P15

The Relationship between Nonthermal Velocities in Different Temperature Regions of the Solar Lower Transition Region

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We analyze the relationship between nonthermal velocities derived from spectral lines of ions formed at different temperatures in the solar lower transition region. The lines formed at different temperatures are observed simultaneously and at the same locations on the solar disk by the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) spectrometer on board the Solar and Heliospheric Observatory (SOHO). In order to improve the accuracy of the nonthermal velocities determined from the full width at half maximum (FWHM) intensities of the lines, we select data with sufficient counting statistics such that the uncertainty of the nonthermal velocity is less than 10 % of its value derived from the FWHMs. Even without this restriction, we find a high degree of correlation between nonthermal motions arising at temperatures ranging between about 3×10^4 K to about 2.5×10^5 K over $1''$ spatial scales in quiet sun regions. We discuss the implications of these results in terms of the physical nature of the transition region.

P28

Downflow as a Reconnection Outflow

Ayumi Asai

Kwasan and Hida Observatories, Kyoto University

We present a detailed examination about the evolution of TRACE downflow motions (sunward motions) seen above post-flare loops. We found that they are seen not only in the decay phase but also in the impulsive and main phases of flares. Moreover, we found that the times when the downflow motions are seen correspond to those of the bursts of nonthermal emissions in hard X-rays and microwave. These results mean that the downflows occurred when strong magnetic energy was released, and that they are, or are correlated with, the reconnection outflows. We also propose an observation of downflows as the reconnection outflows by Solar-B.

P33

The Relationship between Prominence Eruptions and Global Coronal Waves

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There has been much debate over the physical mechanism for producing global coronal waves ('EIT waves'). These waves are seen as a bright wave front followed by a region of dimming, and have speeds of approximately several hundred km/s. When they were first discovered (Thompson et al. 1999) it was thought that they may well be the coronal MHD waves that Uchida had described in 1968. He proposed that the well observed Moreton waves observed in Hα are the footprints of a fast-mode wave in the corona. However there are not many observations of both coronal waves and Moreton waves simultaneously. Other authors have suggested that coronal waves are not related to Moreton waves, but are coronal mass ejections lifting off the disk (e.g. Delannee and Aulanier 1999).

Harra and Sterling (2003) showed an example of a coronal wave that occurred in association with a filament eruption. Biesecker et al. (2002) showed that there is a very strong relationship between the formation of a coronal wave, and the appearance of a coronal mass ejection. In this work, we investigate whether filament eruptions are directly associated with coronal waves. We analyse 45 coronal waves and search for evidence of filament eruptions. We used SOHO-EIT data, and any available ground-based Hα data to search for filament eruptions, and found that more than 50 % of coronal waves are clearly associated with eruptions. The speeds of the coronal waves, and the filament eruptions are similar. We discuss the implications of these results.

Oral

Observing the Reconnection Outflow Termination Shock during Solar Flares

Henry Aurass
Astrophysikalisches Institut Potsdam

Believing models of magnetic reconnection during solar flares, and knowing cusp structures in YOHKOH SXT, and also SOHO-EIT and TRACE images, stimulate the search for observations of the standing or slowly moving fast mode shock below resp. above the diffusion region. We report on radio flare spectra with non-drifting high-frequency type II burst-reminiscent sources in the late stage of some flares. Further, we recognized already in the impulsive flare phase the same non-drifting resp. slowly drifting spectral patterns, in some cases with alternating flux densities at (roughly) 350 and 60 MHz. This corresponds with an alternating upward- and downward-streaming supermagnetosonic outflow. We compare the analysis of the radio spectra with simultaneously visible cusp features in SOHO-EIT images. The superposition of Nancay Multifrequency Radioheliograph images supports our interpretation of the spectra. Thus, radio spectra together with imaging data in different spectral ranges confirm a further observable ingredient of magnetic reconnection during solar flares.

Oral

Recent Progress in High Resolution Observations

Tom Berger
Lockheed Martin Solar and Astrophysics Lab

I review recent progress in high-resolution observations of the solar photosphere and chromosphere. In this context, all observations are from ground-based instruments achieving $0.3''$ resolution or better. We will focus on four recent efforts:

1. Adaptive optics at the Swedish 1-meter Solar Telescope (SST) on La Palma
2. Speckle imaging at the VTT on Tenerife
3. Adaptive optics at the Dunn Solar Telescope (DST) at Sac Peak
4. High resolution spectropolarimetry with the DST/DLSP

We conclude with a list of science topics derived from the recent observations that are well suited for investigation by Solar-B.

P29

Spectroscopic Detection of Magnetic Reconnection Evidence in the Solar Atmosphere with Solar-B/EIS

David H. Brooks
Kwasan Observatory, Kyoto University

2.5D MHD simulations of CMEs and flares are combined with improved accuracy density sensitive line emission contribution functions from the ADAS database to study profiles of spectral lines which will fall within the wavelength range of the Solar-B Extreme ultraviolet Imaging Spectrometer (EIS). The objective is to study the signatures of magnetic reconnection associated flow phenomena in the line profiles. 90 spectral lines of different transition types from ions of several elements are considered. We assess which of the lines are best suited for detecting/analysing the considered plasma motions and determine the optimal lines of sight for mass flow detection. We also conduct a survey of the influence of simulation parameters such as electron temperature and density and the effects of heat conduction. Illustrative results are presented for the reconnection jet, reconnection inflows, the coronal counterpart of the Moreton wave and the slow shock attached to the reconnection jet (or outflow).

P1

The Decay of a Simulated Pore

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Using MURAM – (the Max-Planck Institute for Aeronomy, University of Chicago, RAdiative Magnetohydrodynamics code), an MHD code which includes both radiative transfer and partial ionization, we have studied the decay phase of a pore.

The simulations are sufficiently realistic in their treatment of the photosphere to allow a direct comparison with current observations and are of sufficiently high spatial and temporal resolutions to allow comparisons with upcoming observing missions.

We shall specifically discuss the nature and consequences of shallow field aligned convective rolls which are an important feature of our solutions.

Oral

Chromospheric Heating and Dynamics

Mats Carlsson
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The existence of a wide variety of wave-like phenomena are inferred from observations of the solar upper atmosphere. Acoustic waves play an important role for the dynamics and energetics of the chromosphere but additional heating seems necessary even for the internetwork regions.

Table of contents:

(1) Observational evidence
(2) Generation of waves
(3) Acoustic waves and shocks in the solar chromosphere
(4) Mode conversion, refraction and reflection

P5

Asymmetric Stokes-V Profiles at the Penumbral Boundary of a Sunspot

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We present the spectropolarimetric measurements of a sunspot in the active region NOAA 6958 (15S03W), situated near the central meridian disk passage. The follower polarity sunspot was somewhat symmetrically round shaped with an elongated penumbra. There were several opposite polarity magnetic elements at, and beyond, the penumbral boundary. The Hα images of the sunspot show the bright emission regions near the penumbral boundary towards the sun-center, which was of opposite polarity with respect to the main spot. The net-circular polarization (NCP) map shows that NCP is negative in the inner part of the spot and positive at the penumbral boundary and near the Hα plage. The Doppler velocities were determined by measuring the center-of-gravity (COG) of the Stokes-I profile and zero-crossing (ZC) wavelength of the Stokes-V profiles. The COG velocity map in general agrees with the Evershed flow. In addition, it shows the up flow in the penumbral region. The ZC velocities show the strong down flow at the penumbral boundary. Double-lobed Stokes-V profiles are observed at the locations where the penumbral fibrils terminate, coinciding the Hα plage. The Double lobed profiles had an unshifted component similar to the Stokes-V profiles of the sunspot penumbra and a shifted component with a velocity of about 5 km/s. The amplitude of the second component increases along the penumbral fibril as a function of the distance from the center of the sunspot. In this paper we discuss the role of emerging flux in generating the observed double lobed profiles. Based on our present observations, we propose to observe with the Solar-B Spectropolarimeter for understanding the nature of emerging flux near the sunspots.

