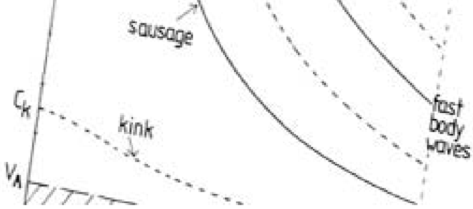

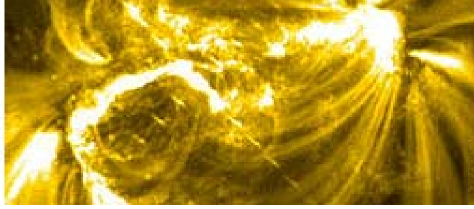
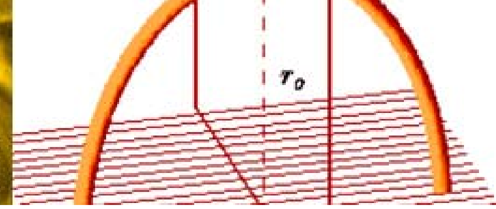

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Scientific Programme and Abstract Booklet

School of Mathematics and Statistics, St Andrews University, 9-11 June 2010

BUKS 2010 Scientific Programme

Wednesday 9 June

9.00 - 9.15 Registration
9.15 - 9.30 Welcome (B. Roberts)

Session chair: A Hood
9.30 - 9.50 Impulsively generated wave trains in a solar coronal loop (P. Jelinek)
9.50 - 10.10 Van Doorsselaere et al: The first measurements of the effective adiabatic index in the corona gives surprising results (T. van Doorsselaere)
10.10 - 10.30 Overdriven coronal loops by global EIT waves (I. Ballai)
10.30 - 11.10 Coffee break and poster session (Room 1A)

Session chair: J. L. Ballester
11.10 - 11-30 Arregui etal: Damping of transverse kink waves in two-dimensional non-uniform threads (I. Arregui)
11.30 - 11.50 Persistency of long period oscillations in sunspots (N. Chorley)
11.50 - 12.10 Large amplitude transverse oscillations in a multi-stranded EUV prominence, triggered by transient disturbances (J. Harris)
12.10 - 12.30 Damping of kink oscillations in partially ionized prominence fine structures (R. Soler)
12.30 - 14.00 Lunch in New Hall

Session chair: I. De Moortel
14.00 - 14.45 [Solicited review] Observations of the solar corona: first results from SDO/AIA (L. Golub)
14.45 - 15.05 Application to torsional Alfven waves (R. Erdelyi)
15.05 - 15.25 Coronal active region loop oscillations with background flow (L. Ofman)
15.25 - 16.00 Coffee break and poster session (Room 1A)
16.00 - 16.20 Exploiting the coronal slow mode (M. Marsh)
16.20 - 16.40 Effects of thermal conduction and compressive viscosity on the period ratio of the slow mode (C. Macnamara)
16.40 - 17.40 Discussion/summary (Chairs AWH, IDM, JLB)

Thursday 10 June

Session chair: M. Ruderman
9.00 - 9.45 [Solicited review] (I. Mann)

9.45 - 10.05 Al-ghafri et al: Damping of magneto-acoustic oscillations in a hot and dynamic coronal plasma (A. Al-ghafri)
10.05 - 10.25 Phase mixing of non-linear Alfven waves (J. McLaughlin)
10.25 - 10.45 Alfven phase mixing and damping in the ion-cyclotron range of frequencies (J. Threlfall)
10.45 - 11.25 Coffee break and poster session (Room 1A)
11.25 - 11.45 Alfvenic vortex shedding in compressible plasmas (M. Gruszecki)
11.45 - 12.05 Long wavelength torsional modes of solar coronal plasma structures (S. Vasheghani Farahani)
12.05 - 12.25 Magnetoseismology of the chromosphere with torsional Alfven waves (G. Verth)
12.25 - 14.00 Lunch in New Hall

Session chair: V. Nakariakov
14.00 - 14.20 A variational principle for linear MHD normal modes in stationart equilibria (J. Andries)
14.20 - 14.40 Quasi-periodic propagating signatures in the corona: waves or flows? (S. McIntosh)
14.40 - 15.00 Mode coupling in the lower solar atmosphere (D. Jess)
15.00 - 15.20 Chromospheric large scale Ca jet as evidence of propagation waves at multiple null point reconnection (cancelled)
15.20 - 16.00 Coffee break and poster session (Room 1A)
16.00 - 16.20 Magnetic Rossby waves and Rieger-type periodicities in the solar activity (T. Zaqarashvili)
16.20 - 16.40 From large-scale loops to the sites of dense flaring loops: preferential conditions for long period pulsations in solar flares (C. Foullon)
16.40 - 17.40 Discussion/summary (Chairs VN MR BR)

Friday 11 June

Session chair: R. Erdelyi
9.00 - 9.20 Spatial seismology of a large coronal loop arcade from TRACE & EIT observations of its transverse oscillations (E. Verwichte)
9.20 - 9.40 Kink oscillations of coronal loops (A. Scott)
9.40 - 10.00 Transverse oscillations in multi-stranded coronal loops (M. Luna)
10.00 - 10.20 The effect of density stratification on the transverse oscillations of two parallel coronal loops (D. Robertson)
10.20 -10.40 Selective spatial damping on propagating coronal kink waves due to resonant absorption (J. Terradas)
10.40 - 11.20 Coffee break and poster session (Room 1A)
11.20 - 11.40 Coupled Alfven and kink oscillations in an inhomogeneous corona (D. Pascoe)
11.40 - 12.00 Temporal evolution of linear fast and Alfven MHD waves in a solar coronal loop (S. Rial)
12.00 - 12.40 Overall summary and general discussion (Chairs RO RE MG)
12.40 - Lunch and end of meeting

Posters

1- Time damping of non-adiabatic MHD waves in a partially ionised prominence plasma: The effect of material flows
J. L. Ballester
2- The spatial damping of magnetohydrodynamic waves in a flowing partially ionised prominence plasma.
Carbonell, M. ; Forteza, P. ; Oliver, R. ; Ballester, J. L.
3- Prominence thread seismology using the P1/2P2 ratio
Antonio J. Diaz, Ramon Oliver, Jose L. Ballester
4- 3D numerical simulations of MHD waves (torsional Alfven waves)
V. Fedun, R. Erdelyi
5- Independent signals from the influence of internal magnetic layers on the frequencies of solar p-modes
C. Foullon, V. Nakariakov
6- On the Multi-spacecraft Determination of Periodic Surface Wave Phase Speeds and Wavelengths
C. Foullon, C.J. Farrugia, A.N. Fazakerley, C.J. Owen, F.T. Gratton and R.B. Torbert
7- Damping of slow MHD coronal loop oscillations by shocks
M. Haynes, T.D. Arber, C.S. Brady
8- The Period Ratio for the Fast Kink Mode with an Epstein Density Profile
C. Macnamara, B. Roberts
9- Early Observations With CoMP
Scott W. McIntosh, Steven Tomczyk, The HAO/CoMP Team & Bart De Pontieu
10- Quasi-periodic pulsations in the gamma-ray emission of a solar flare
Nakariakov, V.M., Foullon, C., Myagkova, I.N., Inglis, A.R.
11- Symmetry breaking in 3D Active Region - why are vertical kink osillations observed so rarely?
Mag Selwa, Sami K. Solanki, Leon Ofman
12- Solar photospheric vortices
S. Shelyag, M. Mathioudakis, F.P. Keenan
13- Fine spatial structure of three-minute oscillation sources above sunspots
Sych, R., Anfinogentov, S., Nakariakov, V.M., Shibasaki, K.
14- Long-Duration Observation of Propagating Slow Magnetoacoustic Waves
Ding Yuan, Valery Nakariakov and Claire Foullon

