Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM32-01 Room:503 Time:May 2 09:00-09:15

A new instability along toroidal magnetic field in differentially rotating plasmas

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We discuss a new type of instability expected to take place in an accretion disk, which has a differentially rotating plasma threaded by a weak magnetic field, by performing linear eigenvalue analysis. We study the linear stability of a disk with a localized, toroidal magnetic field in the radial direction, which can be expected in an accretion disk during the nonlinear evolution of the magneto-rotational-instabilities (MRI).

The MRI is believed to be a strong source of magneto-hydro-dynamic (MHD) turbulence and the resultant angular momentum transport in the accretion disk, which is required for the gas to accrete onto the central object. Once the MRI grows, the system is chiefly governed by the toroidal and radial magnetic field newly generated by the dynamo action of MRI. Such a configuration allows the Alfven waves to propagate along toroidal direction.

In this talk, we study the linear stability of the Alfven wave in the local Cartesian coordinate, the so-called shearing periodic box, and show that the toroidally propagating Alfven wave can become unstable if its wavelength is larger than the length scale of the localized magnetic field gradient. We investigate our results of the linear eigenvalue analysis by changing the structure of the localized magnetic field, and discuss some properties of the instability with examining the eigenvectors and eigenvalues. It is revealed that this type of instability may also appear in non-rotating plasma, but it is highly suppressed in a rigid body rotating plasma. In addition to the linear analysis, the corresponding nonlinear behavior will also be discussed by using MHD numerical simulations. This instability plays an important role in the plasma transport because it probably couples with the magnetic reconnection occurring in the equatorial plane and then to contributes to the saturation mechanism of the MRI.

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PEM32-02 Room:503 Time:May 2 09:15-09:30

Particle acceleration and angular momentum transport during magnetorotational instability in kinetic accretion disks

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Magneto-rotational instability (MRI) in a gravitational rotating system is known to play an important role on the formation of the astrophysical accretion disk and the angular momentum transport, and the nonlinear time evolution of magneto-rotational instability has been extensively investigated by using MHD simulations so far. The mean free path of plasma, however, is not necessarily smaller than the characteristic scale length for some classes of astrophysical accretion disks, and the collisionless behavior of MRI beyond the MHD approximation needs to be understood. In this talk, we study momentum transport and particle acceleration of the kinetic (collisionless) MRI by focusing on magnetic reconnection. We discuss that a strong pressure anisotropy is associated with the formation of the channel flow, and the anisotropic channel flow can lead to a rapid magnetic reconnection, that can occurs sporadically in three-dimensional system. As a result of the reconnection, non-thermal power law distribution with a hard spectral index p=1-1.5 is quickly formed. We also discuss that the so-called alpha parameter in the standard accretion disk model, which is numerically measured from the Reynolds and Maxwell stresses, can be dramatically enhanced during the nonlinear time evolution of MRI. The kinetic MRI is one of plausible mechanisms to explain much more efficient angular momentum transport and high-energy particle emissions observed from massive black holes such as Sgr A*.

Keywords: Space and astrophyiscal plasmas, accretion disk, particlle acceleration, magnetic reconnection, angular momentum transport

PEM32-03 Room:503 Time:May 2 09:30-09:45

Numerical Simulation of Kinetic Magnetorotational Instability using a new Hybrid Technique

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The evolution of Magnetorotational instability (MRI) is considered to be important in the context of efficient angular momentum transport in the accretion disks in our universe. Conventionally, the nonlinear evolution of MRI is studied under the MHD approximation which assumes the mean free path of the plasma is sufficiently small compared to the actual size of the disk. However some classes of the accretion disks, for example the disk around SgrA∗, are found to be constituted with a collision less plasma and therefore the kinetic effect of the plasma, such as generation and relaxation of the pressure anisotropy, should be taken into account.

For the inclusion of the kinetic plasma effects, hybrid code, which treats ions as particles and electrons as massless charge neutralizing fluid, may provide a robust approach resolving the ion scale physics and integrating over the Keplerian time scale. However in the 2 dimensional simulation of the MRI, it is well known that the system eventually grows to a set of channel flows. In this state, the density of the plasma is found to be extremely low in the region where the magnetic field is enhanced as a result of a strong dynamo effect of the differential rotation of the disk. In this low density, strong magnetic field region, the CFL condition determined by the R-mode wave is found to be severe. Moreover, since the extremely low density region is generated in the channel flow, the division-by-density operation in the conventional hybrid code leads to an unexpected termination of the calculation.