Oral

X-ray and EUV Observations of Large-Scale Coronal Structures

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Large-scale coronal streamers, first recognized in solar eclipse images and in white-light coronagraph data, are now more frequently observed with space-borne coronagraphs e.g. LASCO on SOHO, to a distance of ~30 $R_\odot$. Observations of emission from the corona by Yohkoh SXT and SOHO EIT at soft X-ray and EUV wavelengths have revealed the nature of diffuse coronal structures to heights of ~ 1.5 – 2.0 $R_\odot$ above the limb. The SOHO spectrometers, CDS and SUMER, have been used for emission line intensity studies of these structures with increasing $R_\odot$. The SOHO UVCS has undertaken UV spectroscopy and visible polarimetry studies of the corona to a height of ~ 12 $R_\odot$. Items of interest in the study of these large structures include i) shape and evolution, ii) values of temperature, density and element abundance, iii) solar cycle variation, iv) origin of the slow solar wind, and v) energy supply and the role of the magnetic field. Yohkoh SXT observations of large coronal structures, made in the period before December 1992, will be discussed. Subsequent observations by the SOHO instruments relevant to these systems will be reviewed along with further Yohkoh results from joint Yohkoh/SOHO campaigns. In relation to energy supply, recent work on the relationship between coronal X-ray radiance and emerging magnetic flux, using data from Yohkoh/SXT and SOHO/EIT along with magnetic field observations with SOHO/MDI and ground-based observatories (Pevtsov et al. 2003, in press), will be presented. Finally the properties of large transequatorial loop systems will be reviewed. Although simpler than streamers, these structures have their origin in similarly widely separated activity centres. While their behaviour is often more dynamic in terms of the related occurrence of flare-like activity and CMEs, sharply cusped streamers are also often associated with CME launches and have associated underlying prominence material. Thus the existence of transequatorial loops may also be related to the global magnetic field of the sun.

Oral

Dynamo Models

Mausumi Dikpati
High Altitude Observatory, NCAR

Cyclic evolution of solar magnetic features is believed to be due to a dynamo operating in the Sun. Solar dynamo mechanisms in the past involved two basic processes: (i) generation of toroidal fields by shearing pre-existing poloidal fields by differential rotation (the omega-effect), (ii) re-generation of poloidal fields by lifting and twisting of toroidal fluxtubes (the alpha-effect). According to recent concepts, it also involves an essential third process – flux transport by meridional circulation. Flux-transport type solar dynamos have been very successful in explaining many large-scale solar cycle features, including the phase relationship between the equatorward migrating sunspot belt and the poleward drifting large-scale, diffuse fields. This has been a particularly difficult feature to reproduce. The dynamo cycle period in such models is primarily governed by the meridional flow speed. After giving a historical background on classical dynamo models, we review the successes of various recent flux-transport dynamos. We will then demonstrate how the meridional circulation plays a key role in governing the Sun's memory about its own magnetic field. Therefore, a flux-transport dynamo-based scheme can be built and that can be used as a tool for predicting future solar cycles. We will close by showing how this predictive tool can explain the cause of the very slow polar reversal in the so-called "peculiar" cycle 23 (compared to that in cycles 20, 21 and 22).
We acknowledge support from NASA through awards W-19752, W-10107 and W-10175.

Oral

Dynamics of Emerging Flux Tubes

Yuhong Fan
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Bipolar magnetic regions on the solar surface are believed to correspond to the topmost portions of Ω-shaped arching flux tubes that have risen buoyantly from the base of the solar convection zone, where strong toroidal magnetic fields are being generated by the dynamo process. The dynamic evolution of such rising flux tubes in the solar convection zone has been studied extensively using a simplified thin flux tube model, and more recently with direct multi-dimensional MHD simulations. In this talk I will give an overview of some recent results of MHD simulations of the formation and dynamic rise of buoyant Ω loops in the solar convection zone. I will discuss the question about the necessary twist for maintaining cohesion of the rising flux tubes and how 3D stratified convection can affect the rise and the structure of buoyant flux tubes. Finally I will also show simulations of the emergence of twisted magnetic flux tubes into the solar atmosphere.

Oral

Large-Scale Coronal Dynamics

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Modern ground- and space-based observatories such as TRACE, RHESSI, SOHO, Yohkoh, and BBSO have provided new insights into the large-scale dynamics of the solar atmosphere. As new details are revealed, theorists are challenged to provide quantitative explanations of the observed structures and their evolution. In this review, I will discuss our current theoretical and observational understanding of: pre-eruption structures (loops, filaments, active regions) seen at Hα, EUV, and X-ray wavelengths; the initiation and acceleration of CMEs in the low corona with particular regard to recent findings from RHESSI and TRACE; and the subsequent expansion and propagation of CMEs into interplanetary space visible with the LASCO instrument onboard SOHO. Additional large-scale dynamical phenomena such as coronal dimmings, streamer blow-outs, and recent evidence for current-sheet formation will also be discussed.

Table of contents:

- Introduction
- Active Region and Filament Evolution
  - Magnetic field topology from the photosphere to the corona
  - The complexity of magnetic fields
  - Energy build-up via flux emergence/motion
- Trigger Mechanisms
  - Interacting magnetic fields
  - Magnetic reconnection
  - MHD instabilities
- Compact and Eruptive Events
  - The relationship between flares, filaments, and CMEs
  - Driving eruptive events: Current sheet formation
  - Recent advances in CME modeling (Break-out, flux rope, etc)

P22

Relating Magnetic Field Strengths to Hard X-ray Emission in Solar Flares

C.P. Goff, S.A. Matthews, and L.K. Harra
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The observation of hard X-ray emission in solar flares provides important diagnostic information about the acceleration and subsequent transport of energetic electrons in the flare process. While hard X-rays are thought to be emitted from flare footpoints through thick-target Bremsstrahlung interactions, the details of the transport of accelerated electrons through the solar atmosphere still remains unclear. Trapping of the electrons is one particular effect that is expected to occur as a result of the convergence of the magnetic field between the corona and the chromosphere. In this case the brightness of the HXR footpoints should be related to the strength of the magnetic field present and we would expect greater precipitation and higher HXR intensities at footpoints with lower magnetic field strengths. Using data from Yohkoh's Hard X-ray Telescope (HXT) and SOHO's Michelson Doppler Imager (MDI) we have studied the magnetic field strengths at the footpoints of a sample of over 40 flares and have compared them to the hard X-ray brightness. We present results on a number of events where brighter hard X-ray sources lay in regions of higher magnetic field strength in contrast to those which follow the Sakao (1994) relation of the brightest source forming in the weaker magnetic field, as would be expected through the argument of magnetic trapping. The implications of these results in terms of standard flare models are discussed.

Solar-B's Focal Plane Package (FPP) vector magnetograph will provide us with much better estimates of the magnetic field strength at the footpoints. In addition, measurements of plasma flow velocity from Solar-B EIS will allow us to determine more fully the mechanisms involved.

Oral

XRT DEM Diagnostics

Leon Golub
Smithsonian Astrophysical Observatory

The X-ray Telescope (XRT) flown on the Solar-B mission will be the highest spatial resolution X-ray telescope ever flown for solar studies, with performance at wavelengths > 60 Å limited only by diffraction. The XRT also has an exceptionally broad temperature response and highly versatile focal plane analysis filters, with thicknesses ranging from 0.16 μm to 1 mm. Combined with the shutter speeds of 1 ms to > 1 s and the large dynamic range of the CCD camera, the XRT is sensitive to a range of $> 10^{10}$ in coronal X-ray brightness. In this paper we examine the ability of the XRT to accurately reproduce the differential emission measure (DEM) of a coronal emission source. We have developed a DEM analysis tool (which will be made available to the public as part of the Solar-B analysis software) that uses a forward-feedback method to perform spline fits and χ^2-minimization to produce a DEM distribution from a set of observations. We find that the XRT produces accurate fits, and we note that a) a large enough set of filters must be used if accurate DEMs are to be obtained, and b) the fits must be carried out over a range of coronal temperatures consistent with the filters being used.

P11

Phase Relationship between the Activity Cycles of Sunspots and Polar Faculae

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The number of polar faculae shows an eleven-year cyclic variation, but its phase is shifted by half a cycle with respect to the sunspot activity cycle. Namely, polar faculae are most numerous at sunspot minimum, and vice versa. Polar faculae represent poloidal magnetic fields in polar regions, while sunspots represent toroidal magnetic fields. Therefore, the phase relationship among the two will be important in studying the basic driving mechanism of solar activity. Specifically, we are interested in whether sunspots are better correlated with polar faculae of the previous cycle or of the following cycle.

We analyzed the counts of sunspots and polar faculae recorded on sunspot drawings obtained at Mitaka over four activity cycles. These counts were separately obtained for northern and southern hemispheres. We adopted two methods to study the phase relationship between sunspot and facular counts. The first method is the usual cross-correlation analysis. The second method uses a wavelet transform and the progression of the phase of the wavelet transform is studied. Both methods give the same trend in that the polar faculae are better correlated with the sunspots of the previous cycle. Compared to this trend, the correlation of the sunspot counts with the polar faculae of the previous cycle is weaker.

