WAVE LEAKAGE AS PHASE MIXING OF LEAKY CONTINUUM MODES: IMPLICATIONS FOR THE INITIAL VALUE PROBLEM

J. Andries[1], J. Terradas[1,2] and M. Goossens[1]

[1] *Centrum voor Plasma-Astrofysica, KULeuven, Belgium;*
[2] *Departament de Fisica, Universitat de les Illes Balears, Mallorca, Spain*

Recently we have reported on the self-adjointness of the magnetohydrodynamic operator when it is considered on unbounded spatial domains, and have shown the existence of an additional continuum of linear magnetohydrodynamic (MHD) modes due to fast or slow lateral wave leakage (in addition to the well-known Alfvén and slow resonant continuum). These findings can help to judge about the physical relevance of certain discrete leaky modes with complex frequencies, which are to be interpreted as quasi-modes. In this contribution we emphasize that the detection of enhanced frequency power around certain frequencies (that are determined by the equilibrium) is very much dependent on the initial conditions. We describe the evolution of a wave signal and its subsequent decay due to leakage in terms of phase mixing of the excited leaky continuum modes. In this view, it is straightforward to derive rough indications on the importance of the initial conditions to the typical behavior of the evolving wave signal. For some initial conditions the observed frequency power depends almost solely on the initial conditions while for other initial conditions, the observed power is completely characterized by the equilibrium. Thus, whether the frequencies and damping times predicted by the quasi modes can be observed depends not only on the equilibrium but also on how these waves are excited. Implications for the detectability of leaky quasi-modes in coronal loop oscillations are discussed in this framework.

ON THE FREQUENCY DISTRIBUTION OF HEATING EVENTS IN CORONAL LOOPS, SIMULATING OBSERVATIONS WITH HINODE/XRT

P. Antolin[1], K. Shibata[1], D. Shiota[2] and D. Brooks[3]

[1]*Kwasan Observatory, Kyoto University;*
[2]*National Astronomical Observatory of Japan;*
[3]*Naval Research Laboratory*

Alfvén waves are good candidates to heat and maintain the solar corona to the observed few million degrees (Alfvén 1947, Hollweg 1982). Another appealing candidate is the nanoflare heating, in which energy is released through many small reconnection events (Parker 1988; Priest et al. 2002). Distinguishing the observational features of each mechanism is an extremely difficult task. On the other hand, solar flares down to microflares are found to follow a power law distribution in frequency (Shimizu 1995). The power law index is important as it shows which events are the main heating contributors (Hudson 1991). In this work we propose a link between this index and the operating heating mechanism in a loop. We set up two coronal loop models using the CIP-MOCCT scheme (Evans & Hawley 1988, Yabe & Aoki 1991). The first model, following Moriyasu et al. 2004, is a 1.5-D MHD code in which Alfvén waves created by sub-photospheric motions at both footpoints dissipate their energy through shocks. The second model is a 1-D HD code in which numerous heating events are input randomly along the loop (uniformly or footpoint concentrated). We analyze the intensity flux distribution as would be observed with Hinode/XRT and find that Alfvén wave heated coronas and nanoflare heated coronas present intensity histograms with power-law indexes which differ considerably. The difference in the index as a signature of the heating mechanism is discussed.

DAMPED TRANSVERSAL OSCILLATIONS OF TWO INTERACTING CORONAL LOOPS

I. Arregui[1], J. Terradas[1,2], R. Oliver[1] and J. L. Ballester[1]

[1]*Departament de Física, Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain*
[2]*Centrum voor Plasma Astrofysica, KULeuven, Celestijnenlaan 200B, B-3001 Heverlee, Belgium*

TRACE observations often show the collective excitation of oscillations in a system of coronal loops rather than in individual structures. However, most of the theoretical models used for the study of these oscillations make use of isolated single coronal loop models concentrating the analysis on the fundamental MHD kink mode. In this work, first, the transversal oscillatory modes of a system of two close coronal loops are studied. For these solutions, the period and the damping rate due to resonant coupling to Alfvénic motions are computed as a function of several equilibrium parameters, such as the density contrast, the width of the inhomogeneous density layers surrounding the loops and the distance between them. The parameters that determine when oscillations of individual loops in such a system cannot be considered independent are quantified for realistic parameter values. Second, the time-dependent problem, for given initial disturbances, is solved and the conditions under which these oscillations are excited and then damped are investigated.

FUNDAMENTAL PHYSICAL PROCESSES IN CORONAE: WAVES, TURBULENCE, RECONNECTION, AND PARTICLE ACCELERATION

M. Aschwanden

Solar & Astrophysics Laboratory, Lockheed Martin ATC, Bldg. 252, Org. ADBS, 3251 Hanover St., Palo Alto, CA 94304, USA; e-mail: aschwanden@lmsal.com

Our understanding of fundamental processes in the solar corona has been greatly progressed based on the space observations of SMM, Yohkoh, Compton GRO, SoHO, TRACE, RHESSI, and STEREO. We observe now acoustic waves, MHD oscillations, turbulence-related line broadening, magnetic configurations related to reconnection processes, and radiation from high-energy particles on a routine basis. We review a number of key observations in EUV, soft X-rays, and hard X-rays that innovated our physical understanding of the solar corona, in terms of hydrodynamics, MHD, plasma heating, and particle acceleration processes.

GLOBAL CORONAL SEISMOLOGY

I. Ballai

Solar Physics and Space Plasma Research Centre (SP^{2}RC). Dept. of Applied Mathematics, University of Sheffield, Hicks Building, Hounsfield Road, Sheffield, S3 7RH, United Kingdom

Observations in EUV lines of the solar corona (SOHO/EIT, TRACE/EUV and STEREO/EUVI) revealed large scale propagating waves generated by eruptive events. *EIT waves* are large scale waves, covering an extended area of the solar corona (comparable to the solar radius. Waves (similar to EIT waves) are able to carry information about their environment. This attribute is used to develop one of the most dynamic branches of solar physics called *coronal seismology*. EIT waves can be used to sample the coronal local and global magnetic field. This contribution presents theoretical models for finding values of magnetic field in the quiet Sun and coronal loops based on the interaction of global waves and coronal loops as well as results on the generation and propagation of EIT waves. The physical connection between local and global solar coronal events (e.g. flares, EIT waves and coronal loop oscillations) will be also explored.

OBSERVATIONAL REVIEW ON THE GLOBAL SOLAR AND STELLAR CORONAL SEISMOLOGY

D. Banerjee

Indian Institute of Astrophysics, Koramangala, Bangalore 560034, India

With multi-wavelength observations from ground and space-based instruments it has been possible to detect waves in a number of different wavelengths simultaneously and to, consequently, study their propagation properties. High-resolution wave observations combined with forward MHD modelling can give an unprecedented insight into the connectivity of the magnetized solar atmosphere, which further gives us a realistic chance to construct the structure of the magnetic field in the stellar atmosphere. This type of exploration is also termed as magnetic seismology. In this review I will focus on global waves, like EIT waves. I will also address the possibility of finding out the properties of magnetic structures while studying the interaction of global waves with coronal loops. A Promising new way to probe stellar atmosphere is to use our knowledge of coronal seismology on the Sun and to apply it to more distant stars. It will also enable us to measure properties such as the lengths of loops linked with stellar flares and the strengths of coronal magnetic fields on stars. In the last part I will review the current status of the stellar coronal seismology.

