Japan Geoscience Union Meeting 2011
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PEM026-01 Room:101 Time:May 24 14:15-14:30

Finite amplitude Alfven waves in hot collisionless plasmas: An exact solution

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We demonstrate monochromatic, circularly polarized finite amplitude Alfven waves, which are special solutions of the Vlasov-Maxwell system in hot plasmas. It is shown that a bi-Maxwellian distribution with oscillating transverse bulk motion suggested by the maximum entropy principle is one of the solutions. Alfvenic correlation between transverse bulk motion and magnetic field given by the distribution is consistent with the equilibrium point of the single particle system.The parallel to perpendicular temperature ratio is explicitly related with the wave frequencies. A stability of the distribution function is numerically discussed by using an ion-hybrid simulation code.

Keywords: Alfven wave, Vlasov-Maxwell system, exact solution, equilibrium state, solar wind plasma

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PEM026-02 Room:101 Time:May 24 14:30-14:45

Nonlinear Mirror Mode Structures in the Three-dimensional Model

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[1]RISH, Kyoto University, [2]NCU, Taiwan

The temperature anisotropy ($T_{per}/T_{par}>1$) of ions in the magnetosheath drives the mirror instability. We performed two-dimensional (2D) and three-dimensional (3D) hybrid simulations in open boundary models to study the nonlinear mirror mode structures. In the open boundary systems, because of the propagation of EMIC waves, we can obtain the clearer non propagating mirror mode structures. We analyzed the relation between the mirror instability and the magnetic peaks and dips which are peculiar magnetic structures observed in the magnetosheath. In the 2D open boundary model, we obtain the clear magnetic dips at the nonlinear stage. The magnetic structures become larger in the parallel directions rather than the perpendicular directions. In the 3D model, on the other hand, the mirror instability makes the magnetic peaks structures with the same parameters. We obtain the cigar-like magnetic peaks structures, because of the nonlinear evolution of mirror instability and the symmetric structure in the perpendicular directions. We also performed parametric analyses on the ion beta in both 2D and 3D models. We find that the magnetic peaks also arise in the 2D high beta case as shown in the Cluster observations. Considering the pressure balance between the magnetic field and plasma, we show how the ion beta dependence of the magnetic structures appears. In all parameters, we obtain the magnetic peaks in the 3D models.

Keywords: Mirror instability, Magnetic peak, Magnetic dip, 3D hybrid simulation

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PEM026-03 Room:101 Time:May 24 14:45-15:00

Coarse-grained entropy of collisionless plasemas

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It is known space plasmas often have non-equilibrium distribution functions because their binary collision frequencies are extremely low. Given a non-equilibrium distribution f(x,v), it is possible to calculate information theoretic entropy by integrating f log f. It is known, but not well understood, that the information theoretic entropy is not directly related to thermodynamical entropy; thermodynamical entropy is defined only when the system is in equilibrium.

The author has reported difficulties related to collisionless entropy at the last fall meeting of SGEPSS, and proposed a way to calculate the upper limit of free energy via virtual adiabatic processes. In the present paper, the problem of coarse-graining, which may be the most serious difficulty in application, will be discussed

It can be easily shown that the entropy calculated from the distribution function in the Vlasov equation is a time constant. Therefore, this entropy cannot be regarded as to represent the irreversibility of collisionless systems. When we introduce so called coarse-grained distribution function, which is the one averaged over small but finite volumes in the phase space, the entropy can change in the time evolution. Although it is yet to be proved that this entropy is a time-increasing function, we can relate this entropy to thermodynamical quantities by assuming that.

There is, however, a problem in coarse-graining; the value of entropy depends on the coarse-graining size. This may be a serious problem in application. The distribution functions obtained by spacecrafts are coarse-grained by the resolution of the detectors, and thus the calculated entropy must depend on detectors. Kinetic simulation has the same problem; the entropy must depend of the grid size. The details of this problem and possible solutions will be discussed in the presentation.

Keywords: Collisionless Plasma, Vlasov Equation, Entropy, Thermodynamics

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PEM026-04 Room:101 Time:May 24 15:00-15:15

Non-Linear Evolution of Magneto-Rotational Instability under the effect of Dust Acoustic Wave mode

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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.

On the other hand, recent study has shown that the dust grains which carries about 1% of mass in the astrophysical matter can carry about 10^3 of negative charges through several atomic processes like collisions with charged electrons or ions and photoionization effect. These new heavy plasma components may excite new dusty plasma wave modes in low frequency regime such as dust acoustic wave (DAW), and may modify behavior of plasma instabilities and plasma wave propagation.

Here, we perform both linear and non-linear analysis of multi-fluid plasma equations and study the modification of MRI by existence of charged-up dust particles. In this study, we assume fully ionized multi-component plasma with finite temperature to include the effect of dust acoustic wave (DAW). In the limit of parallel mode, we found the DAW may barely modify the behavior of MRI. On the other hand, result from the linear simulation implied a coupling between MRI and DAW in the oblique mode of MRI.

In this presentation, we would like to discuss a behavior of MRI in the non-linear stage and the effect of dusty plasma with results from numerical simulation.

Keywords: Space Plasma, Accretion Disk, Magneto-Rotational Instability, Dusty Plasma

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PEM026-05 Room:101 Time:May 24 15:15-15:30

Numerical simulation of plasma acceleration due to Rotating Magnetic Field

Kazuki Yamanokuchi[1*], Tohru Hada[2], Shunjiro Shinohara[3]

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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 [1], in order to pursue research and development of completely electrodeless thrusters.

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 components, axial Lorentz force is generated. This Lorenz force accelerates ions in cylindrical plasma, producing a thrust [4].