Chromospheric Large Scale Ca Jet as Evidence of Propagation waves at Multiple Null Points Reconnection

Tavabi,E.; Koutchmy,S.; Ajabshirizadeh,A.

Abstract

We presented Hinode SOT observations that include high-resolution HCaII and Hα lines images of solar limb chromosphere in a first test to study how cool dynamics jets are driven by multiple nulls and the transversal wave generation. We have also provided evidence for these jet transversal motions across the spine. We know that the azimuthally symmetric (m=0) modes are the only modes associated with topological reconnection and it is shown that reconnection can only occur in the case of purely radial disturbances and allows a finite current parallel to the spine at the neutral point. Indeed, the separator lies in the fan plane of each null between nulls when the perturbation is applied to one of the nullpoints in double null the situation changes. From theoretical point of view the nature of fast magnetoacoustic or Alfven wave propagation in the neighborhood of two nullpoints have been investigated in more detail by several authors. To our knowledge, the propagation of MHD waves in jets have never been seen in coronal hole x-ray jet, for this hot event only we see the sling-shot motion of spine axis during their evolution. Also our amplitude spectrum analysis show a clear transversal wave propagation inside the jet with a phase speed about of 30 to 40 km/s which comparable to the speed of Alfven wave in low chromosphere. So our results confirm with theoretical predictions very well.

Damping of magneto-acoustic oscillations in a hot and dynamic coronal plasma

K. S. Al-ghafri, R.J. Morton and R. Erdelyi

Abstract

In this paper, we investigate the propagation of MHD waves in a homogenous magnetized plasma in a weakly stratified atmosphere, representing hot coronal loops, where the the background plasma cools during the propagation of the magneto-acoustic wave. In this model the background pressure is allowed to change as a function of time due to thermal conduction causing the cooling. The ubiquitous magnetic field is assumed to be uniform and pointing in the vertical (z) direction. The background plasma is assumed to be cooling on a time scale comparable to the characteristic period of the perturbations. Our aim is to investigate the influence of the cooling of the background plasma on slow waves. We argue that the plasma cooling may be accountable for the damping of the MHD waves. The dispersion relation which describes the properties of the magneto-acoustic MHD waves is derived by using the WKB theory. The amplitude of waves are found by taking first order equation and solved analytically. The method of characteristics is used to find an approximate solution. Numerical calculations are applied to obtain insight into the behavior of the MHD waves in a system with variable background. The result shows that there is a heavy damping of MHD waves that can be linked to the widely observed damping of hot coronal loop oscillations.

A variational principle for linear MHD normal modes in stationary equilibria

Jesse Andries

Abstract

The theoretical foundation of the study of linear MHD waves and instabilities in stationary equilibria, is much less developed than it's counterpart in static equilibria. Goedbloed (2009), recently devised a method to construct the full eigenfrequency spectrum for linear MHD oscillations on a stationary background. The method is based on quadratic forms (over the Hilbert space of Lagrangian displacement vectors) and their known (Frieman and Rotenberg, 1960) relation to the eigenfrequencies and exploits the solution of an associated boundary value problem. The method involves two steps. The first step yields paths in the frequency space along which solutions have to be found. A second step is concerned with finding which of the points on the paths effectively represent eigenmodes.

In the present treatment we formulate an alternative method from a purely eigenvalue perspective. It is shown that the eigenfrequency spectrum can be obtained from a variational principle which reduces to the conventional Rayleigh-Ritz principle in absence of any flow (and in the presence of a uniform flow). However, like the method described by Goedbloed (2009), the variational principle follows a two-step scheme. Normal modes are found on paths where at all points (i.e. vectors in the Hilbert space) along the path a restricted variation principle holds where the variation is not taken over all directions in the Hilbert space but restricted to a hyper surface. The stationary points determined by the variation condition thus form a 1-D path through the Hilbert space and normal modes only correspond to certain points along those curves where the solutions are commensurable with a temporal behaviour of normal mode form. The generalised Rayleigh quotient which appears in the variational principle consists of quadratic forms which can comfortably be interpreted in terms of energies. The treatment is finally related to a simple mechanical analogue from classical mechanics (discrete instead of continuous) where a non-holonomic constraint enters in the Lagrange formalism through an undetermined Lagrange multiplier.

Damping of transverse kink waves in two-dimensional non-uniform threads

I. Arregui, R. Oliver, J.L. Ballester

Abstract

We have studied the oscillatory properties of resonantly damped transverse oscillations in two-dimensional filament threads. The fine threads are modeled as cylindrically symmetric magnetic flux tubes with a dense central part with prominence plasma properties and an evacuated part with near coronal plasma properties, both surrounded by coronal plasma. The equilibrium density is thus allowed to vary non-uniformly in both the radial and the longitudinal directions. Periods, damping times and damping rates for transverse kink modes are computed by solving the linear resistive MHD equations. The examined parameters are the length of the thread, the density ratio between the prominence and coronal plasma, the density in the evacuated part of the tube, and the radial and longitudinal non-uniform length scales. Among other results, we find that the ratio of the length of the thread to the length of the tube is a very relevant parameter. This is of particular importance if we notice that observations allow us to measure the length of the thread, the part of the tube filled with cool absorbing material, while the supporting magnetic flux tube is probably much larger and not even observed.

Overdriven coronal loops by coronal global EIT waves

Istvan Ballai

Abstract

Coronal kink oscillations can be understood as the result of the interaction of an external driver (e.g. coronal global EIT wave) and coronal loops. The investigation of the signature of possible oscillations in a coronal loop depending on the type of the driver (harmonic oscillation, finite lifetime wavetrain, random pulses) reveals that the observed loop frequencies always contain information about the characteristics of the driver. The theoretical results are compared to the observational findings of an oscillating loop occurred on 13 June 1998 and seen by the TRACE/EUV instrument. Standard seismological techniques are used to find the magnetic field inside the loop as well as the degree of internal density structuring. The studied coronal loop is found to have two periods which could be interpreted as belonging to the fundamental and first harmonic but also could reflect the stage of an overdriven loop. The obtained values for the magnetic field are found to be dependent on the scenario employed to explain the periods of oscillations.