CLOSING REMARKS: REFLECTING THE PAST AND THE FUTURE

A. O. Benz

Institute of Astronomy, ETH Zurich, Switzerland

Why is the dynamics of the solar gas flows so much more complex than the waves at the beach? I will review the contributions to the Symposium in the perspective of plasma physics, the common ground of a large variety of phenomena observed and modeled in the solar corona. The most fundamental processes can be put into a reasonable order. We are still in a situation in which we do not understand the basic processes in detail but may conjecture which are important. The consequences for the history of the Sun and its formation are also of great interest. Theories may explain what has been observed. Are there predictions we can test in the future? If possible, it will be based on solar observations. It is esssential to concentrate on the important ones.

THE NATURE OF RUNNING PENUMBRAL WAVES REVEALED

D. S. Bloomfield, A. Lagg, and S. K. Solanki

Max Planck Institut für Sonnensystemforschung,
Max-Planck-Str. 2, 37191 Katlenburg-Lindau, Germany

Spectropolarimetric time series data of the primary spot of active region NOAA 9451 were obtained on 2001 May 9 in the photospheric Si I 10827 Å line and the chromospheric He I 10830 Å multiplet with the Tenerife Infrared Polarimeter. Throughout the time series the spectrograph slit was fixed over a region covering umbra, penumbra, and quiet sun. We present an analysis of running penumbral waves in the chromosphere, their Fourier phase difference relations to both photospheric and chromospheric umbral oscillations, and their dependence on the magnetic field topology.

DYNAMICS OF HIGH TEMPERATURE PLASMA IN THE SOLAR ATMOSPHERE FROM OBSERVATIONS OF THE CORONAS-F SATELLITE

S.A. Bogachev, S.V. Kuzin, I.A. Zhinik, A.M. Urnov, V.A. Slemzin, S.V. Shestov, A.A. Pertzov

Lebedev Physical Institute of Russian Academy of Science, Leninskii prospect, 53, Moscow, Russia

We review main findings of the CORONAS-F mission concerning dynamics of high-temperature plasma in the solar corona. The CORONAS-F satellite covered the maximum and decay phase of the last solar cycle and provided unique information on the origin and physical characteristics of solar plasma in the temperature range of about 10 MK. From 2001 to 2005, the dynamic of several hundreds high-temperature objects (cusp-like regions, hot flare loops, above-loop-top sources) were observed with temporal resolution less then 1 minute. We present these results of observations and provide their theoretical interpretation from the point of the current views on magnetic reconnection and energy release in the solar corona.

CORONAL WAVES OBSERVED WITH SOHO AND STEREO

V. Bothmer[1], A. Vourlidas[2] and R. Howard[2]

[1]*Institute for Astrophysics, University Goettingen, Germany;*
[2]*Naval Research Laboratory, Washington, D.C., USA*

We present a summary on coronal wave phenomena EIT waves, outward propagating waves as indicated by streamer kinks, shock wave features ahead of CMEs indicative for driven waves, global coronal waves accompanying CME onsets - observed by SOHO/EIT/LASCO. Additionally, new observations of coronal waves from STEREO will first be presented. The wave properties and their implications for coronal seismology will be discussed.

ON THE SOLAR DYNAMO AND THE CRUCIAL ROLE PLAYED BY THE TACHOCLINE

Allan Sacha Brun

CEA-Saclay, Service d'Astrophysique, France

We present recent 3-D high resolution MHD simulations made with the ASH code to model self-consistently the solar global dynamo in a turbulent convection zone coupled with a stable sheared region below. We show that the introduction of such a stable layer indeed favors the emergence of strong axisymmetric magnetic field which otherwise would not exist in a purely unstable convective layer rotating at the solar rate. The dynamo action operating in the convection zone is found to be highly intermittent both in space ant time. Further it is found that large scale meridional flows, magnetic diffusion and turbulent convective plumes serve to pump down magnetic field in the stable sheared layer. There, the ω-effect acts efficiently to organize the field into strong toroidal structures (the mean toroidal energy being about 100 times higher). This field is found to be antisymmetric with respect to the equator, as observed in the Sun and is associated with a deep poloidal (dipolar like) field. This stable organised poloidal field seems to stabilize the poloidal field generated by the turbulent and intermittent convection envelope. As of today we haven't observed either a reversal of the field polarity in the stable layer but this exciting adventure continues.

REVIEW OF POLAR FACULAE : EFFECT ON SUNSPOT CYCLE, DYNAMO AND INTERPLANETARY FIELD

D. K. Callebaut[1], A. H. Khater[2] and V. V. Makarova[3]

[1] *Physics Dept., CGB, University of Antwerp, B-2020 Antwerp, Belgium*
[2] *Math. Dept., Faculty of Science, Beni Suef University, Beni Suef, Egypt*
[3] *Kislovodsk Solar Station of Pulkovo Observ., 357700 Kislovodsk, Russia*

Makarov and co-authors have established several relations (duration, intensity, peaks, secular evolution) between a polar faculae cycle and the following sunspot cycle: the latter repeats roughly the polar faculae cycle with a time shift of about half a cycle. Moreover those findings are confirmed by CaII-K bright spots and by the global magnetic regions, again preceding the sunspot cycle by about half a cycle. These relations (some expressed in approximate equations) imply adaptations for various dynamo theories: Babcock-Leighton, Choudhury et al., Dikpati et al., Callebaut and coworkers, etc. The theory of Callebaut allows the polar faculae and the sunspots to be generated by the same mechanism, the delay between them is attributed to the torsional oscillations which start at higher latitudes and evolve toward the equator, automatically implying a suitable time shift. The total number of polar faculae, somewhat representative for the solar interplanetary flux, does not stand in a simple relation to the Wolf number. In fact their number increased by a factor more than 3 during the last four cycles, while the Wolf number did not vary drastically. This may be attributed to the combination of 3 effects.

SEISMOLOGY OF OPEN AND CLOSED MAGNETIC STRUCTURES - SIMULATIONS

M. Carlsson, V.H. Hansteen and B.V. Gudiksen

Institute of Theoretical Astrophysics, University of Oslo

We use self-consistent 3D radiative MHD simulations to study the excitation, propagation and mode conversion of MAG waves in open and closed magnetic structures. The simulations include the upper convection zone, photosphere, chromosphere, transition region and corona with a realistic equation of state. The equation of radiative transfer is solved along 48 rays including the effect of scattering in spectral lines. Optically thin radiative losses are included in the transition region and corona. Optically thick radiative energy exchange in the chromosphere in lines from hydrogen and singly ionized calcium is included using an escape probability method. Conduction is treated implicitly using a multi-grid method. The observability of waves present in the simulations is also studied through the detailed calculation of observables.

CONNECTING THE DYNAMICS OF THE CHROMOSPHERE AND TRANSITION REGION WITH HINODE/SOT AND EIS

B. De Pontieu[1], V. Hansteen[1,2], S.W. McIntosh[3,4], M.P. Carlsson[2]

[1]*Lockheed Martin Solar & Astrophysics Lab, Palo Alto, CA, USA;*
[2]*Institute for Theoretical Astrophysics, University of Oslo, Norway;*
[3]*High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, USA;*
[4]*Department of Space Studies, Southwest Research Institute, Boulder, CO, USA*

Hinode/SOT Ca II broadband images and movies show that there are several different types of spicules at the limb. These different types are distinguished by dynamics on different timescales. The first type involves up- and downward motion on timescales of 3-5 minutes. The dynamics of these spicules are very similar to those of fibrils and mottles as observed on the disk. Recent work suggests that these are driven by slow-mode magnetoacoustic shocks that form when convective flows and global oscillations leak into the chromosphere along magnetic flux tubes. The second type is much more dynamic with typical lifetimes of 10-60 s. These spicules are characterized by sudden appearance and disappearance that may be indicative of rapid heating to TR temperatures. We will use coordinated Hinode SOT/EIS observations that include high-resolution magnetograms, chromospheric and TR imaging and TR/coronal spectra to study the impact both spicule types have on the TR, what role reconnection plays in creating the second type of spicules, whether these features dominate heating of the magnetized chromosphere, and more generally to connect the dynamics of the chromosphere with those of the TR. In addition, we will perform detailed comparisons of these different types of jets with synthetic Ca images derived from advanced 3D numerical simulations that encompass the convection zone up through the corona.