In this study we adopted a new approach of hybrid simulation to a differentially rotating system. In this approach, the finite electron inertia is taken into account which gives a upper bound in the phase velocity of the R-mode wave, providing a reduced CFL condition. In addition, the new approach is almost free from the division-by-density operation and the extremely low density region generated in the channel flow can then be calculated appropriately. With this new code we would like to discuss the nonlinear evolution of the 2 dimensional kinetic MRI.

Keywords: Magnetorotational Instability, Kinetic Plasmas, Accretion disks, Collisionless Plasmas, Hybrid code

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PEM32-04 Room:503 Time:May 2 09:45-10:10

Self-organization and flow in high-beta magnetized plasmas

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The self-organized plasmas with high-beta such as spheromaks have the common features as magnetic reconnection, kinking behavior, particle acceleration and shock wave which are observed in space phenomena. Dynamical process of explosive plasmoid ejection, magnetic field's twisting and reconnection could account for the various phenomena called astrophysical jets, solar coronal loops and Jupiter's zonal flow driven by thermal convection. As for fusion plasmas, to control externally plasma flow or rotation plays an important role on maintaining high-beta confinements with an optimized pressure gradient. It is well known that for example, the H-mode transition in tokamak plasmas is created by inward radial electric field and poloidal shear flow. The diamagnetic configuration like Field Reversed Confinement (FRC) with super high beta, in which ion flows generate currents, is normally analyzed based on two-fluid MHD relaxation model. In helicity-driven system, non-axisymmetric dynamic processes create current due to the dynamo action in the plasmas and relax them toward certain minimum energy equilibria. The non-axisymmetric behavior, which arises from a helical kink instability on the open flux, could be responsible for the formation and sustainment of the configurations by helicity injection [1]. In this conference, we will present recent topics about dynamics and relaxed states relevant to MHD relaxations, plasmoid ejection, dynamo and kinking behavior which are recognized as analogical phenomena in astrophysical and fusion plasmas.

It is possible to replicate astrophysical plasma phenomena in the laboratory because MHD has no intrinsic scale. The governing MHD equations can be expressed in a dimensionless form that is equally applicable to systems having scale lengths with many orders of range. Now, a point is how to produce flexibly plasmoid eruptions like solar flares by taking critical issues of geometry and topology into consideration. We will introduce the magnetized coaxial plasma gun (MCPG) to make it possible to investigate such a bubble burst-like behavior. The MCPG is often used to produce spheromaks with poloidal and toroidal magnetic fields generated by internal current. Historically the spheromak was for the first time produced by Alfven et al. by using the MCPG.

The driven-relaxed configurations with open field lines, as well as closed systems, are described by the force-free equilibrium (Jensen-Chu) equation,$\bigtriangledown \times$B=λB, where λ is the force-free parameter. The nature of the relaxed states in helicity-driven systems is characterized by the strength of the external toroidal field and the value of λ determined by coupling to the MCPG. Note that in the doubly connected helicity-driven system, the flipped spherical torus (ST) state appears in the regime of $\lambda<\lambda$e, where λe is the lowest eigenvalue, so that it could be observed in laboratory experiments. The structural formation of the flipped field configuration incorporates the self-reversal process of the toroidal and poloidal fields. This self-organizing phenomenon may have some analogy to reversal of the dipole field of Earth generated by a dynamo action. It is fundamentally important to elucidate a current-reversal phenomenon occurring in space and laboratory plasmas. We have observed this novel current-reversal phenomenon in our HIST experiment [2, 3]. The most important discovery of this experiment is that spherical torus plasmas tend to self-organize to the flipped states while reversing the direction of the external toroidal field [2, 3]. This experimental finding provides, for the first time, evidence for the existence of the relaxed states which were theoretically predicted.

References

[1] M. Nagata et al., Phys. Rev. Lett. 71, 4342 (1993)
[2] M. Nagata et al., Phys. Rev. Lett. 90, 225001 (2003)
[3] M. Nagata et al., Phys. Plasmas 10, 2932 (2003)

Keywords: plasmoid, spheromak, flow, self-organization, MHD relaxation, dynamo

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PEM32-05 Room:503 Time:May 2 10:10-10:30

Observations of Alfvenic waves in the solar atmosphere

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Coronal heating and the acceleration of the solar wind are unsolved problems in solar physics. The propagation of Alfven waves along magnetic field lines is one of the candidate mechanisms to carry energy to large distances from the surface and heat the coronal plasma. However, such waves had not been observed for years.

