Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PEM26-01 Room:102B Time:May 22 13:45-14:00

Plasmoid-induced turbulence in 3D magnetic reconnection

FUJIMOTO, Keizo[1*], SYDORA, Richard[2]

[1]RIKEN, [2]University of Alberta

One of the main issues on magnetic reconnection processes is the mechanism breaking the frozen-in condition around the x-line and providing the electric resistivity in collisionless plasmas. It has been recognized empirically in magnetohydrodynamic simulations that the Petschek-type fast reconnection can be achieved only when an intense resistivity arises locally near the x-line. However, the generation mechanism of the resistive effects in collisionless plasmas is poorly understood in the kinetic framework. In 2D reconnection, it has been demonstrated by kinetic simulations that the momentum transport due to the Speiser-type motion of the electrons around the x-line gives rise to the so-called inertia resisticity which results in the electron viscosity term in the generalized Ohm's law. Although the electron inertia resistivity gives intense dissipation under the thin current layer on the order of the electron inertia length, such a thin current sheet has been observed neither in the laboratory experiments nor in the geomagnetosphere. The observational results have shown that the current sheet width during the fast reconnection is much larger than that in the 2D kinetic simulations and electromagnetic wave activities are usually accompanied. These characteristics infer the existence of the anomalous effects due to wave-particle interactions that are not incorporated in the 2D simulations.

In order to investigate the 3D effects in the dissipation process, the present study has performed large-scale particle-in-cell (PIC) simulations in 3D system. The code employs the adaptive mesh refinement (AMR) and is massively parallelized, which enables us to perform highly efficient simulations on state-of-the-art supercomputers. The 3D simulations revealed that the thin current layer is unstable to a low-frequency electromagnetic mode with $\mathrm{w}_{ci} < \mathrm{w} < \mathrm{w}_{LH}$, where w_{ci} and w_{LH} are the ion cyclotron frequency and the lower hybrid frequency, respectively. The mode propagates in the cross-field direction and produces the turbulent flow around the electron current layer, so that the electron current is impeded by the turbulence on average. The turbulence effect is evaluated by the anomalous terms in the generalized Ohm's law and is found to provide significant contribution to the force balance. In particular, it is very interesting to remark that the turbulence effect is strongly enhanced in association with the plasmoid ejections. Although the present simulations have been carried out for an unrealistic ion-to-electron mass ratio (mi/me = 100), the linear analyses have demonstrated that the mode still survives for the real mass ratio (mi/me = 1836).

In this paper, we show the recent kinetic simulation results in large-scale 3D system, where it is described that the intense turbulence is caused due to the plasmoid ejections. The possible scenario under the real mass ratio will be discussed using the linear analyses based on the two-fluid equations.

Keywords: 3D magnetic reconnection, dissipation mechanism, turbulence, plasmoid, AMR-PIC simulation

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PEM26-02 Room:102B Time:May 22 14:00-14:15

Local Hybrid Simulation of Magneto Rotational Instability in dilute differentially rotating disks

SHIRAKAWA, Keisuke[1*], HOSHINO, Masahiro[1]

[1]School of Sci. Univ. of Tokyo

Magneto-Rotational Instability (MRI) is a plasma instability which is considered to take place in a magnetized differentially rotating astrophysical disks. It is first proposed by Velikhov in 1959 and later by Chandrasekhar in 1960. Its importance in astrophysical rotating disk was pointed out by Balbus and Hawley in 1991.

This instability can generate MHD turbulence within a few periods of orbit and can generate a strong turbulent viscosity. Thus this instability is considered to play a major role in the context of accretion which requires a strong viscous effect to transport angular momentum in the disk. These nonlinear behaviors of MRI, such as generation of turbulence or accretion due to the strong turbulent viscosity, are mainly studied by numerical simulations under MHD approximation which assumes the plasma as a single component fluid.

However, recent analytical and numerical studies have shown that kinetic effects can be important on the evolution of MRI in dilute accretion disks which are often found around black holes. These studies have mainly focused on the generation of pressure anisotropy during the evolution of MRI, and the plasma which constitutes the accretion disk is treated as a Landau fluid.

In this study, we developed 2-dimensional hybrid code to study local differentially rotating collisionless plasma. We treated ion as a particle and electron as a massless fluid, and included the effect of gravity and tidal force. In this presentation, we would like to discuss the generation and relaxation process of pressure anisotropy during the evolution of MRI.

Keywords: Plasma instabilities, Accretion disks, Magneto Rotational Instability, Kinetic plasma effects

Japan Geoscience Union Meeting 2012
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PEM26-03 Room:102B Time:May 22 14:15-14:30

Evolution of proton temperature anisotropy and Alfvenic turbulence in the radially expanding solar wind

NARIYUKI, Yasuhiro[1*]

[1]KNCT

In the present study, we develop an analytical model of the radially expanding solar wind plasma that includes the proton temperature anisotropy and low-frequency Alfvenic turbulence. The conservation of the "apparent temperature" in the flux tube is derived as the Bernoulli law in the magnetohydrodynamic (MHD) equations with the pressure anisotropy. Our analytical model shows that the conversion from "apparent temperature" to "real temperature" occurs in the radially expanding solar wind.