MHD MODES IN PROMINENCE FIBRILS

A. J. Díaz, R. Oliver, and J. L. Ballester

Departament de Física, Universitat de les Illes Balears, E07122, Palma, Spain

Recent high-resolution observations have pointed out that prominences are made of small threads (also named fibrils) piled up to form the body of the prominence. These fine structures also seem to support their own oscillatory modes, while their effect on the global modes of the prominences are less certain. We explore the different types of ideal MHD modes that the fibrils can support, first analytically by exploring limits in which the wave equations are decoupled, and then by solving computationally the full problem. Finally, we compute the range of periods that can be expected in the observations and review how the global modes might be recovered.

OBSERVATIONAL ASPECTS OF PROMINENCE OSCILLATION

O. Engvold

Institute of Theoretical Astrophysics
University of Oslo, Norway

Seismology has become a useful tool in studies of the magnetic structure of solar prominences. Solar prominences/filaments oscillate over a large range of spatial scales and periods. The periods of hr and longer may reflect eigenmode oscillations of large-scale structures, whereas oscillations with shorter periods down to a few minutes presumably are magnetohydrodynamic modes in individual small-scale, thin threads. The talk will discuss observations over the past decennia in the context of current theoretical models.

THE LEAKAGE OF INTERIOR MOTION AND ITS IMPACT ON THE LOWER SOLAR ATMOSPHERE

R. Erdélyi

Solar Physics and Space Plasma Research Centre (SP^{2}RC), Dept of Applied Mathematics, University of Sheffield

Recent advances in lower atmospheric seismology will be reviewed from a theoretical perspective. The problem is twofold: On the one hand, localised solar magnetic structures in the higher solar atmosphere influence the frequencies and lifetimes of the solar global acoustic oscillations (e.g. f/p-modes) trapped in the solar interior. This is because these global oscillations, though evanescent in their nature, penetrate and interact with the magnetised atmosphere. On the other hand, the motions (e.g. in the form of waves) generated in the lower regions are able to propagate into the higher atmosphere, where they are guided by the structured and stratified magnetic field. Several mechanisms through which this may occur will be presented, with particular emphasis on the resonant coupling. The observational consequences (e.g. spicules, or running coronal waves) and energetic implications will be addressed. Observations of MHD waves could be used as a tool to uncover the processes occurring in the magnetised regions of the solar atmosphere, leading to the emergence of the field of solar magneto-seismology.

TURBULENT HEATING OF CORONAL ACTIVE REGIONS: STATISTICS OF DISSIPATION EVENTS

Daniel Gómez[1,2] and Pablo Dmitruk[3]

[1]*Instituto de Astronomía y Física del Espacio, CONICET, Argentina;*
[2]*Departamento de Física, Universidad de Buenos Aires, Argentina;*
[3]*Bartol Research Institute, University of Delaware, Newark DE 19716, USA.*

The internal dynamics of coronal loops in active regions is numerically simulated within the reduced MHD approximation. The application of a stationary velocity field at the photospheric boundary leads to a turbulent stationary regime after several photospheric turnover times. This regime is characterized by a broadband power spectrum and heating rate levels compatible with the heating requirements of active region loops.

The energy dissipation rate as a function of time displays a complex superposition of impulsive events, which we associate to the so-called nanoflares. A statistical analysis of these events yields a power law distribution as a function of their energies, which is consistent with those obtained for flare energy distributions reported from X-ray observations. We also study the distributions of peak dissipation rates, durations, and waiting times between events.

SEISMOLOGY OF KINK OSCILLATIONS IN CORONAL LOOPS: TWO DECADES OF RESONANT DAMPING

Marcel Goossens

Centre Plasma Astrophysics, K.U.Leuven

The detection of rapidly damped transverse oscillations in coronal loops by Aschwanden et al. and Nakariakov et al. in 1999 gave a strong impetus to the study of MHD waves and their damping. The common interpretation of the observations of these oscillations is based on kink modes. In this review I will focuss on resonant absorption as damping mechanism for kink oscillations in coronal loops. I will start with the 1988 paper by Hollweg and Yang and will discuss subsequent developments in theory and its applications to seismology of coronal loops. I will address the consistent use of observations of periods and damping times as seismological tools within the framework of resonant absorption. I will discuss how periods and damping times are related to density contrast, inhomogeneity length scale and internal Alfvén velocity. I will explain the recent finding that within the framework of resonant absorption infinitely many equilibrium models can reproduce the observed values of periods and damping times. Although infinitely many equilibrium models are possible, they all have their internal Alfvén velocity constrained to a narrow interval.

THE INTERNAL MAGNETIC STRUCTURE OF SOLAR CORONAL LOOPS

Boris V. Gudiksen[1] **and James A. Klimchuk**[2]

[1]*Institute for Theoretical Astrophysics, University of Oslo, Sem Sælandsvei 13, 0315 Oslo, Norway ;*
[2]*Space Science Division, Naval Research Laboratory, 4555 Overlook Avenue SW, Washington, DC 20375*

Coronal loops have been observed with a number of instruments on a number of space craft. In spite of increased spatial resolution, there has so far not been observed loops that have measured more than a few pixels in diameter and therefore largely unresolved. That leaves us with little observational help in determining the internal structure of loops. Understanding the internal structure of loops could answer a number of very intriguing questions. Among them why coronal loops do not get appreciatively wider with height, how waves are damped when traveling in them and how the dynamics are affected by the internal structure. In a number of test cases we have investigated how flux tubes between two driving surfaces behave through time, and how the internal structure varies with driving type. The results from these simplified models will be shown and discussed.

ALFVÉN WAVES AND OTHER WAVES IN THE SOLAR CHROMOSPHERE

V.H. Hansteen[1,2], B. De Pontieu[2], M. Carlsson[1] and S.W. McIntosh[3,4]

[1]*Institute of Theoretical Astrophysics, University of Oslo;*
[2]*Lockheed Martin Solar and Astrophysics Lab;*
[3]*Department of Space Studies, Southwest Research Institute;*
[4]*High Altitude Observatory, National Center for Atmospheric Research*

We analyze high-resolution images of the solar chromosphere obtained with the Solar Optical Telescope (SOT) onboard Hinode to show that Alfvén waves with strong amplitudes of order 10-25 km/s and periods of 150-400 s permeate the magnetized chromosphere. Our timesequences obtained at the solar limb in the chromospheric Ca II 3968 Å line reveal that the magnetized chromosphere is dominated by a multitude of long and thin short-lived jets that are aligned with the magnetic field. We find that most of these jets undergo significant swaying motions with transverse displacements of order 500-1,000 km. Such motions are compatible with the presence of ubiquitous Alfvén waves in the chromosphere. Estimates of the energy flux carried by these strong Alfvén waves and comparisons to advanced radiative MHD simulations indicate that these waves can play a significant role in the acceleration of the solar wind, and possibly the heating of the quiet Sun corona. We will discuss the generation of these waves and their relation to other chromospheric dynamics on the basis of the observations and numerical simulations.