We will show the results of numerical modeling of the interaction between the cylindrical plasma and the RMF. It is very important that we understand situations in cylindrical plasma with the radial magnetic field. Three essential, non-dimensional (normalized) parameters in the system are the plasma dissipation, driving RMF magnitude, and the radial magnetic field strength. Fraction of the magnetic field penetration into the plasma as well as the penetration time scale will be discussed in detail.

[1] This work was supported by the Grants-in-Aid for Scientific Research under Contract No.(S)21226019 from the Japan Society for the Promotion of Science.
[2] cf. Shinohara, S. et al., Phys. Plasmas vol. 16, 057104, 2009.
[3] Jones, I. R., Phys. Plasmas vol. 6, 1950, 1999.
[4] Inomoto, M., I.E.E.J. Trans. vol. 128, 319, 2008.

Keywords: electric thruster, electrodeless thruster, rotating magnetic field

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PEM026-06 Room:101 Time:May 24 15:30-15:45

Full particle-in-cell simulation study on the solar wind interactions with small scale dipole field

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We have been investigating the solar wind interaction with small-scale dipole magnetic fields comparable to or less than the ion inertial length by performing full particle-in-cell simulations. Such micro-scale magnetosphere would be used for the next-generation interplanetary flight system called Magneto Plasma Sail (MPS) which has been proposed as one of the innovative interplanetary flight systems by JAXA. In the current paper, we focus on the analysis of current layer caused by the interaction of the solar wind at the boundary of the dipole field. The current layer is very important for the MPS thrust which can be evaluated with the Lorentz force obtained with the magnetic field component induced by the current layer and the current by a superconducting coil at the satellite. In a situation where the ion inertia length is larger than the dipole field region, electron interaction with the magnetic field becomes important. The ions, which are basically unmagnetized in such as situation, can be indirectly influenced by the presence of the dipole field due to the electrostatic force cause by the difference from the electron dynamics. We will examine the formation of a small-scale magnetosphere in such a situation as well as the features of the current layer in terms of location, location and width for modeling the current layer.

In addition, IMF effect such as the formation of shock structure and magnetic field reconnection can affect the formation of the current layer. In the preliminary two dimensional PIC simulations, magnetic reconnection takes place at the night side of the magnetosphere even in the northward IMF case. A current density peak is formed inside the magnetosphere due to the electron backflow from the reconnection region, in addition to the induced current density at the front boundary layer where the solar wind momentum is primarily diverted. Consequently, when we consider the IMF effect, we could observe expansion of the dipole field structure and the increase of the MPS thrust at the satellite. We will perform a multi-scale three dimensional PIC simulation to understand the detailed process of the solar wind interaction with a small scale dipole field and point out the difference from those obtained with two dimensional model.

Keywords: dipole magnetic fields, solar wind interactions, particle simulation, magnetoplasma sail

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PEM026-07 Room:101 Time:May 24 15:45-16:00

3D hybrid simulation of the mini-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 and additionally includes a fluid ion component to approximate the cold background plasma component. The hybrid simulation is suitable for the study of the mini-magnetosphere which scale is the order of the ion Larmor radius of the solar wind ions at the magnetopause, because the ion kinetic effects are important for the structure of the mini-magnetosphere. In the northward interplanetary magnetic field (IMF) solar wind case, the shape of the mini-magnetosphere more or less resembles the down-sized geomagnetosphere. On the other hand, in the southward IMF solar wind case, the dayside magnetopause boundary layer became unclear and the density is enhanced in the cusp region. We will discuss the structures of the mini-magnetosphere in the various solar wind conditions.

Keywords: Interaction between solar wind and mini-magnetosphere, 3D hybrid simulation

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PEM026-08 Room:101 Time:May 24 16:00-16:15

Particle acceleration by external electromagnetic field for the next generation electric thrusters

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[1]Kyushu Univ., [2]Tokyo Univ. of Agriculture & Technol.

We have examined particle acceleration by ponderomotive force in divergent magnetic field by test particle simulations, and applied this concept to the next generation electric thrusters, as a part of the HEAT (Helicon Electrodeless Advanced Thrusters) project. In this configuration, two acceleration processes coexist: the ponderamotive acceleration, which is the parallel acceleration of ions along the background magnetic field, and the ion cyclotron resonance, which basically is the perpendicular ion heating followed by energy conversion from the perpendicular to the parallel directions by the mirroring effect. The former is preferable for the electric thrusters since the enthalpy production is less (pure acceleration) and also since the particle wall interaction is less pronounced. In this presentation we show the results of a parametric survey to compare the efficiency of the two processes by varying the external electromagnetic field and the background field parameters. The collision effect with neutral particle and the shielding effect due to the plasma will be mentioned as well.

Keywords: particle acceleration, electric thruster, electrodeless thruster

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PEM026-09 Room:101 Time:May 24 16:30-16:45

Hall effects for three-dimensional magnetic reconnection with finite width along the direction of the current

Takuma Nakamura[1*], Rumi Nakamura[2], Alexandra Alexandrova[2], Yasubumi Kubota[3]

[1]ISAS,JAXA, [2]IWF, OEAW, [3]NICT

We have performed three-dimensional Hall magnetohydrodynamic (MHD) simulations of magnetic reconnection with finite width along the current direction. Previous MHD simulations have revealed that such localized three-dimensional situations produce the so-called fast reconnection process, in which an Alfvenic fast and narrow jet flows from the localized reconnection region, and the reconnected field lines are strongly piled-up at the head of the jet. Our Hall MHD simulations also confirmed a similar fast reconnection process. On the other hand, our Hall MHD simulations also revealed that the Hall effects critically change the results obtained from MHD simulations regarding the physics of the reconnection region; in the Hall MHD cases, the reconnection region itself broadens in the current and anti-current directions due to the plasma flow related with the current. This means that the location and the size of the reconnection region are unsteady features in Hall MHD regime. In this presentation, we will show the detailed results of our Hall MHD simulations and discuss their implications to the observations in the planetary magnetotail.

