Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM26-01 Room:302 Time:May 24 09:00-09:15

Magnetic reconnection in viscosity-dominated plasmas

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Magnetic reconnection is essentially multi-scale phenomenon. From fully kinetic to magnetohydrodynamic (MHD) scales, a wide variety of models are utilized to identify triggering mechanisms for fast reconnection. The so-called GEM reconnection challenge has compared numerical simulations with fully kinetic (Particle-In-Cell), partly kinetic (Hybrid and Hall-MHD), and conventional resistive MHD models under the same initial condition, and it has shown that only the MHD model cannot achieve fast reconnection (Birn et al. 2001). This result indicates that kinetic effects are the essential physics and the resistive MHD is insufficient to model fast reconnection.

There are several kinetic effects proposed for the candidate to trigger fast reconnection, such as the Hall effect, the dispersion of whistler waves, the electron inertia and pressure anisotropy. We particularly focus on a two-scale structure in the diffusion region. In the fully kinetic model of electron-ion plasmas, the diffusion region is composed of a thinner electron diffusion region embedded in a thicker ion diffusion region. We hypothesize that fast reconnection may be triggered even in the MHD model if it attains a two-scale diffusion region like the kinetic model. Since the ion and electron diffusion regions are respectively measured as the vortex and current sheet, the two-scale diffusion region may be observed in the visco-resistive MHD with the viscosity larger than the resistivity (i.e., magnetic Prandtl number is larger than unity). However, this is not expected in conventional MHD simulations because they often use only the resistivity and ignores the viscosity (i.e., magnetic Prandtl number is almost zero).

Then, we perform two-dimensional visco-resistive MHD simulations of magnetic reconnection in viscosity-dominated plasmas. A simple Harris sheet configuration with uniform viscosity and resistivity is assumed as an initial configuration. When the viscosity is sufficiently high, the two-scale structure of thicker vortex and thinner current sheet is observed in the diffusion region, and subsequently, the diffusion region begins to thin down. The thinning speed increases with decreasing the thickness, implying that the thinning is driven by the viscous vortex motion. The vortex originates from the viscous heating at the downstream. High viscosity immediately dissipates and opens the outflow jet, thus tends to localize the diffusion region. We observe the upstream propagation of rarefaction waves, which accelerate the plasma toward the diffusion region. As a result, the current sheet in the visco-resistive MHD model becomes much thinner than in the resistive MHD model. Explosive reconnection is expected in the visco-resistive MHD. Since the magnetic Prandtl number is estimated to be much larger than unity in hot and tenuous astrophysical plasmas (e.g., stellar corona and active galactic nuclei disks), our result indicates the importance of the visco-resistive MHD against the conventional resistive model.

Keywords: magnetohydrodynamics (MHD), magnetic reconnection

PEM26-02 Room:302 Time:May 24 09:15-09:30

Numerical simulation of asymmetric reconnecton with GPU

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Magnetic reconnection is generally accepted as an important elementary process in the geo-magnetosphere. Especially, the asymmetric reconnection is more general than the symmetric one. So it takes an important role on clarifying Anemone type flares and flux transfer events at the dayside magnetopause, and so on. However, it is also a phenomenon that have many unsolved problems. We aim to understand the asymmetric magnetic reconnection by numerical simulation based on MHD equations.

In this calculation, GPU-accelerated computing(GPGPU) was performed. Although we use only one GPU now, we are going to use multiple GPUs. In that case, the slow transmission speed between CPU and GPU becomes a large problem. On the parallel computing with multiple GPUs, calculation domain is divided into arbitrary pieces and each GPU must have the information required to calculate in a each device memory. However, the transferring of the data between GPU-GPU is not permitted. Instead of it, we use the communication between CPU-GPU. This process becomes the bottle neck and this GPU-accelerated computing is not effective. In order to avoid this problem, we hide the data communication between CPU-GPU behind the GPU calculation.

Furthermore, using this GPGPU code we confirmed the previous study by Cassak & Shay in 2007 that in the asymmetric reconnection, X-point moves toward the weak magnetic field side.

Keywords: asymmetric reconnection, GPGPU, parallel calculation

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PEM26-03 Room:302 Time:May 24 09:30-09:45

An MHD-scale dynamics of collisionless magnetic reconnection

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We usually believe that an MHD-scale dynamics can be adequately described with the MHD approximation. However, this idea is not always straightforward in collisionless plasmas, where the time scale of thermal relaxation is much larger than that of phenomena of interest. The present study considers this problem for magnetic reconnection.

Magnetic reconnection is an explosive energy converter from the magnetic field energy into plasma kinetic energy. The reconnection processes are believed to play a key role in energetic phenomena in space such as geomagnetic substorms, solar flares, and the generation of the pulser wind. One of the main issues in reconnection has been the mechanism that enables fast energy release in a realistic time scale. Since the reconnection processes give rise to a MHD-scale dynamics, a lot of reconnection models have been developed historically in the MHD framework. One of the most promising models is the Petschek model suggested in 1964. The Petschek model provides a fast reconnection in a wide range of plasma conditions (leading to magnetic Reynolds number). The key assumptions of the model are a compact diffusion region localized in the vicinity of the x-line and a pair of the switch-off slow shocks extending from the x-line. The compact diffusion region is necessary to keep the reconnection rate high, avoiding the current sheet from elongation. Most part of the plasma is accelerated at the slow shocks, which allow the energy conversion in a broad area downstream the x-line. Although the Petschek model has been demonstrated by the MHD simulations under certain setups, the model has not been accepted. In fact, the dynamical behavior of reconnection depends significantly on the resistivity model in the MHD simulations, and clear slow mode shocks have merely been observed in geo-magnetosphere.

To assess the MHD reconnection model, the present study has performed huge-scale particle-in-cell (PIC) simulations with the help of the adaptive mesh refinement (AMR). The simulation domain extends to more than 600 ion inertia length in the outflow direction with a large ion-to-electron mass ratio and an open boundary condition. We believe that the system size is sufficiently large to describe the MHD-scale dynamics of reconnection. After a long-time evolution, we find that a long current layer is formed in the exhaust, which is reminiscent of the Sweet-Parker reconnection model. However, the magnetic dissipation takes place only around the x-line, so that the reconnection rate remains high as in the Petschek model. The transient region formed around the field line separatrix almost satisfies the Rankine-Hugoniot relation for the slow mode shock. However, we found that no plasma acceleration occurs in the transient region. Instead, the ions are accelerated in the current layer through the Speiser motions, while the electrons gain the energy in the Hall region from the reconnection electric field. Therefore, the plasma acceleration mechanism in collisioneless reconnection is different clearly from that in the Petschek model. The decoupling motions between the ions and the electrons generate the Hall current even far downstream the x-line. Thus, the dynamics in the exhaust is not able to be described in the MHD framework. The present study suggests that magnetic reconnection is an MHD-scale phenomenon, but the MHD approximation is not adequate in collisionless plasmas.