Keywords: solar wind, proton temperature anisotropy, Alfvenic turbulence

PEM26-04 Room:102B Time:May 22 14:30-14:45

Numerical calculation of solar thermal convection with the Reduced Speed of Sound Technique

HOTTA, Hideyuki[1*], Matthias Rempel[2], YOKOYAMA, Takaaki[1], IIDA, Yusuke[1], Yuhong Fan[2]

[1]University of Tokyo, [2]High Altitude Observatory

We suggest the new technique to calculate solar internal convection efficiently. It is important to understand the solar internal convection. This issue is deeply related to investigation of the solar global flow and the solar dynamo problem. There is a difficulty to solve the solar internal convection numerically, i.e. the speed of sound. The speed of sound is about 200 km/s, whereas the speed of convection is about 50 m/s at the base of the convection zone. The time step is significantly short with this high speed of sound. The anelastic approximation is often adopted to avoid this difficulty and there are many works with this approximation. This approximation, however, requires the frequent global communication in parallel computing and the efficiency becomes bad with large number of CPUs. A larger resolution with larger number of CPUs is essential to solve the proper angular momentum transport by turbulence. Therefore, we are looking for another way, i.e. RSST(Reduced Sound Speed Technique). The speed of sound is artificially reduced with the transformed equation of continuity and the time step can be took large. This technique does not require the global communication. We investigate the validity of this technique to describe the convection. 3D simulations of the convection shows that the characteristic features does not change with RSST when Mach number is smaller than 0.7.

Keywords: sun, convection, numerical calculation

PEM26-05 Room:102B Time:May 22 14:45-15:00

The role of magnetic field on the scale of solar surface convection

IIJIMA, Haruhisa[1*], YOKOYAMA Takaaki[1]

[1]Department of Earth and Planetary Science, University of Tokyo

We are investigating the magnetoconvective effect on the solar surface convection.

The solar surface velocity spectrum has two peaks at the scales of granulation and supergranulation. Supergranulation has strong magnetic field at its boundary, so it is important for the heating of upper atmosphere.

Supergranulation was first discovered in 1950s. Since then, the origin of supergranulation has been an open question. Traditionally, it is believed that the reconbination of helium is the main driver. But the recent study reports that there does NOT appear a supergranular peak in the state-of-art numerical simulation including the effect of partial ionization.

Crouch et al. (2007) suggest the magnetoconvective origin of supergranulation.

The aim of our study is to confirm Crouch's scenario with realistic radiative magnetoconvection simulations.

No supergranular peak was found in our non-magnetic hydrodynamical simulation. This result is consistent with previous studies.

We will report the result with magnetic field and discus the role of magnetic field on the creation process of supergranulation.

Keywords: sun, photosphere, convection, magnetic field

Japan Geoscience Union Meeting 2012
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PEM26-06 Room:102B Time:May 22 15:00-15:15

Magnetospheric sources and mechanisms of Region 2 field-aligned currents

HANAOKA, Tomoki[1*], WATANABE, Masakazu[1], FUJITA, Shigeru[2], TANAKA, Takashi[3], SHINAGAWA, Hiroyuki[4], MURATA, Ken T.[4]

[1]Graduate School of Sciences, Kyushu University, [2]Meteorological College, Japan Meteorological Agency, [3]SERC, Kyushu University, [4]National Institute of Information and Communications Technology

Field-aligned currents (FACs) are the electric currents that flow along magnetic field lines between the ionosphere and the magnetosphere. In the ionosphere, large-scale FACs reside in an annulus that encircles the geomagnetic pole. The FACs located on the poleward side are called <region 1>, while those located on the equatorward side are called <region 2>. Of the two FAC systems, the latter Region 2 FACs are thought to be closed on the nightside, driven by the pressure gradient in the ring current region or the inner edge of the plasma sheet. In order to drive FACs constantly, there must be a region where $j*E < 0$ (with j and E being the current density and electric field, respectively). In the past, this basic energetics of the current system has not been seriously considered. To investigate the source mechanisms of region 2 FACs, we performed global MHD simulation and examined the dynamo processes in the magnetosphere. Our new finding is that the region 2 FACs are closed not only on the nightside, but also on the dayside even in a quasi-stationary magnetosphere. Similar to the nightside region 2 system, dayside region 2 FACs are driven by the plasma pressure gradient and their energy source is the thermal energy of the plasma. However, unlike the nightside region 2 system, the dynamo region of the dayside region 2 system is located at high latitudes just equatorward of and adjacent to the dayside cusp. Thus the dayside cusp is essential for the generation of dayside region 2 FACs. We discuss in detail the physical processes associated with the dayside region 2 system.

Keywords: Magnetosphere, Field-aligned current, MHD simulation

Japan Geoscience Union Meeting 2012
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PEM26-07 Room:102B Time:May 22 15:30-15:45

Plasma particle simulations on spacecraft wake effects on electric field measurements

MIYAKE, Yohei[1*], USUI, Hideyuki[1]

[1]Graduate School of System Informatics, Kobe University

Electrostatic wakes formed behind spacecraft in streaming plasmas are often identified as a potential source of errors in electric field measurements based on the double-probe technique. Particularly in tenuous plasma environments, a positively-charged spacecraft causes enhancement of wake structures and their resultant potential signatures, leading to serious spurious electric fields observed by double-probe instruments [1]. For study of the wake effects, we perform particle-in-cell simulations on the wake structure around the Cluster satellite. In the simulations, we include numerical models of both spacecraft body and conducting booms simultaneously in the simulation system and consider the presence of multi-species ion streams.

For the analysis, we use our own plasma particle simulation code EMSES. Conceptually EMSES can solve floating potentials of multiple conducting elements in a self-consistent manner. Meanwhile, an extreme difference between typical boom radii (of the order of mm) and spacecraft dimensions (of the order of m) is too difficult to simulate within a limited spatial resolution. Therefore, we use a fixed-potential boundary condition for the conducting surfaces instead of the self-consistent treatment of floating potentials. We mimic the extremely-thin boom wire by setting an effective potential value to nearest neighbor grid points from the boom center axis, which is lessened from a real boom potential according to the distances of the grid points from actual boom wire surfaces. The current analysis focuses on the wake structures around the positively-charged Cluster satellite in a tenuous, streaming plasma with multi-species ions (proton and O+).