P23

Hα Impact Polarization Observed in a Gradual Flare

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National Astronomical Observatory of Japan

Linear polarization of chromospheric lines including the Hα line observed in solar flares is interpreted as impact polarization produced by accelerated high-energy particles precipitating into the chromosphere. We started a regular observation of linear polarization in the Hα line in 2002 July at NAOJ/Mitaka, and we detected linear polarization in the flare kernels of a gradual flare, which was accompanied by a filament eruption. The maximum degree of polarization of this flare exceeds 1 %, and the orientation of the polarization is approximately perpendicular to the flare ribbons. These results can be explained with the assumption that the observed polarization is impact polarization produced by accelerated protons. The hard X-rays observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) show a thermal component, but there is no detectable power-law component due to accelerated electrons. Therefore, protons are presumed to be not only the cause of the polarization, but also a possible candidate of the principal heating agent in this flare, which lacks high-energy electrons.

Although the linear polarization was detected in the above flare, most of the observed flares show no detectable (>1 %) polarization. Therefore, more precise polarimetry is required to study the impact polarization further. We are planning to start the polarimetry with a new polarimeter equipped with ferroelectric liquid crystals, and on the other hand, we are expecting Solar-B, because the SOT has a high polarimetric performance in some chromospheric lines as well as in the photospheric lines for the magnetic measurements.

P14

Variation of the X-ray Bright Point Number over the Solar Activity Cycle

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(2) *Suginami Science Center, Suginami-ku, Tokyo*

We have counted the number of X-ray bright points (XBPs) in the quiet-Sun region from Yohkoh soft X-ray images during a period of 1993–2000. Since we define XBPs as a small region that is less than 60 arcsec with a significantly enhanced emission in soft X-ray intensity compared with the adjacent background corona, the number of XBP in the whole Sun area is affected by the soft X-ray intensity of the background corona and the presence of the solar active regions. Under these conditions, the number of XBPs in the whole Sun area is anti-correlated with the sunspot number owing to the change of background X-ray intensity and the occultation by active regions during the 11-year solar activity cycle. In order to estimate the real number variation with little artifact, we have calculated the number of XBPs in a unit area by limiting the X-ray intensity range of the background corona and by removing a bias effect of a selected intensity threshold for the XBP counting. The evaluated change of the XBP number density in the quiet Sun is less than a factor of two over the period in the present study, and there is no clear enhancement in XBP number near the solar minimum. We conclude that the number density of XBPs is nearly independent of the 11-year solar activity cycle. Since an XBP found in the quiet Sun is recognized to be an event which is produced through an interacting process of opposite-polarity magnetic fields in the quiet Sun, the low-amplitude variation of the XBP number density suggests that there is a mechanism to create solar magnetic fields, which are different from those associated with active regions, irrespective of the 11-year solar activity cycle.

P34

Flare-Induced Coronal Disturbances Observed with Norikura 'NOGIS' Coronagraph : A CME Onset

Kuniko Hori[1], Kiyoshi Ichimoto[2], Takashi Sakurai[2], Yohei Nishino[2], and NOGIS Team

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(2) *National Astronomical Observatory of Japan*

We present the first detection of a CME onset in the coronal green line emission (Fe XIV 5303 Å, 2 MK) by a 2D Doppler coronagraph 'NOGIS' at the Norikura Solar Observatory, NAOJ. The NOGIS instrument can measure the line-of-sight velocity of a 2 MK plasma up to 25km/s with a sensitivity of about 1 km/s.

The event we report was associated with an M6.5 flare on June 2, 2003 that occurred in the AR #10365 located at the west limb. The NOGIS observed the flare region (S06) together with an aggregate of face-on loops lying above a quiescent filament (N15) within a FOV of $677'' \times 898''$ ($1.84''$/pixel). The observation continued over 10 hours with a 43 s cadence. As the solar disk was occulted up to the height of $30''$ in the NOGIS images, we examined the evolution of the flare region using SOHO EIT 195 Å (1.6 MK) images and microwave (17 GHz) images from the Nobeyama Radioheliograph. We also examined the white-light images from the SOHO LASCO/C2 coronagraph to grasp a CME and surrounding streamers during the event.

The first precursor of the flare-CME event was a gradual enhancement in the intensity of the green line in tall edge-on loops that occupied the space between the AR #10365 and the loop system centered at N15. After 30 minutes from the start of this intensity enhancement, the ejection of a blue-shifted collimated jet was observed between the feet of the intensity-enhanced loops (S05), together with a flare expansion in the neighboring AR #10365. These expansions produced a blue-shifted blast wave, or an expanding low-density bubble, that propagated toward the outer corona with an initial velocity of 400 km/s. A significant dimming region appeared after the passage of the blast wave in the coronal green line and in the EUV emission. The blast wave pushed the southern side of the loop system at N15 and triggered a damped oscillation in Doppler shifts that apparently propagated from the inner toward the outer loops within the loop system over 100 minutes. After 44 minutes from the start of the flare expansion, the LASCO/C2 observed a partial halo CME that had an angular extension corresponding to the northern end of the loop system and the southern end of the AR #10365, respectively.

On the basis of the coronal disturbances described above, we will discuss how and where the CME plasma was supplied and what triggered the massive ejection. An application to the EIS observation will be proposed considering the ability of the temperature diagnosis of the EIS.

P19

Studies on the Flare Energy Build-up Process Using Solar-B/Solar Optical Telescope (SOT) and Solar Magnetic Activity Research Telescope (SMART) at Hida Observatory

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Evolution of active regions is one of the key topics for understanding the energy storage and triggering mechanisms of flares. In our previous studies, we found that the twisted structure of emerging magnetic flux bundles is the essential feature of flare-productive active regions (Ishii et al. 2000; Kurokawa et al. 2002). Vector magnetic field data sets are necessary to examine the twisted magnetic field structures (e.g. shear and helicity). The Solar-B/Solar Optical Telescope (SOT) enables us to study the detailed magnetic field configuration with a high spatial resolution. Recently we have constructed our new telescope, Solar Magnetic Activity Research Telescope (SMART) at Hida Observatory. Vector magnetic field telescope of SMART has a much wider field of view (FOV) than that of SOT. In this presentation, we propose an observational plan of the active region evolution and flare energy build-up process using SOT and SMART.

P2

Three-Dimensional MHD Simulation of Convection and Emerging Flux

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We report the results of a three-dimensional MHD simulation of convection and flux emergence into the upper atmosphere. Our primary goal is to investigate the interaction of convection and magnetic field, particularly the effect of convection on the emerging flux. The simulation domain includes the upper convection zone, photosphere, chromosphere and corona. Initially, statistically steady and field-free convection is developed in the model convection zone, then magnetic field, either horizontal sheet or twisted tube, is injected in the convection zone. Our preliminary results show that the emerging flux is broken by the convective flow and cannot keep coherence even when the field strength is as strong as the equipartition value with the kinetic energy of convective flow.

Oral

Properties of Photospheric Magnetic Fields at Footpoints of Hot and Cool Loops

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(2) *National Astronomical Observatory of Japan*

Coronal loops are not represented by single temperature, but cover wide temperature ranges. Cool (T∼ 1 MK) and hot (T>2 MK) loops are not spatially coincident. The heating rate has to differ by one order of magnitude to produce such different temperatures. Properties of magnetic fields at footpoints of the hot and cool loops are investigated with Advanced Stokes Polarimeter (ASP) coordinated with SXT and TRACE to understand what makes the large difference in the heating rate.

Footpoints of the hot loops are diffuse when observed with SXT, and the identification of footpoint locations is ambiguous. We instead use the moss observed with TRACE, which is low-lying EUV emission at footpoints of hot loops, to identify the footpoint locations of the hot loops. Properties of photospheric magnetic fields observed with ASP are compared between moss regions and footpoints of the cool loops. Both regions have magnetic fields whose strength is 1.2 kG and the orientation is vertical to the surface. A significant difference between the moss and the cool loops is found in the magnetic filling factor, which is defined by the fraction of the resolution element filled with a magnetized atmosphere. Moss regions, i.e. the footpoints of the hot loops, have lower filling factor than the footpoints of the cool loops. This result suggests that dispersed magnetic elements at the photosphere are more efficient to provide the heating energies to the corona, thus leading to the hot loops.