Keywords: magnetic reconnection, particle-in-cell simulation, MHD-scale dynamics, plasma acceleration

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PEM26-04 Room:302 Time:May 24 09:45-10:00

Study of fast magnetic reconnection by using newly high resolution MHD scheme

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Magnetic reconnection is an important process to drive explosive release of magnetic energy by reconnecting anti-parallel magnetic lines in space plasma, such as particle acceleration in solar flares and large-scale convection in the Earth's magnetosphere. Magnetohydrodynamics (MHD) simulation where plasmas are treated as fluid is one of the useful methods to learn macroscopic effects of magnetic reconnection. However, kinetic effects of plasma particles around an X-line are significant to drive fast reconnection, since the MHD approximation is broken in the vicinity of the X-line. Consequently, reconnection rate which means energy release efficiency is low ,the so called slow reconnection. Previous researches have shown that particle simulations including kinetic effects achieve fast reconnection, while MHD simulations do not[e.g., J. Birn et al., 2001].

In this study,we attempt to simulate the fast magnetic reconnection by using a newly high order MHD scheme proposed by S. Kawai[2013]. The results show reconnection rate is higher than previous results by MHD simulations.In addition, we confirm the dependence on spatial resolution of reconnection rate. As the resolution is higher, the reconnection rate is expected to be higher, since current sheet becomes thinner. As a result, global reconnection rate increases in proportion to the resolution. Note that simulations with high resolution allow secondary magnetic islands. That is, the increase of global reconnection rate is due to the multiple X-lines. We confirm, however, local reconnection rate at one of the X-lines, and the rate is equivalent to that from previous particle simulations. Consequently, these results show that the newly scheme enables us to perform fast magnetic reconnection and is useful to study magnetic reconnection in the MHD-scale phenomenon.

Keywords: magnetic reconnection, magnetohydrodynamics

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PEM26-05 Room:302 Time:May 24 10:00-10:15

Dynamical Petschek Reconnection: New Mechanism of Fast Magnetic Reconnection

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Magnetic reconnection is a process to change the connectivity of magnetic field lines and thought to play a core role for explosive energy conversion from magnetic energy to kinetic and thermal energies during solar flare, magnetospheric substorm, and tokamak disruption. However, electric conductivity in the solar corona, where solar flares occur, is quite large. According to the Sweet-Parker theory, it is difficult to conduct magnetic reconnection efficiently in such highly conductive field. Petschek proposed another reconnection theory, in which small magnetic diffusion region realizes effective reconnection even in the solar corona. Magnetic energy is converted to thermal and kinetic energy in slow mode MHD shocks. Recent numerical simulations, however, suggest that Petschek reconnection is not stable in a system of spatially uniform resistivity. Some mechanism such as anomalous resistivity is needed to sustain the local diffusion region. It is, therefor, not elucidated yet that Petschek reconnection occurs spontaneously.

We perform resistive MHD simulation in a large system with a high spatial resolution and find slow mode MHD shocks, which are predicted by Petschek, spontaneously form even with the uniform resistivity. In this process, fast motion of large plasmoids in the current sheet play an important role and slow mode shocks form in front of moving plasmodia (fig1). This process exceeds magnetic reconnection intermittently and repeatedly because plasmoids are ejected and form repeatedly. This process enhances reconnection and achieve normalized reconnection rate of 0.01, which is necessary to explain the time scale of solar flares (fig2).

We name this fast reconnection regime ’Dynamical Petschek Reconnection’. In this regime, microscopic physics or anomalous resistivity is not necessary and only uniform resistivity is enough to realize fast reconnection. Motion of plasmoid affect the surrounding plasma flow and this flow play a role to localize electric current. As a consequence, slow mode MHD shocks, which are predicted by Petschek, form spontaneously and energy conversion occurs efficiently.

Keywords: Magnetic reconnection, Solar flare

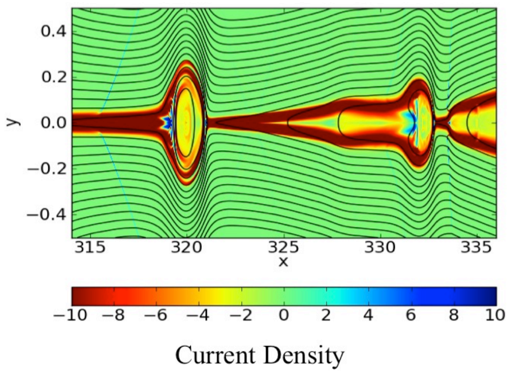

Fig1. Current distribution at the slow shocks

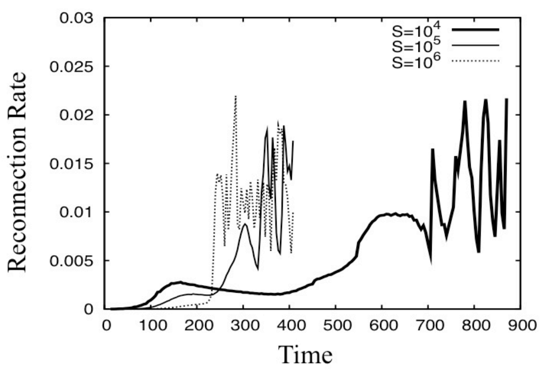

Fig2. Temporal evolution of Reconnection Rate

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Resistive magnetic reconnection in a plasma stream

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Magnetic reconnection is a fundamental process in plasma physics which plays an essential role for various space and astrophysical explosive phenomena. It is one of the most important issues in plasma physics to elucidate the physical mechanism of fast magnetic reconnection in high Lundquist number plasmas. In recent years, using high-resolution MHD simulations, it has been shown that a new fast magnetic reconnection process may be driven by a secondary instability in a thin current sheet involving a plasma stream (Sweet-Parker-type current sheet) [1]. Moreover, state-of-the-art very-high-resolution MHD simulation indicated that Petschek-type magnetic reconnection may dynamically be triggered by a complicated interaction with the plasma stream around the current sheet [2]. Therefore, we can expect that magnetic reconnection in the plasma stream becomes a key process for fast magnetic reconnection in high Lundquist number plasmas.