Keywords: magnetic reconnection, Hall MHD, three-dimensional simulation

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PEM026-10 Room:101 Time:May 24 16:45-17:00

3D dynamics of thin current layer formed during fast magnetic reconnection

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Magnetic reconnection is a common process in space and laboratory plasmas, facilitating fast release of energy stored in the compressed magnetic field into plasma kinetic and thermal energy. It is well known in theoretical and simulation studies that a thin current layer characterized by the electron inertia length is formed around the magnetic X-line associated with 2D magnetic reconnection. In the thin current layer, the electrons are intensely accelerated by the reconnection electric field and are quickly ejected toward the downstream region. This electron behavior gives rise to the electric resistivity, so-called the inertia resistivity, in the current layer, which results in the dissipation of the magnetic field and plays a significant role in the reconnection processes. However, it is easy to expect that such a thin current layer would be unstable to current driven modes which propagate in the current density direction and are artificially suppressed in the 2D system. In fact, the simulation studies in a 2D plane orthogonal to the magnetic field have revealed that the Harris-type current sheet is unstable to the lower hybrid drift instability (LHDI) and a kink instability. In particular, it has been suggested that in high mass ratio regime (mi/me > 100) the kink mode decouples into two modes: the ion-ion kink mode with kyL ~ 1 and a smaller-scale mode with an intermediate scale of the ion and electron Larmor radii. Because of the high nonlinearity and the limitation of computer resources, it has been very difficult to investigate the role of the current-aligned modes in magnetic reconnection.

In order to challenge large-scale 3D simulations of kinetic reconnection with high mass ratio (mi/me > 100), we have recently developed a massively-parallel code of the electromagnetic particle-in-cell (PIC) model with the adaptive mesh refinement (AMR). The AMR technique enables efficient high-resolution simulations of the current sheet evolution, while the parallelization on the distributed memory system allows us to use much computer resources for a single simulation run. Thus the massively-parallel AMR-PIC code is a strong tool to achieve the large-scale 3D simulations.

The present study investigates 3D effects of the reconnection processes for the cases of high mass ratio with mi/me > 100. The main difference between 2D and 3D reconnections is the fact that in 3D case the thin current layer is unstable to a kink mode even in a quasi-steady phase. The kink mode has a scale with kyLe ~ 1 and propagates in the ion drift direction, where Le is the half width of the thin current layer and is characterized by the electron inertia length. The mode is neither the LHDI nor the ion-ion kink mode. Since the wavelength is comparable with the electron meandering scale, this mode can scatter the electrons and yield the anomalous resistivity.

In this paper, we show the initial results of large-scale 3D simulations of magnetic reconnection and describe the 3D aspects of the processes in the thin current layer. The mechanisms of the magnetic dissipation and particle acceleration will be discussed.

Keywords: 3D magnetic reconnection, AMR-PIC simulation, dissipation mechanism, kink mode

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PEM026-11 Room:101 Time:May 24 17:00-17:15

Can slow-mode shocks be really formed in collision-less magnetic reconnection?

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The issue that whether or not slow-mode shocks are formed in magnetic reconnection has been one of long-standing problems in space physics since Petschek [1964] proposed his idea that most energy conversion from the magnetic field to plasmas can be achieved by two pairs of slow shocks attached to the central diffusion region. Until now, both observations and MHD simulations have confirmed the existence of slow shocks in magnetic reconnection. However, none of kinetic simulations, like hybrid and particle-in-cell simulations, have shown the efficient dissipation of the magnetic field along reconnection layers, which is the strong evidence of slow shocks.

We suggest that the causality, which prevents slow shocks from being formed in collision-less plasmas, is the ion temperature anisotropy enhanced at the downstream region of the reconnection layer. Many preceding studies (both observations and simulations) have shown that such temperature anisotropy is due to the relative bulk velocity between cold ions convected from two lobes and PSBL (Plasma Sheet Boundary Layer) beam ions. Thus, the ion temperature parallel to the magnetic field ($T_{i,para}$) is usually higher than that perpendicular to the magnetic field ($T_{i,perp}$). On the other hand, according to the MHD Rankine-Hugoniot (RH) theory in anisotropic plasmas, it is known that as the temperature anisotropy, $T_{i,para}/T_{i,perp}$, becomes large, slow shocks cease to exist especially within low upstream Alfven Mach numbers.

Until now, by using an electromagnetic hybrid code, we showed that such temperature anisotropy relaxes with increasing the distance from the magnetic neutral point and made a prediction that slow shocks will be formed at about 150-200 ion inertial lengths from the neutral point. Then, we perform a large scale simulation enough to answer the suggestion. Our simulation results, for the first time, show the sharp bentness of magnetic field lines and the two-way current, which indicate the existence of slow shocks in collision-less magnetic reconnection. In this presentation, we will discuss the discontinuity formed along the reconnection layer in terms of MHD RH relations in anisotropic plasmas and, then, reveal the structure of the discontinuity in ion inertial scales.

