Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-01 Room:301A Time:May 24 09:00-09:15

Relaxation of pressure anisotropy and the evolution of Magneto Rotational Instability in collisionless accretion disk

Keisuke Shirakawa[1*], Masahiro Hoshino[1]

[1]Earth and Planetary 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 was 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 effect of pressure anisotropy and results from the linear theory indicates that initial pressure anisotropy may severely affect the evolution of MRI. Since these studies were carried out with Landau fluid closure, relaxation process of ion pressure anisotropy was included by so-called ”Hard Wall approximation”.

In this study, we newly developed a hybrid code in a local differentially rotating system, including the process of ion’s pitch angle scattering in a self consistent manner. From the results, we find a relaxation of pressure anisotropy by effective pitch angle scattering during the evolution of MRI. In this presentation we would like to focus on the effect of initial pressure anisotropy on the evolution of MRI.

Keywords: Collisionless Plasma, Accretion disk, Magneto Rotational Instability

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PEM27-02 Room:301A Time:May 24 09:15-09:30

The structure of an outflow during an X-line retreat

Kenya Shimizu[1*], Masaki Fujimoto[2], Iku Shinohara[2]

[1]University of Tokyo, [2]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency

Particle-in-cell simulations of magnetic reconnection are performed to study the structure of an outflow in asymmetric reconnection. Here the asymmetry is introduced by setting a hard wall that blocks one of the outflows from the reconnection region while leaving sufficient free space in front of the other outflow. Eventually this setting leads to a slow motion of the diffusion region away from the wall, the so-called 'X-line retreat'. During the retreat the structure of the electron outflow against the wall is similar to that seen in a reconnection jet just prior to termination of reconnection in a size-limited simulation box. This implies that the X-line retreat occurs to keep the minimum open space in front of the outflow that makes a reasonably good reconnection rate to be available.

Keywords: magnetic reconnection

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PEM27-03 Room:301A Time:May 24 09:30-09:45

Simulation study of magnetic reconnection in high Raynols number plasma

Takashi Nakabou[1*], Kanya Kusano[1], Takahiro Miyoshi[2], Grigory Vekstein[3]

[1]STEL, Nagoya Univ., [2]Hiroshima Univ., [3]Manchester Univ.

Magnetic reconnection is important process for dynamics in space and laboratory plasmas. Magnetic reconnection is basically dominated by magnetic diffusion at thin current sheet as proposed by Sweet (1958) and Parker (1963). According to their theory, the reconnection rate must be inversely proportional to the square root of the magnetic Reynolds number (S). But in spite of high magnetic Reynolds number (>10ˆ12) in magnetosphere or the solar corona, fast reconnection which rate is about 10ˆ-2 is observed. Slow shock, the Hall- effect and some other processes are considered as the cause of accelerating reconnection. But the mechanism is not fully understood yet. Although in the Sweet and Parker theory, the stability of current sheet is assumed. The recent studies pointed out that current sheet can be destabilized when the magnetic Reynolds number is very large.

Lapenta (2008) investigated how the stability of current sheet and the reconnection rate depend on S using the numerical simulations. As a result, they suggested that, once the instability of current sheet grows, fast reconnection is realized and the reconnection rate becomes insensitive to the magnetic Reynolds number. However they studied the cases only for S = 10ˆ3 to and 10ˆ4 and in which relatively large disturbance of magnetic field is initially imposed to drive the instability of current sheet. Therefore, the transition from the Sweet-Parker type reconnection to the current sheet instability is not yet well understood.

In this paper, we developed the high-resolution magnetohydrodynamics (MHD) simulation of magnetic reconnection in high-S regime aiming at revealing the acceleration mechanism of magnetic reconnection . To obtain this purpose, we apply the HLLD Rieaman solver which was developed by Miyoshi and Kusano (2005) to the high resolution two-dimensional MHD simulation of current sheet dynamics. The HLLD Rieaman solver is a highly accurate and efficient scheme and recently adopted by many standard MHD packages.

In our model, the initial state is given by the Harris sheet equilibrium plus perturbation, of which the amplitude is varied as a parameter. We will talk about the dependency of magnetic reconnection rate, which is defined as the production rate of reconnected magnetic flux, both on S and the amplitude of initial perturbation. We also discuss how the size distribution of plasmoids generated by the current sheet instability is related to the acceleration of magnetic reconnection.

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PEM27-04 Room:301A Time:May 24 09:45-10:00

Validation of a newly developed divergence-free high-resolution MHD code against magnetic reconnection related problems

Yusuke Ohyama[1*], Soshi Kawai[2], Masaki Fujimoto[2]

[1]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, [2]Institite of Space and Astronautical Science, Japan Aerospace Exploration Agency

Understanding the physics of unsteady turbulent magnetic reconnection phenomena in compressible flows is of significant interest in a wide range of space plasma sciences. Early computational works for such turbulent magnetic reconnection flows were dedicated to use a conventional approximate Riemann-type solver, and thus are often too dissipative to resolve the broad range of scales of MHD turbulence and the resultant reconnection phenomena. As a result, the prior simulations employed an anomalous resistivity with some tuned parameters to generate active magnetic reconnection, and they also concluded that at least Hall MHD simulation is necessary to investigate the reconnection phenomena. However, we emphasize that these conclusions were drawn based on using a conventional low-order accurate numerical method. The whole point of our thinking is that if we could construct a physically-consistent high-order accurate numerical method within the MHD approximation, the high-order accurate MHD simulation could be possible to predict the physics of unsteady magnetic reconnection phenomena. We verified this idea by developing a physically-consistent high-order accurate numerical method for compressible MHD simulation and applying it to the problem of interaction of multiple magnetic islands in a long current sheet. The results showed that similar to the two-fluid simulation and PIC simulation the MHD simulation successfully predict the unsteady nature of the active magnetic reconnection phenomena such as X-lines movement and the growth of the magnetic island. The results demonstrate the importance of employing the physically-consistent high-order accurate numerical method for studying the magnetic reconnection phenomena. Furthermore, we think that this study could be extended to investigate the physics of turbulent (thus three-dimensional) magnetic reconnection and planetary formation phenomena.

Keywords: magnetic reconnection, MHD simulation

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PEM27-05 Room:301A Time:May 24 10:00-10:15

Three-dimensional asymmetric magnetic reconnection

Satoshi Takeuchi[1*]

[1] Faculty of Life and Environmental Science, University of Yamanashi

A kinetic model of asymmetric magnetic reconnection in three-dimensional space is analyzed theoretically and with numerical calculations. Consider the case where the two magnetized plasmas are colliding each other; for example suppose that the plasma shock is propagating through the uniform background plasma.