Although several theoretical and numerical studies for the tearing instability in an anti-parallel magnetic field including a field-aligned plasma stream, i.e., the streaming tearing instability, have been reported so far [3], the nonlinear dynamics of well-developed magnetic reconnection in the plasma stream has not been clarified yet. Thus, the objective of this paper is to explore the nonlinear dynamics of resistive magnetic reconnection in the plasma stream using the MHD simulation. In this study, nonlinear magnetic reconnection was triggered by a large perturbation in the Harris-type equilibrium with a localized field-aligned plasma stream. The results indicated that the current sheet structure of the reconnection point is varied depending on the bulk speed of the localized plasma stream. We found that the current sheet can be localized when the bulk speed is less than the Alfven speed.

[1] N. F. Loureiro, et al., Phys. Plasmas, 19, 042303 (2012)
[2] T. Shibayama, et al., in preparation
[3] T. Sato, R.J. Walker, J. Geophys. Res., 87, 7453-7459 (1982)

Keywords: magnetic reconnection, plasma stream, MHD

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PEM26-07 Room:302 Time:May 24 10:30-10:45

Loading Relativistic Maxwell Distributions in Particle Simulations

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[1]NAOJ

Numerical algorithms to load relativistic Maxwell distributions in particle-in-cell (PIC) and Monte-Carlo simulations are presented. For stationary relativistic Maxwellian, the inverse transform method and the Sobol algorithm are reviewed. To boost particles to obtain relativistic shifted-Maxwellian, two rejection methods are proposed in a physically transparent manner. Their acceptance efficiencies are 50% or 100%, respectively. Our simple methods can be combined with arbitrary base algorithms and arbitrary distribution functions.

Keywords: PIC simulation, relativity, Monte-Carlo

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PEM26-08 Room:302 Time:May 24 11:00-11:15

Effects of EMIC rising tone emissions on energetic particles in the inner magnetosphere

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Rising tone electromagnetic ion cyclotron (EMIC) emissions, or so-called EMIC triggered emissions, have been observed in the inner magnetosphere. In order to reproduce the EMIC triggered emissions, we perform self-consistent hybrid simulations with a real scale non-uniform ambient magnetic field model. We obtained two different triggered emissions, coherent rising tone emission and broadband EMIC bursts, which are generated in high and low magnetic field gradient model, respectively. We estimate effects on plasmas by the EMIC rising tone emissions in the inner magnetosphere. For energetic protons, which drive EMIC waves, broadband emissions induce rapid precipitation of energetic protons into the loss cone since the scattering by the concurrent triggering takes place faster than that of the coherent emissions. On the other hand, the coherent triggered emission causes efficient proton acceleration around the equator because of the stable particle trapping by the coherent rising tone emission. The rising tone EMIC waves also causes an effective heating of cold heavy ions by parallel electric field induced by counter-propagating EMIC waves. The generation of the EMIC waves are also modulated due to the cold ion heating. Relativistic electron scattering by the rising tone emissions reproduced by the hybrid simulations are also estimated by test particle simulations. Nonlinear trapping causes significant electron scattering in wide energy range. Broadband EMIC waves induce rapid, weak and continuous precipitations.

Keywords: inner magnetosphere, hybrid simulation, wave-particle interaction

PEM26-09 Room:302 Time:May 24 11:15-11:30

Dependencies of the generation process of whistler-mode emissions on temperature anisotropy of energetic electrons

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By a series of electron hybrid simulations, we study dependencies of the generation process of whistler-mode chorus and hiss-like emissions on temperature anisotropy of energetic electrons.

Whistler-mode chorus emissions are electromagnetic plasma waves commonly observed in planetary magnetospheres. In the Earth's inner magnetosphere, chorus emissions are observed mostly on the dawn side and are enhanced during geomagnetically disturbed periods. Chorus emissions appear in the typical frequency range from 0.2 to 0.8 f_{ce0} with a gap at the half f_{ce0}, where f_{ce0} represents the electron gyrofrequency at the magnetic equator. Recent in situ observation in the magnetosphere revealed the presence of whistler-mode hiss-like emissions, whose wave amplitude is comparable to those of chorus emissions.

The generation process of chorus has been reproduced in electron hybrid simulations and has been explained by the nonlinear wave growth theory [see review by Omura et al., in AGU Monograph "Dynamics of the Earth's Radiation Belts and Inner Magnetosphere, 2012]. The generation mechanism of hiss-like emissions is also explained by the nonlinear wave growth theory and has been reproduced by simulations [Katoh and Omura, JGR 2013]. In the present study, by an improved electron hybrid code with OhHelp library [Nakashima et al., 2009], we conduct a series of electron hybrid simulations for different temperature anisotropy (A_T) of the initial velocity distribution function of energetic electrons. We vary A_T in the range from 3 to 9 with changing the number density of energetic electrons (N_h) so as to study whether distinct rising-tone chorus emissions are reproduced or not in the assumed initial condition. Based on the simulation results, we reveal properties of the chorus generation for the assumed A_T parameter range.

Keywords: whistler-mode chorus, the Earth's inner magnetosphere, numerical experiments

PEM26-10 Room:302 Time:May 24 11:30-11:45

A self-consistent model of helicon plasma production

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Helicon plasma is a high-density and low-temperature plasma generated by the electromagnetic (Helicon) wave excited in the plasma. Then, helicon plasma is expected for various applications. On the other hand, there still remain a number of unsolved physical issues regarding how the plasma is generated using the helicon wave. The mechanism of helicon plasma production includes the wave propagation in the plasma (dispersion relation), collisional or non-collisional wave damping and plasma heating, and ionization/recombination of neutral particles which causes time evolution of the dispersion relation. In this study, we use the linear theory of helicon plasma, fluid simulation, and particle simulation to construct self-consist model including these physics.