The simulation result exhibits the wake formation for both proton and O+ densities. However, the wake structures for the two species are clearly different; the wake signature of proton density is largely enhanced compared with the spacecraft and boom geometries, while the wake has a more geometric structure for O+ density. We find a single negative potential peak at about 80 m downstream of the spacecraft body, while potential is positive at a probe position because of the positive spacecraft and boom potential influence. The rate of the positive potential decay is greater for downstream than that for upstream, resulting in potential difference between opposed probe positions. This potential difference may cause a spurious electric field with magnitude of 3–5 mV/m. The field magnitude tends to be smaller for larger proportion of O+ ions. The current analysis should be followed by a dependency analysis on an angle formed between the boom and flow directions, which is left as a future work.

[1] E. Engwall et al., Wake Formation Behind Positively Charged Spacecraft in Flowing Tenuous Plasmas, Phys. Plasmas, 13, 062904, 2006.

Keywords: Electric field sensor, Spacecraft wake, PIC simulation

Japan Geoscience Union Meeting 2012
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PEM26-08 Room:102B Time:May 22 15:45-16:00

Dissipation of electromagnetic energy at relativistic shocks

AMANO, Takanobu[1]*, John Kirk[2]

[1]Nagoya University, [2]Max-Planck-Institut fur Kernphysik

Poynting-flux dominated relativistic flows are thought to occur in many high-energy astrophysical environments, including pulsar winds, jets in active galactic nuclei and gamma-ray bursts. In the case of a pulsar wind, the relativistic flow is terminated by a standing shock (the termination shock) occurring at the point where the pressure of the flow equals to that exerted by a surrounding medium. Although neither ideal magnetohydrodynamic (MHD) flows nor ordinary MHD shocks do not convert the dominant electromagnetic energy into the kinetic energy of particles, observations do suggest that the kinetic energy is dominant in the downstream of the shock, indicating the presence of an efficient energy conversion mechanism. Magnetic reconnection is often invoked as a mechanism that annihilates the fluctuating component of magnetic fields originating from obliquely rotating central objects. However, it is suggested that magnetic reconnection cannot provide sufficient dissipation, so that the fluctuating component remains until the wind reaches the termination shock.

Motivated by this, the dynamics of a relativistic shock standing in a highly magnetized wind containing a fluctuating component is studied. The fluctuation is modeled by a circularly polarized magnetic shear wave embedded in the flow (i.e., an entropy mode wave.) The frequency of the wave measured in the shock rest frame is boosted by the relativistic Doppler shift, and thus, can be higher than the plasma frequency in a parameter regime relevant to pulsar winds. This opens up a new dissipation channel. The upstream wave can be converted into electromagnetic waves (or photons) by the discontinuity and the dissipation may be triggered through subsequent instabilities. By utilizing a newly developed relativistic two-fluid code for pair plasmas, such a energy conversion mechanism is actually shown to exist. It is demonstrated that the shock is strongly modified by self-consistently generated intense electromagnetic waves. A precursor region is formed ahead of the shock in which significant amount of the electromagnetic energy is dissipated into particles. It is found that an initial highly magnetized wind is converted into a particle-energy-dominated, non-relativistic flow across the shock, as required by the boundary condition imposed by a surrounding medium.

Keywords: shock, electromagnetic wave, relativistic

Japan Geoscience Union Meeting 2012
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PEM26-09 Room:102B Time:May 22 16:00-16:15

Vlasov simulation of the interaction between the solar wind and a dielectric body with magnetic anomaly

ITO, Yosuke[1*], UMEDA, Takayuki[1], OGINO, Tatsuki[1]

[1]STEL, Nagoya Univ.

The interaction of a plasma flow with an unmagnetized object is quite different from that with a magnetized object such as the Earth. Due to the absence of the global magnetic field, the unmagnetized object absorbs plasma particles which reach the surface, generating a plasma cavity called ”wake” in the anti-solar side of the object. Since the velocity of the solar wind (SW) is larger than the thermal velocity of ions, ions cannot penetrate into the nightside of the moon. However, ions were observed in the deep wake by a Japanese spacecraft SELENE (KAGUYA) which is orbiting the moon in a polar orbit around 100km altitude. A key mechanism of this phenomenon is thought to be scattering of SW ions at the lunar dayside surface by an interaction between the Interplanetary Magnetic Field (IMF) and a lunar magnetic anomaly. In the present study, we examine entry processes of ions into the wake due to the interaction between IMF and the magnetic anomaly via a full-kinetic Vlasov simulation.

There are two processes that the ion entry into the wake. A shock is formed by the interaction between the dipole magnetic field and the SW. A part of SW ions are reflected at the shock and enter the wake due to the ion gyro motion. On the other hand, the electric field toward the body is generated by the negative charge on the nightside surface. SW ions enter the wake due to the out-of-plane magnetic convection induced by the electric field.

Keywords: Vlasov, Global simulation, magnetic anomaly, full-kinetic

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PEM26-P01 Room:Convention Hall Time:May 22 10:45-12:15

Magnetic neutral line formation in three-dimensional spontaneous fast reconnection

SHIMIZU, Tohru[1*]

[1]Ehime University, RCSCE

Theoretically and numerically, it is still unclear how the three-dimensional fast magnetic reconnection occurs in a one-dimensional current sheet often observed in space plasma explosive phenomena, such as geomagneto-tail. This previous study showed that the classical two-dimensional fast reconnection is unstable for three-dimensional resistive perturbation. It means that two-dimensional fast reconnection can be spontaneously destabilized in the sheet current direction even in an exactly one-dimensional current sheet. In this presentation, it is reported that the magnetic neutral lines are intermittenty formed and disappear and its formation tends to be guided to the sheet current direction.