Time damping of non-adiabatic MHD waves in a partially ionised prominence plasma: The effect of material flows

J. L. Ballester

Abstract

Solar prominences are partially ionised plasmas displaying flows and oscillations. These oscillations exhibit time damping and have commonly been explained in terms of magnetohydrodynamic (MHD) waves. Here, we study the effect of material flows on the behaviour of the time damping of non-adiabatic MHD waves in a partially ionised plasma with physical properties akin to those of solar prominences. In particular, we focus on the effect of flow on the critical wavenumbers for fast and Alfvén waves, and in the modifications produced by the flow on the period versus damping time for slow waves.

The spatial damping of magnetohydrodynamic waves in a flowing partially ionised prominence plasma.

Carbonell, M. ; Forteza, P. ; Oliver, R. ; Ballester, J. L.

Abstract

Solar prominences are partially ionised plasmas displaying flows and oscillations. These oscillations exhibit time and spatial damping and have commonly been explained in terms of magnetohydrodynamic (MHD) waves. We study the spatial damping of linear non-adiabatic MHD waves in a flowing partially ionised plasma with prominence-like physical properties. We consider single fluid equations for a partially ionised hydrogen plasma by including in the energy equation optically thin radiation, thermal conduction by electrons and neutrals, and heating. By keeping ω real and fixed, we solved the dispersion relations obtained for the complex wavenumber, k, and analysed the behaviour of the damping length, wavelength and the ratio of the damping length to the wavelength, versus period, for Alfvén, fast, slow, and thermal waves. In the presence of a background flow, the results indicate that new strongly damped fast and Alfvén waves appear that depend on the joint action of flow and resistivity. The damping lengths of adiabatic fast and slow waves are strongly affected by partial ionisation, which also modifies the ratio between damping lengths and wavelengths. The behaviour of adiabatic fast waves also resembles that of Alfvén waves. For non-adiabatic slow waves, the unfolding in both wavelength and damping length induced by the flow allows efficient damping to be found for periods compatible with those observed in prominence oscillations. This effect is enhanced when low ionised plasmas are considered. Since flows are ubiquitous in prominences, in the case of non-adiabatic slow waves and within the range of periods of interest for prominence oscillations, the joint effect of both flow and partial ionisation leads to a ratio of damping length to wavelength denoting a very efficient spatial damping. For fast and Alfvén waves, the most efficient damping occurs at very short periods not compatible with those observed in prominence oscillations.

Persistency of long period oscillations in sunspots

N. Chorley, B. Hnat, V. M. Nakariakov, K. Shibasaki

Abstract

Previous work (e.g. Chorley et al. 2010, A&A 513, 27) revealed the presence of long period oscillations (periods of several tens of minutes) in the radio emission above several sunspots observed with the Nobeyama Radioheliograph. Here, we present the analysis of the oscillations above one of those sunspots over the course of 9 days. The long period oscillations are found to be a stable and robust feature of the emission, present in both the brightness temperature and polarisation signals.

To model the persistency of such oscillations, we use a decaying and externally excited nonlinear oscillator and present here preliminary results.

Prominence thread seismology using the P1/2P2 ratio

Antonio J. Diaz, Ramon Oliver, Jose L. Ballester

Abstract

Prominence threads are expected to have inhomogeneities along the magnetic field, and hence, the ratio of the fundamental period and its first overtone $P_1/2P_2$ must differ from one. We investigate the dependence of this ratio on the equilibrium parameters of prominence threads and its possible use as a diagnostic tool for prominence seismology.

Potentials of magneto-seismology of the solar chromosphere: Application to torsional Alfven waves

Erdelyi, R.

Abstract

Inspired by the recent discovery of solar chromospheric torsional Alfven waves by Jess et al. (2009), we present here the application of a novel MHD theory, in the form of combined forward 3-D modelling complemented with analytical studies, to torsional Alfven waves observed by the UK funded ROSA (Rapid Oscillations in the Solar Atmosphere) instrument in solar magnetic bright points (MBPs). MBPs are ubiquitous in the lower solar atmosphere and are ideal candidates to be representative building blocks. Our recently developed theory predicts how the observable properties of MHD waves (e.g., frequency, amplitude and phase speed) are evolving while propagating through realistically stratified magnetic waveguides connecting the solar photosphere to corona.

We show that propagating MHD waves (slow, fast and Alfven) are excited by swirly photospheric motions observed in and around numerous MBPs. We present how torsional Alfven waves, in particular, can be fully exploited as a unique magneto-seismological tool to probe the unresolved plasma structure of the solar atmosphere. We argue that the magneto-seismologic exploitation of torsional Alfven waves offer an unprecedented and real practical mapping of the 3-D magnetic structure of the solar atmosphere. This type of exploitation of torsional Alfven waves may lead us to conclude about such fundamental question as to what extent the solar magnetic field is potential or non-force free.

The magneto-seismologic recipe outlined can be applied to the latest high spatial and temporal resolution data from the much-awaited SDO (Solar Dynamics Observatory) satellite in order to give further insight into solar wave dynamics and MHD waveguide structures.

3D numerical simulations of a MHD waves (torsional Alfven waves)

Viktor Fedun and Robert Erdelyi

Abstract

Recent high-resolution ground-based observations provide clear evidence for the existence of waves and oscillations driven by localised twisting motions at footprints of solar flux tubes. The generated torsional oscillations within flux tubes are associated with Alfven waves. It is of particular interest to understand the excitation and propagation of torsional Alfven waves into the upper, magnetised atmosphere because they can channel considerable photospheric energy into the corona.

Here we examine numerically the direct propagation of such torsional waves, driven at the foot-point of a solar magnetic flux tube, into a three-dimensional magnetised atmosphere representing the solar atmosphere between the photosphere and low corona. The simulations are based on fully compressible ideal magneto-hydrod ynamical modelling. The model solar atmosphere is constructed based on realistic temperature and density stratification derived from VAL IIIF, and are most suitable perhaps for a bright network element or magnetic pore.

We analyse how torsional phosphoric motion can excite Alfven and other types of MHD waves that reach the upper parts of the solar atmosphere. We also give an insight into the energetic implications as far as heating is concerned. Finally, we briefly discuss the observational signatures of these waves.