In previous, we studied the helicon wave propagation and the process of plasma heating. And we showed the efficiency of mode conversion in bulk plasma depends strongly on the magnitudes of dissipations. However, there is a problem that has not been much studied: How do the helicon and TG modes influence the plasma density, electron temperature and their profiles? While the helicon mode is absorbed in the bulk plasma, the TG mode is mostly absorbed near the edge of the plasma. The local power deposition in a helicon plasma is mostly balanced by collision loss. This local power balance can give rise to an inhomogeneous electron temperature profile which is related to time evolution of density profile. In our study, we construct a self-consistent discharge model which includes wave excitation, classical electron heat transfer, and diffusion of charged particles.

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A theoretical model of nonlinear Alfven waves including kinetic compressional modes

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It is well known that magnetohydrodynamic (MHD) turbulence in solar wind plasmas often has clear correlations between magnetic field and velocity field (Alfvenic correlations). Although it is widely believed that Alfvenic fluctuations play important role in making developed MHD turbulence and scattering charged particles, damping processes of the fluctuations have not been clarified yet. Over the nearly four decades, nonlinear evolution equation of Alfven waves has been discussed by many authors. Mio etal(1976) and Mjolhus(1976) derived a nonlinear evolution equation of envelope-modulated Alfven waves. Rogister(1971), Mjolhus and Wyller(1988), and Spangler(1989,1990) derived a kinetic-fluid model including nonlinear Landau damping of compressional fluctuations. Hada (1993) derived a nonlinear evolution equation set including compressional propagating mode by using a novel expansion. In the present study, we discuss a nonlinear evolution equation of Alfven waves including both kinetic effects and compressional modes. Such a model was phenomenologically discussed by Nariyuki and Hada(2007). We here systematically derive and discuss the expansion of Hada (1993) in the resultant kinetic-fluid model. We also discuss effects of mean fields and thermal noises.

Keywords: Alfven waves, kinetic theory, solar wind

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PEM26-12 Room:302 Time:May 24 12:00-12:15

A Pedagogical Calculation on the Poraziation Vector in an MHD Wave

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The concept of electric polarization has been examined using an MHD (magnetohydrodynamic) wave for educational purpose. The polarization in an MHD wave can be easily derived from the basic equations, and its mechanism is transparent undergraduate students.

The polarization vector may be one of the most unclear concept in electromagnetism for students. Standard explanation of P is based on the molecular polarization of a dielectric medium, however, actual mechanism of the polarization is not consistently treated in textbooks usually. One needs to examine the molecular dynamics of the medium, which requires to solve quantum many-body problem somehow, to this end. A consistent quantum model is beyond the power of undergraduate students who are starting electromagnetism.

In the present paper, a simple and selfconsistent example of the electric polarization is introduced: an magnetohydorodynamic (MHD) wave in a collisionless plasma. The molecular polarization is not the only mechanism to cause the polarization vector. It can be the result of any current in the medium invoked by the electric field E, as long as E and P
are in linear relation.

When we examine the polarization in an MHD plasma closely, we find that the polarization vector P does not correspond to any actual physical entity. The response of the plasma as a dielectric media takes place in the form of the polarization current, and P is a convenient mathematical expression to handle the effect of the polarization current. This situation is somewhat similar to the relation of an electric potential to electric fields. What we actually observe is the electric fields, but calculations become easier when we introduce a potential function.

Keywords: MHD wave, Polarization Vector, Electric field and Electric Flux

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PEM26-13 Room:302 Time:May 24 12:15-12:30

Modeling of Particle Acceleration in Shock-Shock Interaction

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It is known that collisionless shocks produce high energetic particles (cosmic rays). Most of the past studies have been dedicated to discussing particle acceleration in a single shock system. Particle acceleration in multiple shocks, however, is considered to be highly efficient[Gieseler and Jones, 2000, Melrose and Pope, 1993]. In space, two shocks are frequently come close to and even collide with each other. For instance, it is observed that a coronal mass ejection(CME) driven shock collides with the earth's bow shock[Hietala et al., 2011,Concharov et al., 2014], or interplanetary shocks pass through the heliospheric termination shock[Lu et al., 1999].

To investigate the shock-shock interaction, we perform one-dimensional full particle-in-cell simulation in which two identical shocks collide. We found that electrons are accelerated through multiple reflection between the two shocks(Fermi acceleration). These electrons excite large amplitude waves between the two shocks and are scattered in their pitch angles. The scattering results in that some electrons can have sufficiently large pitch angles so that they are easily reflected when they reach at a shock next time. We model the acceleration process and discuss the suitable condition for particle acceleration.

Keywords: Collisionless Shocks, Shock-Shock Interaction, Particle Acceleration

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PEM26-14 Room:302 Time:May 24 12:30-12:45

Detection of Group of Black hole Binaries at the Center Part of Our Galaxy Based on

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1. Introduction Through the current studies on the detection of Ker

Black holes located at the center part of our Galaxy, being based on the observations of decameter radio wave pulses, the investigation of the accurate source direction has been made for the largest case of Gaa and Gab. In this study, the works has been expanded to other 3 cases such as , Gac-Gad, Gae-Gaf and Gag-Gah systems. The directions of sources of decameter wave pulses are analyzed using newly observed data in 2014 considering the deviation effects, of the ionosphere, on the propagating direction of radio wave.

2. Observation System The observations to determine the source direction of

the decameter radio wave pulses have been carried out using the long baseline decameter radio wave interferometer of Tohoku university which consist of three observation stations located at Yoneyama, Kawatabi and Zao in Miyagi Prefecture, Japan; the longest baseline is 84km and shortest baseline is 44km. The signals observed at 22.186MHz with band width of 1kHz are sent from each station through the telemetry system directly to the central station at Sendai where the detected signals are converted into digital signals by AD converters with conversion rate of 6000 data per second being divided into 3 channels with 100Hz band width.

3. Data Analyses Observations in 2014 have been made from early

February to 10th of April. In this work the data observed March 18, 19, and 20 are selected for analyses. The pulse form is detected by applying period correlated accumulation method (so called box car method modified for varying periods) together with analyses of correlation between interferometer fringe and template fringes to decide the source direction. To form the template fringe the ionosphere effect for propagation of radio waves at 22.816MHz are considered by applying 3-layer-ionosphere model where foF2 values observed at Kokubunji station are applied. A fine adjustment to compensate the systematic bias of the detected source direction due to the characteristic of the selected ionosphere model, is made by searching the direction of the template fringe.