The solar physics satellite, Hinode, was launched in 2006, and it opened the door to the world of coronal waves. Hinode observations have directly resolved small-scale transverse oscillations of field lines as a result of Alfven/Alfvenic waves in prominences (Okamoto et al. 2007) and spicules (De Pontieu et al. 2007) which are typical chromospheric features embedded in the corona. These waves had a period of 2-5 minutes (low frequency) and the velocity amplitudes are up to 20 km/s. If we assume these are propagating waves, the waves have enough power to heat the corona. However, since the wavelength of these waves is as long as or longer than the observed structures, it is difficult to resolve the phase difference along the field lines. This means we cannot know whether they are propagating or standing waves.

More recently, we had a challenge to detect "propagating" waves (Okamoto and De Pontieu 2011). In this study, we developed an algorithm to detect spicules and phase difference of waves along them automatically. As a result, upward- and downward-propagating waves as well as standing waves were successfully detected. With statistical analyses, it is found that the behaviour of waves depends on the evolution of spicules, and numerous waves are reflected at the top of spicules. These waves detected in this study are high-frequency ones, and the energy is not larger than that of low-frequency ones. Hence, it is suggested that low-frequency waves are more important for coronal heating.

Finally, oscillations/waves shown here are ubiquitous in the solar atmosphere and "wave hunting" is getting more active after the Hinode launch. In addition, investigation of coronal waves is important for the derivation of physical parameters such as coronal magnetic field strength, which it is difficult to measure in observations. In this talk, I will show these studies with Hinode and introduce a new result with a new satellite "IRIS".

Keywords: Sun, corona, wave, Hinode

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PEM32-06 Room:503 Time:May 2 10:30-10:45

2.5D MHD Simulations of Solar Filament Formation by Condensation

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We investigate the formation mechanism of solar filaments by two-dimensional magnetohydrodynamic (MHD) simulations. Solar filaments are cool dense plasma clouds in the hot tenuous corona. Filaments abruptly erupt with flares, hence, they are the important objects to comprehend the explosive events in the solar atmosphere. On the other hand, their formation mechanism is still unclear as well as the mechanism for eruptions.

Filaments always appear inside the coronal arcade fields, and the cool dense plasma is sustained by the magnetic forces. Observations show that filaments are categorized as normal polarity filaments or inverse polarity filaments. The normal polarity filaments have the same polarity with the surrounding coronal magnetic fields, while the inverse polarity filaments have opposite polarity. One candidate to explain the origin of the cool dense plasma is condensation by the radiative cooling in the corona. The current condensation model can reproduce the normal polarity filaments, but not the inverse polarity filaments. We propose a new condensation model to reproduce the inverse polarity filaments, and demonstrate it by two-dimensional MHD simulations including radiative cooling, thermal conduction along the magnetic field and gravity. Our model starts from the formation of the magnetic flux rope. The relatively dense plasma at the lower corona is trapped inside the flux rope and lifted up to the upper corona. The dense plasma causes imbalance between the radiative cooling and the background heating, while the thermal conduction along the closed field line of the flux rope does not suppress the thermal imbalance. Consequently, the condensation process is triggered and the cool dense plasma is formed. We test two types of heating term (one depends on magnetic pressure and the other depends on density) and two types of formation mechanisms of the flux rope (one is the conversing motion at the footpoints of the coronal arcade field and the other is the interaction between the emerging flux and the coronal arcade field). As a result, the cool dense plasma is formed inside the flux rope in every case. We also show that our model has a possibility to reproduce the density of solar filaments, which is 10 -100 times larger than that of the surrounding corona, qualitatively.