BULK VISCOSITY DAMPING OF MAGNETOSONIC WAVES PROPAGATING IN A PHOTOIONIZED PLASMA

Miguel H. Ibáñez S.

Centro de Física Fundamental, Universidad de los Andes, Apartado 26, Ipostel, La Hechicera, Mérida Venezuela

As it was shown in a previous paper (Phys. Plasmas 2004) for certain kind of plasmas the coefficient of second (bulk) viscosity can be orders of magnitude larger than the coefficient of the dynamical viscosity and the thermometric conductivity. At the present paper the damping effects of the second viscosity on the hydromagnetic waves propagating in optically thin plasmas of arbitrary metallicity Z is analyzed. The plasma is assumed to be embedded in a constant magnetic field $\mathbf{H}$ and ionized by photons with mean energy E.

SOLAR FEATURE TRACKING IN BOTH SPATIAL AND TEMPORAL DOMAINS

D. B. Jess[1,2], M. Mathioudakis[1], R. Erdélyi[3], G. Verth[3] and R. T. J. McAteer[2]

[1]*Astrophysics Research Centre, School of Mathematics and Physics, Queen's University, Belfast, BT7 1NN, Northern Ireland, U.K.*
[2]*NASA Goddard Space Flight Center, Solar Physics Laboratory, Code 612.1, Greenbelt, MD 20771, USA*
[3]*Department of Applied Mathematics, The University of Sheffield, Sheffield, S3 7RH, England, U.K.*

Here we present an image-contrast improving technique utilizing a Laplacian filter. From photometric images with improved contrast, we show how fractal and multi-fractal analysis techniques can be implemented to track solar features. This provides a platform to search for, detect, and record oscillatory behaviour both in the temporal and spatial domain. Initial results drawn from the implementation of these techniques to TRACE observations, will also be presented.

HEATING AND DYNAMICS OF THE QUIET SOLAR CHROMOSPHERE

W. Kalkofen

Harvard-Smithsonian Center for Astrophysics

The quiet solar chromosphere is bifurcated into the magnetic network on the boundary of supergranulation cells and the nonmagnetic cell interior. The cell interior was believed to be heated by acoustic waves. However, recent space observations with TRACE have found at most 10% of the necessary acoustic flux. To explain the low measurement it was speculated that the nonmagnetic chromosphere is heated mainly by waves related to the magnetic field. Yet the emergent radiation shows none of the signatures of magnetic waves; it shows only those of acoustic waves. Essentially all the heating of the nonmagnetic chromosphere must therefore be due to acoustic waves. In the magnetic network, on the other hand, since the filling factor of the magnetic field is very small in the photosphere, only a small fraction of the wave flux that travels upward to heat the chromosphere is channeled by the magnetic field. Hence, while some of the energy is in the form of magnetic waves, most of the energy that is dissipated in the magnetic network must be in the form of acoustic waves. I conclude that the quiet solar chromosphere, magnetic as well as nonmagnetic, is heated mainly by acoustic waves. The full wave flux heating the quiet chromosphere must therefore travel through the photosphere. The failure to observe the full acoustic flux heating the nonmagnetic chromosphere may be due to the limited spatial resolution of TRACE.

EXPLORING OF THE SHORT PERIOD OSCILLATION IN THE QUIET FILAMENTS

N. I. Kobanov, D.Y. Kolobov, S.A. Chupin

Institute of Solar-Terrestrial Physics, RAS SB, P.O. Box 291, Irkutsk 664033, Russia

Authors analyzed sources of false Doppler velocity signals of high frequencies (10mHz and higher) in observations of filaments. In ground-based observations, spectrograph's noise and image shifting at the spectrograph's entrance slit are the main causes of the false signal. It is shown, that using differential methods and telluric lines as reference lines significantly reduces the influence of the first factor. Periodical image shifting along the spectrograph's slit can be compensated during data reduction (high spatial resolution is helpful in this case). Analogous image motions across the slit are the most probable source of spurious oscillations. Analysis of simultaneous fluctuations of continuum and magnetic field is useful to distinguish artificial oscillations. In some cases detected high-frequency oscillations appear to be real.

WAVES AND OSCILLATIONS IN SOLAR AND STELLAR INTERIORS - DYNAMO WAVES

Sasha Kosovichev

Stanford University, Palo Alto, California, USA

The analysis of acoustic wave properties is the primary way to probe stellar interiors and search for clues to the physical basis of stellar magnetism. For the solar case, helioseismology has revealed several aspects important for dynamo theory, such as the existence of the tachocline, the penetration of the torsional oscillation through the convection zone, and properties of the meridional flow. Local helioseismology is also used to probe the subsurface structure and dynamics of active regions, image sunspots on the solar farside, and map flows in the convection zone. With the advent of asteroseismology, which is now able to reliably detect solar-like oscillations in distant stars, we should be able to obtain further clues about the dynamo mechanism across the HR diagram. In this presentation, the latest relevant results in helio- and asteroseismology will be discussed.

MAGNETOSEISMOLOGY OF SOLAR FLARES

A.G. Kosovichev

Stanford University

Recent observations of helioseismic response to solar flares have revealed an interesting relationship between the seismic waves, propagating through the solar interior in active regions, and the wave-like process of magnetic reconnection in the corona. In several cases, the observed flare seismic waves are highly anisotropic with the strongest wave amplitude in the direction of the expanding flare ribbons. The flare ribbons represent the footpoints of the reconnecting magnetic field lines, which move apart during flares because the magnetic reconnection gradually extends into higher and higher atmospheric layers, according to the standard flare model. The seismic waves are excited by the hydrodynamic impact (caused by heating of the chromospheric plasma by high-energy electrons) at the rapidly moving footpoints of the reconnecting magnetic lines . The supersonic motion of these seismic sources (footpoints) on the solar surface results in strong anisotropy in the seismic wave amplitude. I present the helioseismic, optical, EUV and X-ray observations from the space missions SOHO, RHESSI, TRACE and HINODE, which demonstrate the chain of the wave processes in solar flares, and discuss the physics of the observed wave phenomena.

ELECTRON ACCELERATION IN SOLAR FLARES: X-RAY AND IN-SITU ELECTRON OBSERVATIONS

Säm Krucker

Space Sciences Lab, UC Berkeley, USA

X-ray observations reveal that solar flares are efficiently accelerating electrons up to relativistic energies. The acceleration mechanisms, however, are not understood. The observed X-ray emissions are produced by

collisions between flare-accelerated electrons and the ambient plasma (i.e. non-thermal bremsstrahlung emission). As the bremsstrahlung mechanism is well understood, X-ray observations provide excellent remote sensing diagnostics of electron acceleration in solar flares providing quantitative measurements such as spectral shape and energy content of flare-accelerated electrons. Further diagnostics are provided by in-situ particle observations in interplanetary space of electrons escaping the flare site allow us to directly measure flare-accelerated electrons.

After an extensive introduction, I will review recent observational results from the NASA small explorer mission RHESSI.