From large-scale loops to the sites of dense flaring loops: preferential conditions for long-period pulsations in solar flares

C. Foullon, I. Hannah, E. Verwichte, B. Cecconi,
L. Fletcher, V.M. Nakariakov, K.J.H. Phillips, B.L. Tan

Abstract

Long-period quasi-periodic pulsations (QPPs) of solar flares are a class apart from shorter period events. By involving an external resonator, the mechanism they call upon differs from traditional QPP models, but has wider applications. We present a multi-wavelength analysis of spatially-resolved QPPs, with periods around 10 min, observed in the X-ray spectrum primarily at energies between 3 and 25 keV. Complementary observations obtained in Halpha and radio emission in the kHz to GHz frequency range, together with an analysis of the X-ray plasma properties provide a comprehensive picture that is consistent with a dense flaring loop subject to periodic energisation and thermalisation. The QPPs obtained in Halpha and Type III radio bursts, with similar periods as the QPPs in soft X-ray, have the longest periods ever reported for those types of datasets. We also report 1-2 GHz radio emission, concurrent with but unrestricted to the QPP time intervals, which is multi-structured at regularly separated narrowband frequencies and modulated with 18-min periods. This radio emission can be attributed to the presence of multiple 'quiet' large-scale loops in the background corona. Large-scale but shorter inner loops below may act as preferential resonators for the QPPs. The observations support interpretations consistent with both inner and outer loops subject to fast kink magnetohydrodynamic waves. Finally, X-ray imaging indicates the presence of double loop-top sources in the flaring sites, which could be the particular signatures of the magnetically-linked inner loops. We discuss the preferential conditions and the driving mechanisms causing the repeated flaring.

On the Multi-spacecraft Determination of Periodic Surface Wave Phase Speeds and Wavelengths

C. Foullon, C.J. Farrugia, A.N. Fazakerley,
C.J. Owen, F.T. Gratton and R.B. Torbert

Abstract

Observations of surface waves on the magnetopause indicate a wide range of phase velocities and wavelengths. Their multi-spacecraft analysis allows a more precise determination of wave characteristics than ever before and reveal that approximations, which take a predetermined fraction of the magnetosheath speed or the average flow velocity in the boundary layer, can overestimate phase speeds. We show that time-lags between two or more spacecraft can give a qualitative upper estimate, and we confirm the unreliability of flow approximations often used by analysis of a few cases. Using two-point distant magnetic field observations and spectral analysis of the tailward magnetic field component, we propose an alternative method to estimate the wavelength and phase speed at a single spacecraft from a statistical fit at the other site.

Independent Signals from the Influence of Internal Magnetic Layers on the Frequencies of Solar p-modes

C. Foullon and V.M. Nakariakov

Abstract

The discovery that p-mode frequencies of low degree do not follow changes of solar surface activity during the recent solar minimum offers the possibility of a new diagnostic signature of the responsible pressure perturbation in the wave guiding medium, potentially rich of information regarding the structure of the Sun and the cause of the unusually long solar minimum. Magnetic fields, as well as temperature changes, introduce equilibrium pressure deviations that modify the resonant frequencies of p-mode oscillations. Assuming the perturbation to be caused by a horizontal layer of magnetic field located in a plane-stratified model of the Sun, we compile analytical frequency shifts and process them to allow direct comparison with observations. The effect of magnetism itself on the central p-mode frequencies can be neglected in comparison with the thermal effect of a perturbative layer buried in the solar interior. A parametric study shows that a layer as thin as 2100 km at subsurface depths is able to reproduce reported mean anomalous frequency shifts (not correlated with the surface activity), while a layer of size around 4200 km increasing by a small amount at depths near 0.08 Rsun can explain individual low-degree shifts. It is also possible to obtain the mean shifts via the upward motion through depths near 0.03 Rsun of a rising perturbative layer of thickness around 7000 km. Hence, the anomalous frequency shifts are best explained by thermal effects in the upper regions of the convection zone. The effects of latitudinal distribution are not treated here.

Observing the Solar Corona: First Results from SDO

Leon Golub

Abstract

The Solar Dynamics Observatory (SDO) includes a set of telescopes called the Atmospheric Imaging Assembly (AIA). The AIA provides full Sun images of the solar corona in eight different UV and EUV passbands, at a spatial resolution comparable to that of our previous small Explorer satellite, the Transition Region and Coronal Explorer (TRACE). We will present a description of the scientific goals of the mission and early results from this experiment. In keeping with NASA's policy, all of the images from SDO are freely available to the entire scientific community worldwide.

Alfvenic vortex shedding in compressible plasma

M. Gruszecki, V. M. Nakariakov, T. Van Doorsselaere, T. D. Arber

Abstract

Periodic generation of Alfvenic vortices by the interaction of plasma flows with cylindrical obstacles, e.g. line-tying coronal loops is modelled. The model is restricted to the case when the external magnetic field is parallel to the cylinder. It is found that this phenomenon is a robust feature of the interaction in a broad range of plasma parameters: for plasma-beta from 0.025 to 0.5, and for the flow speeds from 0.1 to 0.99 fast magnetoacoustic speeds. The dimensionless parameter, linking the period of vortex shedding, the upstream flow speed and the diameter of the obstacle, the Strouhal number, was found to be about 0.2 for a broad range of parameters.

The density is found to decrease in the vortex centers by about 10clearly visible in the mass density perturbations. In the vortex periphery, the density is enhanced by up to 50-70essentially compressible.

The size of the vortices is about the size of the cylindrical body. The magnetic field at the vortex centre is decreased. The transverse gradients in the magnetic field generate the electric current according to Amper Law. All quantities in the vortex show filamentary structure.

Large amplitude transverse oscillations in a multi-stranded EUV prominence, triggered by transient disturbances

J.M. Harris, C. Foullon, V.M. Nakariakov, E. Verwichte

Abstract

We present the analysis of two successive trains of large amplitude transverse oscillations in an EUV prominence, observed on the North-East limb on 30 July 2005. The oscillatory trains are triggered by transient disturbances produced by two successive flares, which occurred about 11 hours apart in the same remote active region (located just north of the equator, around 500 Mm from the prominence). We use the SOHO/EIT 195 Åimages with a 12 minute cadence to compare oscillatory properties spatially, in different strands of the prominence, and between the two successively excited oscillatory trains. The evolution of the prominence's apparent height above the limb is determined using 304/195 Åimage ratios from SOHO/EIT, and this correction is applied to account for the solar rotation. The various filamentary strands are seen to exhibit different oscillatory behaviour, in terms of their amplitudes, phases and periods. The largest amplitudes, which occur at the prominence apex, are 48 km/s for the first oscillatory train and around 8 km/s for the second, while the period is approximately 100 minutes in both cases. Some strands show decaying oscillations with a decay time of about 4 hours, while oscillations of other strands are decayless and last for six cycles. We discuss how the observations may shed light on the nature of the oscillations and the triggering mechanism.

Damping of slow MHD coronal loop oscillations by shocks

M. Haynes, T.D. Arber, C.S. Brady

Abstract

The damping of slow magnetoacoustic coronal loop oscillations by shock dissipation is investigated. Observations of large amplitude slow mode observations by SUMER show a clear dependency of the damping rate on the oscillation amplitude. Fully nonlinear MHD simulations of slow mode oscillations in the presence of thermal conduction are performed that show that shock dissipation is an important damping mechanism at large amplitudes, which enhances the damping rate by up to 50% above the rate given by thermal conduction alone. A comparison between the numerical simulations and the SUMER observations shows that, although the shock dissipation model can indeed produce an enhanced damping rate that is function of the oscillation amplitude, the found dependency is not as strong as that for the observations, even after considering observational corrections and the inclusion of enhanced linear dissipation.