Keywords: reconnection, shock, slow shock, temperature anisotropy, hybrid, reconnection layer

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PEM026-12 Room:101 Time:May 24 17:15-17:30

3D structure and dynamics of plasmoids associated with spontaneous fast reconnection process

Tohru Shimizu[1*], Koji Kondo[1]

[1]Ehime university, RCSCE

3D structure and dynamics of plasmoids generated in spontaneous fast magnetic reconnection are studied by MHD numerical simulations. In solar flares and substorms, the fast magnetic reconnection is considered to play a crucial role. In recent space satellite observations, plasmoids associated with the reconnection process are studied but its structures and dynamics are still unclear. According to our numerical and theoretical studies, 1D current sheet can be destabilized by a 3D perturbation, resulting in intermittent and random 3D fast reconnection via 2D and then 3D instabilities. In this paper, those our results are applied for the plasmoid's characteristics obtained in space satellite observations.

Keywords: magnetic reconnection, three-dimensional, plasmoid, MHD

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PEM026-13 Room:101 Time:May 24 17:30-17:45

The SCOPE mission

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SCOPE is a space plasma physics mission that consists of five spacecraft and that will perform simultaneous multi-scale observations of dynamic space plasma phenomena. The target processes are shocks, reconnection and turbulence. The orbit is ~10 x ~30 Re in the earth's magnetosphere and in the solar wind, which allows the spacecraft to encouter and us to study these physical processes of fundamental importance. The simultaneous multi-scale observations are performed by a pair of mother-near-daughter (M-ND) spacecraft and the formation of three far-daughter (FD) spacecraft that surrounds the spacecraft pair. The M-ND pair with small inter-spacecraft distance will zoom-in to the electron dynamic scale while the FDs, located at larger distances, will observe the larger-scale (ion- and MHD-scales) dynamics that surrounds the key micro-region observed by the M-ND pair. The mission is planned to have substantial internation contributions. In this talk, we will summarize the recent progress of the mission study. Expectations of space plasma simulations from the SCOPE's point of view are also described, with the intention of enhancing the ties between the mission study and the space plasma physics research via simulation.

Keywords: SCOPE, Multi-scale physics, Large-scale particle simualtions

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PEM026-14 Room:101 Time:May 24 17:45-18:00

A kinetic model for Alfvenic interactions in magnetosphere-ionosphere coupling

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

[1]National Institute for Fusion Science

Alfvenic interactions of the magnetosphere and the ionosphere (M-I) play a key role in spontaneous growth of quiet auroral arcs in the polar region. The feedback instability has been formulated in terms of the reduced magnetohydrodynamic (MHD) equations [1], and is recently investigated in detail in the dipole configuration with realistic Alfven velocity profiles [2]. Non-linear simulations of the feedback instability in the M-I coupling system also reveal that the secondary instability growth of the Kelvin-Helmholtz-like mode leads to deformation of vortex, current, and density profiles associated with auroral arcs [1].

A variety of non-MHD effects, however, appear in the magnetosphere with low-density and high-temperature plasma. The finite ion gyroradius effect is, for example, non-negligible in the vicinity of the magnetic equator region with the weak magnetic field and the high ion temperature. While some of the non-MHD effects can be incorporated in terms of extended fluid models, a kinetic model is still necessary for more complete description of the magnetospheric plasma dynamics.

In this study, we consider a gyrokinetic model of the magnetospheric plasma, where the finite gyroradius and other kinetic effects are preserved while deleting fast time-scales associated with gyro-motions. In the gyrokinetics, the kinetic Alfven waves are compactly formulated in terms of the polarization density of ion gyro-centers and the parallel electron current. We would discuss some basic properties of the kinetic model for Alvenic interactions in the M-I coupling system in comparison to the reduced MHD model.

[1] T.-H. Watanabe, ”Feedback instability in the magnetosphere-ionosphere coupling system: Revisited”, Phys. Plasmas, Vol.17, 022904-1 - 022904-8 (2010).

[2] Y. Hiraki, and T.-H. Watanabe, in preparation for submission (2011).

Keywords: aurora, magnetosphere-ionosphere coupling, Alfven wave, gyrokinetics, simulation

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PEM026-15 Room:101 Time:May 24 18:00-18:15

Performance evaluation of various supercomputer systems with Vlasov code

Takayuki Umeda[1*], Keiichiro Fukazawa[2], Yasuhiro Nariyuki[3], Tatsuki Ogino[1]

[1]STEL, Nagoya University, [2]Kyushu University, [3]Kochi National College of Technology

More than 99% of the "top 500" supercomputer systems in the world now adopt scalar processors. Almost 90% of the supercomputer systems consist of the 64bit x86 processor architecture. The POWER processor architecture has a 8% share, and the SPARC processor architecture has only a 0.4% share. In general, the computational efficiency (the ratio of the effective performance to the theoretical performance) of user applications on a scalar computer tends to be low (less than 10%), although the computational efficiency of the LINPACK sometimes exceeds 80%. Therefore, it is important to develop a high-performance user application for space plasma simulations on scalar-type massively parallel supercomputer systems. In this paper, a performance measurement study of the first-principle Vlasov-Maxwell solver is carried out on various scalar-type supercomputer systems in Japan.

In December 2010, the Solar-Terrestrial Environment Laboratory (STEL) at Nagoya University installed a now supercomputer system, DELL PowerEdge R815. The DELL PowerEdge R815 supercomputer system at STEL has the same specification with the T2K open supercomputers in Japan. The system is a PC-cluster-type supercomputer consisting of 48 nodes, and each node has four AMD 12-core Opteron 6174 processors (2.2GHz, L2: 512KB/core, L3: 12MB/CPU) and 96GB DDR3 memory. As for the internode connections, each node has two InfiniBand QDR links with a bandwidth of 4GB/s per link. The peak performance of the system is 20TFlops. The system has just started pre-operation in January 2011, and the preliminary result of the performance measurement will also be presented.