Keywords: Three-dimensional magnetic reconnection, MHD, Magnetic neutral line, instability

PEM26-P02 Room:Convention Hall Time:May 22 10:45-12:15

The effect of temperature anisotropy on magnetic reconnection in ion-scale current sheet:PIC simulation

YASUDA, Norio[1*], Masaki Fujimoto[2], Iku Shinohara[2]

[1]Univ of Tokyo, [2]ISAS/JAXA

”not yet set”

Keywords: Space plasma, Collisionless magneticreconnection, Particle-in-cell simulation, Temperature anisotropy

Japan Geoscience Union Meeting 2012
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PEM26-P03 Room:Convention Hall Time:May 22 10:45-12:15

Dependence of the initial plasma beta on the structure of the reconnection exhaust

HIGASHIMORI, Katsuaki[1*], HOSHINO, Masahiro[1], Nobumitsu Yokoi[2]

[1]University of Tokyo, Department of Earth and Planetary Science, [2]University of Tokyo, Institute of Industrial Science

One of the most important problems on magnetic reconnection has been in the point that how fast reconnection occurs even in the situation with high magnetic Reynolds number. In order to explain this problem, for example, two pairs of slow-mode shocks attached to the localized diffusion region [e.g., Petschek, 1964], the Hall effect [e.g., Birn, et al., 2001], and the existence of turbulence [e.g., Matthaeus and Lamkin, 1986] have been discussed. Recently, some authors advocated fast reconnection theories from the viewpoint of MHD turbulence [e.g., Lazarian and Vishniac, 1999; Yokoi and Hoshino, 2011], and the turbulence magnetic reconnection is the hotly-debated issue not only in terms of the reconnection problem itself but also in many astrophysical phenomena (e.g., Magneto rotational instability in the accretion disk, whose saturation level is supposed to be controlled by magnetic reconnection in turbulent structures [e.g., Sano, et al., 2004]).

We focus on turbulence in magnetic reconnection, and, especially in this study, self-generation of turbulence in “collisionless” magnetic reconnection is investigated by using a two-dimensional electromagnetic hybrid code. We suggest that whether or not reconnection exhausts become turbulent or laminar strongly depends on the ion plasma beta in the initial inflow region. In order to clarify this, we present some simulation results, where the plasma beta in the initial inflow region is controlled by varying the ion temperature with Alfven velocity constant. Results show that the turbulent reconnection exhaust is observed with $b_{i0}<0.1$, where b_{i0} is the initial ion plasma beta in the inflow region, while the reconnection exhaust becomes laminar in the range of $b_{i0}>0.1$. In addition, reconnected magnetic flux increases as the initial ion plasma beta becomes smaller. It is also suggested that such turbulence in low beta plasmas is associated with electromagnetic waves generated in the plasma sheet boundary layer (PSBL) rather than the central plasma sheet. In this presentation, we mainly discuss why such turbulent structures appear only in the low beta plasma with attention to the property of waves generated in the PSBL.

Keywords: reconnection, turbulence, laminar flow, hybrid simulation, kinematics, ion temperature

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PEM26-P04 Room:Convention Hall Time:May 22 10:45-12:15

Estimations of Diffusion Regions in Global MHD simulations

MURATA, Ken T.[1*], KUBOTA, Yasubumi[1], FUKAZAWA, Keiichiro[2], WATARI, Shinichi[1], WATANABE, Hidenobu[1], YAMAMOTO, Kazunori[1], TANAKA, Takashi[2]

[1]NICT, [2]Kyushu University

It has been widely believed that reconnection takes place around the diffusion regions at the dayside magnetopause of the Earth magnetosphere. However, nobody has ever succeeded in visualizing the reconnection phenomenon in Global MHD simulations.

We have constructed a system on the NICT science cloud that traces each magnetic field lines in the 3D space of Global MHD simulations. The tracing method is based on an assumption of frozen-in of plasma to magnetic field lines. It implies that we cannot trace in the vicinity of the diffusion regions. In order to recognize the region and timing of the dayside magnetic reconnection, thus, we need to examine the diffusion ratio around the Earth magnetosphere.

In the present study, we estimate the diffusion ratio using the break of the frozen-in assumption. We first estimate an amount of magnetic flux around an arbitrary point. We then trace the point, and magnetic flux around the point. The diffusion ratio herein is estimated by the change from the initial flux.

Our estimation indicates that the diffusion regions are located widely upper and lower side of the magnetic equator. The range area is more than 5 Re from the equator. It suggests that the reconnection takes place on at a certain point but around the wide area in front of the magnetosphere.

Keywords: Global MHD simulation, diffusion region, magnetic field line, 3D visualization, reconnection

Japan Geoscience Union Meeting 2012
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PEM26-P05 Room:Convention Hall Time:May 22 10:45-12:15

Abraham-Minkowksi controversy view from MHD theory

NAKAMURA, Tadas[1*]

[1]Fukui Prefectural University

The Minkowski-Abraham controversy has been discussed by a number of authors over a hundred years. Minkowski (1910) proposed the electromagnetic momentum density in a dielectric medium must be **D x B**, while Abraham (1909) proposed **E x H**. There have been published numerous papers on this problem both theoretically and experimentally, but the final conclusion is still yet to come; papers are still being published in this century.