In order to provide a clear understanding of the magnetic reconnection presented here, we show a simple representation of the model with the cartoon in Fig.1. *PlasmaA* is the stationary plasma whose magnetic field is given by B_1. *PlasmaB* is propagating with the velocity v_s in the positive y direction. The electric field of this plasma is given by $E_2=(v_s/c)B_2$ (c being the velocity of light). The magnitude of the field is smaller than that of the field B_1, i.e., $B_1 < B_2$. The crossing angle is defined as the angle between the fields B_1 and B_2. This angle plays an important role in generating the magnetic neutral sheet. If the crossing angle is greater than a right angle, then the magnetic neutral sheet is created in front of the shock. The resonant particle interacting with the shock is trapped by the neutral sheet. Accordingly such the particle is accelerated by the electric field E_2 in the neighborhood of the neutral sheet. If the angle is nearly equal to a right angle, the direction of the acceleration is almost the same as the direction of the magnetic field B_1. The reason is that the direction of the electric field is almost the same as the direction of the field B_1. This is the way of the field-aligned acceleration presented by the author [1]. If the crossing angle is smaller than a right angle, then the magnetic neutral sheet is not created. Therefore the effective energy gain of the particle cannot be expected.

[1] S. Takeuchi, Phys. Plasmas 19, 070703 (2012).

Keywords: asymmetric magnetic reconnection, particle acceleration, plasma shock wave

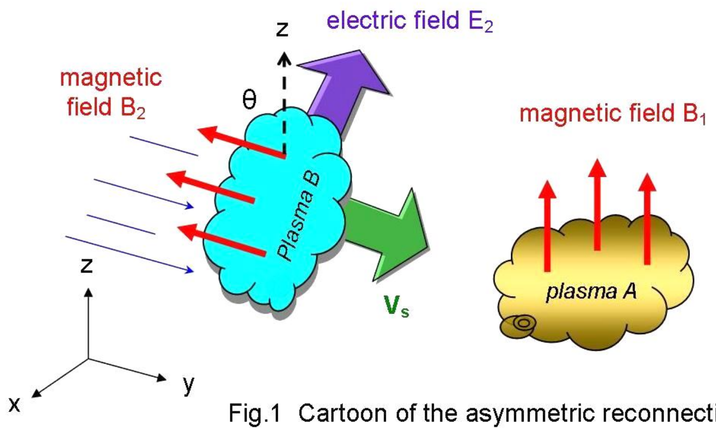

Fig.1 Cartoon of the asymmetric reconnection

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PEM27-06 Room:301A Time:May 24 10:15-10:30

Collisionless magnetic reconnection under the Landau fluid approximation

Kota Hirabayashi[1*], Masahiro Hoshino[1]

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

Magnetic reconnection has been widely researched as a mechanism of generation of hot and fast plasma flow by releasing magnetic enregy stored in a system. Especially, the reconnection accompanied by slow shocks around a localized diffuion region, so-called Petschek type reconnection, is regarded as important from the point of view of the rate for magnetic energy release. In collisionless plasmas, however, the knowledge of this type of fast reconnection is not enough now.

In general, it is known that ions are accelerated along magnetic field lines from a diffusion region. Due to this beam component, the distribution function of ions is largely disorted and the temperature along the magnetic filed is enhanced. Althogh PIC or hybrid simulations have been performed to solve the effect of the beams self-consistently, the results do not indicate the clear evidence for generation of slow shocks predicted by Petschek's theory.

In our research, as an intermediate picture between the ordinary isotropic MHD aproximation and the kinetic theory, we performed a series of fluid simulations by using the double adiabatic limit and the Landau closure model. We investigated the effect of the pressure anisotropy and the Landau damping on global dynamics of magnetic reconnecion.

Under the fluid apprximation, the parallel pressure is enhanced across the slow shock since mirror motions are accelerated with the deformation of magnetic flux tubes. The structure downstream is greatly difference from the isotropic MHD case, and the outflow region becomes wider. In this talk, we report the detail of the structure formation.

Keywords: magnetic reconnection, collisionless plasmas, Landau fluid

PEM27-07 Room:301A Time:May 24 10:30-10:45

Kinetic modeling of asymmetric reconnection

Seiji Zenitani[1*], Michael Hesse[2], Masha Kuznetsova[2]

[1]NAOJ, [2]NASA Goddard Space Flight Center

At dayside magnetopause, magnetic reconnection takes place between the terrestrial dipole field and the solar-wind magnetic field. In such an configuration with asymmetric upstream conditions, reconnection behaves differently from the standard symmetric reconnection in the magnetotail. Since the upcoming MMS mission will extensively probe dayside magnetopause during its first phase, it is of immediate importance to understand key properties of asymmetric reconnection. In the MHD regime, the CSB (Cassak-Shay-Birn) theory is very successful to approximate reconnection properties with asymmetry. However, in the kinetic regime, recent simulations have reported that the reconnection rate is substantially lower than the CSB prediction. We investigate the anomalous slow-down with particle-in-cell simulations. This is attributed to the kinetic dissipation mechanism around the electron-scale dissipation region. In this contribution we discuss the electron motion near the dissipation region, its impact on the global reconnection rate, and the influence of the guide-field geometry.

Keywords: Magnetic reconnection, Kinetic simulation, Magnetic dissipation, Magnetopause

PEM27-08 Room:301A Time:May 24 11:00-11:15

Nonlinear dissipation of the imbalanced Alfvenic turbulence

Yasuhiro Nariyuki[1*], Tohru Hada[2], Ken Tsubouchi[3]

[1]Faculty of Human Development, Univ. Toyama, [2]ESST, Kyushu Univ., [3]Graduate School of Science, Univ. Tokyo

Nonlinear evolution of Alfvenic turbulence is a fundamental process in the solar wind magnetihydrodynamic (MHD) turbulence. The past observational studies suggested that the MHD turbulence close to the sun is the "slab" fluctuation, where the wave number vector is parallel to the ambient magnetic field, while the "2D" fluctuation, where the wave number vector is perpendicular to the ambient magnetic field, becomes dominant with increasing heliocentric distance. However, the energy transfer process from the "slab" fluctuation to the "2D" fluctuation is still unclear. In the present study, we numerically discuss the nonlinear evolution of the "imbalanced (high cross helicity)" Alfvenic turbulence by using a two-dimensional ion hybrid code. The dissipation processes related to the ion kinetics are demonstrated.

Keywords: solar wind, MHD turbulence

PEM27-09 Room:301A Time:May 24 11:15-11:30

Sigma problem of the Crab Nebula & energy dissipation by parametric instability of large amplitude electromagnetic wave

Tatsuhiko Nikai[1*], Takanobu Amano[1], Masahiro Hoshino[1]

[1]EPS, The University of Tokyo

The Crab Nebula is one of the supernova remnants known best. Today a theoretical model for the nebula is established by Kennel&Coroniti(1983). First, the central star (a pulsar) rotates and creates pair plasmas (electron-positron plasmas). Then the plasmas blow outward accompanying a certain wave as pulsar wind. The wind forms a shock wave and its downstream side is observed as the nebula. Although there must be a energy dissipation of extremely high efficiency from the field to plasmas in pulsar wind region, this mechanism is unknown (sigma problem).