Keywords: solar filament, prominence

PEM32-07 Room:503 Time:May 2 11:00-11:15

Comparative study of Observation and Calculation of Hot Fast Flow above a Solar Flare Arcade

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Solar flares are one of the main forces behind space weather events. However, the mechanism that drives such energetic phenomena is not fully understood. The standard eruptive flare model predicts that magnetic reconnection occurs high in the corona where hot fast flows are created. However, there is not enough observational knowledge of the physical parameters in the reconnection region. The inflow into the reconnection region, the temperature of the plasma in the reconnection region, and the temperatures and densities of the plasma jets predicted by reconnection, have not been quantitatively measured in sufficient. First, we will show a flare that occurred on the west solar limb on 2012 January 27 observed by the Hinode EUV Imaging Spectrometer (EIS) and found that the hot (?30MK) fast (>500 km s?1) component was located above the flare loop and discuss how extent we understand the key-region of solar flare. Second, it is important to answer why the most observation cannot detect the predicted flow or temperature in the reconnection region. One of the reasons why we cannot observe inside the magnetic reconnection region is due to its darkness. Generally we can see the bright cusp-like structure during solar flare, although the reconnection region is faint/blind. One may think that the temperature in the reconnection region is enough higher than that of cusp-like flare loops. Thus the wavelength of emission from reconnection region is different from flare loops. However, this is not entirely true. Magnetic reconnection causes rapid heating. Thus ionization cannot reach to the equilibrium stage. We have calculated the ionization process in the down stream of Petschek type magnetic reconnection. From our result, we can clearly see that plasma cannot reach the ionization equilibrium in the down stream of slow-mode shock. The typical emissions from magnetic reconnection region are FeIXX or FeXX, although the plasma temperature is equal to 40MK. The typical temperature and density of post flare loops are 10 MK and 10ˆ11 /cc, and the dominant emissions from post flare loops are from FeIXX to FeXXIII. Thus the wavelength of emission from reconnection region is not so much different from post flare loops. We will discuss how the emissions from reconnection region looks like by using several ionization calculations of magnetic reconnection.

Keywords: flare, corona, non-equilibrium ionization, sun

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PEM32-08 Room:503 Time:May 2 11:15-11:30

Magnetic Evolutions at Extremely High Latitude Region during Polarity Reversal Observed with Hinode

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The magnetic field in the Sun's polar region is a key ingredient of the solar dynamo mechanism because the polar field strength at a solar minimum has a correlation with solar activity of the following cycle. The evolution processes of the polar field (its polarity reversal and its build-up after the reversal) are thought to be caused by magnetic flux transport due to meridional flow and diffusion by turbulent convection. Nevertheless, our understanding of the meridional flow and diffusion in the polar region is still poor because of many difficulties in magnetic observation near the limb.

We recorded time evolution of magnetic polarity distribution within the whole of both polar regions derived from the high-accuracy spectropolarimetric observation with Solar Optical Telescope aboard Hinode. In the north polar region, the latitudinal polarity inversion line (PIL) between the preexisting negative polarity region and transported positive polarity region migrates from 60 degrees latitude at January 2012 to 68 degrees latitude at September 2012. Then the whole of the north polar region becomes positive at September 2013. The migration speed of the PIL is 5 m s^{-1} (January - September 2012) and then becomes 8.5 m s^{-1} (September 2012 - September 2013). According to a flux transport model, the speed-up is understood as a result of a diffusion process. In contrast, the whole of the south polar region observed in March 2013 has still ample positive field. The PIL locates out of the observed region (over 67 degrees latitude).

We examined a few parameter sets of the meridional flow pattern and the diffusion coefficient with an advection-diffusion model. The observed PIL migration in the north polar region can be explained well if there is slightly strong diffusion without the meridional flow.

Keywords: photosphere, magnetic fields, spectropolarimetry, polarity reversal, dynamo

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PEM32-09 Room:503 Time:May 2 11:30-11:45

Properties of small-scale jets in a sunspot chromosphere revealed through spectroscopic observations

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High-resolution observations with HINODE Solar Optical Telescope (SOT) revealed that small-scale jets frequently occur in a sunspot chromosphere though their driving mechanism is not well understood yet because of lack of spectroscopic information, such as temperatures and Doppler velocities, in the chromospheric observations with Hinode SOT. Spectroscopic observations of the small-scale jets were attempted using an Interferometric BIdimensional Spectrometer (IBIS) at the National Soar Observatory (NSO), and suggested that temperature enhancements associated with the jets happened in the lower chromosphere though their upward flows were not clearly detected (Reardon, Tritschler, Katsukawa 2013). We've tried obtaining another spectroscopic data set of a sunspot chromosphere with better spectral resolution with IBIS, and carried out careful analysis of spectral profiles and their temporal evolution. The study shows majority of the heated plasma in the lower chromosphere has a bulk flow slower than the sound speed in the chromosphere. The spectral profiles indicate enhancements in the blue wing, which suggests a part of the heated plasma has a supersonic upflow. In addition, small temperature enhancements are also found in the upper chromosphere near the end of the duration of the jets. The supersonic upflows are possibly responsible for heating in the upper chromosphere. This study provides an important observational support for slow-mode waves as acceleration and heating mechanism in the chromospheric jets. We are going to present a new spectroscopic observation of chromospheric jets made by the Interface Regiong Imaging Spectrograph (IRIS) spacecraft that has just started observations since 2013.

