Flux Emergence

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Investigations of emerging magnetic flux are important for understanding the basic properties of solar magnetism (such as the depth of the solar dynamo processes and ” “nests” of solar activity, formation of sunspots and active regions, organization of solar activity on various spatial and temporal scales), and also for forecasting solar activity and space weather. Local helioseismology is capable of detecting emerging magnetic flux in the solar interior, and determining variations of the sound speed and large-scale flows caused by the emerging flux. The initial results obtained by time-distance helioseismology reveal unexpected properties of the flux emergence and challenge the current theories and models. They also show that it is necessary to develop special local helioseismology methodology for studying fast dynamical processes associated with magnetic flux emergence.

2.2 (Invited)

HINODE Observations of Flux Emergence in Quiet and Active Regions

Bruce W. Lites,¹ R. A. Shine, A. Title, K. Ichimoto, T. Tarbell, S. Tsuneta, Y. Katsukawa, T. Shimizu, M. Kubo, T. Berger, T. Kosugi, and Z. Frank

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The HINODE mission provides us with the first high precision spectro-polarimetric measurements of the solar photosphere. We review a few results of the quantitative observations of both quiet and active regions observed at 0.3 arcsecond resolution. In quiet regions there is common occurrence of horizontal magnetic fields suggesting the presence of emerging, small-scale magnetic flux. Similarly, the evolution of the vector field in and around sunspots will be illuminated by time series of magnetograms and polarimetric spectra.

Subsurface Flows Near (Emerging) Active Regions Studied with Ring-Diagram Analysis

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We measure subsurface flows from high-resolution GONG data using ring-diagram analysis and study the temporal variation of subsurface flows associated with active regions. Here, we focus on four active regions where new flux emerges near disk center. We will present some recent results.

Shear Flows Driven by the Lorentz Force During Flux Emergence: The Energy Source for Coronal Mass Ejections and Flares

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This talk will focus on shear flows in active regions that are readily explained by the Lorentz force that naturally arises when bipolar magnetic fields emerge from the photosphere into the corona. This physical mechanism explains why shear flows are concentrated at the polarity inversion line (PIL) and why the magnetic field evolves to be nearly parallel to the PIL as found at the photosphere and in filaments. The shearing motions transport axial flux, helicity and energy from the submerged portion of the field to the expanding coronal portion, strongly coupling the convection zone to the corona. Numerical simulations of flux emergence reproduce observed shear flows and self-consistently produce eruptions in magnetic arcades and flux ropes that explain flares and the initiation of coronal mass ejections.

Emergence and Surface Flows of Large Scale Solar Magnetic Field

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Observations of the large scale magnetic field in the photosphere taken at Wilcox Solar Observatory since 1976 up to 2006 have been analyzed to deduce its latitudinal and longitudinal structures, its differential rotation, and their variability in time. A new approach has been suggested to reveal the influence of the weak and strong magnetic fields on the organizing of global topology of the field and dynamic of solar variability over the last three cycles, 21, 22, and 23.

The latitudinal topology of the photospheric magnetic field is composed of a four zonal 20-22-year periodical structure and polarity waves running from the equator to the poles with periods of about 2-3 years.

The boundaries of the four zones are located at the equator and at ± 25 degrees (where the solar activity has the highest amplitude). The polarities of the pre-equatorial zones coincide with the polarities of leading sunspots and have opposite signs in the Northern and Southern hemispheres. It is important to study whether the non-zero level of the magnetic field calculated as a mean around the Sun at different latitudes is a component of a basic background field or the result of the imbalance of the strong magnetic field mainly concentrated in active regions.

The polarity waves have different periods in the Northern and Southern hemispheres, but they are synchronized by the solar activity cycle.

The study of the origin of these waves was performed in view of their relationship with the presence of the differential rotation and torsional waves in the magnetic field of the Sun. The velocity of the meridional flows of the magnetic field was calculated.

The North-South asymmetry of the solar magnetic field and its short and long term variability in time have been studied.

The differential rotational rate of the magnetic field and its temporal dependence has been evidenced at different latitudes through the activity cycles.

The time of emergence was estimated.

An extremely interesting longitudinal structure, quasi-stable over 30 years, has been found. Its relation to the latitudinal topology of the magnetic field was studied.

These results are fundamental for the understanding of the magnetic origin of solar activity and dynamics, and of heliospheric structure, and for the prediction of the solar wind and magnetospheric perturbations.

Automatic Active-Region Identification and Azimuth Disambiguation of NSO/SOLIS Full-Disk Vector Magnetograms

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The Vector Spectromagnetograph (VSM) of NSO's Synoptic Optical Long-Term Investigation of the Sun (SOLIS) telescope will provide the first-ever vector magnetic field measurements of the entire visible solar disk. To fully exploit this unprecedented capability, however, one needs to face two major challenges: first, to perform a reliable identification of active regions present on the disk at a given time and, second, to promptly and efficiently remove the azimuthal ambiguity of 180 degrees in the orientation of the transverse magnetic field component in these regions. Here we report on the first results of an effort aimed to address both problems automatically. To identify solar active regions, we apply an algorithm designed to locate complex, flux-balanced magnetic structures with a dominant E-W orientation on the disk. After identification, each of the disk portions belonging to an active region is subjected to the Nonpotential Magnetic Field Calculation (NPFC) algorithm that provides a physically-based solution of the 180-degree ambiguity. The disambiguated active-region magnetograms can be then embedded back into the SOLIS full-disk magnetogram or they can be used separately for further study. We believe that this approach can contribute meaningfully to our emerging capability for full-disk solar vector magnetography, as is being pioneered by SOLIS today and will be carried out by ground-based and space-borne instruments in the future.

In-Situ Flux Losses in Active Regions

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Magnetic flux losses from Active Regions are seen to occur during their disk passage. Large amounts of flux are lost in timescales of a few days (as much as 70 % of the original flux). The obvious candidates for flux losses are flux dispersion (similar to the known process that takes the flux to the polar caps) and flux cancellation. Both processes are observed to occur and their relative importance in the global flux decay of the Active Region will be studied. It is pointed out that our picture of Active Region flux evolution based only on longitudinal magnetograms will always be incomplete.

Magnetic Field Vector Measurements with THEMIS

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The status of the UNNOFIT inversion of the spectropolarimetric data from THEMIS will be reviewed. A new campaign on active region observations will be presented. Besides, two applications will be presented: 1/ Quiet Sun magnetic field (the internetwork); 2/ Surrounding magnetic field evolution before the disappearance of a filament.