NONLINEAR ALFVÉN WAVE MODEL OF SPICULES AND CORONAL HEATING

T. Kudoh

National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan

We have a review about the theoretical studies of the Alfvén wave model of spicules and coronal heating, mainly based on the papers by Kudoh & Shibata (1999), Saito et al. (2000) and Moriyasu et al. (2004) which performed MHD numerical simulations of nonlinear Alfvén waves propagating along a magnetic flux tube in the solar atmosphere. Kudoh & Shibata (1999) and Saito et al. (2000) found that, if the root mean square of the perturbation is greater than ~ 1 km s^{-1} in the photosphere, (1) the transition region is lifted up to more than ~ 5000 km (i.e., the spicule is produced), (2) the energy flux enough for heating the quiet corona ($\sim 3.0 \times 10^5$ ergs s^{-1} cm^{-2}) is transported into the corona by Alfvén waves. Moriyasu et al. (2004) demonstrated that a hot corona is created in an initially cool loop as a result of the nonlinear Alfvén waves produced near the photosphere. We conclude that the nonlinear Alfvén waves are the promising origin of coronal heating and spicules.

MHD WAVE PROPAGATION INTO THE LOWER ATMOSPHERE

M.S. Marsh, J. Ireland, T. Kucera

NASA-GSFC, Code 671, Building 21, Greenbelt MD 20771, USA.

Magneto-hydrodynamic wave modes propagating from the solar photosphere into the corona have the potential to be exploited as an observational tool in an analogous way to the use of acoustic waves in helio/terrestrial seismology. In regions of strong magnetic field photospheric p-modes are thought to undergo mode conversion to slow magneto-acoustic waves, and that these slow-magnetoacoustic p-modes may be waveguided from the photosphere into the solar corona along the magnetic field. Observations are presented of the propagation of these waves and their channelling into the coronal parts of magnetic loops within active regions. A statistical analysis technique is applied which gives new insights into the coupling and propagation of these waves within the solar atmosphere.

CORRELATIVE STUDY OF FLARES ASSOCIATED WITH SUNQUAKES

Martínez-Oliveros J.C, Donea A.-C and Cally P.S.

Centre for Stellar and Planetary Astrophysics,
School of Mathematical Sciences, Monash University, Victoria 3800,
Australia

Multi-wavelength studies of energetic solar flares with seismic emissions have revealed some interesting common features that may help us to identify the linkage of various signatures from the interior to the outer atmosphere and develop diagnostic techniques to aid in their detection. In our study, we make use of the close relationship between the microwave and the hard X-ray emissions associated with such flares to propose a possible scenario that could explain the observations. We explore the possible relation of this scenario with different mechanisms of energy transport to the photosphere, such us back-warming or direct particle impacts.

MHD MODE CONVERSION IN A STRATIFIED ATMOSPHERE

A.M.D. McDougall[1] and A.W. Hood[1]

[1]*School of Mathematics and Statistics, University of St Andrews, KY16 9SS, UK*

Mode conversion in the region where the sound and Alfvén speeds are equal is a complex process, which has been studied both analytically and numerically and has been seen in observations. In order to further the understanding of this process we set up a simple, one-dimensional model, and examine wave propagation through this system using a combination of analytical and numerical techniques. Simulations are carried out in a gravitationally stratified atmosphere with a uniform, vertical magnetic field for both isothermal and non-isothermal cases. For the non-isothermal case a temperature profile is chosen to mimic the steep temperature gradient encountered at the transition region. In all simulations, a slow wave is driven on the upper boundary, thus propagating down from low-β to high-β plasma across the mode-conversion region. In addition, a detailed analytical study is carried out where we predict the amplitude and phase of the transmitted and converted components of the incident wave as it passes through the mode-conversion region. A comparison of these analytical predictions with the numerical results shows good agreement, giving us confidence in both techniques. This knowledge may be used to help determine wave types observed and give insight into which modes may be involved in coronal heating.

SEISMOLOGY OF OPEN AND CLOSED CORONAL MAGNETIC STRUCTURES

V.M. Nakariakov

Physics Department, University of Warwick, Coventry CV4 7AL, U.K.

Magnetohydrodynamic waves and oscillations are natural tools for the diagnostics of the plasma structures which support them. The review presents current trends in the MHD coronal seismology, its recent achievements and future challenges, covering kink, sausage and longitudinal modes of closed coronal structures, and propagating fast wave trains and longitudinal waves in polar plumes and long loops. The seismological techniques for the estimation of the absolute value of the coronal magnetic field, sub-resolution structuring, density stratification and the possible determination of the coronal heating function are discussed.

ULTRA-FINE STRUCTURE OF A SOLAR PROMINENCE AND DISCOVERY OF ALFVEN WAVE WITH HINODE SOLAR OPTICAL TELESCOPE

Takenori J. Okamoto[1,2], Saku Tsuneta[1], Yukio Katsukawa[1], Kiyoshi Ichimoto[1], Yoshinori Suematsu[1], Toshifumi, Shimizu[3], Shin'ichi Nagata[2], Kazunari Shibata[2], Theodore D. Tarbell[4], Richard A. Shine[4], Tomas E. Berger[4], and Bruce W. Lites[5]

[1]*National Astronomical Observatory of Japan;*
[2]*Kwasan and Hida Observatories, Kyoto University;*
[3]*ISAS/JAXA;*
[4]*Lockheed Martin Solar and Astrophysics Laboratory;*
[5]*High Altitude Observatory*

A solar observation satellite Hinode (Japanese for sun rise) was launched in September 2006. Hinode carried 3 advanced solar telescopes, visible light telescope, EUV imaging spectrometer, and X-ray telescope to simultaneously observe the photosphere, chromosphere, transition region, and corona. In the performance verification phase of the Hinode spacecraft with its telescopes, we observed an active region AR10921 near the west limb of the solar disk on November 9 2006. At this point, we planned to observe spicules on the limb with a broadband filter dedicated to Ca II H line (3968Å). Ca II-H emission line (3968Å) comes from plasma with temperature of approx. 10^4 K, which is much lower than the coronal temperature of 10^{6-7} K. In addition to spectacular spicules, we find a large cloud-like structure located 10,000-20,000 km above the limb. The cloud has a very complex fine structure with dominant horizontal thread-like structure. Some features are moving horizontally and also have clear vertical oscillatory motions. The periods and amplitudes of these oscillations are 130-250 seconds and 200-850 km, respectively. The vertical oscillatory motion sometimes has a coherence length as long as 16,000 km. We conclude that from various observational features this vertical oscillation is a signature of Alfven waves propagating along the horizontal magnetic fields. We will discuss their origin and implications.

THEORETICAL ASPECTS OF PROMINENCE OSCILLATIONS

R. Oliver

Departament de Física, Universitat de les Illes Balears,
07122 Palma de Mallorca, Spain

The theoretical modeling of prominence vibrations has been performed mainly through the analysis of the magnetohydrodynamic normal modes of oscillation of simple equilibrium structures. Research on this topic has concentrated mostly on the oscillatory properties of prominence slabs (i.e. without taking into account the internal thread structure) and prominence fibrils (i.e. introducing some of this inherent internal complexity of prominences, although in a simplified manner). In an attempt to understand the observed strong damping of prominence oscillations, work has also been done on the attenuation of waves in these objects. The achievements in this area are reviewed and some trends for possible future research are given.

WAVE-PARTICLE INTERACTIONS, PLASMA HEATING AND PARTICLE ACCELERATION

Vahe' Petrosian

Center for Space Science and Astrophysics, Stanford University;

There are substantial observational evidence and theoretical arguments supporting the view that during solar flares particles are acceleration stochastically via their interactions with plasma waves or turbulence. Turbulence is expected to be generated in flares during the reconnection process because of the prevailing high ordinary and magnetic Reynolds numbers. Nonlinear processes, such as three wave interactions, cause a cascade of the turbulence to smaller scales till wave-particle interactions become important. The latter interactions damp the turbulence, and heat the plasma or accelerate particles. In recent years there has been a substantial progress in understanding these processes. The observational evidence and theoretical developments will be reviewed and results from comparisons of model predictions with observations will be presented.