4. Results and Discussions

4.1Source Direction Source directions are obtained in forms of correction

angles deviating from the predicted Sgr A∗direction that are calculated with consideration of ionosphere effects. The case of Gaa-Gab binary, results are given as Gaa(RA(0.01,0.53);Dec(-0.45,0.63))–Gab(RA(0,109);Dec(-1.53,1.33)). This format indicates that for Gaa average deviation angle for RA (right ascension) of Gaa is 0.01 arc minutes with standard deviation of 0.53 arc minutes and average correction angle for Dec(declination) of Gaa is -0.45 arc minutes with standard deviation of 1.33 arc minutes. Though detail values for other BH binary system will be given in the presentation, the results show that with only one exception of the case of declination of Gab, all average correction angle are within the deviation angle, suggesting that the source directions coincide with SgrA∗within an error of 1.89 arc minutes.

4.1 Parameters of BH binary Systems The sources of pulses are assumed

to be Ker black holes with masses which are approximately proportional to the pulse periods. Applying Kepler law using orbital parameters resulted from observed periods , then masses of BH of binary system have been derived.

5. Conclusion Within determination error of 1.89 arc minutes, there exist

at least 4 binary systems in Sgr A∗such as Gaa-Gab, Gac-Gad, Gae-Gaf, and Gag-Gah system which show orbital periods, respectively 2050 sec, 1024 sec, 1200sec and 325 sec. Each black hole has mass as given with unit of million solar mass from 1.30 to 1.32, for Gaa; from 1.04 to 1.07, for Gab; from 0.82 to 0.84 for Gac; from 0.57 to 0.60, for Gad; from 0. 15 to 0.17,for Gae ; from 0.11 to 0.14, for Gaf ; from 0.17 to 0.18, for Gag and from0.14 to 0.15 for Gah.

Keywords: Black Hole, Binary, Decameter Radiowave, Interferometer, Galaxy Center

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PEM26-15 Room:302 Time:May 24 14:15-14:30

Gas accretion and particle acceleration during collisionless magnetorotational instability

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Enhanced angular momentum transport and efficient particle acceleration during the magnetorotational instability (MRI) in a collisionless accretion disk are studied using three-dimensional particle-in-cell (PIC) simulation with a pitch-angle isotropization model. It is well known that the magnetic reconnection plays an important role on the nonlinear saturation of MRI, and we find that the plasma pressure anisotropy inside the channel flow with $p_\parallel > p_\perp$ induced by active magnetic reconnection during the nonlinear stage of MRI suppresses the onset of subsequent reconnection, which in turn leads to high magnetic field saturation and enhancement of Maxwell stress tensor of angular momentum transport. Meanwhile, during the quiescent stage of reconnection the plasma isotropization progresses in the channel flow, and the anisotropic plasma with $p_\perp > p_\parallel$ due to the dynamo action of MRI outside the channel flow contributes to rapid reconnection and strong particle acceleration. This efficient particle acceleration and enhanced angular momentum transport in a collisionless accretion disk may explain the origin of high energy particles observed around massive black holes.

Keywords: accretion disk, magnetorotational instability, angular momentum transport, particle acceleration, magnetic reconnection, turbulence

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Instability and Turbulence Generation through Non-uniform Toroidal Magnetic Field in Accretion Disks

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Plentiful dynamics observed in accretion disks, e.g. disk winds, jets, and outflows, are believed as the results of angular momentum transport highly enhanced by magnetohydrodynamic turbulence. The magneto-rotational instability (MRI) is one of the most successful mechanisms to drive the required turbulent state, and generates a large toroidal magnetic field in the nonlinear evolution. In this study, we investigate the local stability of accretion disks especially focusing on the stage when the toroidal field is dominant, which is important to understand the dynamics and the nature of turbulence in well-developed disks, and suggest another possible path leading to the turbulent generation.

It is known that the differentially rotating plasmas threaded by the uniform toroidal field are unstable essentially for the perturbation with a vertical wavevector. Our linear analysis, however, shows that if the initial toroidal field has non-uniformity, the unstable modes confined within the equatorial plane, or with no vertical wavenumber, appear. Furthermore, a series of two-dimensional nonlinear simulations reveal that when the plasma beta is not so low (roughly $\beta>1$), this unstable mode can grow as far as the background field configuration breaks down. As another possible situation, we study the stability of the toroidal field with wavy structure. The simulations show that after the above unstable modes grow enough to interact with neighboring modes, they couple, marge, and eventually evolve to very turbulent state. In the saturated stage, the alpha parameter describing the efficiency of the angular momentum transport reaches to the same level with the previous studies of a toroidal MRI. This instability plays an important role in plasma transport since it may couple with magnetic reconnection occurring in an equatorial plane and then contribute to the saturation mechanism of MRI.

PEM26-17 Room:302 Time:May 24 14:45-15:00

Hybrid simulation of an ion scale magnetosphere: Structure of the magnetopause boundary

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An ion scale magnetosphere is studied by performing a three-dimensional hybrid simulation. The hybrid simulation treats the ions as kinetic super particles via a particle-in-cell method and the electrons as a massless fluid. In this study, the ion scale magnetosphere has a dayside stand-off distance which is several to a hundred times larger than the ion Larmor radius of the solar wind proton in the magnetic field strength which magnetic pressure equals to the solar wind dynamic pressure. The dayside magnetopause boundary has a double- or triple-layer flow structure due to the finite Larmor radius effect in the interaction between the solar wind and the magnetosphere. The flow structure is controlled by the interplanetary magnetic field. For the small ion scale magnetosphere, the bow shock cannot well steepen because the dayside sheath thickness is an order of the ion Larmor radius and the shock transition region overlaps with the boundary flow structure. We will discuss the plasma convections, current flows, and field structures in various solar wind conditions.

Keywords: Ion scale magnetosphere, hybrid simulation

PEM26-18 Room:302 Time:May 24 15:00-15:15

Numerical simulation of active spacecraft charging in interplanetary space

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It is well known that spacecraft is charged by the background plasma in space. Since spacecraft charging is a cause of the discharge and malfunction of electric equipment, spacecraft are usually designed to mitigate their surface charging.

However, a new concept of spacecraft orbital control using electromagnetic forces such as the Lorentz force and the Coulomb force has been recently proposed. Spacecraft controls their orbit by controlling their potential using a charged-particle emitter. Various applications of electromagnetic force as the primary means of spacecraft propulsion have been studied.