Keywords: the Sun, chromosphere, jet, spectroscopy, HINODE, IRIS

PEM32-10 Room:503 Time:May 2 11:45-12:00

Fast magnetic reconnection with a moving X-point in resistive MHD

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Fast magnetic reconnection in high magnetic Reynolds number plasmas is one of the most important physical process of explosive phenomena in space and astrophysical plasmas. In recent years, using high-resolution MHD simulations with high magnetic Reynolds numbers, it has been indicated that fast magnetic reconnection may be triggered by the plasmoid instability in a thin current sheet [1]. Moreover, a state-of-the-art high-resolution MHD simulation revealed that some of multiple secondary reconnection are developed as Petschek-like reconnection [2]. However, the detailed structure and dynamics of individual secondary reconnection is not clarified yet.

The objective of this study is to reveal the structure and dynamics of resistive magnetic reconnection with a moving X-point paying attention to the motion of the secondary reconnection. Particularly, we propose an asymmetric reconnection model where a local anomalous resistivity including a shifting motion is added to the two-dimensional Harris equilibrium. A high-resolution MHD simulation for the asymmetric resistive reconnection was performed using the HLLD approximate Riemann solver and analyzed with respect to the structure in detail. Besides, we discussed the possibility of a self-sustaining mechanism of the asymmetric reconnection due to the flow driven by the reconnection itself.

[1] e.g, N. F. Loureiro, et al., Phys. Plasmas, 19, 042303 (2012)
[2] K. Kusano, K. Nakabou, et al., in preparation

Keywords: magnetic reconnection, MHD, anomalous resistivity model

PEM32-11 Room:503 Time:May 2 12:00-12:15

Dynamical Petscheck Reconnection

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Magnetic reconnection is the major mechanism for explosive energy liberation in various plasmas. However, the mechanism of fast reconnection in high magnetic Reynolds number (S) plasmas like the solar corona, in which $S>10^{10}$, is still unclear. The observations suggested that the reconnection rate in solar flares is as large as 10^{-2}, although the classical theory by Sweet (1958) and Parker (1963) predicted that the reconnection rate is limited by $S^{-1/2}$. While Petscheck (1964) proposed the fast reconnection model driven by slow mode shock, the previous simulation study suggested that the Petscheck-type reconnection is not stable in uniform resistivity and some anomalous resistivity or non-MHD effects are needed for fast reconnection.

In this paper, we developed the high-resolution magnetohydrodynamics (MHD) simulation of magnetic reconnection for the high-S ($S\tilde{}10^4$-10^6) regime aiming at revealing the acceleration mechanism of magnetic reconnection in the MHD regime of uniform resistivity. We applied the HLLD Riemann solver developed by Miyoshi and Kusano (2005) to the high resolution two-dimensional MHD simulation of current sheet dynamics. The initial state is given by the Harris sheet equilibrium plus perturbation, and the uniform and constant resistivity model is adopted.

As a result, we found a new type of fast reconnection. When S is larger than 10^4, multiple X-line reconnection appears as a result of the secondary tearing instability and magnetic reconnection is accelerated through the formation of multiple plasmoids. Furthermore, we found that the electric current sheets between some particular magnetic island bifurcate to V-shape current layers and that the reconnection at the apex of bifurcated current layers is preferentially accelerated. The bifurcated current layers create slow mode shocks which more increase the reconnection rate up to about 0.05. The slow mode shocks are repeatedly created and dissolved corresponding to the formation and transportation of plasmoids. These results indicate that, even though resistivity is uniform, when the magnetic Reynolds number is high enough, the multiple X-line reconnection of Sweet-Parker current sheets (plasmoid reconnection) is switched to a new regime called "dynamical Petschek reconnection". The mechanism of transition from the conventional plasmoid reconnection to the dynamical Petscheck reconnection will be discussed.