By the way, in space plasmas, especially for solar wind, shock or magnetic reconnection, nonlinear wave-wave interactions are important. Parametric instability is one of these processes, where an incident nonlinear wave decays into several different wave modes satisfying the matching conditions for both frequency and wavenumber.

In this study, we analyze a parametric instability of relativistically intense circularly polarized electromagnetic waves, considering application on sigma problem. Following Max (1973), Lee&Lerche (1978), we analyzed the instability of these waves in a cold relativistic electron-ion plasma. We then extend the analysis to an electron-positron plasma including the effect of relativistically hot temperature. For simplicity, we use 2-fluid equations and get self-consistent equilibrium solutions. Furthermore, we also consider direct-current magnetic field and derive dispersion relation of the instability.

We also discuss an efficiency of energy dissipation by the instability, using a Particle-In-Cell (PIC) simulation code.

Keywords: relativistic plasma, electron-positron plasma, parametric instability, crab nebula, pulsar, particle simulation

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PEM27-10 Room:301A Time:May 24 11:30-11:45

Effect of the magnetic field inhomogeneity on the generation process of whistler-mode chorus emissions

Yuto Katoh[1*], Yoshiharu Omura[2]

[1]Graduate School of Science, Tohoku University, [2]RISH, Kyoto University

Whistler-mode chorus emissions with rising tones are generated through the nonlinear wave-particle interactions occurring in the region close to the magnetic equator. The mirror force plays an important role in the nonlinear interactions and the spatial inhomogeneity is a key parameter of the chorus generation process. The spatial magnetic field inhomogeneity along a field line is widely changed during a geomagnetically disturbed period. In the present study, by a series of self-consistent electron hybrid code simulations, we discuss the effect of the spatial inhomogeneity of the background magnetic field on the generation process of whistler-mode chorus emissions. We have conducted numerical experiments with different spatial inhomogeneities of the background magnetic field, while we assume that the initial velocity distribution function and the number density of energetic electrons are the same at the magnetic equator in all simulation runs. The simulation results reveal that the spectral characteristics of chorus significantly varies depending on the magnetic field inhomogeneity. In the simulation result assuming the smallest inhomogeneity, we observe the excitation of broadband whistler-mode waves whose amplitude is comparable to distinct chorus elements appeared in other simulation runs. We find that the broadband waves are a group of wave elements with rising tones nonlinearly triggered in the region close to the magnetic equator. Based on the simulation results, we show that the small spatial inhomogeneity of the background magnetic field results in the small threshold amplitude for the nonlinear wave growth and makes the triggering process of rising tone elements to emerge easily in the equatorial region of the magnetosphere.

Keywords: whistler-mode chorus, numerical experiment, wave-particle interaction

PEM27-11 Room:301A Time:May 24 11:45-12:00

Gyrokinetic approach to Alfvenic coupling of magnetosphere and ionosphere plasmas

Tomo-Hiko Watanabe[1]*, Yasutaka Hiraki[1]

[1]National Institute for Fusion Science

The magnetosphere-ionosphere (M-I) coupling through the shear Alfven waves plays a key role in spontaneous growth of quiet auroral arcs in polar regions. The feedback instability in the M-I coupling system, which explains simultaneous growth of ionospheric density, field-aligned current, and electric field perturbations, has often been analyzed by the MHD or two-fluid equations. For a more realistic analysis under the magnetospheric condition, however, kinetic effects of ions and electrons are necessary to be incorporated in the theoretical model.

The gyrokinetic (GK) equations for magnetized plasmas have been derived for describing the Alfven and drift waves of which frequency is much lower than the gyro-frequency. Using a theoretical model reduced from the GK equations, we have developed a linear formulation of the feedback instability in a flux tube geometry, where the finite Lamor radius (FLR) effect of ions can be accurately incorporated. The FLR effect leads to increase of the real frequency of the feedback coupling in a large perpendicular wavenumber region. The dispersive Alfven wave is also described by the gyrokinetic equations for electrons and the ion polarization effect. The feedback instability analysis will also be addressed in case with the kinetic electrons.

Keywords: gyrokinetics, magnetosphere-ionosphere coupling

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PEM27-12 Room:301A Time:May 24 12:00-12:15

Killing Flows and Thermodynamics in Minkowski Space

Tadas Nakamura[1*]

[1]Fukui Prefectural University

Thermodynamical approach is often fruitful in investigating large scale plasma phenomena. Assuming local equilibrium, one can handle physical processes such as heat flow using thermodynamics. In relativity, however, our non-relativistic common sense on thermodynamics is not always directly applicable. For example, it has been well known that the local temperature of a relativistic rotating wheel is lower at the axis than at the rim. In such a situation, heat can spontaneously flow from low temperature regions to high temperature regions.

Therefore, one must know how the relativistic thermal equilibrium can take place globally to investigate thermal processes. The author has discussed relativistic equilibrium with parallel motion and rotation in the past meetings; the present talk is to treat the four dimensional relativistic equilibrium from a more general view point.

Thermal equilibrium can take place when the matter is moving with rigid motion, in other words, the proper distance of each element is unchanged during the motion. Geometrically this kind of motion can be expressed as motion along Killing flows. There can be ten linearly independent Killing flows in a four dimensional Minkowski space, and the simple way to express them is four parallel motion and six rotational motion. Possible Killing flows are superposition of these ten, and can be more complicated. Letaw and Pfautsch (1981) have shown that various Killing flows can be categorized into six groups. The first two are the parallel and rotational motion, for which the author has reported equilibrium states in the past meetings.

The other four contains so called static limits, which means a matter cannot stay at a point with fixed spatial coordinates beyond these limits. The light cylinder and ergo region of a Karr black hole are examples of such limits. Thermodynamics across the static limit is interesting topic itself, and applicable to the thermodynamics of accretion plasmas falling into a black hole.

Keywords: relativity, thermodynamics, Killng flow, black holes

PEM27-13 Room:301A Time:May 24 12:15-12:30

Generation of Radio Waves in the Plasma Environments of Regions close to the Event Horizon of Schiwartschild Black Hole

Hiroshi Oya[1*]

[1]Geophysics, Tohoku Univ.