This orbital control method may provide propellantless orbital control and a very lightweight propulsion system compared with conventional chemical and electric propulsion systems.

Moreover, the system's lifetime is not limited by propellant, so it can extend the spacecraft's orbital lifetime.

To control the electromagnetic force that acts on the spacecraft, it is necessary to actively control the spacecraft's electrical potential.

In this paper, we investigate charging characteristics of active spacecraft charging in interplanetary space. by using 3D Full Particle-in-cell simulation.

We particularly evaluate the effects of the solar wind velocity, beam-emission angle, and photoelectron emission on the spacecraft's electric potential.

Additionally, we also investigate the charging characteristics of an electric solar wind sail, which is proposed as an application of electromagnetic orbital control in interplanetary space.

An electric solar wind sail consists of several-kilometer long, thin, conducting tethers.

Tethers are kept at a high positive potential on the order several kilo-volts by an electron gun.

The positively charged tethers deflect the momentum of solar wind protons which result in a propulsive force.

We analyze the dependency of the electric potential on the length and diameter of charged tethers, and evaluate the effect on thrust characteristics.

Keywords: Spacecraft Charing, Solar Wind, Electric Sail

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

PEM26-19 Room:302 Time:May 24 15:15-15:30

Yin-Yang-Zhong: An overset grid for a sphere

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Computation in a spherical region bounded by a constant radius is important in various fields of science and technology. Spatial discretization inside a sphere is not simple because there is no orthogonal coordinate system that fits to a sphere, without a coordinate singularity. The spherical polar coordinate system, for example, has two kinds of coordinate singularity; one on the poles and another on the origin. Singularity should be avoided in numerical simulations because it causes grid convergence around the singular point. We have developed a new grid system for a sphere, Yin-Yang-Zhong grid, which is an overset grid system composed of Yin-Yang grid and Zhong grid. Yin-Yang grid itself is an overset grid system that covers the outer spherical shell part inside the sphere. Zhong grid is a Cartesian grid-base system to cover the central part of the sphere. We have developed a magnetohydrodynamic simulation code for a sphere based on the Yin-Yang-Zhong grid. The code is parallelized with MPI. We have performed a quantitative tests of the code with diffusion and advection problems.

Keywords: Yin-Yang grid, overset grid, computer simulation, Yin-Yang-Zhong grid

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PEM26-P01 Room:Convention Hall Time:May 24 18:15-19:30

Investigation of Energetic Particle Hybrid Simulation Model

AMANO, Takanobu[1*]

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Energetic particle populations coexisting with the thermal gas are commonly found in space plasma environments. Although the number density of the energetic particles is usually much lower than the thermal population, the energy density is often substantial. Typical examples include the thermal gas and galactic cosmic rays in the interstellar medium, a cold plasma originating from the ionosphere and the energetic ring-current population in the inner magnetosphere.

The typical scale sizes such as the Larmor radius between the two population are vastly different, making it important to take into account kinetic effect of energetic particles even for the macroscopic dynamics in which the fluid approximation for the thermal population is adequate. The difference in scale size makes it impractical to deal with both the components in a fully kinetic manner.

Here we propose a method that deals with only the energetic particles as a kinetic population whereas the fluid approximation is used for the thermal gas. We will demonstrate that this may be achieved as a natural extension of our recently developed quasi-neutral two-fluid plasma simulation code. Several preliminary simulation results will be discussed to investigate the validity of the model.

Keywords: numerical simulation, plasma, cosmic rays

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PEM26-P02 Room:Convention Hall Time:May 24 18:15-19:30

Nonlinear evolution of MRI studied by an MHD code with the compact difference scheme and the LAD method

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The magnetorotational instability (MRI) is one of the most important phenomena in the accretion disk. Turbulence generated by MRI causes the turbulent viscosity in the disk and is a strong candidate of the driver of mass accretion. Recent study suggested that the turbulence induced by MRI also plays an important role in the planetesimal formation in the protoplanetary disk. In the planetesimal formation process, both the ionized gas and dusts coexist in the disk and the motion of dusts is strongly affected by the motion of gas through collisional and/or frictional effects. Kato et al. (2010;2012) showed the possibility that meter-sized dusts are gathered locally due to the modification of the disk gas distribution through the evolution of MRI and that situations favored for the planetesimal formation are created in the localized region. In addition to the effect pointed out by this simulation, we should take into account effects through the Kelvin-Helmholtz instability (Sekiya, 1998; Barranco, 2009) and the streaming instability (Youdin & Goodman, 2005) generated by the dust-gas interaction as well as the time evolution of the global disc structure (Suzuki et al., 2010). In order to carry out the MHD simulation considering these effects, we need to develop the scheme that can accurately resolve both short wavelength waves in turbulence and discontinuity appeared in the evolution of instabilities.

In the present study, we develop an MHD simulation code using an 8th-order compact difference scheme with the local artificial diffusivity (LAD) method (Kawai, 2013). The compact difference scheme proposed by Lele (1992) enables us to solve turbulent flow accurately up to the wavenumber range corresponding to a few grid points. The LAD method for MHD simulation proposed by Kawai (2013) enables us to reduce unphysical oscillations generated in central difference type scheme like the compact difference scheme. We have also applied parallelization by MPI using the pipeline algorithm to the code in order to increase the box size with keeping the high spatial resolution. By using the pipeline algorithm, we have applied the domain decomposition to the code with maintaining the accuracy of the compact difference scheme. We carry out a series of standard test problems for MHD simulations and clarify pros and cons of the developed MHD code for the study of MRI. By conducting spatially 2-dimensional test problems, we find that the maximum value of the numerical error appeared in the computation of the divergence of the magnetic field is the order of 10^{-12}, which is approximately consistent with the results of Kawai (2013).

We then carry out the 3-dimensional MHD simulation of MRI by the developed code. In order to realize the differential rotation, we use the shearing box boundary condition (Hawley et al., 1995) and the 9-wave method (Dedner et al, 2010) so as to suppress the divergence error caused by the interpolation in the shearing box boundary. We initially set the uniform vertical magnetic field and assume the perturbation in the three-components of the velocity vector whose amplitude is 1% of the sound speed. Our developed simulation code can solve the linear growth and nonlinear evolution of MRI. Our newly developed code enables us to solve the MRI driven turbulence accurately, which is important in solving not only a wide range of the evolution of the disk but also the fine structure of the saturation and nonlinear evolution mechanism of MRI. We show the characteristics of the developed code and study results of the 3-dimensional MHD simulation of the nonlinear evolution of MRI.