The momentum of an MHD wave has been examined from the view point of the electromagnetic momentum expression derived by Minkowski in the present study. Basic calculations show that the Minkowski momentum is the sum of electromagnetic momentum and the momentum of the medium, as proposed in some of the past literature. The result has been explicitly confirmed by an example of an MHD wave, whose dynamics can be easily and precisely calculated from basic equations. The example of MHD wave also demonstrates the possibility to construct a symmetric energy-momentum tensor based on the Minkowski momentum.

Keywords: Abraham-Minkowski controversy, electromagnetic momentum, MHD waves

Japan Geoscience Union Meeting 2012
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PEM26-P06 Room:Convention Hall Time:May 22 10:45-12:15

Dispersion relation of helicon waves in a non-uniform cylindrical plasma

ISAYAMA, Shogo[1*], HADA, Tohru[1], TANIKAWA, Takao[2], Shunjiro Shinohara[3]

[1]Graduate School of Engineering Sciences, Kyushu University, [2]Research Institute of Science and Technology Tokai University, [3]Tokyo University of Agriculture and Technology

Electric thrusters, characterized with high specific impulse, are considered to be useful for long term space missions such as those to outer planets. On the other hand, the performance of many of the conventional electric thrusters (e.g., ion engines) is limited by electrode wastage. In order to overcome this difficulty, we have initiated the HEAT (Helicon Electrode less Advanced Thruster) project[1], in order to pursue research and development of completely electrodeless (i.e., no direct contact of electrodes with plasma) thrusters.

The electrodeless thrusters are comprised of a plasma generation part and the plasma acceleration part. Understanding of these parts is a challenging issue both from the plasma physics and technology points of view. While efficient plasma production using a "helicon wave" is well established experimentally, there still remain a number of unsolved issues regarding how the plasma is generated using the helicon wave. This is due to the complexity of the problem: one needs to understand how the helicon waves propagate in the plasma, how electrons are accelerated by the waves, how neutrals are ionized, how the wave dispersion relation is modified as the ionization rate is increased, and how these processes interact with each other.

As a first step to solve this problem, we studied what kind of electric field can be generated when the helicon wave propagates into a non-uniform plasma and how it accelerates the electrons. Previous studies show that an electrostatic wave called TG wave is excited as the helicon wave propagates into the non-uniform plasma, and that these TG waves accelerates the electrons efficiently and plays a crucial role in the plasma production[2]. Depending on the propagation/evanescence of the helicon and the TG waves, the plasma can be divided into three distinct regions (Fig.1). We analyzed detailed wave properties of both the helicon and the TG waves in the three regions within the approximation of the WKB. To be exact, on the other hand, since the helicon wavelength can be comparable or longer than the density gradient scale, and since the non-uniform background makes the Fourier formulation inapplicable, propagation of the waves has to be treated as an eigenvalue problem.

Considering the above, we solved the propagation, damping, and mode conversion of the helicon and the TG waves in a non-uniform plasma, numerically using the shooting method. Radial and anti-radial propagating waves of both the helicon and the TG waves co-exit in the system. Energy loading (wave damping) due mainly to the TG waves is analyzed for varying external parameters including the electron-neutral collision frequency.

Keywords: Electric thrusters, The electrodeless thrusters, Helicon plasma, Helicon wave, TG wave, Dispersion relation

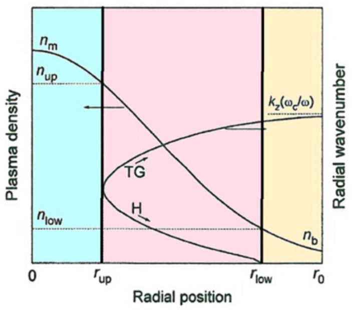

Fig.1 Density profile and solutions of Helicon and TG
・Domain a($n>n_{up}$) : Helicon wave and TG wave can't propagate.
・Domain b ($n_{low}<n<n_{up}$) : Helicon wave and TG wave can propagate.
・Domain c ($n<n_{low}$) : Helicon wave can't propagate, TG wave can propagate.

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PEM26-P07 Room:Convention Hall Time:May 22 10:45-12:15

Numerical study of electric field penetration into magnetized plasmas for a development of electrodeless plasma thruster

OTSUKA, Fumiko[1*], HADA, Tohru[1], Shunjiro Shinohara[2], Takao Tanikawa[3], Takeshi Matsuoka[4]

[1]ESST, Kyushu Univ., [2]Inst. Eng, TUAT, [3]RIST, Tokai Univ., [4]JAXA/ISAS

We have examined ponderomotive acceleration for the development of electrodeless plasma thruster as a part of the HEAT (Helicon Electrodeless Advanced Thrusters) project. When a localized transverse electromagnetic field near ion cyclotron frequency is considered in the plasma region, the ponderomotive force becomes uni-directional in a divergent magnetic field, so that the ion can obtain net energy as it passes through the potential. For the efficient acceleration of the ion, the external electric field near ion cyclotron frequency should penetrate into the magnetized plasmas. In this presentation, we perform electromagnetic PIC simulation by the use of the VORPAL code (Tech-X corp.), and discuss the external electric field penetration near ion cyclotron frequency into the magnetized plasmas. We will elucidate the physical process of the electric field penetration and its influence on the ponderomotive acceleration.