Keywords: Vlasov equation, supercomputer, plasma, performance measurement

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PEM026-16 Room:101 Time:May 24 18:15-18:30

Full-electromagnetic Vlasov simulations with the Multi-Moment Advection scheme

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

[1]IFREE, JAMSTEC, [2]STEL, Nagoya University, [3]Department of Physics, Nagoya University

The Vlasov simulation, which solves the advection equation of the distribution function in phase space, has been proposed for an alternative method of the Particle-In-Cell (PIC) method, to overcome some problems inherent to the PIC. However, suitable methods for the Vlasov simulation have not been established so far, because of the difficulty to accurately solve the advection equation in multidimensions.

We have developed a numerical scheme that enables us to solve the advection equation with quite little numerical diffusion. The scheme is designed to treat not only point values of a profile but also its zeroth to second order piecewise momenta as dependent variables, for better conservation of the information entropy. We have reported one- and two-dimensional schemes and their successful applications to electrostatic and electromagnetic Vlasov simulations.

However, many plasma phenomena of interest require to treat the full three-dimensional velocity space distribution. Therefore we develop the three-dimensional scheme. As well as the one- and two-dimensional schemes, the scheme also provides quite accurate solutions of linear advection and solid-body rotation problems. This is the most important capability for Vlasov simulations of magnetized plasmas.

In this presentation, we show the design of the schemes in detail. We will show some benchmark tests of Vlasov simulations of magnetized plasmas with the scheme in the three-dimensional velocity space.

Keywords: Vlasov simulations

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PEM026-17 Room:101 Time:May 25 08:30-08:45

Fluid Modeling of SLAMS

Tohru Hada[1*], Yasuhiro Nariyuki[2], Marty Lee[3]

[1]ESST, Kyushu University, [2]Kochi National College of Technology, [3]University of New Hampshire

The so-called Short Large Amplitude Magnetic Structures (SLAMS) are frequently observed upstream of quasi-parallel part of the earth's bowshock (Schwartz et al., JGR, 1992). Properties of these structures have been studied extensively (e.g., recent Cluster observations by Lucek et al, Annales Geophys., 2004). On the other hand, the mechanism leading to the formation of the SLAMS remains unclear. Since the SLAMS always grow in a region with a gradient in supra-thermal particle pressure, the ion heat flux is likely to be the main energy source for these structures (Giacalone et al., GRL, 1993). In order to clarify the physical picture of the SLAMS, in this presentation we attempt to model their growth and evolution from the fluid point of view. First we propose a nonlinear MHD model including the effect of the ion heat flux after Hammett and Perkins (PRL, 1990). Numerical simulations show that, in the presence of inverse Landau interaction, a series of magnetic pulsations similar to the SLAMS grow rapidly. Details of the model and the results will be presented.

Keywords: foreshock, SLAMS, nonlinear Landau damping, ion heat flux

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PEM026-18 Room:101 Time:May 25 08:45-09:00

Time Sequence of Energetic Particle Spectra in Quasi-parallel Shocks

Tooru Sugiyama[1*]

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We have studied the transport properties of energetic particles in the upstream region of parallel shocks considering the possibility of anomalous diffusion where the density decay profile has not an exponential profile but a power-law behavior. The results obtained from hybrid simulation model show that the energetic ions with energy of 50-100 E_0 (E_0 is the shock ram energy) spatial profiles are well fitted by a power law distribution and that the value of $< dx^2 >$ / t increases in time. This implies that particle propagation can be described by a super-diffusion profile even though the power of the magnetic wave is sufficient large to scatter the particles.

Keywords: shock wave, particle acceletaion, diffusion process

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PEM026-19 Room:101 Time:May 25 09:00-09:15

Relativistic electron acceleration in a low Mach number shock

Shuichi Matsukiyo[1*], Ryo Yamazaki[2], Yutaka Ohira[3], Takayuki Umeda[4]

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An extreme case of a shock (gradient) drift acceleration process of reflected electrons at low Mach number collisionless shocks is investigated by utilizing one-dimensional electromagnetic full particle simulation. A relativistic shock drift acceleration occurs even in a low Mach number (< 10) moderate quasi-perpendicular shock if a ratio of electron plasma to cyclotron frequencies is small and a plasma beta is high. Such a condition may be realized in some astrophysical environments like a large scale shock in a galaxy cluster, a cosmic ray modified subshock of a supernova remnant, etc. For an almost perpendicular shock with a Mach number of 7.8, a plasma beta of 3, and the frequency ratio of 3, the shock drift acceleration leads to upstream relativistic reflected electrons forming a local relativistic ring-beam distribution function. Additional periodic simulations with a local approximation indicate that the reflected electrons may be possible to self-generate upstream oblique waves, and further be back-scattered toward a downstream by those waves. Coherent wave packets play an important role in the process of back-scattering of the reflected electrons.

Keywords: relativistic electron acceleration, shock, low Mach number

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PEM026-20 Room:101 Time:May 25 09:15-09:30

Field aligned accelerations by plasma shock waves

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High energy distributions have been observed along the shock front in supernova remnants (SNR). To account for this phenomena we proposed here a model of the particle acceleration parallel to the magnetic field of the shock propagating through the interstellar magnetic field (IMF), namely it is the field aligned acceleration by the plasma shock wave. A reasonable formula of the highest energy gain is derived from theoretical analysis of the relativistic equations of motion. The energy gain obtained by a test particle is given by the mutual product between four parameters: the shock velocity, the cross angle between IMF and the magnetic field of the shock, the magnitude of IMF and the acceleration time.