1. Introduction Since 1984, the quest of radio wave pulses from the center of our Galaxy have currently been carried out in our studies. For the decameter and decimeter radio wave pulses it is concluded that these pulses are generated from the rotating black holes whose rotation periods supposed to be coinciding with the observed radio wave pulses. Furthermore it is proposed that the source positions are located in the region very close to the event horizon of the black holes being based on the lowness of the observed frequency and steadiness of the period. In the previous our works where the generation and amplifications of plasma waves near the event horizon of Schiwartschild black holes are theoretically considered being based on the general relativistic electromagnetism apparent possibility of generation of the electromagnetic waves has been verified contrary to the general criticisms that there may no generation of radio wave in the regions close to the event horizon due to depression effects of photon energy caused by the effects of general relativity. In the present works we have further completed the theory and calculated wave parameters which are observable ,as decameter to decimeter wavelength pulses, based on possible plasma condition in the region close to the event horizon of the super massive Schiwartschild black holes.
2. Theory The analyses are based on the 4-dimensional gauge potential equations where the source currents consist of wave components in plasma which are subjected to the momentum transfer from the resonated electron beams that are flowing towards event horizon being enhanced by intense gravity of BH. Improvement has been made to gauge potential equations instead of solving previously proposed 4x4 element matrix to solving the 5x5 elements matrix that are required to have non-trivial solution for the forth dimensional gauge potential equation in plasma. This is caused by consideration of more general constrain for the gauge potential. That is, a new variable should be introduced to obtain self consistent system of equations.
3. Results and Discussion Numerical analyses have been carried out mainly for angular frequency around decameter frequency, 20MHz which are kept as constant value through whole range of space of the present interest, near the event horizon whose position are expressed by the parameter R; R=1-rg/r where rg is Schiwartschild radius and r is the distance from the center of the black hole. Validity of the present new method has been checked by comparing with traditional dispersion equations of Appleton-Hartree in the non relativistic cases (R=1).The amplification of the waves are indicated for the case where the wave propagate with directional component towards the event horizon that is in parallel to the direction of the electron beam. Significant growth of the waves take place in the regime of the UHR branch that appears between local plasma frequency and upper hybrid frequency.The results give confirmation to the previous results that the wave make significant growth even in region deep inside or close to the event horizon R=1E-5 .

Investigations of plasma parameters in the region R=1E-2 to R=1E-6 indicate that local plasma frequency and electron cyclotron frequency are in the range from 1E11 to 1E14 Hz, when we consider the intrinsic values. That is we are observing these high frequency phenomena translated to the range of decameter to decimeter wave length range because of effects of general relativity.
4. Conclusion The present study on generation of the plasma waves based on the improved approach of general relativistic electromagnetic equations, considering together the beam plasma wave interaction, gives results that the region deep inside, toward event horizon, even at R=1E-6 ,for an example, there becomes the source region of the low frequency radio wave such as the case of decameter to decimeter wavelength radio waves.

Keywords: Black Hole, Shiwartzschild, General Relativistic EM Theory, Plasma Waves, Near Event Horizon

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PEM27-14 Room:301A Time:May 24 14:15-14:30

International collaborative study on spacecraft-plasma interactions in the near-Sun environment

Yohei Miyake[1*], Hiroaki Urabe[2], Hideyuki Usui[1], ISSI Team: Spacecraft interaction with space environment[3]

[1]Graduate School of System Informatics, Kobe University, [2]Department of Computer Science and Systems Engineering, Kobe University, [3]International Space Science Institute

Space exploration and exploitation have been rapidly increasing, and a strong demand arises regarding comprehensive understanding of spacecraft-plasma interactions. Numerous numerical tools have been developed in response to such requests, such as Nascap-2k, SPIS, MUSCAT, and other original codes developed by individual researchers. However, it is difficult to understand diverse conditions of spacecraft-plasma interactions by using only one model, because each model has its own advantages and disadvantages depending on employing numerical schemes and modeling techniques. Hence, we have organized an international team for the study of spacecraft-plasma interactions from 2011 and worked on a common problem via multiple numerical tools.

As one of such collaboration 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 a large photoelectron emission current caused by an intense solar flux and a secondary electron emission current due to ambient plasma impingement on the spacecraft surfaces, which lead to much different nature of spacecraft-plasma interactions from that in the near-Earth environment. Consequently, the spacecraft is reported to be charged 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 using the multiple numerical tools. We particularly focus on the properties of negative potential barriers created by a dense photoelectron cloud and the wake structure behind the spacecraft to understand the process of spacecraft-plasma interactions. We will show some preliminary simulation results mainly obtained from our original PIC simulator EMSES.

Keywords: spacecraft-plasma interactions, solar coronal plasma, spacecraft charging, photoelectron emission, spacecraft wake, PIC simulation

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PEM27-15 Room:301A Time:May 24 14:30-14:45

Structures of bow shock and boundary layer of ion scale magnetosphere

Masao Nakamura[1*]

[1]Osaka Prefecture University

Interaction between the solar wind and the mini-magnetosphere of dipolar magnetized objects is investigated by a three-dimensional hybrid simulation, which treats the ions as kinetic super particles via particle-in-cell method and the electrons as a massless fluid. The hybrid simulation is suitable for the study of the mini-magnetosphere which scale is an order of the ion Larmor radius of the solar wind ions at the magnetopause boundary, because the ion kinetic effects are important for its structure. Since the dayside sheath thickness is also an order of the ion Larmor radius, the bow shock has a downstream transition region which overlap with the boundary layer of the magnetosphere. We will also discuss the effects of the interplanetary magnetic field (IMF) condition for the bow shock and boundary layer structures of the ion scale magnetosphere.

Keywords: ion scale magnetosphere, 3D hybrid simulations, bow shock

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PEM27-16 Room:301A Time:May 24 14:45-15:00

A finite volume formulation of the multi-moment advection scheme for Vlasov simulations

Takashi Minoshima[1*], Yosuke Matsumoto[2], Takanobu Amano[3]

[1]JAMSTEC, [2]Chiba University, [3]University of Tokyo

The Vlasov simulation is known as one of plasma kinetic simulation methods, in which the Vlasov equation is discretized on grid points in phase space. Compared to the Particle-In-Cell (PIC) method, the Vlasov simulation is free from the statistical noise and is easy for parallel computation. On the other hand, the Vlasov simulation has the difficulty in advancing the distribution function in velocity space. Especially, the Vlasov simulation of magnetized plasma is quite difficult, owing to the gyro motion around the magnetic field line (solid body rotation in velocity space).

To overcome the difficulty, we have developed a multi-moment advection scheme (Minoshima et al. 2011; 2013). The scheme treats not only point values of a profile but also its zeroth to second order piecewise moments as dependent variables. The scheme remarkably reduces numerical diffusion and is suitable for advancing the distribution function in velocity space. We have successfully applied the scheme to electromagnetic Vlasov simulations.