Keywords: electric thruster, plasma acceleration, electrodeless electric thruster, ponderomotive force, electric field penetration

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PEM26-P08 Room:Convention Hall Time:May 22 10:45-12:15

The relationship between the plasma density profile and penetration of magnetic fields due to the RMF acceleration

YAMANOKUCHI, Kazuki[1*], HADA, Tohru[2], Shunjiro Shinohara[3]

[1]ESST,Kyushu Univ, [2]ESST,Kyushu Univ, [3]Inst. Eng, TUAT

Electric thrusters, characterized with high specific impulse, are considered to be useful for long-term space missions such as those to outer planets. On the other hand, the performance of many of the conventional electric thrusters (e.g., ion engine) is limited by electrode wastage. In order to overcome this difficulty, we have been engaging in the research and development of the next generation thrusters in which electrodes do not contact the plasma directly (the Helicon Electrodeless Advanced Thruster project).

Among several different types of electrodeless plasma acceleration schemes we propose, in this presentation we discuss the acceleration concept utilizing the Rotating Magnetic Field (RMF), which has been developed primarily for an application to the plasma confinement in the field-reversed configuration [3]. In this scheme, a rotating external magnetic field is applied to the cylindrical helicon plasma [2], in such a way that the external magnetic field drives the azimuthal electron current. If the background magnetic field has a finite radial component, axial Lorentz force is generated, which can be used as a thruster power [4].

We will show the results of numerical modeling of the interaction between the cylindrical plasma and the RMF. In the past, numerical modeling of the RMF has been studied assuming a uniform density profile in the cylindrical plasma geometry [5]. However, the plasma density in the actual experiment is non-uniform and is low near the boundary. While the low density implies easy penetration of the RMF into the plasma and the generation of the axial Lorentz force, it also implies reduced energy flux of the accelerated plasma, and thus it is important to make a systematic parameter survey to determine the conditions that can yield the maximum thrust. Details of the computations will be given in the presentation.

Keywords: Electric thruster, Electrodeless thruster, Rotating Magnetic Field

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PEM26-P09 Room:Convention Hall Time:May 22 10:45-12:15

Full particle-in-cell simulation on the dynamics of electrons for charge neutralization of a local ion engine beam

USUI, Hideyuki[1*], MIYAKE, Yohei[1]

[1]Graduate school of system informatics, Kobe University

By performing full particle simulations, we have been studying the transient response of electrons emitted for the charge neutralization of a local ion beam originated from an ion engine which is one of the electric propulsion systems. From a macroscopic point of view, ion beam emitted from an ion engine is overall neutralized with thermal electrons emitted from a neutralizer attached next to the engine. In the vicinity of the engine where the emitted electrons are mixed into the ion beam, however, the mixing process of electrons are not so obvious because of large difference of dynamics between electrons and ions. A heavy ion beam basically propagates away from the engine and forms a positive potential region with respect to the background. Electrons emitted for the neutralizer are electrically attracted or accelerated to the core of the ion beam and some of them which has lower energy than the ion beam potential are reflected back to the opposite direction at the beam front. They are also reflected at the engine exit and propagate in the forward direction. In other words, electrons moves along the ion beam with a multi-streaming structure in the beam region. Since the locations of the electron emitter and the ion beam exit are different, the above-mentioned electron motion is also observed in the direction of the beam diameter. We will report the detailed analysis of the electron dynamics in the local beam region and discuss the effect on the spacecraft environment.

Keywords: ion engine, PIC simulation, charge neutralization, electron dynamics

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Angular Beaming Characteristics of Auroral Kilometric Radiation Attributed to Cyclotron Maser Mechanism

IMAI, Masafumi[1*], MACHIDA, Shinobu[1]

[1]Department of Geophysics, Graduate School of Science, Kyoto University

Earth's Auroral Kilometric Radiation (AKR), whose sources are confined in density cavity along the auroral field line, has been observed from spacecraft in the frequency range from 50 to 700 kHz with right-hand and left-hand polarization. From the theoretical point of view, it is widely accepted that the cyclotron maser instability (CMI) plays a role in generating primary in the right-hand extraordinary (R-X) mode of AKR. Previous studies suggested that the beam structure of AKR corresponds filled or hollow cones along magnetic field, but the tangent plane beaming model proposed by Mutel et al. [2008] is the most plausible candidate. In this model, the emissions are confined to a plane tangent to the source local magnetic latitude but refracted upward. More recent work by Menietti et al. [2011] extends this model to the source region as a thin sheet of elementary "sourcelets" using ray tracing technique, in agreement with AKR observations. In terms of numerical simulation, we have used a 2-1/2D electromagnetic electron hybrid code in which we consider the cold electrons to be a fluid, the hot electrons to be finite-size relativistic particles, and the ions to be a charge-neutralizing stationary component. Such velocity distributions as loss-cone, ring-shell and horseshoe, are assumed in the center of the simulation region, while denser cold plasma surrounds this region whose right and left boundaries are terminated by wave absorption regions. This vertical region, in which periodic boundary conditions are assumed, is along Earth magnetic field. We will report the result of this computation concerning the beam structure of AKR as well as the generation process.

Mutel, R. L., I. W. Christopher, and J. S. Pickett (2008), Cluster multispacecraft determination of AKR angular beaming, Geophys. Res. Lett., 35, L07104, doi:10.1029/ 2008GL033377.

Menietti, J. D., R. L. Mutel, I. W. Christopher, K. A. Hutchinson, and J. B. Sigwarth (2011), Simultaneous radio and optical observations of auroral structures: Implications for AKR beaming, J. Geophys. Res., 116, A12219, doi:10.1029/2011JA017168.