P24

Hard X-ray Spectral Observation of a High-Temperature Thermal Flare

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(3) *Institute of Space and Astronautical Science*
(4) *ClearPulse, Co.* (5) *Mitsubishi Heavy Industries*

We discuss the design and observational results of a balloon-borne hard X-ray spectrometer developed at the National Astronomical Observatory of Japan. The instrument uses sixteen $10 \times 10 \times 0.5$ mm CdTe detectors, and achieves 3 keV energy resolution over an energy range of 15–120 keV. The instrument is designed for a 1-day balloon flight at an altitude of 42 km. Two flights were conducted in 2001 and 2002. The second flight, on May 24, 2002, succeeded in observing a class M1.1 flare. Our data indicate that this is an unusual flare, having an extremely hot 47 MK thermal component and no detectable non-thermal component. The RHESSI satellite observed the first part of the flare, and our analysis shows that the RHESSI data are consistent with ours. Simultaneous data from the Nobeyama Radio Polarimeter can also be explained by thermal processes alone.

Oral

Helioseismology for Solar-B and Joint Investigations with SDO/HMI Project

Alexander Kosovichev
Stanford University

New methods of local helioseismology provide information about subsurface convective and shear flows, thermal and magnetic structures, which is critical for accomplishing the Solar-B scientific objectives. I review the current status of acoustic tomography, observational requirements and limitations, and discuss observations of supergranular convection and helical motions, subsurface transport and flux emergence, formation and decay of sunspots and active regions, and links between subphotospheric dynamics, magnetic topology and coronal activity.

P7

Vector Magnetic Field of Moving Magnetic Features around a Well-Developed Sunspot

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(2) *National Astronomical Observatory of Japan*

We identify about 30 moving magnetic features (MMFs) to investigate their magnetic field structures and horizontal motions. Stokes profiles obtained with Advanced Stokes Polarimeter are examined with the magnetogram movie of SoHO/MDI. MMFs are small magnetic features, which move outward from the penumbral edge of sunspots.

It is found from viewpoint of vector magnetic field and its motion that MMFs can be classified into three types. The first type of MMFs has magnetic fields nearly parallel to the solar surface ($< 10°$) with the horizontal velocity of 400–700 m/sec. The second type of MMFs has magnetic fields with 40–60 degrees to the surface and rather slow horizontal velocity (< 400 m/sec). The third type is between the first and second types. This presentation will discuss the magnetic field properties of MMFs in terms of the three types including their spatial distribution in radial and azimuth direction, which may help us to understand the decaying process of sunspots.

Oral

Study of Magnetic Helicity in the Solar Corona

Kanya Kusano
Graduate School of Advanced Sciences of Matter, Hiroshima University

Magnetic helicity, which is a measure of magnetic flux linkage, is widely believed as an important quantity for the understanding of stability and equilibrium of the magnetohydrodynamic plasmas in several systems. Although a great attention has been paid to the role of magnetic helicity in the solar corona, the physical relationship between magnetic helicity and the coronal activity, for instance solar flares, is not yet well understood. In this talk, we will first review the recent progress in the magnetic helicity physics of the solar corona about the following three topics,

(1) the methodology of helicity measurement,
(2) the correlation with coronal heating, and
(3) the trigger mechanism of solar flares.

In particular, we will present a new model that solar flares can be triggered by the annihilation of magnetic helicity, based on the observational and numerical studies carried out in our group recently. Secondly, we will discuss about what we can do and what we should do about the study of magnetic helicity with Solar-B program.

P36

Investigation of Loop-Type CMEs with 3D MHD Simulations

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The loop-type CMEs, which are one of the two types of CMEs we found (Uchida et al. 2001), have a characteristic structure suggestive of helical instability in a magnetic loop, namely, both footpoints being fixed on the solar surface during the time evolution. We also found that, before the occurrence of some CMEs, there are already magnetic field lines linking the footpoints of the loop-type CME and the region where the associated arcade flare is to take place. We here propose a scenario for the loop-type CMEs based on these observations as follows.

Before a loop-type CME to occur, the large-scale magnetic field of the relevant region is composed of (1) a separated pair of magnetic sources located at the footpoints of the subsequent loop-type CME, and (2) another, smaller pair of poles located somewhere between the footpoints where the associated arcade flare is to take place. The torsional Alfvén wave packets (TAWPs) may escape from the arcade flare region and propagate to the footpoints of the loop-type CME. The TAWPs are then reflected at the footpoints and propagate upward along the large loop newly formed by the magnetic reconnection. The packets may eventually collide at the loop top.

We treat such a situation with 3-dimensional MHD simulations, in order to understand the physical mechanisms involved in the process of the deformation and acceleration of the loop-type CMEs.

[†] deceased 2002 August 17

P8

Measuring Magnetic Helicity Transport in Solar Active Regions: The Need for Vector Magnetic Fields

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The emergence and accumulation of twisted (helical) magnetic fields in the solar atmosphere are essential in the process which powers solar flares and eruptions. Berger and Field (J. Fluid Mech., 147, 144, 1984) showed that the flow of helicity into a volume comprises two terms. Advection twists preexisting fields. Emergence carries pre-twisted fields into the volume directly. On the Sun, the emergence term is not measurable from line-of-sight magnetic observations; it requires vector field observations. We have derived a set of analyses that permit a full characterization of helicity transport from vector field observations using data from the Mees Solar Observatory Imaging Vector Magnetograph. These include the rate of helicity transport, as well as the time series of the actual helicity content. We anticipate better physical understanding of helicity transport from the improvements in spatial resolution using Solar-B, and in global perspective using Solar Dynamics Observatory.

P6

Three-Dimensional Structure of the Active Region Photosphere as Revealed by High Angular Resolution

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Blue continuum images of active regions at $\sim 60°$ from the center of the solar disk obtained with the new Swedish 1-m Solar Telescope reveal heretofore unreported structure of the magnetized solar atmosphere. Perhaps the most striking aspect of these images is that, at an angular resolution of $0.12''$, they show clearly the three-dimensional structure of the photosphere. In particular, the Wilson depression of the dark floors of pores is readily apparent. Conversely, the segmented structure of light bridges running through sunspots and pores reveal that light bridges are raised above the dark surroundings. The geometry of light bridges permits estimates of the height of their central (slightly darker) ridge: typically in the range 200 – 450 km. These images also clearly show that facular brightenings outside of sunspots and pores occur on the disk-center side of those granules just limbward of intergranular lanes that presumably harbor the associated plage magnetic flux. In many cases the brightening extends $0.5''$ or more over those granules. Furthermore, a very thin, darker lane is often found just centerward of the facular brightening. We speculate that this feature is the signature of cool down flows that surround flux tubes in dynamical models. These newly recognized observational aspects of photospheric magnetic fields should provide valuable constraints for MHD models of the magnetized photosphere, and examination of those models as viewed from oblique angles is encouraged.

P25

Particle Acceleration Associated with Three-Dimensional Fan Magnetic Reconnection

Yuri Litvinenko
University of New Hampshire

Particle acceleration associated with three-dimensional magnetic reconnection is analyzed. Orbits of charged particles in the current sheet located in the fan of a magnetic null point are described analytically in both nonrelativistic and ultra-relativistic limits. An orbit instability effect is described, which limits the acceleration times and kinetic energy gains in the reconnection-related electric field. The results are discussed using exact MHD solutions for fan reconnection, discovered by I.J.D. Craig and co-workers. The use of an analytical self-consistent MHD solution to derive the magnetic field configuration near the null point leads to constraints on local parameters in the magnetic reconnection region. As a consequence, simple conditions can be identified for effective particle acceleration in realistic reconnecting geometries. Applications to particle acceleration in solar flares are discussed.

Oral

Injection of Magnetic Energy and Magnetic Helicity into the Solar Atmosphere by an Emerging Magnetic Flux Tube

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We present a detailed investigation of the dynamical behavior of emerging magnetic flux using 3-dimensional MHD numerical simulation. A magnetic flux tube with a left-handed twist, initially placed below the photosphere, emerges into the solar atmosphere. This leads to a dynamical expansion of emerging field lines as well as an injection of magnetic energy and magnetic helicity into the atmosphere. The field-aligned distributions of forces and plasma flows show that emerging field lines can be classified as either expanding field lines or undulating field lines. A key parameter determining the type of emerging field line is an aspect ratio of its shape (the ratio of height to footpoint distance). The emergence generates not only vertical flows but also horizontal flows in the photosphere, both of which contribute to injecting magnetic energy and magnetic helicity. The contributions of vertical flows are dominant at the early phase of flux emergence, while horizontal flows become a dominant contributor later. The emergence starts with a simple dipole structure formed in the photosphere, which is subsequently deformed and fragmented, leading to a quadrupolar magnetic structure.