Impulsively Generated Wave Trains in a Solar Coronal Loop

P. Jelinek, M. Karlicky

Abstract

Impulsively generated fast magnetoacoustic wave trains in a solar coronal loop are numerically studied. The problem is considered as two-dimensional in space and for the description the full set of magnetohydrodynamic (MHD) equations is used. The numerical solution of MHD equations is performed by means of Lax-Wendroff algorithm on uniformly structured mesh. The wavelet analysis of obtained wave trains shows out the typical tadpole shapes, i.e. a narrow tail followed by a broad-band head. In presented contribution we discuss the propagation speed and periods of wave trains as well as the shapes of tadpoles in dependence on the plasma beta parameter. These studies are very important in connection with observations because the tadpole signatures, firstly discovered during the solar eclipse in 1999 by SECIS instrument, were recently recognized also in decimetric type IV radio event by the Ondrejov radiospectrograph.

Mode Coupling in the Lower Solar Atmosphere

D. B. Jess, D. J. Christian, M. Mathioudakis

Abstract

Traditional observations of mode coupling in the solar atmosphere involve the conversion of transverse oscillations into longitudinal motions. We utilize the Rapid Oscillations in the Solar Atmosphere (ROSA) multi-camera imaging system to present high resolution observations of the photosphere and chromosphere. These observations demonstrate signatures of reversed coupling, on spatial scales as small as 350 km (0.5").

Transverse oscillations of multi-stranded coronal loops

M. Luna, J. Terradas, R. Oliver, J. L. Ballester

Abstract

We investigate the transverse oscillations of a line-tied, multi-stranded coronal loop composed of several parallel cylindrical strands. First, the collective fast normal modes of the loop are found with the T-matrix theory. There is a huge quantity of normal modes with very different frequencies and a complex structure of the associated magnetic pressure perturbation and velocity field. The modes can be classified as bottom, middle and top according to their frequencies and spatial structure. Second, the temporal evolution of the velocity and magnetic pressure perturbation after an initial disturbance are analyzed. We find complex motions of the strands. The frequency analysis reveals that these motions are a combination of low and high frequency modes. The complexity of the strand motions produces a strong modulation of the whole tube movement. We conclude that the presumed internal fine structure of a loop influences its transverse oscillations and so its transverse dynamics cannot be properly described by those of an equivalent monolithic loop.

Effects of Thermal Conduction and Compressive Viscosity on the Period Ratio of the Slow Mode

C. Macnamara, B. Roberts

Abstract

The period ratio between the fundamental mode and its first harmonic is a valuable tool for coronal seismology. Recent observations of multi-periodicities in slow modes have found period ratios of 0.77 and 0.92 (Srivastava & Dwivedi 2010). Here we examine the role of damping on the period ratio, in sounds waves in an isothermal atmosphere, considering the effects of thermal conduction and compressive viscosity. The effect of thermal conduction is small producing period ratios of 0.9 or larger. Compressive viscosity may have a more important role, giving smaller period ratios but only in in short hot loops. The combined effects of damping and non-isothermality are likely to be needed if observations are to be understood.

The Period Ratio for the Fast Kink Mode with an Epstein Density Profile

C. Macnamara, B. Roberts

Abstract

The period ratio for fast kink waves has been observationally determined and falls below its ideal value of unity; for example, $P_1/2P_2 = 0.79$ and $P_1/2P_2 = 0.90$ (Verwichte et al. 2004; Van Doorselaere et al., 2007). Theoretical investigations have suggested that longitudinal density structuring plays an important role in reducing the period ratio from unity. McEwan et al. (2006, 2008) have examined a linear profile and an exponential density profile. We consider the Epstein density profile and investigate the period ratio. The difference between the internal and external densities and thus the Alfvén speeds of a loop cause a decrease in the period ratio from unity to a minimum value of $P_1/2P_2 = 1/\sqrt{2}$.

Exploiting the Coronal Slow Mode

M.S. Marsh and R.W. Walsh

Abstract

Observations of the three-dimensional propagation of waves within active region coronal loops and a measurement of the true coronal slow mode speed are obtained using STEREO. Intensity oscillations are observed to propagate outward from the base of a loop system, consistent with the slow magnetoacoustic mode. The wave phase velocity is measured in the observations from the A and B spacecraft. These stereoscopic observations are used to infer the three-dimensional velocity vector of the wave propagation and magnitude of 132 ± 9 km/s, giving the first measurement of the true coronal longitudinal slow mode speed, and an inferred temperature of 0.84 ± 0.12 MK. These results are confirmed using HINODE spectroscopic observations. It is found that the loop has a uniform temperature profile with a mean temperature of 0.89 ± 0.09 MK, in agreement with the temperature determined seismologically using the STEREO observations. The true 3D wave dissipation scale length is also measured which has implications for the dissipation mechanism.

Quasi-periodic Propagating Signatures In The Corona: Waves Or Flows?

Scott W. McIntosh & Bart De Pontieu

Abstract

Since the discovery of quasi-periodic oscillations with periods of order 3-10 minutes in coronal loops with TRACE and EIT (and later with EUVI and EIS), these oscillations have mostly been interpreted as evidence for propagating slow-mode magnetoacoustic waves in a low plasma beta environment. We show that this interpretation is not unique, and that at least for plage-related coronal loops, it may not be the most likely cause for the observed quasi-periodicities. We use Monte Carlo simulations to show that current oscillation detection methods based on wavelet analysis, and wave tracking cannot distinguish the quasi-periodic signals of such waves in coronal imaging timeseries with those caused by the faint signal from upflows at 50-150 km/s that have lifetimes of order 1-2 minutes and that occur randomly in time and occur on granular timescales. Such upflows were recently discovered as blueward line asymmetries with EIS and have been linked to chromospheric, spicular upflows that are rapidly heated to coronal temperatures. We use EIS and SUMER spectra to show that these faint upflows at the footpoints of coronal loops sometimes occur quasi-periodically on timescales of order 5-15 minutes. Finally, we show that recent EIS measurements of intensity and velocity oscillations, that have been interpreted as direct evidence for propagating waves, are fully compatible with a scenario in which faint upflows at high speed occur quasi-periodically. We show evidence from spectral line asymmetry analysis that support this scenario. We suggest that a significant fraction of the quasi-periodicities observed with coronal imagers and spectrographs that have previously been interpreted as propagating magnetoacoustic waves, may instead be caused by these upflows. The uncertainty in the identification of the physical cause for coronal oscillations significantly impacts the prospects of successful coronal seismology using propagating, slow-mode magneto-acoustic waves.