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PEM26-P03 Room:Convention Hall Time:May 24 18:15-19:30

Yin-Yang Dynamo Simulation with in-situ visualization Using ParaView/Catalyst

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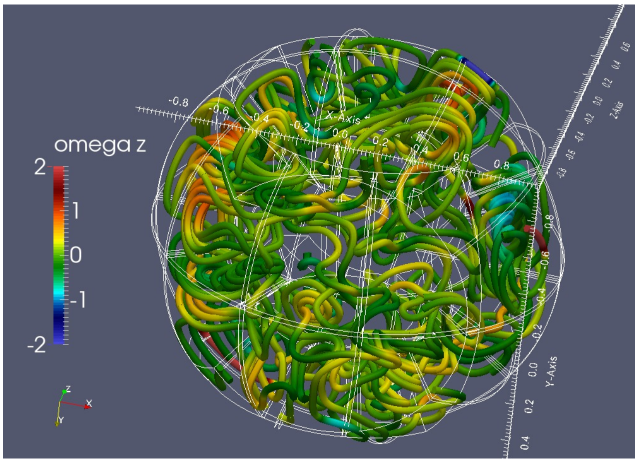
In accordance with the development of high performance computers, the data size of large scale simulations is exponentially growing. The post process visualization, which is currently the major approach to the data analysis in computer simulation research, might be in deadlock in the near future. The in-situ visualization method is attracting attention as a solution to this problem. We have recently realized an in-situ visualization of a magnetohydrodynamic (MHD) dynamo simulation using the Yin-Yang grid. We have used ParaView and Catalyst for visualization engine and its interface to the MHD simulation code for the in-situ visualization.

Keywords: Visualization, in-situ visualization, Yin-Yang grid



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PEM26-P04 Room:Convention Hall Time:May 24 18:15-19:30

PIC simulations on magnetic perturbation around the Solar Probe Plus spacecraft

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For future space exploration, it is necessary to predict the nature of spacecraft-plasma interactions in extreme plasma environmental conditions. As one of such activities, we study on the physics of spacecraft-plasma interactions in the near-Sun environment. The spacecraft environment immersed in the solar corona is characterized by the small Debye length due to its high density (7000 /cc) and a large photo-/secondary electron emission current emitted from the spacecraft surfaces, which lead to much different nature of spacecraft-plasma interactions from that in the near-Earth environment. Consequently, the spacecraft charges negatively near the Sun unlike usual photo-emitting spacecraft in the near-Earth environment. In the present study, we reproduce the plasma environment around the Solar Probe Plus satellite planned by NASA by means of numerical simulations based on the Particle-in-cell method. We report recent research progress on near-spacecraft magnetic perturbations, which is generated by a complex current closure around the spacecraft.

Keywords: spacecraft-plasma interaction, solar coronal plasma, spacecraft charging, photoelectron emission, magnetic perturbation, PIC simulation

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PEM26-P05 Room:Convention Hall Time:May 24 18:15-19:30

Electron temperature anisotropy during compression of current sheets thicker than the ion skin depth

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Collisionless magnetic reconnection drives explosive release of magnetic energy to kinetic and thermal energy of plasmas in space plasma phenomena, such as solar flares and convection of plasmas and magnetic fields in the Earth's magnetosphere. Satellite observations in the Earth's magnetotail have shown that an initial current sheet ten times thicker than the local ion skin depth gets as thin as the ion skin depth, when magnetic reconnection is triggered in the sheet. According to the linear analysis of the tearing instability, the thicker the thickness of current sheets is, the exponentially lower the growth rate is, while the stronger the anisotropy of plasmas is, the higher the growth rate is. Current sheets can be thin due to the Dawn-Dusk electric field associated with the convection of magnetic fields in the Earth's magnetosphere and effects of the lower-hybrid drift instability. However, it is not fully understood how magnetic reconnection is triggered in a current sheet much thicker than the ion skin depth.

In this study, we perform the current sheet thinning by using the one-dimensional PIC simulation imposed the Dawn-Dusk electric field at boundaries with various initial parameters. We investigate the dependence on the initial parameters of the strength and the distribution of the anisotropy and of the compression level of current sheets. The results show that (1) the distribution of the anisotropy changes with the initial thickness of current sheets, (2) the strength of the anisotropy at the center of current sheets is explained by the adiabatic heating perpendicular to magnetic fields regardless of the initial parameters, (3) the compression level of current sheets normalized by the local ion skin depth is much lower than the ratio of the terminal strength of the lobe magnetic field to the initial strength of that. These results can be useful to understand processes of the current sheet thinning and the trigger of magnetic reconnection in multidimensional simulations including the tearing instability and/or the lower-hybrid drift instability.

Keywords: magnetic reconnection

PEM26-P06 Room:Convention Hall Time:May 24 18:15-19:30

Validity of gyro-averaging method for oblique whistler-mode wave particle interaction

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We perform test particle simulations of energetic electrons interacting with oblique whistler-mode waves in the Earth's magnetic field. We first solve exact equations of motion of test electrons under the electric and magnetic fields of obliquely propagating coherent wave with right-hand polarization. In this test, the energetic electrons undergo multiple cyclotron resonances. We also apply gyro-averaging method by treating electron motion as its guiding center motion to simplify the complicated cyclotron motion [1,2]. The result shows that the gyro-averaging motion is successfully consistent with the direct motion of the electron. Applying this result we can just use the guiding center motion of electrons to represent the completed motion of electrons. Therefore, these method can be utilized in the particle simulations of oblique propagation waves to reduce the relativistic equations of motion and minimize the computation resources, which makes simulations of multiple particles more feasible.

References

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[2] Nunn and Omura, A computational and theoretical investigation of nonlinear wave particle interactions in oblique whistlers, Submitted to *J. Geophys. Res.*.