P20

Coronal Hard X-ray Source Accompanying a Plasma Ejection

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In many of flares occurring near the solar limb, a hot-plasma ejection is observed in soft X-rays during the impulsive phase. This is one of evidence to support the flare models which are based on the cusp-type magnetic reconnection high in the corona. Sometimes a compact hard X-ray source is observed above the soft X-ray flaring loop at the same time. This clearly indicates that the flare-energy release, probably magnetic reconnection, occurs above the soft X-ray loop. Fast-reconnection downward flow impinges on the closed magnetic loops and high-energy electrons are produced there. In this scenario, the above-the-looptop hard X-ray source is directly related to the reconnection downward flow.

How is the reconnection upward flow observed? Recently it is found in the impulsive phase of an M-class flare that a hard X-ray (above 20 keV) source exists slightly below a soft X-ray ejected feature which is located far above the soft X-ray flaring loop. This hard X-ray source might be a counterpart of the hard X-ray source related to the downflow. This might be caused by interaction between the reconnection upward flow and the ejected hot-plasma. We discuss how such high-energy electrons are produced there.

Oral

Conservation of Both Current and Helicity in Solar Flares

Don Melrose
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A model for magnetic reconnection transferring magnetic flux and current between two pairs of footpoints (Melrose 1998) is modified to take account of conservation of magnetic helicity. The helicity is expressed in terms of a double integral over the current, analogous to the double integral for the magnetic energy, which is approximated by a sum of a discrete set of currents and their self and mutual helicities. It is argued that the double integral for the helicity may be approximated in an analogous way by using the force-free condition. The conditions under which magnetic reconnection is energetically favorable, conserving both the net current and the net helicity, are explored.

P3

Jet Phenomena in the Solar Atmosphere Caused by Interaction between Emerging Flux and Pre-Existing Coronal Magnetic Fields

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We have studied solar coronal jet phenomena theoretically with MHD numerical simulations. Emerging flux interacts with pre-existing magnetic fields in the upper atmosphere through magnetic reconnection process. Then, enormous magnetic energy is released and magnetic topology drastically changes. Jet phenomena are caused through this process by released thermal energy and/or magnetic pressure, and so on. We introduce our theoretical results with MHD numerical simulations, and suggest the targets for Solar-B mission.

Oral

Coronal Heating, Spicules, and Solar-B

Ron Moore, David Falconer, Jason Porter, David Hathaway[1], and Yohei Yamauchi[2]
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Falconer et al (ApJ, 593, 549, 2003) investigated the heating of the quiet corona by measuring the increase of coronal luminosity with the amount of the magnetic flux in the underlying network at solar minimum when there were no active regions on the face of the Sun. The coronal luminosity was measured from Fe IX/X–Fe XII pairs of coronal images from SOHO/EIT, under the assumption that practically all of the coronal luminosity in these very quiet regions came from plasma in the temperature range 0.9×10^6 K $< T < 1.3 \times 10^6$ K. The network magnetic flux content was measured from SOHO/MDI magnetograms. It was found that luminosity of the corona in these quiet regions increased roughly in proportion to the square root of the magnetic flux content of the network and roughly in proportion to the length of the perimeter of the network flux clumps. From (1) this result, (2) the observed occurrence of many fine-scale explosive events (e.g., spicules) at the edges of network flux clumps, and (3) a demonstration that it is energetically feasible for the heating of the corona in quiet regions to be driven by explosions of granule-sized sheared-core magnetic bipoles embedded in the edges of the network flux clumps, Falconer et al. (2003) infer that in quiet regions that are not influenced by active regions the corona is mainly heated by such magnetic activity in the edges of the network flux clumps. From their observational results together with their feasibility analysis, Falconer et al. (2003) predict that (1) at the edges of the network flux clumps there are many transient sheared-core bipoles of the size and lifetime of granules and having transverse field strengths greater than $\sim$ 100 G, (2) $\sim$ 30 of these bipoles are present per supergranule, and (3) most spicules are produced by explosions of these bipoles. The photospheric vector magnetograms, chromospheric filtergrams, and EUV spectra from Solar-B are expected to have sufficient sensitivity, spatial resolution, and cadence to test these predictions. The mixed-polarity magnetic flux at the base of spicules which Falconer et al. (2003) inferred is compatible with the observed magnetic structure of Hα macrospicules recently found by Yamauchi et al. (Y. Yamauchi, R.L. Moore, S.T. Suess, H. Wang, and T. Sakurai, The Magnetic Structure of Hα macrospicules in Solar Coronal Holes, submitted to ApJ, September 2003, and presented as a poster paper here at the Fifth Solar-B Science Meeting).

P18

Coordinated Observation by Solar-B and Solar Magnetic Activity Research Telescope (SMART) for Probing the Coronal Loop Heating Mechanism

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Multi-temperature nature of the solar corona has been extensively studied by the recent X-ray and EUV observations. In terms of temporal behavior the corona is composed of a high temperature ($T > 5$ MK) transient component and a low temperature ($T < 5$ MK) persistent component (Yoshida and Tsuneta 1996). It is revealed that loops consisting the persistent component are not isothermal and the peak temperatures of their differential emission measure distributions are different with each other (Nagata et al. 2003; Schmelz et al. 2001). These observations imply that the inhomogeneity of the coronal heating rate is distributed in a scale of loop size ($1''$–$5''$) at the photosphere. In this paper, we discuss the coordinated observation plan for the coronal loop heating study by X-ray/EUV instrument aboard Solar-B and ground based wide field of view magnetograph on Solar Magnetic Activity Research Telescope (SMART). The SMART is a new ground based solar telescope constructed at Hida Observatory of Kyoto University and has two filter vector magnetographs with wide filed of view ($2000''\times2000''$–$400''\times400''$). We also report the results from recent joint observation with Advanced Stokes Polarimeter at Sac Peak and SoHO CDS carried out as a preview science with Solar-B and SMART.

Oral

Coronal Waves: Coronal Heating and Coronal Seismology

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SOHO and TRACE missions have demonstrated that wave phenomena are abundant in the corona and provided us with an observational basis for MHD coronal seismology. This review covers the recent observational findings of coronal wave phenomena and their theoretical models. The relevance of these observational and theoretical efforts to the coronal heating is discussed. An emphasis is put on the observational strategies for the study of the coronal wave activity with EIS and XRT instruments. The talk contents are:

1. Introduction: why waves are crucial for our understanding of coronal dynamics
2. The method of MHD coronal seismology
3. Direct observational evidence for coronal waves and observability of these phenomena with Solar-B

3.1 Flare-generated kink oscillations of coronal loops

3.2 Propagating slow waves

3.3 Standing slow waves

3.4 Sausage modes

3.5 Propagating fast wave trains

4. Indirect observations of coronal waves: Observational strategies with Solar-B
5. Coronal heating by waves and how Solar-B can test it
6. Conclusions

P12

Kink Oscillations in the Solar Corona

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The solar coronal plasma is highly structured in the magnetic field, density and temperature. This plays a crucial role in the theory of MHD oscillations. These oscillations have been known to play an important role in the heating of the corona. The presence of inhomogeneities in the corona makes it difficult to have a global picture of the dynamics involved in understanding phenomena such as loop structures, coronal holes, solar wind etc. In this study we model a coronal loop to be made up of a cylindrical tube of constant cross-section. However, the magnetic field, the pressure and density are assumed to be different both inside and outside the tube (though uniform). The tube admits oscillations such as sausage (symmetric), kink (asymmetric), surface and body modes. The dispersion relation of the modes for a cylindrical tube which is compressible, infinitely conducting with uniform flows inside the tube is derived. Limiting cases such as no flows, incompressible flows, short and long wavelength are discussed briefly. The phase speed of the kink mode can be used as a diagnostic for determining the magnetic field of the corona. It is clear from this study that the magnetic field depends on the distance between the foot points of the coronal loop, the period of oscillation and the ratio of the plasma density both inside and outside the loop. For different values of the coronal plasma parameters, the magnetic field varies from a few Gauss to 40 Gauss.