Early Observations With CoMP

Scott W. McIntosh, Steven Tomczyk,
The HAO/CoMP Team & Bart De Pontieu

Abstract

We will present details of the observations made by the HAO Coronal Multi-channel Polarimeter (CoMP) following its recent deployment at the Mauna Loa Solar Observatory. As well as presenting the synoptic data products, measurements, and data access we will discuss monitoring of solar coronal magnetism, its evolution and MHD wave properties with this unique instrumentation.

Phase mixing of non-linear Alfvén waves

J.A. McLaughlin, I. De Moortel, A.W. Hood

Abstract

We consider the behaviour of non-linear, non-ideal Alfvén wave propagation within an inhomogeneous environment in both 1D and 2D and find clear evidence for the ponderomotive effect and visco-resistive heating. The ponderomotive effect generates a longitudinal component to the transverse Alfvén wave with a frequency twice that of the driving frequency. Analytical work shows the addition of resistive heating. This leads to a substantial increase in the local temperature and thus thermal pressure of the plasma, resulting in material being pushed along the magnetic field. Considering Alfvén wave propagation in 2D with an inhomogeneous density gradient, we find that the equilibrium density profile is significantly modified by both the flow of density due to visco-resistive heating and the non-linear response to the localised heating through phase mixing.

Quasi-periodic pulsations in the gamma-ray emission of a solar flare

Nakariakov, V.M., Foullon, C., Myagkova, I.N., Inglis, A.R.

Abstract

Quasi-periodic pulsations (QPP) of gamma-ray emission with a period of about 40 s are found in a single loop X-class solar flare on 2005 January 01 at photon energies up to 2-6 MeV with the SOlar Neutrons and Gamma-rays (SONG) experiment aboard the CORONAS-F mission. The oscillations are also found to be present in the microwave emission detected with the Nobeyama Radioheliograph, and in the hard X-ray and low energy gamma-ray channels of RHESSI. Periodogram and correlation analysis show that the 40-s QPP of microwave, hard X-ray and gamma-ray emission are almost synchronous in all observation bands. Analysis of the spatial structure of hard X-ray and low energy (80-225 keV) gamma-ray QPP with RHESSI reveal synchronous while asymmetric QPP at both footpoints of the flaring loop. The difference between the averaged hard X-ray fluxes coming from the two footpoint sources is found to oscillate with a period of about 13 s for five cycles in the highest emission stage of the flare. The proposed mechanism generating the 40-s QPP is a triggering of magnetic reconnection by a kink oscillation in a nearby loop. The 13 s periodicity could be produced by the second harmonics of the sausage mode of the flaring loop.

Coronal active region loop oscillations with background flow

L. Ofman, J. Schmidt, T.J. Wang

Abstract

Recent coronal loop observations with high resolution instruments such as TRACE, and Hinode indicate that background flow is present in some oscillating coronal loops. We investigate the excitation and damping of such oscillations in coronal loops with background flow by developing 3D MHD model of active loops in realistic magnetic field geometry. The magnetic loops are filled with higher density plasma by the flow initiated at corona/chromospheric boundary. We find that the impuslive inflow can generate all modes of oscillations of the corona loop. The oscillations are damped mainly by leakage of the wave energy outside the loop in the complex magnetic geometry of the active region. We investigate the influence of flow magnitude on the wave excitation and compare the results to observations.

Coupled Alfvn and Kink Oscillations in an Inhomogeneous Corona

D. J. Pascoe, A. N. Wright, and I. De Moortel

Abstract

Observations have revealed ubiquitous transverse velocity perturbation waves propagating outward in the solar corona. To investigate the nature of transverse waves propagating in the solar corona and their potential for use as a coronal diagnostic in MHD seismology, we perform three-dimensional numerical simulations of footpoint-driven transverse waves. We consider the effect of structuring on their propagation and behaviour. When density structuring is present, resonant absorption in inhomogeneous layers leads to the coupling of the kink mode to the Alfvén mode. The decay of the propagating kink wave as energy is transferred to the local Alfvén mode is in good agreement with a modified interpretation of the analysis of Ruderman & Roberts for standing kink modes. Numerical simulations support the most general interpretation of the observed oscillations as a coupling of the kink and Alfvén modes. This coupling may account for the observed predominance of outward wave power in longer coronal loops since the observed damping length is comparable to our estimate based on an assumption of resonant absorption as the damping mechanism.

Temporal evolution of linear fast and Alfvén MHD waves in a solar coronal.

Samuel Rial, Ingo Arregui, Jaume Terradas,
Ramon Oliver, Jose Luis Ballester

Abstract

We investigate the excitation and temporal evolution of impulsively generated perturbations when considering a density enhancement (representing a coronal loop) embedded in potential coronal arcade. The linearised time dependent MHD wave equations have been numerically solved in Cartesian and field related coordinates and the time evolution of the initial perturbations has been studied in the zero-β approximation. As we neglect gas pressure, the slow mode is absent. Several numerical experiments have been performed. First, wave leakage from the loop has been explored in the absence of longitudinal propagation along the coronal arcade. To test the numerical solution comparations with the theoretical frequencies given by normal mode analysis are carried out whenever is possible. Second, the longitudinal propagation of perturbations have been included which gives rise to the coupling between fast and Alfvén waves. Finally we outline the main disadvantages of the Cartesian coordinate system when compared to the flux coordinate system and discuss the numerical results obtained using the two coordinate systems.

The effect of density stratification on the transverse oscillations of two parallel coronal loops

D Robertson, M. S. Ruderman, Y. Taroyan

Abstract

Transverse oscillations of coronal magnetic loops are routinely observed during the space missions. Since the first observation these oscillations were interpreted in terms of kink oscillations of magnetic tubes. Sometimes collective oscillations of two or more coronal loops are observed. This makes the development of a theory of collective oscillations of several loops a desirable one. Another reason for the development of this theory is that there are evidences that at least some coronal loops are not monolithic but consist of many thin magnetic threads. Here the linear theory of kink oscillations of two parallel magnetic tubes with the density varying along the tubes is developed. This system is used to study the effect of density variation on the eigenfrequencies of collective oscillations.

Kink Oscillations of Coronal Loops

A. Scott, M. S. Ruderman

Abstract

Many types of oscillations have been observed on the Sun, including kink oscillations of coronal loops. The simplest model used to investigate these oscillations is a circular magnetic cylinder. Recently more sophisticated models have been used. However, all of them concerned oscillations of planar loops. We have considered a simple three dimensional model of a curved, non-planar loop, with helical geometry. Using the thin tube approximation we have examined the kink oscillations of this loop. In particular, we have found that, depending on the direction from which we observe the loop oscillation, it is possible for the fundamental mode of a helical loop to look like the second harmonic of a planar loop.

Symmetry breaking in 3D Active Region - why are vertical kink osillations observed so rarely?