Here, we newly propose a simplified form of the multi-moment advection scheme. The new scheme treats zeroth to second order piecewise moments as dependent variables at cell center, while point values of a profile are not. Then the scheme adopts a collocated grid system. The basic equation is discretized in a finite volume formulation. A numerical flux at cell face is evaluated by a one-dimensional high-order interpolation, even in multi-dimensional problems. These modifications greatly simplify the scheme compared to the previous one. Benchmark tests of a multi-dimensional advection and rotation problem show that the new scheme keeps profile well for very long time calculation (~1,000 rotations). The application of the scheme to electromagnetic Vlasov simulations will be presented.

Keywords: Vlasov simulations

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PEM27-17 Room:301A Time:May 24 15:00-15:15

High-resolution global Vlasov simulation of small body in the solar wind using K computer

Takayuki Umeda[1*], Yosuke Ito[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University

The interaction between a plasma flow and a small dielectric body with a weak intrinsic global magnetic field is studied by means of a five-dimensional full electromagnetic Vlasov simulation with two configuration and three velocity spaces. The interaction of a plasma flow with a dielectric object is quite different from that with a magnetized object such as the Earth. Due to the absence of the global magnetic field, the dielectric object absorbs plasma particles which reach the surface, generating a plasma cavity called a wake on the anti-solar side of the object. In the present study, entry processes of ions into the nightside wake tail are examined. A high-resolution simulation run is now performed by using the K computer. A preliminary result will be shown.

Keywords: computer simulation, Vlasov code, K computer, small body

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PEM27-P01 Room:Convention Hall Time:May 24 16:15-17:30

Effects of turbulence in fast magnetic reconnection

Katsuaki Higashimori[1*], Nobumitsu Yokoi[2], Masahiro Hoshino[1]

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

Since a magnetic Reynolds number R_m is very large in space, turbulence can be observed in many situations, e.g., in the solar wind and the Earth's magnetosphere. And turbulence is considered to play important roles in various situations such as magnetic reconnection and the diffusive acceleration in shocks. Here, we focus on the relationship between turbulence and magnetic reconnection.

The research on magnetic reconnection itself started around 1960, and it has attracted much attention because of the unique phenomenon that efficiently converts magnetic field energy to kinetic and thermal energy of plasmas. It is well known that the reconnection rate depends on a magnetic Reynolds number (propotional to ${R_m}^{-1/2}$) from a representative theory for reconnection [Sweet, 1958; Parker, 1957]. However, a major problem has been that their model can not explain the fast reconnection observed in space where the magnetic Reynolds number is sufficiently large. Recently, turbulence has been paid much attention as one of agents to solve this problem. For example, it is shown by large scale numerical simulations that a reconnection rate becomes independent of magnetic Reynolds number, R_m, as R_m increases, if turbulence exists [Loureiro+, 2009]. Another study addressed an importance of self-generation of turbulence in magnetic reconnection from the viewpoint of the theory of turbulence [Yokoi and Hoshino, 2011]. This theory predicts that the cross helicity (which is defined as a macroscopic value for turbulence) generated by the breaking of symmetry in magnetic reconnection would enhance the reconnection rate dramatically.

We have developed a new simulation code based on the MHD turbulence model [e.g., Yoshizawa, 1990] in order to clarify the relationship between turbulence and magnetic reconnection. In our simulation code, equations of time evolution for the cross helicity and turbulent kinetic energy are solved in addition to the ordinal MHD equations. Then, these quantities for turbulence interact with mean quantities, like the magnetic field and the velocity, through the turbulence electromotive term in the Ohm's law. Simulation results show the generation of the cross helicity along the reconnection exhaust as the theoretical prediction. It has also turned out the effective turbulent diffusion were localized around the reconnection point due to the spatial inhomogeneity of the cross helicity, and this results in a fast magnetic reconnection. In this presentation, from the result of our simulation, we present an overview of MHD turbulence model and discuss the importance of transport and localization of turbulence in the fast magnetic reconnection.

Keywords: magnetic reconnection, turbulence, cross-helicity, laminar flow, reconnection rate, simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P02 Room:Convention Hall Time:May 24 16:15-17:30

Revisiting hybrid and Hall MHD models for space plasma simulations

Takanobu Amano[1*]

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

One of the outstanding difficulties for modeling space plasma phenomena is the huge gap between many different temporal and spatial scales. Accordingly, there exist several physical models suitable to describe phenomena occurring on a specific scale. The well-known magnetohydrodynamics (MHD) description gives an adequate view for macroscopic phenomena like global magnetospheric dynamics. On the other hand, key phenomena such as reconnection at the near earth neutral line is believed to be crucial even for the global dynamics of the magnetosphere. This calls for a more sophisticated model that is able to, at least in an approximate manner, describe kinetic effects controlling the key processes, while keeping the global dynamics yet computationally tractable. It is known that when the spatial scale becomes of the order of ion inertial length, the Hall term starts to play a role. Indeed, the importance of the Hall term in reconnection physics has been recognized for years. The Hall MHD model would therefore be the simplest model beyond ideal MHD. One may also includes kinetic effects by treating ions as an ensemble of macroscopic particles rather than a fluid. The hybrid model usually do so while approximating electrons as a massless charge-neutralizing fluid, thus ignoring their finite inertia and kinetic effects. Since these models do not include high frequency waves associated with electron scale physics, computational requirement is much less than the fully kinetic model in which both electron and ions are treated as kinetic particles. It appears that they are useful tools to describe physics beyond ideal MHD. In reality, however, they tend to be numerically unstable when dealing with the scale length smaller than the ion inertial length. Because of this, the applicability of the models have been severely limited to date.

Here, we look for the reason for the numerical difficulty and reconsider the formulation of these models. By analyzing the linearized magnetic field induction equation including the Hall current, we find that the problem seems to become ill-conditioned for the high frequency whistler mode branch. Namely, for whistler waves, even a small numerical error in the ion fluid velocity would be substantially amplified, implying a numerical instability. We suggest that the problem may be resolved by retaining an approximate non-zero electron inertial current term. Since the exact expression for the electron inertial current is not desirable for our purpose of describing waves with frequency much smaller than the electron cyclotron frequency, we assume that electrons are magnetized. Under this assumption, the electron inertial current may be approximated by a temporal derivative of the electric drift velocity, which makes the equation of motion of the electron fluid as essentially an equation describing time evolution for the electric field. In this model, the induction equation no longer involves explicit dependence on the ion fluid velocity. Linear analysis has been carried out to find that the present model gives an adequate description for scales larger than the electron inertial length. Comparisons with other models (MHD, Hall MHD, two fluid) as well as the applicability of the model will be addressed.