Keywords: reconnection, Petscheck reconnection, MHD, simulation, slow mode shock

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Thermal conduction effect on the Petschek magnetic reconnection

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We simulated the magnetic reconnection including the nonlinear thermal conduction effect with two-dimensional MHD equations. Magnetic reconnection is considered to be the basic process of the solar explosive phenomena. In the atmosphere with high temperature and low density like solar corona, time-scale of the nonlinear heat conduction becomes shorter and can become comparable to the Alfven time-scale. Thermal conduction effect should be considered. Previous studies have showed that, in the model of magnetic reconnection produced by Petschek, adiabatic slow mode shock wave generated from the localized diffusion region is dissociated into isothermal shock wave and conduction front due to the thermal conduction. However, the effect of the thermal conduction on the energy release rate in the magnetic reconnection is not explained enough in the past.

Here we investigated how the thermal conduction influences the energy conversion rate. We calculated the energy release rate in different magnitude of the magnetic diffusivity to see the dependence on the Lundquist number. As a result, due to the thermal conduction effect, adiabatic shock wave is dissociated into isothermal shock wave and conduction front and this makes temperature in the reconnection outflow jet smaller. In the outflow region with small temperature, density becomes larger. Considering mass conservation between the mass flux in the reconnection inflow and that in the outflow, inflow velocity is accelerated because of larger density in the outflow region. This causes increase of the energy release rate in the magnetic reconnection. That increase rate tends to become larger as the magnitude of magnetic diffusivity becomes smaller. Smaller magnetic diffusivity correponds to the larger Lundquist number. In the real solar atmosphere, plasma gas has larger Lundquist number than that in this numerical simulation. This means that thermal conduction effect on the energy release rate in magnetic reconnection might become more effective in the real solar atmosphere.

Keywords: solar flare, magnetic reconnection, thermal conduction, corona

PEM32-13 Room:503 Time:May 2 12:30-12:45

Analysis on turbulent reconnection of three-dimensional resistive MHD simulation

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This study starts from a three-dimensional current sheet with random perturbation on velocity, in order to understand more on the 3D reconnection in a more general way.

Due to the periodic boundary condition, the core of current sheet quickly develops a resonance netlike pattern under tearing instability. Small reconnection site mainly form two chains on either side of the current sheet center and constitute a zigzag arrangement. The outflow from one reconnection site is fed into the counterpart on the other side thus composes a positive feedback system resembles even double tearing mode. As the inflow being enhanced, slow-mode shocks are identified along the current sheet. The conversion of the magnetic energy is further raised. Total kinetic energy of the current sheet presents 4 steps of development while first 3 exhibit linear growing tendency. At the same time, reconnection rate increases by 5 times compared with the early phase. Thus we have achieved faster reconnection without localized resistivity in a more universal idea.

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Ion Acceleration Mechanisms in the Exhaust Region of Magnetic Reconnection

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Magnetic reconnection is considered to be a key mechanism to convert magnetic field energy into plasma kinetic and thermal energy in various plasma phenomena, in particular, in many astrophysical systems. In collisional plasma, many works assuming magnetohydrodynamic approximation have revealed that plasma jets can be accelerated up to the upstream Alfven velocity. However, in the case of the collisionless plasma, which is common in many astrophysical phenomena, there is still no conclusive theory of the ion acceleration mechanism and the maximum plasma jet velocity because of the complexities of plasma phenomena and the associated high numerical cost.

In this study, we performed a large-scale 2D particle-in-cell simulations with adaptive mesh refinement under an open boundary condition. The simulation was performed until the MHD condition is well-satisfied in the exhausts,

which allows us to study a long-time dynamical evolution of the structure of the diffusion region and exhausts.

To analyze the detailed mechanisms of the ion acceleration in the exhausts, we also performed test particle simulations on the dynamical background plasma. We found that the ions are accelerated mainly by the electric field perpendicular to the reconnection plane. However, effects from other electric field components are not negligible;

in particular, the contribution from the electric field along the exhausts becomes significant as the ions are accelerated. We also compared the results with the velocity distribution functions inside of the exhausts.

In this talk, we present our numerical results of the particle-in-cell simulation, and discussed its physical interpretations of the structure. We also discuss the ion kinetic mechanisms leading to the formation of reconnection jets.