Oral

Observations of Flare-Associated Waves with Solar-B

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In Hα, a flare-associated chromospheric wave (called Moreton waves) was discovered in 1960, and after that such waves are sometimes observed. Uchida (1968, 1973, 1974) identified the Moreton wave as the intersection of a coronal MHD fast-mode shock and the chromosphere. Recently, Yohkoh/SXT observed coronal wave-like disturbances (X-ray waves). Narukage et al. (2002) showed that an X-ray wave is an MHD fast-mode shock, i.e., a coronal counterpart of the Moreton wave. The Solar-B has SOT, XRT and EIS on board and will be launched in 2006. We expect SOT, XRT and EIS will detect chromospheric Moreton waves, coronal X-ray waves and line-of-sight velocity of waves, respectively. In preparation for Solar-B, we examine the detection possibility of waves with these telescopes and suggest the observational methods.

Oral

Magnetohydrodynamics of the Solar Atmosphere

Åke Nordlund
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I will review recent progress in the understanding of solar atmospheric magnetohydrodynamics, triggered by new high resolution observations and by recent advances in 3-D numerical modeling. I will discuss particular requirements for realistic numerical modeling of solar magnetohydrodynamics and outline the primary requirements for further progress, in particular in the direction of chromospheric modeling.

P10

Magnetic Helicity, Magnetic Energy, and EUV Variability

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It is essential to accurately measure three-dimensional magnetic field and three-dimensional velocity field on the photosphere in order to estimate energy and helicity flux to the corona. We employ the vector magnetograms of Advanced Stokes Polarimeter (ASP) for three-dimensional magnetic fields. Velocity tangential to the solar surface is extracted from the magnetograms of SOHO/MDI by local correlation tracking technique for longitudinal magnetic images. In order to obtain the velocity normal to the solar surface we must select the most suitable methodology from three different procedures, namely, Dopplergram of SOHO/MDI, Dopplergram of ASP, and the inversion of induction equation method developed by Kusano et al. We select the inversion method in our study but we will also discuss the discrepancies found in the comparison of these procedures. With these data of magnetic fields and velocity fields we estimate the rate of magnetic helicity/energy injection rate due to shear motion effect and due to flux emergence effect separately for several active regions.

We calculate a degree of variability of EUV emission observed by SOHO/EIT. First we make the time dependent profile of EUV intensity averaged over the spatial domain of an active region. Then the standard deviation of this profile divided by the mean is calculated as the degree of variability. We compare the magnetic helicity and energy injected into the corona above active regions with the degree of variability of EUV and find out that the magnetic helicity supplied by the photospheric shear motion has a correlation with the degree of variability of EUV.

Oral

The Magnetism of the Very Quiet Sun

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Instituto de Astrofisica de Canarias

Most of the solar surface appears non-magnetic when it is observed in routine synoptic magnetograms. However, magnetic fields are detected almost everywhere, also in internetwork (IN) regions, when the polarimetric sensitivity and the angular resolution exceed a threshold. These magnetic fields are now accessible to many existing spectro-polarimeters, and they will be easy to observe with Solar-B. They cover much of the solar surface and, therefore, they may be carrying most of the unsigned magnetic flux and energy existing on the solar surface at any given time. This makes the IN potentially important to understand the global magnetic properties of the Sun (solar dynamo, coronal heating, sources of the solar wind, ...). I will review the main observational properties of these fields, as deduced from recent measurements (magnetic field strength and inclination, magnetic flux content, etc.). In addition, I will mention the physical mechanisms put forward to explain their origins, with pros and cons.

P21

Statistical Study of Hard X-ray Footpoint Region Observed with YOHKOH

Jun Sato
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We show some characteristics of hard X-ray footpoints derived from *The YOHKOH Flare Image Catalogue* covering the whole YOHKOH mission period (1991/08–2001/12). We mainly revealed that A) the hard X-ray emission comes from above the Hα emitting region and accelerated electrons lose their energy (10–100 keV) within about 1000 km length, and that B) the most of hard X-ray footpoint sources show a broken power-law spectrum with very hard spectrum in the low energy range (20–30 keV), suggesting the existence of cut off energy of accelerated electrons around 20–30 keV.

Oral

SOT Local-Helioseismology Programme

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Local helioseismology is proving to be a powerful tool in revealing small-scale flow and inhomogeneity in subsurface layers. The Solar Optical Telescope (SOT) is capable of producing very high-resolution Dopplergrams that can be used for this new method of helioseismology. I will review what little we know about small-scale wavefield and discuss what can be learned with SOT local helioseismology, as well as what should be done for a successful programme.

Oral

A Pumping-Up Mechanism of Mass and Energy from the Photosphere into the Upper Atmosphere

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A new mechanism is proposed to pump up mass and energy from the photosphere into the upper atmosphere; the chromosphere, the transition region and the corona. Recent high spatial resolution and high cadence observations at various temperature ranges revealed extremely dynamical features in the atmosphere such as ejections, flows and heating. Most of these activities have been attributed to magnetic reconnection of various scales. Dynamical features of plasmas have been interpreted as jets caused by reconnected magnetic tension force and evaporation or ablation due to high temperature as the result of magnetic reconnection. However, most of the observational evidences of magnetic reconnection are indirect. In this work, we propose to apply high-beta disruption as the cause of these activities. Curved magnetic loops with high-beta plasma inside and/or high velocity flow are unstable at their outer boundary surface. Localized interchange instability called "ballooning instability" can develop into non-linear phase and eventually disrupt the loop and fed the plasma into the surrounding magnetic structures. Starting from the photospheric granulation size up to Coronal Mass Ejection size, this mechanism can act as the converter of thermal and kinetic free energy, in the form of plasma confinement and flow, into other forms such as plasma ejection, particle acceleration, and eventually heating. Curved magnetic loops with enough plasma inside can pump up energy and mass into the upper atmosphere.

Oral

MHD Shock Waves in the Corona

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We review the recent research of MHD shock waves and related phenomena in the corona, with emphasis on the progress in the understanding of Moreton waves, for which late Professor Uchida established in early 1970's that they are chromospheric manifestations of coronal MHD shock waves.

Table of Contents:

1. Introduction
2. Early Observations
3. Uchida Theory
4. New Observations
   - (a) EIT waves
   - (b) X-ray waves
   - (c) Moreton waves
   - (d) Radio observations
5. Theory and Simulations
6. Summary

P26

Slow Shock Formation and Plasmoid Structure in Fast Magnetic Reconnection

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Fluid element trajectories based on magnetohydrodynamic (MHD) simulations are studied to analyze the relation between slow shock formation and plasmoid structure in the fast magnetic reconnection, including supersonic or subsonic expansion/acceleration process in the plasma. When the fast magnetic reconnection is well developed, either supersonic or subsonic expansion/acceleration process of the plasma occurs in front of the plasmoid, which additionally accelerates the reconnection jets generated by slow shocks. In particular, when the jet is supersonic, strong plasma heating and compression are observed in the plasmoid. According to the study of the fluid element trajectories, another pair of slow shocks is formed around the plasmoid, which is separated from a pair of slow shocks located in the upstream of the fast reconnection jet. In addition, thin high speed jet layers are observed inside of the plasmoid.

P16

Derivation of DEM Distribution Using YOHKOH/Soft X-ray Telescope

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It is very important for understanding of coronal heating to derive the Differential Emission Measure (DEM) distribution. However, it is difficult to know DEM distribution using X-ray images since most X-ray images are taken using some broad-band X-ray filters, like YOHKOH/SXT and SOLAR-B/XRT. We try to derive the DEM distribution using YOHKOH/SXT images and the Withbroe-Sylwester method (Withbroe 1975; Sylwester et al. 1980). In this paper, we present the preliminary results of the DEM analysis for an active region which was observed by SXT using five different X-ray filters. The temperature range of the DEMs is from 2 MK to 20 MK. The DEMs of the quiet loops in the center of the active region show the power-law distribution with an index of 4–5. We also examine the time evolutions of DEMs at the brightening loops and found that the index of the DEM distributions slightly decreases during the loop brightening.

P30

XRT and EIS Observations of Evidence of Magnetic Reconnection

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Magnetic reconnection is widely believed to play an important role in various solar activities such as solar flares. However, we could find only indirect evidence of reconnection, such as cusp-shaped loop, the motion of flare ribbons, and so on. Also, the theory of magnetic reconnection has not been established. Imaging and spectroscopic observations of reconnection-associated flows by Solar-B will improve our understanding of the basic process of magnetic reconnection in the solar atmosphere.

We performed 2.5-dimensional magnetohydrodynamic simulations of a coronal mass ejection (CME) associated with a giant arcade with a model of magnetic reconnection coupled with heat conduction. Based on the numerical results, we calculate the theoretical images taken by X-Ray Telescope and EUV Imaging Spectrometer, and predict the observation of evidence of magnetic reconnection such as inflow, outflow and shock structures. Furthermore, we discuss ‘dimming’ mechanism at CME site.