Keywords: space plasma, numerical simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P03 Room:Convention Hall Time:May 24 16:15-17:30

Simulation study on the hemispheric asymmetry of the solar dynamo cycle based on the flux transport dynamo model

Daishi Shukuya[1*], Kanya Kusano[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University

It is well known that the polarity of the solar magnetic fields on the poles periodically reverse at about 11 years. And it is also known that the reversal at one pole is followed by that on the other pole. The time difference of magnetic field reversal between the poles was first noted by Babcock (1959) from the very first observation of polar field. Svalgaard and Kamide (2013) recently indicated that there is a relation between the time difference of polarity reversal and the hemispheric asymmetry of the sunspot activity. However, the mechanisms for the hemispheric asymmetry are still open to be revealed.

In this paper, we study the asymmetric feature of solar dynamo based on the flux transport dynamo model (Chatterjee et al. 2004). We carried out the mean field dynamo simulations using the updated SURYA code which was originally developed by Choudhuri and his collaborators (2004). We analyzed the phase relation between the symmetric and asymmetric components, which correspond respectively to the quadrupole and dipole-like components, using the field decomposition technique proposed by Nishikawa and Kusano (2008). As a result, we found that the two components are mixed even if the dipole-like component is predominant and that the mixing of the two components causes the time lag of polar field reversals between the different hemispheres.

We will discuss also about the causal relationship between the time lag of polar field reversals and the asymmetric activity of sunspot focusing on the influence of nonlinear feedback processes driven by the magnetic buoyancy.

Keywords: solar dynamo, simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P04 Room:Convention Hall Time:May 24 16:15-17:30

Particle-In-Cell simulation on the interactions between the solar wind and a magnetic anomaly on the moon

Misako Umezawa[1*], Hideyuki Usui[1], Masaharu Matsumoto[1], Masaki N Nishino[2], Yohei Miyake[1]

[1]Graduate school of system informatics, [2]JAXA/ISAS

The objectives of the current research is to reveal the plasma environment in terms of plasma distribution and field enhancement caused by the interactions between the solar wind and magnetic anomaly found on the moon surface by considering the plasma kinetics. We perform plasma particle simulations for the current study. To increase the spatial resolution at the high density region of magnetic field as well as plasma, we utilize our new particle code called PARMER in which adaptive mesh refinement is incorporated. First, we analyzed simple cases where small-scale magnetic dipole is immersed in a plasma flow. Then we examined a case of magnetic anomaly found in Reiner Gamma on the moon and analyzed the solar wind interactions.

If we define the dipole size L as the distance between the dipole center and a position where the solar wind dynamic pressure balances the magnetic pressure, L of our interest is in the meso-scale which implies the size smaller than the ion's inertia length and sufficiently larger than the electron Larmor radius in the solar wind. Contrary to the Earth's magnetosphere, difference of dynamics between ions and electrons with respect to the local magnetic field play an important role in the magnetosphere formation. In other words, electron-ion coupling through a dipole field becomes important.

The simulation results obtained with the plasma particle simulations we performed so far show that electron interactions are important in the process of meso-scale magnetosphere formation. Around the distance of L from the dipole center, charge separation occurs because of the difference of dynamics between electrons and ions. Then intense electrostatic field is induced and ions, which can be assumed unmagnetized in the present dipole size, are eventually influenced by this electric field.

In the case of magnetic anomaly found in Reiner Gamma, the magnetic field is almost perpendicular to the solar wind. In such a situation, increase of plasma and magnetic field densities is found at the dayside region in the simulation results. When the direction of IMF changes, their increase fluctuates because of the magnetic field reconnection. One of the interesting findings is that the solar wind ions do not reach the moon surface in Reiner Gamma. We will discuss this point by considering the plasma dynamics as well as the electrostatic field observed over the Reiner Gamma region.

Keywords: Plasma particle simulation, magnetic anomaly, small-scale magnetic dipole, solar wind, Reiner Gamma

PEM27-P05 Room:Convention Hall Time:May 24 16:15-17:30

Numerical study on particle acceleration in multi-shock system

Masaru Nakanotani[1]*, Tohru Hada[1], Shuichi Matsukiyo[1]

[1]ESST, Kyushu Univ

One of the plausible mechanisms producing cosmic rays is the first order Fermi acceleration in a collisionless shock wave. Most of the previous studies on this process are based on the assumption that charged particles interact with a single shock wave. However, a number of shock waves are ubiquitous in space. Two shocks frequently come close to or even collide with each other. For example, in the heliosphere, it is usual that an interplanetary shock collides with a terrestrial bow shock or the termination shock. In our research, we discuss particle acceleration processes in a system including two collisionless shock waves.

First, test particle simulations are performed to reproduce the particle acceleration process in a system including two motionless shocks. We find that power-law index of particle energy spectrum depends on particle energy, i.e., high energy particles show hard spectrum, while low energy particles denote soft one. We have extended the diffusion convection model to discuss the double shock system. The results are understood as follows: the high energy particles with a large diffusion coefficient are able to cross the two shocks within a typical scattering length scale and are efficiently accelerated as if they cross a single shock with a very large effective compression ratio. However, the low energy particles, associated with small diffusion coefficients, can cross only one shock within the same time scattering scale. The power-law index in the double shock system can be, then, harder than that of the strong shock limit (=2) in the single shock system.

Next, we investigate the process of particle acceleration when two collisionless shocks collide with each other by using one-dimensional full particle-in-cell (PIC) simulation. In the previous work [Cargill et al, 1986], they used a hybrid simulation and indicated that ions were efficiently accelerated when two supercritical shocks collided. However, electron dynamics are neglected in a hybrid simulation. Therefore, it cannot resolve the microstructures of the two colliding shocks. Here, we perform the PIC simulation to discuss detailed electromagnetic structures of the colliding shocks as well as the associated acceleration processes of ions and electrons.

Keywords: multi-shock waves, particle acceleration, numerical simulation

PEM27-P06 Room:Convention Hall Time:May 24 16:15-17:30

The effect of magnetic field on cosmic ray modified shocks

Tatsuhiko Saito[1*], Masahiro Hoshino[1], Takanobu Amano[1]

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

Galactic cosmic rays are believed to be accelerated by the supernova remnant shocks. When the acceleration process enters the nonlinear regime, the cosmic rays exert back reactions to the shocks (Drury & Falle 1981). Recent some observations of supernova remnants imply this back reactions actually occur (Helder et al. 2009; Hughes et al. 2000; Vink et al. 2006). These shocks whose structures change because of the existence of cosmic rays are called cosmic ray modified shocks.

On the other hand, there is the maximum energy problem as one of important subject in acceleration mechanism of galactic cosmic rays. To this issue, the solutions by magnetic amplification is proposed by many researches. Among them, Malkov & Diamond (2010) suggest that the instability due to back reactions of cosmic rays, particularly a gradient of cosmic ray pressure (Drury & Falle 1986), plays a dominant role in this matter.