Strong shocks in SNR have been remarkable as a candidate of the high energy accelerator of cosmic rays. The mechanism of particle acceleration is explained by the diffusive shock acceleration (DSA) in which there exist two types of acceleration. One is the perpendicular shock where the direction of IMF is perpendicular to the shock normal and the other is the parallel shock where the direction of IMF is parallel to the shock normal. We show here a model of the perpendicular shock where the direction of IMF is perpendicular to both the shock normal and the direction of the wave magnetic field.

We firstly consider the plasma shock wave propagating through the uniform and stationary IMF. The magnetic field of the shock is parallel to IMF, whereas the electric field of the shock is perpendicular to IMF. In laboratory frame, there is no electric field along the magnetic field of the shock, then it is so difficult to predict the field aligned acceleration. Next, let us consider the electric and magnetic fields experienced by the particles on the wave frame of the shock. The electric field of the shock disappears on the wave frame, however the electric field of IMF is generated because IMF moves in the direction of the shock. The direction of the electric field is the same as that of the magnetic field of the shock. As a result, the test particle located near the shock front is accelerated by the electric field parallel to the magnetic field of the shock.

The highest energy gain obtained by the test particle depends on the cross angle between IMF and the magnetic field of the shock. When the angle is smaller than 90 degree, the gain becomes small. Whereas, if the angle is greater than 90 degree, then the magnetic neutral sheet is created in front of the shock. Once the test particle is trapped by the neutral sheet, the particle never escape from the trap[1]. Furthermore, in the vicinity of the neutral sheet, there exists the electric field along the magnetic field. The particle trapped is accelerated by this electric field indefinitely.

Some narrow filament structures in the vicinity of the shock front in SN 1006[2] and extremely fast accelerations[3] also have been observed in another supernova remnant. These phenomena could be explained by the field aligned acceleration presented here.

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Keywords: plasma shock wave, field aligned acceleration, supernova remnant

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PEM026-21 Room:101 Time:May 25 09:30-09:45

Electron acceleration in the foot region of a quasi-perpendicular shock

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We have carried out a three-dimensional simulation of a quasi-perpendicular shock. The full mass ratio M/m=1840 was taken for this simulation, and we can access cross-scale coupling processes in the shock transition though only one ion inertia length square was allocated to the shock plane. In this simulation, efficient production of non-thermal electrons is observed. As reported by Shinohara and Fujimoto (2011), complicated wave activity is found at the most front end of the shock foot region. Comparing with results of 1-D and 2-D simulations with the same parameters, we found that both non-thermal electrons and wave activity emerge only in the 3-D simulation. Detailed analysis of accelerated electron trajectories shows that the acceleration efficiency depends on the phase of the shock self-reformation. Accelerated electrons are keep staying in the foot region due to the scattering by the electromagnetic field fluctuation. The final stage of acceleration at the lamp region occurs during the steepen phase of the self-reformation. The electron acceleration is observed in higher mass ratio runs. We will discuss physics of electron acceleration mechanism and its relation with three-dimensional behavior of the shock transition region.

Keywords: quasi-perpendicular shock, electron acceleration

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PEM026-22 Room:101 Time:May 25 09:45-10:00

Effects of Synchrotron-Weibel Instabilities on Relativistic Perpendicular Shock Acceleration in Pair-Ion Plasmas

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The shock waves are very important structure which may be associated with particle acceleration in magnetosphere and heliosphere, astrophysical sources, and so on. The acceleration of relativistic particles in astrophysical sources of synchrotron emission is one of long-lived unsolved problems. Most of those non-thermal astrophysical sources have shock structures. So collision-less shock waves in relativistic flow have been implicated to energize particles. However, the particle acceleration processes in collision-less shocks have not fully understood yet. The problems are not simply addressed by the macroscopic view point of MHD framework, and we need to approach these questions by microscopic view point.

In order to study these unresolved issues of collision-less shocks, particle-in-cell (PIC) simulation have been recently used as a useful tool to investigate the micro- scopic acceleration mechanisms. For example, Hoshino et al.(1992) and Amato & Arons (2006) have studied the structure of relativistic perpendicular shock wave in electron-positron-ion plasma by PIC simulation, and concluded that the pair plasmas can be efficiently accelerated by the synchrotron instability.

In this presentation, we introduce the effect of two-dimensional structures on the pair plasma acceleration in the relativistic shocks in pair-ion plasmas by using 2D PIC simulation. For sigma value less than 1 plasma, both of the synchrotron instability and the Weibel instability play important roles on high energy pair plasma acceleration. So, we investigate the behavior of above two mechanisms and particle accelerations in both case in which the direction of background magnetic field set to out of plane and in the plane. We find that in the 2D simulation, the synchrotron instability is dominant in out of plane case and the Weibel instability is dominant in the in the plane case. However we can find that the synchrotron instability still work in sigma(elec)= 0.01 case.

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PEM026-23 Room:101 Time:May 25 10:00-10:15

On the reformation at perpendicular shock: 2D full PIC simulation

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A full particle-in-cell (PIC) simulation study is carried out on the reformation at a quasi-perpendicular collisionless shock with a relatively low Alfven Mach number (MA=5) and shock-normal angle of 80 degrees. Previous self-consistent one-dimensional (1D) hybrid and full PIC simulations have demonstrated that ion kinetics is essential for the non-stationarity of perpendicular collisionless shocks. These results have shown that reflection of ions at the shock front is responsible for the periodic collapse and redevelopment of a new shock front on a timescale of the ion cyclotron period, which is called the shock reformation. Recent 2D hybrid and full PIC simulations, however, suggested that the shock reformation does not take place in exactly-perpendicular shocks with MA ˜ 5. By contrast, another 2D hybrid PIC simulation showed that the shock reformation persists in quasi-perpendicular shocks MA ˜ 5. Although these recent two works seem to be inconsistent with each other, this reason is not well understood because of several differences in simulation conditions.