Oral

Spectroscopic Study of Steady Coronal Structures — Line Width Variations with Height of Fe X–XIV Lines —

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We have obtained spectrographic observations of several steady coronal structures at the limb overlying the sunspot regions on several days, simultaneously in the following combinations of emission lines: (1) Fe XIV (5303 Å) and Fe X (6374 Å), (2) Fe X (6374 Å) and Fe XIII (10747 Å and 10798 Å), and (3) Fe X (6374 Å) and Fe XI (7892 Å). The line-width, intensity and line-of-sight velocity for all the lines were computed using Gaussian fits to the observed line profiles at each location of 4×4 arcsec of the observed coronal regions. The line-width measurements indicate that in steady coronal structures the FWHM of the 6374 Å line increases with height above the limb with an average value of 1.02 mÅ per arcsec. Whereas the FWHM of the 5303 Å line decreases with the most frequent value of -0.66 mÅ per arcsec. The FWHM of the 7892 Å and 10747 Å lines increases at a rate of 0.55 and 0.29 mÅ per arcsec respectively. These values are inversely correlated with the corresponding values of ionization temperature for these emission lines. We find that FWHM of emission lines in coronal structures increases with height if the associated ionization temperature is less than 1.7 MK, with gradient depending upon the ionization temperature of the line, while the FWHM decreases with height for lines whose ionization temperature is greater than 1.7 MK. It implies that it may not always be possible to interpret the observed increase in FWHM with height in terms of an increase in the non-thermal velocity.

Oral

Small Scale Solar Magnetic Fields

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Most of the magnetic flux passing through the solar surface is concentrated into small magnetic structures, many of them below the best current spatial resolution. The structure and physics of small scale magnetic fields in the solar photosphere is discussed and current knowledge of their properties is reviewed. An overview is given on both observational results and the results of recent 3-D non-grey radiation MHD simulations.

P31

Tether-Cutting Energetics of a Quiet Region Prominence Eruption

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We study the morphology and energetics of a slowly-evolving quiet region prominence eruption occurring on 1999 February 8–9 in the solar north polar crown region, using Fe XV EUV 284 Å data from the EUV Imaging Telescope (EIT) on SOHO and soft X-ray data from the soft X-ray telescope (SXT) on Yohkoh. After rising at approximately 1 km/s for about six hours, the prominence accelerates to a velocity of approximately 10 km/s leaving behind EUV and soft X-ray loop arcades of a weak flare in its source region. Intensity dimmings occur in the eruption region cospatially in EUV and soft X-rays, indicating that the dimmings result from a depletion of material. Over the first two hours of the prominence's rapid rise, flare-like brightenings occur beneath the rising prominence which may correspond to "tether cutting" magnetic reconnection. These brightenings have heating requirements of up to order 10^{28}–10^{29} ergs, and this is comparable to the mechanical energy required for the rising prominence over the same time period. If the ratio of mechanical energy to heating energy remains constant through the early phase of the eruption, then we infer that coronal signatures for the tether cutting may not be apparent at or shortly after the start of the faster-rise phase of the prominence in this or similar low-energy eruptions, since the plasma-heating energy levels would not exceed that of the background corona. Our findings have strong implications for the correct use of observations in testing theoretical ideas for the onset of solar eruptions.

P35

Observation of Two Different Types of CMEs

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Since 1980s, it has been discussed that CMEs are either planar loop-like(two-dimensional) or bubble-like (three-dimensional) structures. Although loop-like configurations were sometimes mentioned, many researchers seem to think that all of them are bubble-like. We claim, however, that there are at least two different types (not only one) among CMEs. One is the loop-type CME (LCME), and the other is the blast-associated CME (BCME).

An LCME has two distant foot-points fixed on the solar surface, and is associated with an arcade flare that has occurred somewhere between these foot-points. LCME's have the following characteristics: (1) They sometimes have a frontal loop, a cavity, and a core which is the gas moving with a rising dark filament. (2) They have two fixed foot-points. (3) Some of them have been found to have loop structures connecting the flare region and the locations of the pre-flare foot-points. (4) They accelerate outwards: The acceleration is larger when they have a core. (5) The density enhancement over the normal corona is 10–20 %.

A BCME, more popularly known as a halo-type CME, has a dome-like shape propagating outwards from the flare, and we consider a BCME to be associated with the flare blast wave. BCMEs have the following characteristics: (1) They are associated with Moreton waves and EIT waves. (2) They propagate at a roughly constant velocity. (3) The density enhancement of this type is a few percent, much lower than that of LCMEs.

[†] deceased 2002 August 17

Oral

Coronal Heating and Acceleration of the Fast/Slow Solar Wind by Fast/Slow MHD Waves

Takeru Suzuki
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We investigate coronal heating and solar wind acceleration in the open-field region by dissipation of fast and slow MHD waves through the MHD shocks, focusing on an interpretation of the difference between the fast solar wind and the slow solar wind in the solar minimum activity phase.

Linearly polarized Alfvén (or equivalently fast-mode MHD) waves and acoustic (slow-mode MHD) waves traveling upward along the magnetic field line eventually form fast switch-on shock trains and hydrodynamical shock trains (N-waves), respectively, to heat the coronal plasma. The dissipation of the slow waves is rapid and effective in heating of the lower corona to increase the density at the coronal base. As a result, it plays an important role in the formation of the dense slow-solar wind.

On the other hand, the fast waves can carry a sizable energy to the higher level and play important roles in heating of the upper corona and acceleration of the fast-solar wind. Variations of the wave amplitude show a large difference in the fast wind and the slow wind even if the same wave periods are adopted. Observation of propagating wave motions in the fast and slow solar wind region can give constraints on our modeling.

Oral

Coronal Heating with Sweet-Parker Pico-Flares

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Katsukawa and Tsuneta (ApJ, 2001) and Katsukawa (PASJ, 2003) found an excess fluctuation in soft X-rays coming from active regions, and proposed that the fluctuation is attributed to ubiquitous tiny bursts. They estimated the energy range of individual bursts to be 10^{20-22} erg/event. If the energy of an individual burst is 10^{20} erg, 10^{6} events would occur in an active region per second. There appears to be a big desert, the void in which no burst occurs for 6 orders of magnitude in energy from the pico-flare range to the micro-flare range, indicating that a separate physical mechanism is responsible for the pico-flares. We propose that pico-flares are due to Sweet-Parker reconnection, which is presumably easier to occur than the Petschek reconnection responsible for larger flares. Because of its ubiquity, pico-flare reconnection consumes coronal magnetic energy in a time scale of a month. We point out the critical importance of high-cadence, high throughput, and high-resolution observations with Solar-B XRT.

P17

The Features of Solar Telescopes at the Hida Observatory and the Possibilities of Coordinated Observations with Solar-B

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At the Hida observatory, two characteristic solar telescopes, Domeless Solar Telescope (DST) and Flare Monitoring Telescope (FMT), have been worked at multiple observations for studying on solar active phenomena, solar fundamental structures and large scale phenomena which affect interplanetary environment. In addition, an important new telescope, Solar Magnetic Activity Researching Telescope (SMART), was built further in 2003. It is designed so that the chromosphere image of Hα, the vector magnetogram and the photosphere image of continuum light of the whole solar disk can be acquired with the highest spatial resolution in the world. In this paper, we introduce features and solarphysical purposes of these three telescopes, focusing on SMART, and propose about possibilities of coordinated observations with Solar-B.

P38

Precipitation Diffusion Model of Solar Wind for Sky Brightness Variation

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The solar-cycle sky brightness variation discovered by Sakurai is interpreted in terms of the precipitation diffusion model of solar-wind particles. Implication in the solar-cycle global warming is also discussed.

Oral

Nanoflare Heating of the Corona

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If mechanism responsible for creating hot solar corona is a magnetic one, the underlying heating events are likely to be highly fragmented, both spatialy and temporarily. Therefore, heating by nanoflares, where these features are naturally present, looks like an appealing scenario. Here we discuss recent progress, both theoretical and observational, in revealing possible signatures of the nanoflare heating. The emphasis is on probing nanoflares with variability in the coronal X-ray emission. The future progress in this study envisaged with the Solar-B mission is also discussed.