In our research, we investigate the amplification effect of this instability and interaction of it with shocks. Drury & Downes (2012) conducted MHD simulation and showed magnetic amplification. But they treated only with the precursor region which is located in front of shocks without shocks. In out research, we conduct simulations including shocks in self-consistent form. We can discuss the whole system of back reactions of cosmic rays, shock structures and the structure of magnetic field. We also evaluate the relations between magnetic amplification and parameters of shocks.

Keywords: cosmic rays, shock

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P07 Room:Convention Hall Time:May 24 16:15-17:30

1D PIC simulation of electromagnetic field penetration into magnetized plasmas for electrodeless electric thrusters

Fumiko Otsuka[1*], Tohru Hada[1], Shunjiro Shinohara[2], Takao Tanikawa[3]

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

We perform one-dimensional particle-in-cell (PIC) simulation of external electromagnetic field penetration into magnetized plasmas for development of electrodeless electric thrusters. The externally applied electromagnetic field near ion cyclotron frequency is assumed for the ponderomotive acceleration/ion cyclotron resonance (PA/ICR) scheme. We consider two schemes for the electromagnetic field excitation: electrostatic excitation by electrodes and electromagnetic excitation by current antenna. For both schemes we will evaluate a degree of the electromagnetic field penetration and discuss an energy conversion rate of the external field into plasmas in the PA/ICR scheme.

Keywords: external electromagnetic field, electric field penetration, electrodeless electric thruster, plasma acceleration, ponderomotive force, PIC simulation

Japan Geoscience Union Meeting 2013
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PEM27-P08 Room:Convention Hall Time:May 24 16:15-17:30

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

Kazuki Yamanokuchi[1*], Tohru Hada[1], Shunjiro Shinohara[2]

[1]ESST,Kyushu Univ., [2]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) [1].

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 [4]. 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 [5].

We will show the results of two dimensional numerical modeling of the RMF acceleration by Particle-in-Cell method. The axial thrust is generated by Lorentz force, so high azimuthal electric current is effective for electric thruster. We will show how the penetration of RMF depends on the parameters of plasma and RMF, 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.

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Keywords: Electric thruster, Electrodeless plasma acceleration, Rotating Magnetic Field, Numerical simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P09 Room:Convention Hall Time:May 24 16:15-17:30

Dispersion relation of helicon waves with dissipation

Shogo Isayama[1*], Tohru Hada[1], Takao Tanikawa[2], Shunjiro Shinohara[3]

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

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 Electrodeless Advanced Thruster) project, in order to pursue research and development of completely electrodeless (i.e., no direct contact of electrodes with plasma) thrusters.

The electrodeless thrusters are composed of a plasma generation part and the plasma acceleration part. While efficient plasma production using a "helicon wave" is well established experimentally, there still remains 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 one another.

As a first step to solve this problem, we have invetsigated what kind of electric field can be generated when the helicon wave propagates into non-uniform plasma and how it accelerates the electrons. The dispersion relation of helicon waves is obtained in a non-uniform cylindrical plasma. The frequency range of helicon waves is w_{ci}(ion cyclotron frequency)$<<w<<w_{ce}$(electron cyclotron frequency). Thus, helicon waves are a kind of whistler waves propagating at some oblique angle with respect to the back ground axial magnetic field B_0. We assume a bounded cylindrical chamber and axial wave number is fixed by some boundary condition. From the dispersion relation, we obtain the helicon wave (long wavelength: propagating at nearly parallel angle for B_0) and the so-called TG wave (short wavelength: propagating at nearly perpendicular angle to B_0) as solutions. These waves can linearly couple in a non-uniform plasma. In particular, dispersion curves for these waves merge at a certain location, implying that an efficient mode conversion should take place. Previous studies show that an electrostatic TG wave is excited as the helicon wave propagates into the non-uniform plasma. Then, these TG waves efficiently accelerate the electrons and plays a crucial role in the plasma production. First, we discuss dispersion relation of helicon waves in a non-uniform plasma including dissipation using a fluid model. Then, we analyze the dispersion relation using a full PIC simulation.

Keywords: Electric thrusters, The electrodeless thrusters, Helicon wave, TG(Trivelpiece-Gould)wave

Japan Geoscience Union Meeting 2013
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PEM27-P10 Room:Convention Hall Time:May 24 16:15-17:30

An open boundary condition in the AMR-PIC simulations of magnetic reconnection

Keizo Fujimoto[1*]

[1]Division of Theoretical Astronomy, National Astronomical Observatory of Japan

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 viscosity gives sufficient dissipation for supporting the reconnection electric field 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. Recent 3D particle-in-cell (PIC) simulations with the adaptive mesh refinement (AMR) have revealed that an electromagnetic turbulence in the current density direction gives rise to significant anomalous dissipation in association with plasmoid formations and enhances the effective width of the current sheet. However, the observations in space and laboratory have shown even wider current sheet during the fast reconnection, which implies the existence of more intense turbulence. It is reasonable to expect that, in a much larger system in the current density direction, the plasmoid formations are more three dimensional, which results in more turbulent current sheet.

The previous AMR-PIC simulations of magnetic reconnection have employed the periodic boundary condition in the outflow direction and the conducting wall condition in the upstream direction. These boundary conditions have an advantage that the implementation is easy, but they require very large system size for one to investigate the quasi-steady reconnection processes. Furthermore, the particles split around the x-line accumulate eventually in the downstream region, so that the number of the super-particles in the system increases as reconnection goes on. In order to achieve more efficient simulations of quasi-steady reconnection, we have developed an open boundary condition for the AMR-PIC model both in the downstream and upstream directions. The open boundary condition allows the particles and magnetic flux to leave the system in the downstream direction and to enter the system in the upstream direction. There are two advantages of using the open boundary condition: the first is to enable us to shrink the system size drastically in the reconnection plane, and the second is that the total number of the super-particles in the system is decreased. As a result, the redundant computer resources can be used to increase the system size in the out-of-plane direction. We expect that by using the open boundary condition one can obtain one order larger system size in the current density direction.

In this paper, we show initial results of the 2D AMR-PIC simulations of magnetic reconnection under the open boundary condition. It is described that the initial current sheet plasma is removed from the system and quasi-steady reconnection is achieved. By comparing to the results of the previous AMR-PIC simulations, we will discuss the efficiency by using the new boundary condition.