PROGRESS IN CORONAL SEISMOLOGY

B. Roberts

Mathematical Institute, University of St Andrews

Coronal seismology is now a well developed area of solar physics, even though many questions remain for resolution. Here we take stock of the progress made since the topic was reviewed in Roberts (2000).

NON-AXISYMMETRIC OSCILLATIONS OF THIN TWISTED MAGNETIC TUBES

M.S. Ruderman

Solar Physics and Space Plasma Research Centre (SP^{2}RC), Department of Applied Mathematics, University of Sheffield

Since transverse oscillations of coronal loops were first observed by TRACE, and subsequently interpreted as fast kink oscillations of magnetic flux tubes, the theory of non-axisymmetric oscillations of magnetic tubes remains among hot topics in solar physics. We study non-axisymmetric oscillations of a thin straight weakly twisted magnetic tube with the density varying in the longitudinal direction. Using asymptotic expansions with the ratio of tube radius to its length as a small parameter, we derived the second order differential equation describing the tube displacement. Together with the zero boundary conditions at the tube ends this equation forms the Sturm-Liouville problem determining the eigenfrequencies and eigenmodes of the tube oscillation. The dependence of the eigenfrequencies on the density stratification and magnetic twist is investigated. The implication of the obtained results on coronal seismology is discussed.

THE HINODE X-RAY TELESCOPE: AN INTRODUCTION AND FIRST RESULTS

A. Savcheva

Harvard-Smithsonian CfA, 60 Garden St., Cambridge, MA, U.S.A. 02138;

The XRT on Hinode is a high spatio-temporal resolution telescope capable of imaging coronal emission from plasmas with temperatures of 0.7 - 20 MK. The Hinode mission offers the unique opportunity to study the coronal magnetic structures and their reconnection in a wide range of coronal topologies. We will discuss in detail observations of Shibata-type reconnection in coronal hole x-ray jets, slip-run reconnection (or QSL reconnection) in active regions, and x-class flares. We will also discuss the connections between these events and the magnetic field evolution. Access to the data is available to the public as of May 27, 2007. We will provide instructions for retreiving and analyzing the data.

DISSIPATION OF STANDING SLOW MAGNETOACOUSTIC WAVES IN HOT CORONAL LOOPS

L. Di G. Sigalotti[1] and C. A. Mendoza-Briceño[2]

[1]*Instituto Venezolano de Investigaciones Científicas (IVIC), Apartado 21827, Caracas 1020A, Venezuela*
[2]*Centro de Física Fundamental (CFF), Facultad de Ciencias, Universidad de Los Andes, Apartado Postal 26, La Hechicera, Mérida 5251, Venezuela*

The damping of standing slow waves in hot ($T > 6$ MK) coronal loops of semicircular shape is revisited in both the linear and nonlinear regimes. Dissipation by thermal conduction, compressive viscosity, radiative cooling, and heating are examined for nonstratified and stratified loops. We find that for typical conditions of hot SUMER loops, thermal conduction determines the periodicity of damped oscillations, while the decay times are determined by compressive viscosity. Damping due to optically thin radiation is negligible. We also find that thermal conduction alone produces a slow decay of the density and velocity waves. Only when compressive viscosity is added do these waves damp out at the same rate of the observed rapidly decaying modes of hot SUMER loop oscillations, contrary to most current belief that have pointed to thermal conduction as the only leading mechanism. We compare the linear predictions with numerical hydrodynamics calculations. Under the effects of gravity nonlinear viscous dissipation leads to a reduction of the decay time compared to the homogeneous case. This is one major difference with the linear prediction that the damping rates are barely affected by gravity.

THE EFFECT OF THE SOLAR CORONA ON THE ATTENUATION OF NON-ADIABATIC PROMINENCE OSCILLATIONS

R. Soler, R. Oliver and J. L. Ballester

Departament de Física, Universitat de les Illes Balears
E-07122, Palma de Mallorca (Spain)

One of the typical features shown by observations of solar prominence oscillations is that they are damped in time and that the values of the damping times are usually between one and three times the corresponding oscillatory period. However, the mechanism responsible for the attenuation and the influence of the external coronal medium are still not well-known. Here, we assume non-adiabatic effects (thermal conduction, radiation losses and heating) as damping mechanisms and their role on the attenuation of oscillations is evaluated. We consider an equilibrium made of a prominence plasma slab embedded in a coronal medium and take into account two possible orientations of the magnetic field, parallel and transverse to the slab axis. We find that non-adiabatic effects are efficient damping mechanisms for magnetoacoustic modes, but their importance and the influence of the corona are different for each solution. In the range of observed wavelengths of prominence oscillations, radiation from the prominence plasma is responsible for the damping of internal modes, coronal conduction dominates the attenuation of external modes, and the combined effect of both mechanisms governs the damping of hybrid and global modes.

INTERNAL GRAVITY WAVES AND THEIR ROLE IN THE ENERGETICS OF THE SOLAR ATMOSPHERE

Th. Straus[1], B. Fleck[2], S. Jefferies[3], S. McIntosh[4], G. Severino[1], and M. Steffen[5]

[1]*INAF / Osservatorio Astronomico di Capodimonte, Napoli, Italy;*
[2]*ESA, Research and Scientific Support Department, NASA/GSFC, Greenbelt, MD USA;*
[3]*Institute for Astronomy, University of Hawaii, Kula, HI USA;*
[4]*Southwest Research Institute, Boulder, CO USA;*
[5]*Astrophysikalisches Institut, Potsdam, Germany*

We revisit the dynamics and energetics of the solar atmosphere with the help of 3D numerical simulations of the overshoot region of compressible convection into the stable photosphere. We demonstrate the presence of internal gravity waves and estimate their contribution to the energy balance in the photosphere and low chromosphere. Internal gravity waves are found to be the dominant phenomenon in the quiet middle/upper photosphere at low frequencies ($< 2.5\,\mathrm{mHz}$) and to transport a significant amount of mechanical energy into the atmosphere outweighing the contribution of high-frequency ($> 5\,\mathrm{mHz}$) acoustic waves. We compare our results with observations.

EVOLUTION OF ALFVÉN WAVE-DRIVEN SOLAR WINDS TO RED GIANTS

Takeru K. Suzuki

School of Arts & Sciences, University of Tokyo, Komaba, Meguro, Tokyo, Japan

By performing global 1D MHD simulations with radiative cooling and thermal conduction from the photosphere to 30-60 stellar radii, we investigate the heating and acceleration of solar and stellar winds.

First, we show the result of the coronal heating and the solar wind acceleration in the open magnetic field regions. We impose transverse photospheric motions with velocity $\langle dv_\perp \rangle \approx 1$km/s and period between 20 seconds and 30 minutes, which generate outgoing Alfvén waves. We have found that the dissipation of Alfvén waves through compressive wave generation by decay instability is quite effective owing to the density stratification, which leads to the sufficient heating and acceleration of the coronal plasma (Suzuki & Inutsuka 2005, ApJL, 632, L49; 2006, JGR, 111, A06101). Next, we study the evolution of stellar winds from main sequence to red giant phases. When the stellar radius becomes ≈ 10 times of the Sun, the steady hot corona with temperature, $T \approx 10^6$ K, suddenly disappears. Instead, many hot and warm ($10^5 - 10^6$ K) bubbles are formed in cool ($T \leq 2 \times 10^4$ K) chromospheric winds because of the thermal instability of the radiative cooling function; the red giant wind is not a steady stream but structured outflow. Also, the wind velocity is much smaller than the surface escape speed, because the wind starts to be accelerated from several stellar radii (Suzuki 2007, ApJ, 659, 1592).