Mag Selwa, Sami K. Solanki, Leon Ofman

Abstract

We present numerical results of coronal loop oscillation excitation using a three dimensional MHD model of an idealized active region field. The active region is initialized as a potential dipole magnetic configuration with gravitationally stratified density and contains a loop with a higher density than its surroundings. We study different ways of excitation of vertical kink oscillations of this loop by velocity: as an initial condition, and as an impulsive excitation with a pulse of a given position, duration, and amplitude. The position of the pulse varies in the parametric studies. As one would expect, we find that the amplitude of vertical kink oscillations is significantly amplified in comparison to horizontal kink oscillations for exciters located centrally (symmetrically) below the loop for a central (symmetric) loop within the AR. For pulses initiated further from the loop a combination of vertical and horizontal oscillations is excited. The scenario changes significantly when we study an inclined loop (non-symmetric within a dipole field). In this case we do not observe vertical kink oscillations while horizontal ones (transverse to the plane of the loop) can be easily detected. The reason why vertical kink oscillations are so rarely observed is that they require a restrictive set of conditions: pulse located below the apex and the symmetrically located loop within the bunch of field lines connecting two regions of opposite magnetic polarity. We discuss TRACE observations of coronal loops oscillations in view of our findings. We show that examples of pure vertical and horizontal oscillations as well as the combination of these modes observed by TRACE agree with conditions predicted by our simulations.

Solar photospheric vortices

S. Shelyag, M. Mathioudakis, F.P. Keenan

Abstract

Recently observed vortex motions in the solar photosphere may be responsible for the generation of Alfven waves and for energy transport from the solar photosphere to the corona. It is of primary interest to investigate the origins of this vorticity and its connection to the turbulent processes in the photosphere. Using numerical simulations of solar radiative (magneto-)convection, we demonstrate two distinct mechanisms for the generation of photospheric vorticity. Taking into account the non-locality of radiative transport and simulating the parameters of the solar radiation emerging from the model, we investigate the observational signatures of these photospheric vortices.

Damping of kink oscillations in partially ionized prominence fine structures

Roberto Soler, Ramon Oliver, Jose Luis Ballester

Abstract

Transverse oscillations of solar filament and prominence fine structures have been frequently reported. These oscillations have the common features of being of short period (2-10 minutes) and being damped after a few periods. The observations are interpreted as kink magnetohydrodynamic (MHD) wave modes, whereas resonant absorption and ion-neutral collisions are some candidates to be the damping mechanisms. Here, we study both analytically and numerically the time damping of kink MHD modes in a prominence fine structure. First, we consider a 1D model composed of a cylindrical magnetic flux tube filled with homogeneous prominence plasma, representing the fine structure, and embedded in a coronal environment. The cool prominence material is only partially ionized. In addition, we include a transverse inhomogeneous transitional layer between the prominence plasma and the coronal medium, allowing for the resonant damping of the kink mode in the Alfven continuum. We find that the kink mode is efficiently damped by resonant absorption for typical wavelengths of prominence oscillations, the damping time being compatible with the observations. Partial ionization does not affect the process of resonant absorption, and the plasma ionization degree is only relevant for wavelengths much shorter than those observed. Finally, preliminary results considering a 2D model which takes into account the longitudinal plasma inhomogeneity within the fine structure are also discussed.

Fine spatial structure of three-minute oscillation sources above sunspots

Sych, R., Anfinogentov, S., Nakariakov, V.M., Shibasaki, K.

Abstract

Three-minute oscillations of the 17 GHz radio emission observed in the transition region over sunsports with the Nobeyama Radioheliograph are studied. Both antenna correlation curves and sequences of synthesised images are analysed. Oscillations with periods in the range of 2-4 min (with the maximum at about 3 min) are observed to form repetitive oscillation trains, which last typically for 8-20 min. The average duration of the oscillation train is found to be 13 min, and the typical interval between the trains is 30 min. Oscillation trains are non-stationary in the frequency and power: the filling three-minute signals are frequency and amplitude modulated. Wavelet analysis demonstrates that the filling frequency experiences a time drift: inside the oscillation train, the filling frequency can either increase, or decrease, or stay constant. The typical speed of the frequency drift is found to be about 0.4 Hz/min. The frequency drift correlates with the amplitude modulation: the change of the drift direction usually coincides with the beginning or the end of the oscillation trains. It is established that the negative frequency drift occurs more often, 1.7 times more frequently than the positive drift. Analysis of the spatial variation of the oscillations shows that the trains develop along fine structures. Those structures can be associated with waveguides, channeling upwardly propagating slow magnetoacoustic waves. Frequency drifts can be explained in terms of the waveguide curvature, if there are steady flows of matter in the waveguides.

Selective spatial damping on propagating coronal kink waves due to resonant absorption

Terradas, J., Goossens, M., Verth, G.

Abstract

There is observational evidence that propagating kink waves driven by photospheric motions are attenuated as they propagate upwards in the solar corona. In this study, kink MHD waves are studied using a cylindrical model of solar magnetic flux tubes which includes a non-uniform layer at the tube boundary. Assuming that the frequency is real and the longitudinal wavenumber complex, the damping length and damping per wavelength produced by resonant absorption are analytically calculated. The damping length of propagating kink waves due to this mechanism is a monotonically decreasing function of frequency. For kink waves with low frequencies the damping length is exactly inversely proportional to frequency. This dependency means that resonant absorption is selective as it favors low frequency waves and can efficiently remove high frequency waves from a broad band spectrum of kink oscillations. Therefore, the radial inhomogeneity can cause solar waveguides to be a natural low-pass filter for broadband disturbances. Moreover, kink wave trains traveling along coronal loops will have a greater proportion of the high frequency components dissipated lower down in the atmosphere. This could have important consequences with respect to the spatial distribution of wave heating in the solar atmosphere.

Alfvén wave phase-mixing and damping in the ion cyclotron range of frequencies

J. Threlfall, I. De Moortel and K. G. McClements

Abstract

The phase mixing of shear Alfvén waves has been proposed as a mechanism for solar coronal heating [1] and such waves may also play an important role in flare heating and particle acceleration [2]. Any treatment of shear-Alfvén waves with frequencies that are a significant fraction of the ion gyrofrequency must take into account the Hall term in the generalised Ohm's law. We use a numerical scheme, Lare2D, to investigate how the phase-mixing and damping of a shear-Alfvén wave are affected by the inclusion of the Hall term, which splits it into a left-circularly polarised ion cyclotron wave and a right-circularly polarised whistler wave. The presence of a transverse gradient in wave propagation speed causes wave damping to occur via phase-mixing (Heyvaerts and Priest [1]), which can be affected by the dispersive properties of the ion cyclotron and whistler waves. Running Lare2D for the case of a single small amplitude perturbation, we have recovered results obtained by Hood et. al. [3] in the MHD limit and found that these results are only slightly modified by the presence of the Hall term when $k^2 d_i^2 << 1$ where k is wavenumber and d_i is ion skin depth. We are now using the code to model phase mixing in the $k^2 d_i^2 >> 1$ regime.