Keywords: magnetic reconnection, AMR-PIC model, open boundary, turbulence

Japan Geoscience Union Meeting 2013
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PEM27-P11 Room:Convention Hall Time:May 24 16:15-17:30

The effect of the ion gyro motion to the non-linear growth of the Kelvin-Helmholtz instability

Satoshi Ueno[1*], Takayuki Umeda[1], Takuma Nakamura[2], Yosuke Matsumoto[3], Shinobu Machida[1]

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, [2]Los Alamos National Laboratory, [3]Graduate School of Science, Chiba University

The Kelvin-Helmholtz instability (KHI) is one of fundamental hydrodynamic instabilities in plasma. The KHI takes place in a velocity shear layer and has been considered to occur at in the low-latitude boundary layer. In the present study, we examine the effect of the ion gyro motion to the nonlinear growth of the KHI via a full-kinetic two-dimensional Vlasov simulation. We perform two simulation runs. In Run A, the direction of the ion gyro motion is opposite to the rotation direction of the KH vortex. In Run B, on the other hand, the directions are same.

It is found that the growth rate of a wave mode at the ion gyro radius in Run B is smaller than in Run A. This is due to the stabilization effect of the ion gyro motion. In Run A, a secondary instability occurs at the outer edge of the KH vortex where the half thickness of the gradient of the ion density and secondary velocity shear is thinner than the ion gyro radius. On the other hand, the secondary instability does not develop in Run B because the half thickness becomes similar spatial scale as the ion gyro radius.

Keywords: Kelvin-Helmholtz instability, Vlasov simulation, space plasma, ion gyro motion

Japan Geoscience Union Meeting 2013
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PEM27-P12 Room:Convention Hall Time:May 24 16:15-17:30

Test-particle simulation of electron pitch angle scattering into the Saturn's atmosphere by neutral H2O from Enceladus

Hiroyasu Tadokoro[1*], Yuto Katoh[2]

[1]Tokyo University of Technology, [2]Department of Geophysics, Graduate School of Science, Tohoku University

Cassini observations revealed that Saturn's moon Enceladus (3.95Rs) 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 discovered Enceladus footprint aurora with temporal variability and reported that observed field aligned fluxes of electrons and ions are sufficient to brighten the footprint aurora observed by EUV onboard Cassini. They interpreted that the variability of auroral brightness reflects variations of plume activities. In contrast, 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 with monoenergetic electron 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. It is assumed that the cross sections of elastic collisions are Born-dipole approximation [Khakoo et al., 2008]. An interaction between an electron and a background neutral cloud is solved by the Monte-Carlo method using the differential cross sections of elastic collisions for H_2O. We show a preliminary result of the variability of precipitating electrons with several hundred eV to several keV and estimation of the expected brightness of auroral emissions.

Keywords: electron pitch angle scattering, electron-neutral interactions, Enceladus, test-particle simulation, Saturn

Japan Geoscience Union Meeting 2013
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PEM27-P13 Room:Convention Hall Time:May 24 16:15-17:30

Study of the time evolution of magnetic turbulence induced by the magneto-rotational instability

Kazuhito Sai[1*], Yuto Katoh[1], Naoki Terada[1]

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

Magneto-rotational instability (MRI) is thought to be the generation mechanism of turbulence in accretion disks. Since the resultant turbulence stress causes the angular momentum transport and mass accretion, it is necessary to understand the processes determining the saturation level of the turbulent stress. Sai et al. (2013) suggested that the time variation of MRI turbulence is determined by the existence of the poloidal component of background magnetic field. In the nonzero net poloidal flux case, spike shape time variation of turbulent stress is observed and is suggested to contribute to large part of turbulent stress (e.g., Sano and Inutsuka, 2001). However, details of the physical processes have not been analyzed in the previous studies.

We investigate the processes occurring on the MRI turbulence by performing three-dimensional magnetohyrdodynamic simulations. Our study reveals the most part of processes in the nonlinear state of MRI. Specifically, our simulations reveal the existence of characteristic mode which has the largest amplitude in the nonlinear state of MRI. In this presentation, we report the characteristics of the largest amplitude mode and relaxation process in MRI turbulence.

Based on the results of analysis, we find that the observed dominant mode is expected to be the same wave mode which causes the channel flow reported in Sano and Inutsuka (2001). In previous studies, this mode is thought to be caused by the fastest growing mode which is lengthened by amplification of energy from poloidal magnetic field in turbulence (e.g., Sano and Inutsuka, 2001). However, from detailed analysis, although this mode is explained by the dispersion relation of MRI, we clarify that the wave pattern is determined by the disk thickness and the poloidal component of background field rather than the poloidal component of turbulence. This suggests that the determination process of the largest amplitude mode in the nonlinear state is different from the understanding of the previous studies. In saturation and relaxation phases of this mode, the generation of the parasitic instability (Goodman & Xu, 1994) is suggested even in the nonlinear state. From detailed estimation of each term in the MHD equation system, we also succeed to derive the condition for the occurrence of the relaxation. Using this relaxation condition, it is suggested that the amplification of the poloidal component of magnetic field is crucial to onset of turbulent relaxation. This amplification of the poloidal component of field is also expected to be caused by the growth of the parasitic instability. Moreover, the determination manner of the wave length of dominant mode can be explained by the relaxation condition.

Based on our findings, it is consistently explained that the energy ratio between the radial and azimuthal components of magnetic field, which has been reported in the previous simulations (e.g., Hawley et al., 1995) but has been unsolved. The obtained relation means that the field structure on the turbulence can be predicted when the poloidal flux of background field is given. We expect that the net flux dependence of the turbulent property revealed by the present study becomes a strong tool for considering the coagulation of dust particle and estimating the effect of MRI on disk turbulence.

Keywords: accretion disk, magnetohydrodynamics, turbulence, magneto-rotational instability

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

PEM27-P14 Room:Convention Hall Time:May 24 16:15-17:30

Linear dispersion analyses on EMIC waves in oblique propagation in multi-component plasmas

Hajime Sugiyama[1*], Yoshiharu Omura[1]

[1]Reserach Institute for Sustainable Humanosphere, Kyoto University

It is known that high energy particles in the radiation belt of the terrestrial magnetosphere make bad influence on artificial satellites. For example, relativistic electrons intrude artificial satellites, resulting in breakdown by charging. The high energy particles temporarily decrease when a magnetic storm takes place. Nowadays, it is pointed that electromagnetic ion cyclotron waves (EMIC waves), which are also observed in the magnetic storm, are regarded as a potential cause of the decrease by causing pitch angle diffusion of relativistic electrons and dissipation in polar regions. This study makes linear dispersion analyses on EMIC waves in multi-component plasmas. Especially, we study the growth rate and polarization property in oblique propagation.

We have made progress on Kyoto University Plasma Dispersion Analysis Package(KUPDAP) that has been developed at Research Institute for Sustainable Humanosphere of Kyoto University. We explain basic functions and additional functions of KUPDAP such as display of polarization, and demonstrate it.

Keywords: multi-component plasma, EMIC, oblique propagation, linear dispersion analysis