Keywords: whistler-mode wave, oblique propagattion

Japan Geoscience Union Meeting 2015
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PEM26-P07 Room:Convention Hall Time:May 24 18:15-19:30

Effects of the alpha-proton drift velocity on alpha firehose instabilities in the solar wind

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In situ measurements have shown that the less-abundant alpha particles are characterized by temperature anisotropy which could drive the anisotropy-driven kinetic instabilities in the solar wind. In the collisionless limit, the differential alpha-proton flow velocity usually has finite value of the order of the local Alfven velocity. The presence of such differential flow may affect the properties of dispersion relations for anisotropy-driven instabilities. By making use of linear Vlasov theory, the present study investigates the effects of the alpha-proton drift velocity on firehose instabilities driven by parallel temperature anisotropy of alpha particles. It is found that for parallel firehose mode the dispersion properties are asymmetric in that the maximum growth rate is larger for forward propagating mode than for backward propagating one in the proton rest frame. For both parallel (forward propagating mode) and oblique firehose instabilities overall growth rates increase as the alpha-proton drift velocity increases. Consequently, the firehose instability thresholds are distinctly influenced by the presence of the alpha-proton drift velocity.

Keywords: firehose instability, solar wind ions, the alpha-proton drift

PEM26-P08 Room:Convention Hall Time:May 24 18:15-19:30

Vlasov simulation of the Rayleigh-Taylor instability

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[1]Solar-Terrestrial Environment Laboratory

The Rayleigh-Taylor instability (RTI) develops at an interface between two fluids with different densities when an external force is applied from a heavy fluid to a light fluid. In the previous studies of ideal MHD simulations, the RTI develops symmetrically in the horizontal axis. On the other hand, previous hall-MHD and Finite-Larmor-Radius (FLR)-MHD simulations have shown that the RTI develops asymmetrically in the horizontal axis. In this study, we perform four-dimensional Vlasov simulations of the RTI with two spatial dimensions and three velocity dimensions. We vary the ratio of the ion inertial length and/or the ion gyroradius to the spatial scale of the density gradient layer, and discuss the effect of the non-MHD effects on the growth of the RTI.

Keywords: Rayleigh-Taylor instability, Vlasov simulation, space plasma

PEM26-P09 Room:Convention Hall Time:May 24 18:15-19:30

3-dimentional electromagnetic particle simulations about the low frequency component of Broadband Electrostatic Noise

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According to PIC simulations, ESW (Electrostatic Solitary Waves) are generated from electron beam instabilities. ESW correspond the upper frequency component of BEN (Broadband Electrostatic Noise) which is frequently observed in space plasma. The generation mechanism of the low frequency component of BEN, however, is still unexplained.
To clarify whether such low frequency waves are generated, we made statistical analysis on generation conditions of low frequency component of BEN observed by Electric Field Detector (EFD) onboard Geotail spacecraft. We detected low frequency component of BEN automatically from EFD data, and made an occurrence frequency distribution of these waves. Low frequency component of BEN are observed in PS and PSBL region in the magnetosphere.
We studied several plasma parameters at the time when low frequency component of BEN were observed, and found that these waves were observed in the conditions with low ion density and strong B field in these regions. Then, based on these statistical analysis, we are going to perform a series of three-dimensional electromagnetic particle simulations with different parameters on PC-Cluster built in our laboratory.

Keywords: particle simulations, low frequecy component of BEN, Geotail, EFD

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PEM26-P10 Room:Convention Hall Time:May 24 18:15-19:30

Test-particle simulation of electron elastic collision with neutral H2O molecule originated from Enceladus

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Water group neutrals (H_2O, OH, and O) in Saturn's inner magnetosphere play the dominant role in loss of energetic electrons and ions because of abundance of the neutral particles [e.g., Paranicas et al., 2007; Sittler et al., 2008]. The observations of injected electrons and ions in the inner magnetosphere suggest that these particles do not survive very long time due to the neutral cloud originated from Enceladus [e.g., Paranicas et al., 2007; 2008]. Thus, the previous study suggested that the neutral cloud contributes to loss processes of plasma in the inner magnetosphere. However, little has been reported on a quantitative study of the electron loss process due to electron-neutral collisions.

In the present study, we examine the variation of energetic electron pitch angle distribution at the magnetic equator and loss rate of precipitated electrons into Saturn's atmosphere through pitch angle scattering due to elastic collisions with neutral H_2O along Saturn's dipole magnetic field line around Enceladus. We conduct one dimensional test-particle simulation for monoenergetic electrons along Saturn's dipole magnetic field line around Enceladus when the co-rotating electron flux tube passes the dense H_2O region in the vicinity of Enceladus (~6.4 minutes). The initial electron pitch angle distribution is assumed to be isotropic. In case of 1 keV electron, Tadokoro et al., [2014] showed that

1. the equatorial electron pitch angle distribution near the loss cone ($<$20 degrees and $>$160 degrees) decreases with time through pitch angle scattering due to elastic collisions and that the distribution around 90 degrees shows significant scattering due to the dense region of H_2O,

2. It is found that the electrons of ~19 % to the total number of equatorial electrons at the initial condition are lost in ~380 seconds.

3. The calculated loss time is fourth faster than the loss time under the strong diffusion.

We also show the loss rates through pitch angle scattering of electrons with not only 1 keV but also several hundreds eV ? several tens of keV.

Keywords: Test particle simulation, elastic collision, Enceladus, Saturn

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PEM26-P11 Room:Convention Hall Time:May 24 18:15-19:30

Ion kinetic effects to nonlinear processes of the Kelvin-Helmholtz instability

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The nonlinear evolution of the Kelvin?Helmholtz (KH) instability at a transverse velocity shear layer in an inhomogeneous space plasma is investigated by means of a four-dimensional (two spatial and two velocity dimensions) electromagnetic Vlasov simulation. When the rotation direction of the primary KH vortex and the direction of ion gyro motion are the same (i.e. the inner product between the vorticity of the primary velocity shear and the magnetic field vector is negative) there exists a strong ion cyclotron damping. In this case, spatial inhomogeneity inside the primary KH vortex is smoothed and the secondary Rayleigh?Taylor/KH instabilities are suppressed. It is also found that another secondary instability on the electron inertial scale is simultaneously generated at secondary shear layers for both cases, but at different locations. The small-scale secondary instability takes place only when the inner product between the vorticity of the secondary shear layer and the magnetic field vector is positive, suggesting the damping of small-scale processes by ion gyro motion. These results indicate that secondary instabilities occurring in the nonlinear stage of the primary KHI show different evolutions depending on the sign of the inner product between the magnetic field and the vorticity of the velocity shear layer. The difference of the nonlinear evolution depending on the ion-to-electron mass ratio is also discussed.

Keywords: Kelvin-Helmholtz instability, computer simulation, Vlasov equation, non-MHD