PROPAGATING LONGITUDINAL WAVES OVER SUNSPOTS, OBSERVED IN MICROWAVE AND EUV

R. A. Sych[1] **and V. M. Nakariakov**[2]

[1]*Institute of Solar-Terrestrial Physics, 126, Lermontov St., Irkutsk, Russia;*
[2]*Physics Department, University of Warwick, Coventry CV4 7AL, UK*

Compressible perturbations with the period of about 3 min, observed over the isolated sunspot NOAA 0756 on the 1st to the 4th of May, 2005 are studied in the 17 GHz microwave band with the Nobeyama Radioheliograph and in 171Å pass band of TRACE. The global wavelet spectra of the signals demonstrated the presence of a high-quality peak at about 3 min. This spectral peak remains detected during all the observation in both microwave and EUV observational channels. The fine spatial, temporal and phase structure of the oscillation was determined with the Pixelised Wavelet Filtering method. It was found that the 3 min oscillations are situated in two sources which are spatially separated with respect to the central part of the sunspot. The sources coincide with the footpoints of extended coronal structures seen in 171Å, and confirmed by the potential extrapolation of photospheric magnetic sources. The projected speed of the compressible disturbances is estimated as 70 km/s, which is consistent with the expected speed of the slow magnetoacoustic (longitudinal) waves in the EUV coronal structures. The EUV and microwave disturbances are found to propagate in the same direction, along the magnetic field lines upwards to the corona, possibly along large coronal loops. Also, we found a good spatial and time correlation of the 3 min disturbances at the chromospheric and coronal levels, observed in the microwave and EUV channels, respectively.

INTEGRATED APPROACH TO THE CORONAL HEATING PROBLEM

Y. Taroyan

Solar Physics and Space Plasma Research Centre (SP^{2}RC), University of Sheffield

Solving the coronal heating problem involves dealing with a number of steps. Each of these steps poses its unique challenges to theoreticians and observers. It is important to treat the problem in an integrated manner, whereby each component of the problem is treated in its relationship to the other parts rather than in isolation. I will review some of the most recent developments in the field with an emphasis on forward modelling and inversion which provide the necessary interaction between theories and observations.

ON THE PROPERTIES OF MAGNETOHYDRODYNAMIC WAVES IN CURVED CORONAL FIELDS

J. Terradas[1,2], J. Andries[2], M. Goossens[2], R. Oliver[1] and J. L. Ballester[1]

[1] *Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain;*
[2] *Centrum voor Plasma-Astrofysica, KULeuven, B-3001 Leuven, Belgium*

The main aim of this work is to study the combined effect of the magnetic field curvature and line-tying of the properties of magnetohydrodynamic waves in the solar corona. The time-dependent problem of the propagation of the three types of waves, fast, slow and Alfvén, is investigated using a simple potential coronal arcade model. We show the details of the propagation of these waves, and how standing slow and Alfvén waves are eventually formed in the curved configuration. The effect of the coupling between the three waves due to the geometry is also analysed.

ROSSBY WAVES IN SOLAR INTERIOR AND FORMATION OF LARGE-SCALE NON-AXISYMMETRIC CONVECTIVE STRUCTURES

E. Tikhomolov

TRIUMF, Canada's National Laboratory for Nuclear and Particle Physics

Generation of stellar and solar magnetic fields is effected by large-scale non-axisymmetric flows such as Rossby waves. Numerical simulations of such flows can provide information for application of helioseismic methods for their identification. We present numerical simulations which show the evolution of Rossby waves and their interaction with convection. The result of this interaction is large-scale convective patterns, that can be the sources of such phenomena as active longitudes and complexes of activity.

A MINIMAL MODEL OF PARALLEL ELECTRIC FIELD GENERATION IN TRANSVERSELY INHOMOGENEOUS SOLAR CORONAL PLASMAS

David Tsiklauri

Institute for Materials Research, Newton Building, University of Salford, Manchester, M5 4WT, United Kingdom

Particle acceleration during solar flares and acceleration of fast solar wind are likely to be related to the parallel electric fields in solar corona. The generation these parallel electric fields by the propagation of ion cyclotron waves in the plasma with a transverse density inhomogeneity was studied. Using two-fluid, cold plasma linearised equations, it was shown for the first time that, in this particular context, $E_{\parallel}$ generation can be understood by an analytic equation that couples $E_{\parallel}$ to the transverse electric field of the driving ion cyclotron wave. It was proven that the minimal model required to reproduce the previous kinetic simulation results of $E_{\parallel}$ generation (Tsiklauri et al 2005, Génot et al 2004) is the two-fluid, cold plasma approximation in the linear regime. By considering numerical solutions it was also shown that the cause of $E_{\parallel}$ generation is the charge separation induced by the transverse density inhomogeneity. In this simplified model, the generated $E_{\parallel}$ amplitude e.g. for plausible solar coronal parameters attains values of 10^4 Vm^{-1}. Interestingly, because of the oscillatory nature of obtained $E_{\parallel}$, it can possibly act as yet another mechanism for interpreting the peculiar hard x-ray (> 25 keV) solar flare, which is believed to be produced by a non-thermal electron beam (Ofman and Sui, 2006, Nakariakov et al.,2006).

INITIAL RESULTS FROM HINODE

S. Tsuneta

NAOJ

Hinode was launched on 2006 September, and carried the solar optical telescope (SOT), the X-ray telescope (XRT), and the EUV imaging spectrometer (EIS), and has been working properly until now. SOT provides us with photometric and magnetic images with unprecedented high resolution, while XRT has high spatial resolution with wide field of view to track both the global and local evolution. XRT is unique as compared with other EUV telescopes such as TRACE and SDO in its wide temperatures sensitivity. EIS can produce the Doppler and turbulence maps with very high sensitivity (a few percent of coronal Alfvén speed). SOT observes emergence, transport, and disappearance of solar magnetic fields in various forms, while XRT and EIS simultaneously observe dissipation part of the magnetic life cycle. Hinode has been producing extremely interesting results, including detection of waves in various forms. Indeed, SOT detects signature of Alfvén waves and magnetic fluctuations in the photometric and polarimetric data, and EIS detects line broadening around the footpoints of coronal loops. Overview on the initial results from Hinode is presented with emphasis on waves.

CORONAL LOOP SEISMOLOGY USING MULTIPLE TRANSVERSE LOOP OSCILLATION HARMONICS

T. Van Doorsselaere, V. M. Nakariakov and E. Verwichte

Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

TRACE observations (23/11/1998 06:35:57-06:48:43UT) of an active region are studied. In this active region, coronal loop oscillations are observed after a violent disruption of the equilibrium. To investigate the oscillations, a loop segment is traced during the oscillation, and the resulting time series is analysed for periodicities.

In the considered loop segment, two periods are found: $435.6 \pm 4.5\,\mathrm{s}$ and $242.7 \pm 6.4\,\mathrm{s}$, consistent with the periods of the fundamental and 2nd harmonic fast kink oscillation. The small uncertainties allow us to estimate the density scale height in the loop to be 109 Mm, which is double the hydrostatical value of 50 Mm.