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The first measurement of the effective adiabatic index in the corona gives surprising results

Tom Van Doorsselaere, Nick Wardle, Giulio Del Zanna,
Kishan Jansari, Erwin Verwichte, Valery Nakariakov

Abstract

We analyse an observation of a 5 minute quasi-periodic oscillation detected in multiple spectral lines with Hinode/EIS, near the foot-point of a coronal loop. There is strong evidence for the interpretation of the observed phenomenon in terms of a propagating slow magneto-acoustic MHD mode. For the first time, we use spectroscopy to detect oscillations in the electron density and temperature, using the CHIANTI atomic database. Comparing the density variations, the Doppler shifts and the electron temperature allows us to derive the line-of-sight component of the phase speed and the effective adiabatic index, using coronal seismology. This is the first measurement of the effective adiabatic index in the solar corona. Surprisingly, it is found to be $\gamma_{\rm eff} = 0.89^{+0.06}_{-0.12}$ strictly smaller than one. This shows that additional terms are important in the energy equation, and have a large contribution in the physics of these oscillations.

Long-wavelength torsional modes of solar coronal plasma structures

S. Vasheghani Farahani, V.M. Nakariakov,
and T. Van Doorsselaere

Abstract

We consider the effects of the magnetic twist and plasma rotation on the propagation of torsional $m = 0$ perturbations of cylindrical plasma structures (straight magnetic flux tubes) in the case when the wavelength is much longer than the cylinder diameter. The second order thin flux tube approximation is used to derive dispersion relations and phase relations in linear long-wavelength axisymmetric magnetohydrodynamic waves in uniformly twisted and rotating plasma structures. Asymptotic dispersion relations linking phase speeds with the plasma parameters are derived. When twist and rotation are both present, the phase speed of torsional waves depends upon the direction of the wave propagation, and also the waves are compressible. The phase relations show that in a torsional wave the density and azimuthal magnetic field perturbations are in phase with the axial magnetic field perturbations and anti-phase with tube cross-section perturbations. In a zero-β non-rotating plasma cylinder confined by the equilibrium twist, the density perturbation is found to be about 66 percent of the amplitude of the twist perturbation in torsional waves.

Magnetoseismology of the chromosphere with torsional Alfven waves

Gary Verth, Marcel Goossens and Robert Erdelyi

Abstract

Inspired by the first discovery of solar chromospheric torsional Alfven waves by Jess et al. (2009), magnetohydrodynamic theory is developed which predicts how the observable properties, e.g., frequency and amplitude, are evolving while propagating through stratified chromospheric waveguides. Furthermore, we discuss the observational signatures of torsional Alfven waves generated by realistic broadband photospheric drivers, from the point of view of both resonance and cut-off frequency. It is found that these incompressible magnetic waves can be fully exploited as a unique magnetoseismological tool to probe the plasma structure of the Sun's lower atmosphere, e.g., offering a real opportunity to map magnetic field of the chromosphere in 3D. The proposed magnetoseismological techniques can be applied to the latest high spatial/temporal data from the Rapid Oscillations in the Solar Atmosphere (ROSA), Hinode and SDO (Solar Dynamics Observatory) instruments.

Spatial seismology of a large coronal loop arcade from TRACE & EIT observations of its transverse oscillations

E. Verwichte, C. Foullon, T. Van Doorsselaere

Abstract

We present a study of transverse loop oscillations in a large coronal loop arcade, using observations from the Transition Region And Coronal Explorer (TRACE) and Extreme-ultraviolet Imaging Telescope (EIT). For the first time we reveal the presence of long-period transverse oscillations with periods between 24 minutes and 3 hours. One loop bundle, with an oscillation period of 40 min., is analysed in detail and its oscillation characteristics are determined in an automated manner. The displacement profile along the whole length of the oscillating loop is determined for the first time and consistently between TRACE and EIT. By comparing the observed profile with models of the three-dimensional geometry of the equilibrium and perturbed loop, we test the effect of longitudinal structuring (spatial seismology) and find that the observations cannot unambigiously distinguish between structuring and non-planarity of the equilibrium loop. Associated intensity variations with a similar periodicity are explained in terms of variations in the line of sight column depth. Also, we report intensity oscillations at the loop foot point, which are in anti-phase with respect to the intensity oscillations in the loop body. Lastly, this observation offers the first opportunity to use the transverse oscillations of the arcade to model the Alfven speed profile as a function of coronal height.

Long-Duration Observation of Propagating Slow Magnetoacoustic Waves

Ding Yuan, Valery Nakariakov and Claire Foullon

Abstract

Transition Region And Coronal Explorer (TRACE) performed long-term observations over active region AR8253, from 30 June to 4 July 1998 in two EUV bandpasses (171Å and 195Å connected with FeIX and FeXII emission, respectively). The cadence was about either 41 s or 30 s for both EUV bandpasses, 195Å images were normaly captured about 11 s later than the 171Å ones. The data contained several gaps, but the observations covered about 70% and 40% of the time interval in the 171Å and 195Å bands, respectively. In the magnetic fan that forms the leading (Western) part of the active region, propagating periodic variations of the EUV intensity are seen clearly in both bands for almost five days. Our analysis shows that the variations are harmonic with very high quality in both bands. The period is estimated as 179 ± 14 s in the 171Å and 183 ± 16 s in the 195Å bands. The periodicity is found to be persistent and not significantly varying during the whole period of the observation. The behaviour of the parameters of the EUV propagating disturbances is studied by various techniques: the frequency variation is measured by applying wavelet and windowed FFT techniques to the time series of selected macro-pixels of size 3×3 pixels; the phase stability is analysed by fitting the narrowband and autocorrelation signals with a sinusoidal function using the robust Levenberg-Marquardt least-squares method. Preliminary results of this study are reported.

Magnetic Rossby waves and Rieger-type periodicities in the solar activity

Zaqarashvili, T.V., Carbonell, M., Oliver, R., Ballester, J.L.

Abstract

Apart from the 11-year solar cycle, another periodicity around 155-160 days was discovered during solar cycle 21 in high energy solar flares, and its presence in sunspot areas and strong magnetic flux has been also reported. This periodicity has an elusive and enigmatic character, since it usually appears only near the maxima of solar cycles, and seems to be related with a periodic emergence of strong magnetic flux at the solar surface. Therefore, it is probably connected with the tachocline, a thin layer located near the base of the solar convection zone, where strong dynamo magnetic field is stored. We study the dynamics of Rossby waves in the tachocline in the presence of a toroidal magnetic field and latitudinal differential rotation. Our analysis shows that the magnetic Rossby waves are generally unstable and that the growth rates are sensitive to the magnetic field strength and to the latitudinal differential rotation parameters. Variation of the differential rotation and the magnetic field strength throughout the solar cycle enhance the growth rate of a particular harmonic in the upper part of the tachocline around the maximum of the solar cycle. This harmonic is symmetric with respect to the equator and has a period of 155-160 days. A rapid increase of the wave amplitude could give place to a magnetic flux emergence leading to observed periodicities in solar activity indicators related with magnetic flux.