Keywords: magnetic reconnection, ion acceleration

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PEM32-15 Room:503 Time:May 2 14:30-14:45

Waves and particle acceleration around the separatrices of magnetic reconnection

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Understanding the properties of waves in magnetic reconnection is very important in collisionless plasmas. The waves can transport the momentum and energy between the different species in plasmas, which results in the anomalous magnetic dissipation, particle heating, and formation of non-thermal particles. Therefore, the wave activities relevant to the kinetic interactions can have a significant impact on the dynamical behaviour of magnetic reconnection. Theoretical modeling of waves in the reconnection region is also beneficial to reveal the reconnection dynamics using in-situ satellite observations where wave properties are obtained in much higher time resolution than plasma distribution functions.

Recent satellite observations in the Earth's magnetotail have shown that the wave activities are significantly enhanced in a broad range of frequency around the separatrices of anti-parallel magnetic reconnection. The waves were recognized as lower hybrid waves, Langmuir waves, electrostatic solitary waves (ESWs), and whistler waves. In most cases, they were associated with cold electron beams and density cavity. However, because of the limited space-time resolutions of the observations, it has been difficult to identify the generation mechanisms of the waves and their roles in magnetic reconnection.

In this study, large-scale 2D particle-in-cell simulations with adaptive mesh refinement have been performed under an open boundary condition. The simulations use a set of more realistic parameters than those in most other simulations, achieving lower plasma beta in the upstream region that leads to stronger electron beams in the reconnection region. The wave activities are dominant in the inflow side of the separatrices. The waves are generated mainly due to the electron beams that constitute the Hall current. The relatively weak beams before strong acceleration trigger the Buneman instability which results in the waves with a frequency of the lower hybrid range. The strong acceleration occurs along the field line due to a localized potential hump and causes the density cavity. The intense electron beams excite the electron two-stream instability and the beam driven whistler instability. The former mode gives the Langmuir waves and the flat-top electron distributions in the parallel direction, both of which have been observed frequently in the Earth's magnetotail. The latter mode, on the other hand, scatters the electrons in the perpendicular direction, forming isotropic distribution with non-thermal high-energy tail. Both the Buneman and electron two-stream instabilities evolve the ESWs in the nonlinear phases.

In this talk, we present the generation mechanisms of the waves around the separatrices and their roles in magnetic reconnection. The mechanism of the intense electron acceleration along the field line will be discussed.

Keywords: magnetic reconnection, plasma waves, particle acceleration, particle-in-cell simulations

PEM32-16 Room:503 Time:May 2 14:45-15:00

Minimum spatial scale for maintaining vigorous magnetic reconnection

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Magnetic reconnection drives the fast release of magnetic energy in explosive events such as magnetic substorms in the Earth's magnetosphere and flares in the solar corona. On the large scale, reconnection is an MHD-scale process but its rate is controlled by the compact electron diffusion region (EDR), where electrons are not magnetized. Recent kinetic simulations have revealed the structure of EDR in a quasi-steady reconnection rate. In some works, it is suggested that an elongated electron jet in the outflow region does not affect the reconnection rate. However, it is not clear the spatial scale for determining the rate. We find that the minimum spatial scale for maintaining magnetic reconnection by using kinetic simulations on periodic and reflective wall boundary conditions. On the periodic condition, an outflow jet extends a large distance downstream from the X-line with the fast rate of reconnection. However, the influence of periodicity shortens the jet to a narrow structure though the rate of reconnection is still fast. This structure is the minimum spatial scale for maintaining magnetic reconnection. On the other hand, asymmetric reconnection is performed on the reflective wall condition to lead a slow motion of the diffusion region away from the wall, the so called 'X-line retreat.' During the retreat motion an outflow jet is blocked by the wall though the rate of reconnection is maintained. The structure of the blocked jet is very similar to the minimum spatial scale on the periodic condition. We quantitatively show the minimum structure for maintaining magnetic reconnection by comparing the result on these periodic and reflective conditions. We also find the minimum structure is independent of domain sizes but gets smaller with decreasing electron mass.

Keywords: magnetic reconnection, electron diffusion region

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PEM32-P01 Room:503 Time:May 2 16:15-17:30

Magnetothermal instability in the solar outer corona

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We discussed an application of the magnetothermal instability (MTI) to the solar atmosphere. This instability proposed by Balbus (2000) occurs in weakly collisionless plasmas where non-isotropic thermal conduction plays a role in a magnetized atmosphere. The time scale of the maximum growth is given as approximately sqrt(H/g) where H is the scale height, and g is the gravity. The magnetic field must be weak enough since its tension force contributes as a restoring force.