Keywords: Earth's Auroral Kilometric Radiation, Cyclotron Maser Mechanism, Electromagnetic Electron Hybrid Code

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Particle acceleration in relativistic shear flow turbulence

OBI, Yoshio[1*], TERASAWA, Toshio[2]

[1]Graduate School of Science, Tokyo Tech, [2]ICRR, University of Tokyo

Relativistic jets have been observed in a variety of astronomical objects, e.g., AGNs, microquasars and GRBs, etc. Shear flows and turbulence arise around a jet, and some observations indicate the emission of accelerated particles in such regions.

We examine how particles are accelerated in relativistic shear flow turbulence. Some previous studies have shown the test particle calculation in given MHD turbulence field or shear velocity. But, these calculations might not be appropriately able to produce relativistic shear flows and turbulence, because of the static turbulence power spectrum or the static discontinuous shear velocity.

To verify the particle acceleration in more realistic relativistic shear flow turbulence, we calculated a 2D Kelvin-Helmholtz(KH) instability of relativistic MHD(RMHD) simulation and then computed test particle simulations with the electromagnetic field obtained from the RMHD simulation.

We find that a part of particles is stochastically accelerated and this acceleration process is interpreted as the acceleration by gradient B drift along the border of the different magnetic field strength arising from the growth of KH instability. We will report the more detailed consideration of our calculation results.

Keywords: Relativistic shear flow, Turbulence, RMHD simulation, Particle acceleration

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Stability of structure of cosmic ray modified shocks

SAITO, Tatsuhiko[1*], HOSHINO, Masahiro[2]

[1]EPS, the University of Tokyo, [2]Department of Earth and Planetary Science, The University of Tokyo

Galactic cosmic rays are believed to be produced around shocks at supernova remnants in our galaxy. A standard shock acceleration theory of cosmic ray is "Diffusive Shock Acceleration", which is known as first-order Fermi acceleration. Recent observations of supernova remnants have revealed that in some cases, a temperature of downstream thermal plasma is lower than that predicted from Rankine-Hugoniot relations, and energy of cosmic rays is comparable to that of thermal plasma. This fact means that a certain ratio of the upstream kinetic energy is used for the acceleration of cosmic rays, and the proportion of energy used for heating the downstream thermal plasma decreases. In those situations, cosmic rays exert the "back-reaction" to background shocks and change the structure of shocks significantly. These shocks are called "Cosmic Ray Modified Shock (CRMS)". In CRMS, the acceleration of cosmic rays proceeds to the nonlinear phase and cosmic rays are strongly coupled with background thermal plasma, namely with background shocks.

In our research, we base on "MHD two-fluid model", where the background plasma and cosmic rays are described as fluid, to discuss about fluid-scale structures of CRMS. It is known that there are multiple solutions in a Rankine-Hugoniot relation of CRMS in the two-fluid model. This leads that there are three possible downstream states with one upstream state.

We conduct one-dimensional numerical simulations and study the time-evolution from these three possible shock structures. The results show that in the three, the structures that produce the most or the least downstream cosmic rays are stable. On the contrary, intermediate structures between the two are unstable and transit easily to the others. We also find there is no dependency of the stability of structures on upstream shock angles.

Next, we conduct simulations from initial conditions where there are not cosmic rays in the downstream or upstream regions. We confirm analytical steady states are realized in nonstationary time-evolution from those initial states.

Keywords: cosmic rays, shock, nonlinear evolution, stability of structure

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Electron accelerations at super-high Mach number shocks: 2D PIC simulations

MATSUMOTO, Yosuke[1*], HOSHINO, Masahiro[2]

[1]Graduate School of Science, Chiba University, [2]Graduate School of Science, the University of Tokyo

Plasma kinetic processes at collision-less shocks have been investigated and recognized as important for injecting electrons towards so-called the diffusive shock acceleration mechanism. The shock surfing acceleration is one of the prominent mechanisms that can quickly accelerate the electrons at the leading edge of the shock foot region by DC electric fields. The underlying mechanism of the shock surfing acceleration is the plasma kinetic process between the reflected ions and the incoming electrons that leads to the excitation of Buneman instability.

We have examined electron acceleration mechanisms at high Mach number shocks by means of two-dimensional PIC simulations with a large ion-to-electron mass ratio. We found the electrons are effectively accelerated at a super-high Mach number shock (M_A~30 in the shock-rest frame). The shock surfing acceleration is an effective mechanism for accelerating electrons toward the relativistic regime even in two dimension. An additional acceleration by the strong electric fields at the shock surface further energized the pre-accelerated electrons up to gamma ~ 9. These two step accelerations are found only in the super-high Mach number shock with a low upstream electron beta_e condition.

The conditions of the electron shock surfing acceleration toward the relativistc regime have been derived from one-dimensional arguments [Cargill and Papadopoulos; 1988, Papadopoulos, 1988]. These simple estimations still hold in the present two-dimensional simulations. While all our simulation runs satisfies the unstable condition of the Buneman instability, the shock surfing acceleration was observed in two simulation runs which also satisfied the trapping condition of accelerated electrons by the excited electric field. A similar aspect holds in recent two-dimensional PIC simulations with different parameters from our simulation runs [Umeda et al., 2009; Riquelme and Spitkovsky, 2011].

Exception is also found in a high beta_e condition. In this run, the Buneman instability was destablized in the foot region. However, its peak amptitude is not so large that electrons can be escaped from the trapping region before reaching the relativistic regime. A similar exception was also found by Kato and Takabe [2010]. Although their linear analysis revealed that the foot region in their simulation result was destabilized by the Buneman instability, the resultant energy spectrum showed a Maxwellian like what we see in the present study. These results indicate that we cannot simply understand the high electron beta_e simulations from the linear and quasi-linear theories of cold plasma, and detailed analysis of the saturation mechanism of the Buneman instability with finite electron temperature effects is necessary.