In the present study, we performed a 2D full PIC simulation of a quasi-perpendicular shock to make a direct comparison between quasi- and exactly-perpendicular shocks with almost the same condition. It is found that the time development of the shock magnetic field averaged over the shock-tangential direction shows the transition from the reformation to no-reformation phase, which is consistent with the recent full PIC simulation results of exactly-perpendicular shocks. On the other hand, local shock magnetic field shows the evident shock reformation, and the period of the reformation is changed in the no-reformation phase.

Keywords: perpendicular shock, PIC simulation, reformation

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PEM026-24 Room:101 Time:May 25 10:15-10:30

Efficiency of Electron Shock Drift Acceleration in the Presence of Ion-scale Rippling

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It is known that a number of plasma instabilities are excited in and around collisionless shocks and are believed to play the role for the dissipation at the shocks. Among them, the electromagnetic ion cyclotron (EMIC) instability can be excited by the temperature anisotropy of ions at the quasi-perpendicular shock transition region. Particle-in-cell (PIC) and hybrid simulations have demonstrated that the shock surface is strongly modulated most likely due to this instability. The spatiotemporal scale of the resulting ripple structure is determined by Larmor radius and frequency of ions. The rippling can, however, also affect the dynamics of electrons.

We have investigated the trajectories of electrons within the shock in the presence of the rippling. The electromagnetic field in the time-dependent (i.e., rippled) shock structure is given by an analytical form. Test-particle trajectories in the assumed field are then followed numerically. We have found that some electrons are "trapped" in the transverse direction due to the compression of the magnetic field. These trapped electrons are eventually transmitted to the downstream even when the initial pitch angles (in the de Hoffmann Teller frame) are out of the loss cone. The resulting energy gain of these electrons are larger than those expected from simple adiabatic theory. We will also present a more detailed analysis of the acceleration mechanism. The efficiency, and the consequence of this study are discussed in a quantitative fashion.

Keywords: collisionless shock, particle acceleration

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PEM026-P01 Room:Convention Hall Time:May 25 10:30-13:00

Stability problem of cosmic ray modified shock

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Cosmic rays whose energy is less than $10^{15.5}$ eV are thought to be generated from galactic supernova explosion. Blast waves blown from explosion are main accelerator of high-energy cosmic rays. Standard acceleration theory of cosmic rays at supernova shock was proposed by Bell (1978), Blandford and Ostriker (1978), and so on, and was called Diffusive Shock Acceleration (DSA) theory.

However, the possible maximum energy expected from DSA theory was 10^{14} eV, which is less than knee-energy ($10^{15.5}$ eV) by an order of magnitude. And this energy gap problem has not been solved clearly yet.

One remarkable idea to this difficult problem is cosmic ray modified shock, which was proposed by Drury and Volk (1981). In cosmic ray modified shock, cosmic rays have back reaction to shock structure and make shock more compressive, and then compressed shock can generate cosmic rays more effectively. Recent observations of supernova remnants reveals that temperature of thermal plasma is lower than expected temperature from Rankine-Hugoniot relations, and this fact is supporting to this idea (Hughes 2000, Helder 2009). So, we should consider about cosmic ray modified shock in supernova remnants.

Our research is based on "two fluid model" , which is proposed Drury and Volk (1981). In this model, there are partially multiple shock solutions, each of them satisfies Rankine-Hugoniot relations. By numerical calculation, we find that two of them are stable and the other is unstable, and that transition of shock structure occurs when solution is unstable. Consequently, cosmic ray pressure becomes maximum or minimum.

Moreover, Mond and Drury (1998) suggested that corrugation instability occurs when shock solution is unstable. We investigate this suggestion by two-dimensional simulation.

Keywords: cosmic rays, shock acceleration, stability

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PEM026-P02 Room:Convention Hall Time:May 25 10:30-13:00

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

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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, the ions were observed in the deep wake by a Japanese scapecraft 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 a magnetic anomaly. In the present study, we examine the orbit of SW ions scattered by the magnetic anomaly at the moon via a full-kinetic Vlasov simulation.

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PEM026-P03 Room:Convention Hall Time:May 25 10:30-13:00

Particle simulations about generation mechanism of low frequency component of BEN

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According to PIC simulations, ESW (Electrostatic Solitary Wave) is generated from electron beam instabilities. We know ESW composes the upper frequency part of BEN (Broadband Electrostatic Noise) which is frequently observed in space plasma. The generation mechanism of the low frequency component of BEN, however, is still unexplained. To clarify whether such low frequency waves are generated by electron beam instabilities, we performed a series of two-dimensional electrostatic particle simulations of beam instabilities with different parameters, and observed time evolutions of these beam instabilities, in time as well as in space.

In this study, we investigate parameter dependence on the formation mechanism of ESW and the excitation conditions of low frequency electrostatic waves after long-time evolution of weak electron beam instabilities. We performed a series of simulations with different parameters, electron cyclotron frequencies and drift velocities of the electron beam, and then confirmed that low frequency waves are excited with plasma parameters in the magnetospheric region. These low frequency waves are polarized in the perpendicular direction to the ambient magnetic field.

According to the simulation results, Wee confirmed the excitation of harmonic low frequency waves in the perpendicular direction to the magnetic field. We are going to investigate the effect of ion dynamics on these waves, and compare frequency spectra of satellite observation with those of simulation result. We perform more detailed simulations with various parameters in order to clarify the excitation mechanism of these low-frequency waves.