Oral

A Weak Component of Solar Magnetism

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Solar intranetwork (IN) magnetic elements seem to represent a weak component of solar magnetism, which is intrinsically distinct from network (NT) magnetic field. They are in fast emergence, migration, interaction and disappearance. Their lifetime is approximately 2 hours. They not only contribute huge amount of magnetic flux, but also continuously interact with stronger network field, resulting many types of activity on the quiet Sun. The interaction between IN and NT fields at strong network boundaries appears to be the key element in coronal heating and solar wind acceleration. Solar-B will be the ideal tool for quantitative measurements of this weak component of solar magnetism. To spatially resolve these weak field elements, the sensitivity of Solar-B magnetograph becomes a decisive factor.

P37

Interplanetary Flux Ropes and their Coronal Counterparts

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We study coronal signatures of interplanetary flux ropes (magnetic clouds) which produce high magnetospheric activities. Our provisional study of interplanetary flux ropes observed near the Earth during the ascending phase of the Solar Cycle 23 (1997–1998) shows a tendency that flux ropes with high inclination with respect to the ecliptic plane were observed during the high solar-activity phase. Since the large-scale coronal current sheet on the source surface warps extensively during the high solar activity phase, a close connection between the current sheet and interplanetary flux ropes is suggested. Detailed analysis of coronal images taken by Yohkoh/SXT and SOHO/EIT shows that eruption of large-scale trans-equatorial loops connecting active regions in the opposite magnetic hemisphere initiates CME activity and that the inclination of the associated interplanetary flux rope is similar to that of the heliospheric current sheet situated above the erupting coronal loops.

Oral

Electron Densities of High-Temperature Coronal Loops

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Yohkoh has revealed the existence of persistent high-temperature plasmas in solar active regions where major flare activity takes place. Density at the energy release site for coronal heating determines the efficiency of magnetic heating, and hence the heating energy flux.

Temperatures and densities of solar (and stellar) flares at the pre-flare states are compiled. Pre-flare conditions are basically derived from the data taken with the same instruments several tens of minutes before the onset of the impulsive phase of subsequent flares. It is found that the temperature increase from the preflare to flare states is only $\Delta \log T = 0.2$, and that density and flux increases are roughly independent of the flare thermal energy. Namely large flares take place at the coronal loops where both temperatures and densities are already high.

Several line pairs exist in the EIS observing wavelengths, which are suitable for plasma density diagnostics, covering wider temperature ranges. Combining with the emission measure information, "differential" filling factors will reveal the fundamental structures of coronal loops proceeding to abrupt magnetic activity.

P4

Nonlinear Force-Free Magnetic Field Configurations

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A method for calculating nonlinear force-free magnetic field configurations based on a Grad and Rubin type current-field iteration procedure is being developed. Goals include the investigation of energies of coronal magnetic fields for different boundary conditions, and eventually, the reconstruction of coronal fields based on vector magnetograph data. In this poster the methodology is presented, and initial test cases are shown.

P9

Magnetic Helicity Injection and Sigmoidal Coronal Loops

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Sigmoidal loops are believed to be closely associated with flares, coronal dimming and coronal mass ejections. Sigmoidal loops look more twisted than ordinary coronal loops. Therefore, they may have more free energy and may cause explosive phenomena. However, the sigmoidal loops are defined from morphology, and little is known about their physical parameters. Recently Kusano et al. (2002) proposed how to quantitatively evaluate the magnetic helicity injection. We adopted their method and studied the evolution of sigmoidal active regions with emphasis on the magnetic helicity injection.

Examples of sigmoidal loops were listed in Canfield et al. (1999). We used the vector magnetograms obtained with the Solar Flare Telescope of NAOJ and SOHO/MDI magnetograms to calculate the magnetic helicity injection. Three sigmoidal and two ordinary active regions were selected from the list of Canfield et al. (1999), which had good data coverage. We found larger (but not impulsive) helicity injection in sigmoidal active regions than in ordinary active regions. This may be a feature distinguishing the sigmoidal regions from ordinary regions. SXT images tend to show higher X-ray intensities where the helicity injection is larger than the surroundings.

P13

Macrospicules, Coronal Heating, and Solar-B

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Measurements of the high-speed polar solar wind by Ulysses have shown the wind to carry some fine-scale structures which have magnetic switchbacks caused by large-amplitude Alfvén waves. The lateral span of these magnetic switchbacks, translated back to the Sun, is of the scale of the lanes and cells of the magnetic network in which the open magnetic field of the polar coronal hole and polar solar wind are rooted. This suggests that the magnetic switchbacks might be formed from network-scale magnetic loops that erupt into the corona and then undergo reconnection with the open field. This possibility motivated us to undertake the study reported here of the structure of Hα macrospicules observed at the limb in polar coronal holes, to determine whether a significant fraction of these eruptions appears to be erupting loops. From a search of the polar coronal holes in 6 days of image-processed full-disk Hα movies from Big Bear Solar Observatory, we found a total of 35 macrospicules. 15 out of 35 events were in the form of an erupting loop, 17 were in the form of a single-column spiked jet, and 3 events were unclassifiable. The erupting-loop macrospicules are appropriate for producing the magnetic switchbacks in the polar wind. The spiked-jet macrospicules show the appropriate structure and evolution to be driven by reconnection between network-scale closed field (a network bipole) and the open field rooted against the closed field. This evidence for reconnection in a large fraction of our macrospicules supports models in which the coronal heating and solar wind acceleration in coronal holes are driven by explosive reconnection events seated in the network (e.g., Axford and McKenzie 1992, 1997; Fisk et al. 1999; Falconer et al. 2003). We believe that the vector magnetograph on the forthcoming Solar-B mission will provide critical clues to the mechanisms of coronal heating and solar wind acceleration by detecting magnetic activities at the base of macrospicules in the network and spicules rooted in the edges of the network flux clumps.

P32

Association of Coronal Mass Ejections and Metric Type II Radio Bursts with Impulsive Solar Energetic Particle Events

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The impulsive solar energetic particle (SEP) events, known as ^{3}He-rich (Z-rich) events, are typically short-lived and are small compared to the large gradual SEPs. There is a consensus that large gradual SEPs are associated with fast coronal mass ejections (CMEs), but it was thought that the CME association for the impulsive SEPs is not important. However, Kahler et al. (2001) found that an impulsive SEP event on 2000 May 1 was associated with a fast narrow CME. Additionally, Gopalswamy et al. (2003) reported that an impulsive SEP event was associated with a fast and wide CME as in large SEP events. We identified 38 impulsive SEP events using the Wind/EPACT instrument and investigated their association with coronal mass ejections (CMEs) and type II radio bursts. We found that (1) at least 27–37 % of impulsive SEP events were associated with CMEs, (2) Only 8–13 % were associated with type II radio bursts. The statistical properties of the associated CMEs were investigated and compared to those of all CMEs and CMEs associated with large gradual SEP events. The CMEs associated with impulsive SEP events were significantly slower (median speed of 613 km/s) and narrower (49°) than those of CMEs associated with large gradual SEP events (1336 km/s, 360°), but faster than the average CMEs (402 km/s).

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P27

MHD Simulations of Magnetic Reconnection with Finite-Amplitude Fluctuations

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The dissipation mechanism at the magnetic X-point of the reconnection process in solar flares is studied. Although the Petschek model is a promising mechanism to explain the rapid energy release, the estimated size of the diffusion region in this model would be extremely small, i.e. less than centi-meter if we adopt the Spitzer-type resistivity. Even the scale size in which various microscopic processes become efficient is still 10 meter or so, which is much less than the typical size of a flare. So there must be a meso-size scale where the MHD turbulence plays a role. In order to study the effect of the MHD turbulence on the magnetic reconnection, we are performing a series of MHD simulations of magnetic reconnection with finite amplitude fluctuations. A temporal evolution of a simple current sheet with almost uniform resistivity is investigated after imposing a finite-amplitude fluctuations (whose strength is approximately Alfvén speed) all over the computation domain. Multi-dimensional simulations showed no effective enhancement in the energy release rate.

Oral

Large-Scale Solar Coronal Dynamics Observed by SOHO/EIT

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A review of coronal observations made by the SOHO/EIT is presented. A particular emphasis is put on the Coronal Mass Ejections initiation process, with EUV dimmings and EIT waves being the main CME signatures in the low corona. The observed characteristics and morphologies of EIT waves/EUV dimmings are described and their basic properties are summarized. It appears that EIT waves can be regarded as a bimodal phenomenon. The pure wave mode represents a wave-like propagating disturbance; the eruptive mode is a propagation of a dimming as a result of magnetic field opening during the CME lifting. It is shown that at present it is difficult to reconcile all the observational facts into a coherent physical model. Some implications for the Solar-B mission will be discussed.