The solar corona is a dilute hot atmosphere where the thermal conduction is non-isotropic. The MTI is possible to work in the upper corona around a few solar radii above the photosphere where the temperature is decreasing outward and the scale height is about one solar radius. The condition for weak horizontal magnetic field might be satisfied above a closed loop in the lower corona. If the MTI is effective in such regions, it might contribute to generate the waves or perturbations in the solar wind.

We found that the MTI is unlikely to work in the upper corona because of its strong magnetic field that suppress the growth of the geometrically possible wavelength modes. It is found that when the field strength is 0.1 times the real corona, the wavelength for the maximum growth is comparable with the geometrical radius. The growth time for this setup can be consistent with the low frequency fluctuations in the solar wind.

Keywords: Sun, corona, plasma, magnetohydrodynamics

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Cosmic-ray Parker Instability and Galactic Plane Symmetry

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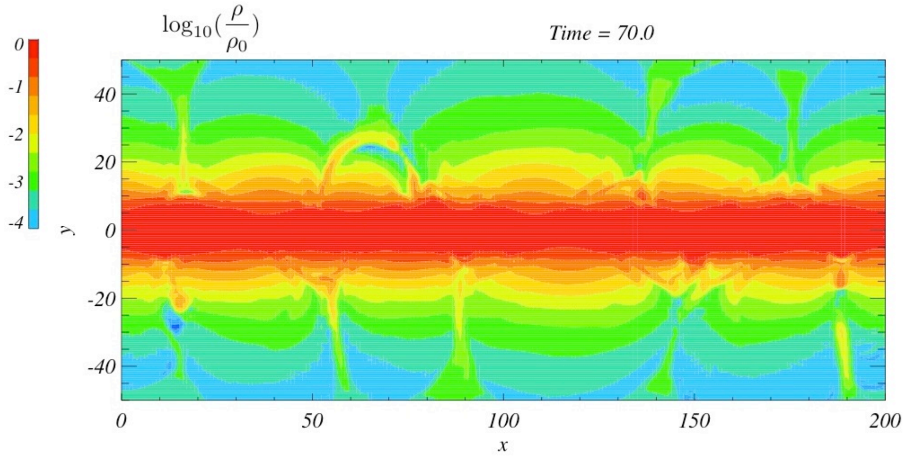
We study two-dimensional MHD numerical simulations of the Parker instability with the cosmic-ray pressure under the circumstance of the galactic disk. Instead of the symmetric boundary conditions on the galactic plane as often used, we solve the entire region of the disk. Numerical simulations show that the symmetric mode on the disk also grows when the cosmic-ray pressure is relatively large, while the glide reflection symmetric mode dominates on the disk when the cosmic-ray pressure is small. We confirm that the results are consistent with those of the liner analyses: the growth rate of the symmetric mode approaches that of the glide reflection symmetric mode as the cosmic-ray pressure becomes relatively large.

In the nonlinear stage, some loop structures of the magnetic field lines expand rapidly and grow into large structure when the cosmic-ray pressure is relatively large. Other loops, which start to grow a little later, are suppressed by faster growing loops located nearby and do not reach the nonlinear expansions. Eventually, the loop structure at the nonlinear stage is larger than that is expected form the linear analysis when the cosmic-ray pressure is relatively large.

When the nonlinear fast growing loops collide with another loops, the high density thin gas layers are formed by the compression between the loops. The figure shows the logarithmic density at that stage. Some of the high density gas shows filament structures and some of them look like high density loops. Similarities of these structures with some observational features and the relation of star formation activities can be studied further.

Keywords: MHD, Interstellar gas, Cosmic rays



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Formation of Dense, Cold Loops by Parker Instability in Galactic Gas Disks

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We performaced two dimensional numerical simulations of Parker instability taking into account the cooling and heating functions of the interstellar medium (Inoue et al. 2006). Our numerical experiment is based on the simulation code "CANS+" in which the HLLD Riemann solver (Miyoshi & Kusano 2005) is used to solve the MHD equations. We found that the cold, dense filaments formed at the valley of magnetic field lines by Parker instability coupled with the cooling instability are deformed into loops of dense, cold gas when the Ram pressure at the left- and right-hand side of the filament is different. The maximum number density and the lowest temperature of cold, dense filament at 100Myrs is about 200 per cubic cm and 50K, respectively. These results support the model in which thermal instability triggered in the dense region formed by Parker instability is responsible for the formation of molecular loops found in the Galactic center region (e.g., Fukui et al. 2006).