Because a loop segment is traced, the amplitude dependence along the loop is found for each of these oscillations. The obtained spatial information is used as a seismological tool to give details about the geometry of the observed loop.

MAGNETIC RECONNECTION AND CORONAL HEATING

G.Vekstein

School of Physics and Astronomy, The University of Manchester, UK

The present review addresses two closely related issues: the process of magnetic reconnection and the mechanism of solar coronal heating. Thus, we will discuss firstly how the Hall effect, which originates from the two-fluid (electrons and ions) description of a plasma, can increase the rate of magnetic reconnection well above the rate predicted by the standard single-fluid MHD, and its possible implications to the solar coronal activity. As far as the coronal heating is concerned, all advances, both observational and theoretical, strongly support the nanoflare heating scenario, when hot coronae of the Sun and other magnetically active stars are formed by numerous small-scale reconnection events. Here we will report recent studies aiming to probe properties of nanoflares by analyzing variability of the coronal X-ray and EUV emission observed with Yohkoh/SXT and TRACE . A future progress envisaged with the Solar-B (Hinode) mission will be also discussed.

SPATIAL MAGNETO-SEISMOLOGY OF THE SOLAR CORONA

G. Verth and R. Erdélyi

Solar Physics & Space Plasma Research Centre (SP^{2}RC), University of Sheffield, Hicks Building, Hounsfield Road, Sheffield, S3 7RH, England (UK)

The extreme-ultraviolet (EUV) imagers onboard the planned Solar Dynamics Observatory (SDO) and Solar Orbiter (SO) will offer the best chance yet using observations of post-flare loop oscillations to probe the fine structure of the corona. Recently developed MHD wave theory has shown that the properties of loop oscillations depend on their fine structure, e.g., magnetic and density stratification. Up to this point, many studies of coronal loop oscillations have concentrated solely in the frequency domain. With the advent of fast time cadence, high resolution 2D EUV images, the spatial properties of loop oscillations can be explored in more detail. We illustrate how the amplitude profile of loop oscillations depends on their fine structure and how this can be used to determine the fundamental palsma parameters of the corona.

SMALL-SCALE STRUCTURE, DYNAMICS, AND HEATING OF THE LOWER SOLAR ATMOSPHERE

S. Wedemeyer-Böhm

Institute of Theoretical Astrophysics, University of Oslo, Norway

The chromosphere of the quiet Sun is a highly intermittent and dynamic phenomenon. Three-dimensional radiation (magneto-)hydrodynamic simulations with CO5BOLD exhibit a mesh-like pattern of hot shock fronts and cool expanding post-shock regions. The pattern is produced by propagating shock waves, which are excited at the top of the convection zone and in the photospheric overshoot layer. The magnetic field is much more homogeneous in the model chromosphere than in the layers below but evolves much faster. The surface of plasma beta unity – on average at a height of 1000 km – separates two dynamically distinct domains where different wave modes prevail. Waves are of large interest with regard to the chromospheric heating mechanism, in particular after the possible heating by dissipation of acoustic waves became challenged by observations with TRACE. A contrary conclusion is derived via synthetic intensity image sequences for the numerical models discussed here. They provide an acoustic energy flux sufficient for heating the solar chromosphere, while a significant heating contribution might remain undetected due to the limited spatial resolution of available instruments. High-resolution observations – e.g. with the future ALMA – thus are badly needed for thorough comparisons with the present models and thus must be regarded the key to a comprehensive understanding of the wave nature of the solar chromosphere.

DYNAMO WAVES IN INTERFACE SOLAR DYNAMOS

Keke Zhang

Center for Geophysical and Astrophysical Fluid Dynamics and Department of Mathematical Sciences, University of Exeter, EX4 4QE, UK;

Recent studies suggest that the solar tachocline, a highly differentially rotating transition zone between the convection envelope and radiative core of the Sun, is the key region for generating large-scale solar magnetic activities. Moreover, the solar dynamo is believed to be of alpha-omega type in which a strong toroidal field is primarily produced by the differential rotation within the tachocline while the small-scale turbulence generates a weak poloidal field. We have employed a three-dimensional, finite-element spherical model to investigate the solar interface dynamo without the assumption of the axial symmetry in spherical model. It is shown that non-axisymmetric dynamo waves similar to that observed in the Sun can be produced by the fully three-dimensional, nonlinear, time-dependent interface solar dynamo.

THE CORRELATION OF LATITUDINAL DISTRIBUTIONS OF SUNSPOT AREAS AND MAGNETIC FIELDS WITH THE BACKGROUND SOLAR MAGNETIC FIELD IN THE CYCLE 23 AND ITS EFFECT ON THE SOLAR DYNAMO

S.I.Zharkov [1], E.Gavryseva[2] and V.V.Zharkova[3]

[1] *Department of Applied Mathematics, University of Sheffield, Sheffield, UK; s.zharkov@sheffield.ac.uk*
[2] *Arcetri Observatory/ University of Florence, Florence, Italy*
[3] *Department of Computing and Mathematics, University of Bradford, Bradford, UK*

The latitudinal distributions of sunspor areas during the cycle (a butterfly diagram) and their resulting (excess) magnetic fields closely correlate with the solar magnetic field in their migration during the cycle from higher latitudes of $35-40°$ towards the equator. The residuals of the sunspot areas averaged over 1 year minus those averaged over 4 years revealed a well defined priodicity of 2-2.5 years that is similar to the period of the North-South asymmetry in sunspot area and active region areas. During the whole period of observations the sunspot areas for the near-equator latitudes are cross-correlated with the WSO Solar Magnetic Field (SMF) that reveal a strong positive correlation around a zero time lag plus minus 2 years. The correlation coefficients are distributed into the four zones reflecting the sunspot migration directions: the two polar zones above $\pm 45°$ with the positive correlation increasing towards the poles (the sunspot migration towards the poles) and the two equatorial zones from $-40°$ to $+40°$ with the positive correlation increasing toward the equator (the butterfly diagrams). These correlations are likely to reflect the modulating effect of the symmetric component of the SMF on the flux tube emergence in the 'royal zone that, in turn, suggests the magnetic field in sunspots to be a derivative of the global SMF generated by the solar dynamo.

ON THE ORIGIN OF HELIOSEISMIC RESPONSES ASSOCIATED WITH FLARES

V.V.Zharkova [1] and S.I. Zharkov[2]

[1]*Department of Computing and Mathematics, University of Bradford, Bradford, UK;v.v.zharkova@brad.ac.uk*
[2]*Department of Applied Mathematics, University of Sheffield, Sheffield, UK; s.zharkov@sheffield.ac.uk*

We present a comparative study of the momenta and start times measured from the TD diagrams and local hollography methods for solar quakes for a few different flares with those delivered to the photosphere by the hydrodynamic shocks caused by different kinds of high energy particles. The particle parameters are deduced from hard X-ray and γ-ray emission. The resulting hydrodynamics by energetic protons is shown to deliver momentum high enough and to form the hydrodynamic shocks deeply in a flaring atmosphere. These shocks are found capable of delivering the measured momenta to the photosphere through much shorter distances and times then those by pure energetic electrons. We also explore the non-thermal ionization of the ambient plasma by high energy particles and its effect on Ni line 6768$\mathring{A}$ variations during these flares. This joint hydro-radiative approach allows to understand the observational results for solar quakes obtained simultaneously by the time-distance diagram and hollography techniques.