Keywords: Supernova remnants, collision-less shock, electron acceleration, high perfomance computing

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PEM26-P14 Room:Convention Hall Time:May 22 10:45-12:15

Reformation at low-Mach-number perpendicular shocks

UMEDA, Takayuki[1*], KIDANI, Yoshitaka[1], MATSUKIYO, Shuichi[2]

[1]STEL, Nagoya Univ., [2]ESST, Kyushu Univ.

Large-scale two-dimensional full particle-in-cell simulations are carried out for studying periodic self-reformation of supercritical perpendicular shocks. It is confirmed that the structure and dynamics of shocks are affected by the coupling between ripples and microinstabilities at the shock front. The shock reformation is absent when electromagnetic instabilities such as the modified two-stream instability are dominant at the shock foot. Electromagnetic whistler mode waves excited by the modified two-stream instability couples with the shock-front ripples, resulting in strong scattering of reflected ions at the shock front. On the other hand, the shock reformation is persistent when there is no microinstabilities or electrostatic instabilities are dominant at the shock foot. However, the reformation period is modified essentially due to the shock-front ripples because reflected ions are less scattered at the shock front.

Keywords: shock waves, particle simulation, cross-scale coupling, instability

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Test-particle analysis of electron scattering in the Saturn's inner magnetosphere by neutral H2O from Enceladus

TADOKORO, Hiroyasu[1*], KATOH, Yuto[1]

[1]Graduate School of Science, Tohoku University

Cassini observations revealed that Saturn's moon Enceladus ejects neutral H_2O from its southern pole with temporal variability [e.g., Hansen et al., 2006]. This volcanic activity, so-called 'plumes', leads to the electromagnetic coupling between Saturn's ionosphere and plasmas around Enceladus. The coupling causes auroral activities around the footprint of Enceladus [Pryor et al., 2011]. They reported that observed field aligned fluxes of electrons and ions are sufficient to brighten the footprint aurora observed by EUV onboard Cassini. On the other hand, an electron precipitation into the atmosphere through pitch-angle scattering also causes auroral emissions. The dominant physical process controlling the activity of the footprint aurora is still controversial.

In the present study, for the quantitative evaluation of auroral emissions caused by the pitch-angle scattering through elastic collisions between magnetospheric electrons and H_2O particles, we have developed a spatially one dimensional test-particle simulation code along a dipole magnetic field at Enceladus (L = 3.95). We assume that the initial velocity distribution of energetic electrons at the magnetic equator forms a velocity distribution with a loss-cone. An interaction between an electron and a background neutral cloud is solved by the Monte-Carlo method using differential cross sections of elastic collisions for H_2O. We show a result of the variability of precipitating electrons and estimation of the expected brightness of auroral emissions.

Keywords: test particle simulation, Enceladus torus, Saturn, elastic collision, H2O plume, pitch angle scattering

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Simulation study of whistler-mode wave propagation in the dipole coordinate

KATOH, Yuto[1*]

[1]Dept. Geophys., Grad. Sch. Sci., Tohoku Univ.

In the Earth's inner magnetosphere, whistler-mode chorus emissions are observed mostly on the dawn side and are enhanced during geomagnetically disturbed periods. Chorus emissions are narrow band emissions observed in the typical frequency range of 0.2 to 0.8 ¥Omega$_{e0}$ with a gap at the half ¥Omega$_{e0}$, where ¥Omega$_{e0}$ represents the electron gyrofrequency at the magnetic equator. Components of emissions in the frequency range lower and higher than 0.5 ¥Omega$_{e0}$ are respectively called the lower-band and upper-band chorus emissions. The gap at 0.5 ¥Omega$_{e0}$ has been understood by the difference of the propagation characteristics of whistler-mode waves of frequency higher or lower than 0.5 ¥Omega$_{e0}$ propagating along the field aligned ducts of enhanced/depleted plasma density [e.g., Bell et al., 2009]. The difference of the characteristics of upper-band and lower-band chorus emissions has been explained by the different propagation properties of whistler-mode waves of different wave frequency. For the discussion of the properties of whistler-mode wave propagation in the dipole magnetic field, we have developed a simulation code with a dipole geometry.

In this presentation we show initial results of the simulation of the whistler-mode wave propagation in the inner magnetosphere. We assume the wave source of monochromatic whistler-mode waves in the equatorial region of the magnetosphere. By assuming a cold plasma density distribution with a spatial gradient in both latitudinal and radial direction in the dipole magnetic field, we study the difference of propagation properties of whistler-mode waves of different wave frequency.

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Response of earth's magnetosphere to IMF rotation

IWADACHI, Atsushi[1*]

[1]Solar-Terrestrial Environment Laboratory

I examined response of earth's magnetosphere to IMF rotation by using high-resulution MHD simulation with fine grid, and focus on relation between current and vorticity.The simulation model adopts a half model by assuming a morning-evening symmetry. The grid point is (nx,ny,nz)=(900,400,800), except on both boundary points. The grid interval is dx=dy=dz=0.1Re. This interval can caluculate vorticity grow by Kelvin-Helmholtz instability.The solar wind density is 10/cc, velocity is 300km/s, and temperature is 20000K. I examine response of earth's magnetosphere to IMF rotation by divideing current and vorticity between parallel and perpendicular component to magnetforce, and clarify effect on By component to magnetosphere in case that IMF rotates one degree by one minute.

Keywords: MHD, simulation, Magnetic reconnection, Kelvin-Helmholtz, current, vorticity