Keywords: Broadband Electrostatic Noise, Particle simulation, Low frequency plasma wave

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PEM026-P04 Room:Convention Hall Time:May 25 10:30-13:00

The influence of the initial magnetic field configuration on the nonlinear state of MRI

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The magneto - rotational instability (MRI) is one of the MHD instabilities evolving in differentially rotating plasma, like accretion disks. MRI amplifies magnetic field perturbations and makes the system in a magnetic turbulent state. Previous studies have suggested that MRI and resultant magnetic turbulence play important roles in some phenomena occurring in accretion disks, such as mass accretion, mass loading, and planet formation.

A lot of three-dimensional simulation studies have been performed to clarify the dependence of MRI turbulence and amplitude of turbulent stress on initial settings such as the density profile, plasma beta, etc. They have revealed that initial settings of the background magnetic field have significant influence on the saturation states of MRI turbulence. Hawley et al. (1995) showed that the turbulent stress and plasma beta in saturation states are two orders greater for poloidal field situations than those for toroidal field situations in an unstratified disk model, in which the density and pressure are assumed to be constant.

On the other hand, most of the recent simulation studies using a stratified disk model, in which density and pressure profiles have a gradient in the poloidal direction due to gravitational acceleration by central objects, have considered only the situations of purely toroidal or poloidal magnetic field whose profile is sinusoidal, therefore averaged poloidal component is zero. However, the formation process of accretion disks is thought that interstellar gas rotation is spun up due to the gravitational acceleration by central objects, after moving along magnetic field lines and gathering on the same surface perpendicular to magnetic field lines. Therefore the initial magnetic field having a perpendicular component to a disk surface is plausible and need to be investigated in a stratified disk model.

In the present study, using an originally developed three-dimensional MHD code, we perform numerical experiments of MRI in a stratified disk model under the situation where the spatially averaged perpendicular component of initial magnetic field is non-zero. As results, we find that in the early stage of the simulation magnetic field energy is increased with the time scale consistent with the linear growth rate of MRI, while the magnetic field turbulence is gradually amplified by MRI after the transition to the nonlinear stage. In addition, before the saturation state is set up, we find a higher level of turbulent stress than expected from observations and an accretion flow around the equatorial plane of the disk. We also find that the density profile observed in the simulation results is significantly modified by the turbulent magnetic field during several rotation periods and that the assumption of the Keplerian rotation required from the local shearing model used in our simulation is eventually disrupted. In this presentation, we show details of these simulation results and discuss the effects of the turbulent stress and the magnetic field amplification by MRI on the dynamics of the disk gas. In the formation process of the disk, the situation where the initial magnetic field has both perpendicular and parallel components to the disk surface is possible to occur. We also treat such situations and discuss the dependence of the nonlinear stage of the MRI turbulence on the initial magnetic field configuration.

Keywords: MHD, accretion disk, magneto - rotational instability

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PEM026-P05 Room:Convention Hall Time:May 25 10:30-13:00

Effect of ion composition on vortex structures in drift wave turbulence

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In the ionosphere, Io torus, and fusion plasmas, gradients of density, pressure, and temperature ubiquitously exist, which excite drift wave turbulence. The Hasegawa-Mima equation is known as a basic equation, which describes the dynamics of such drift wave turbulence. In a recent experimental study, a streamer, which is a bunching of drift-wave turbulence, have been observed. In addition, these streamer structures were revealed to be equivalent with soliton solutions (vortex structures) in nonlinear equations, which is a subset of the Hasegawa-Mima equation. However, the effect of multiple ion species and ion-electron temperature ratio is unclear, since a single species of cold ions is assumed in the ordinary Hasegawa-Mima equation.

In the present study, we first drive the extended Hasegawa-Mima equation, in which diamagnetic drifts of multiple ion species are included. Then, we derive a KdV equation from the obtained Hasegawa-Mima equation and evaluate the dependence of soliton solution on ion-electron temperature ratio and ion composition.

Keywords: drift wave, vortex structures, ion composition

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PEM026-P06 Room:Convention Hall Time:May 25 10:30-13:00

Confirmation of Decimeter Radio Pulses From our Galaxy Center Comparing with a Time Series of Pseudo Random Number

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In 1999, the discovery of 24 kinds of radio pulses was made in the decameter radio wave frequency range [Oya and Iizima, 1999]. The levels of these pulses were in a range with the order of about 0.1% of the background level of the decameter radio waves from the center part of our Galaxy. As origins of these decameter radio wave pulses, the authors proposed possible radiations from the rotating black holes in the center part of our Galaxy. The 24 kinds of periods ranging from 0.327214sec to 129.992sec are considered to be generated from the rotating Kerr black holes coinciding with the rotation periods of black holes. Further studies for the radiation characteristics of Kerr black holes [Oya,2011] indicate that the detectable period of the radio wave pulses have sources near the event horizon. These works also indicate that the rotation periods show divergence for the radiation sources which are located at the position a part from the event horizon. The deviation rate of the rotation period becomes larger corresponding to longer distance apart from the event horizon, even in the region close to the event horizon. It is further clarified by his paper that the red shift rate of the radiated electromagnetic waves varies as a function of the source position, approximately depending on the root of the deviation rate of distance from the event horizon. When it is assumed that the radiation frequency is controlled by the red shift rate, it is suggested that the decimeter radio wave pulse period is spread wider than the cases of decameter radio wave pulses. To confirm this theoretical prediction, we observed center part of our Galaxy at 1.4GHz with 10m dish antenna, in 2007 and 2008 at Fukui University of Technology where the receiving systems for decimeter radio waves are facilitated.

The present studies are concerned with analyses of the observation data of decimeter radio wave pulses whose levels show a range from 1/1000 to 1/10000 of the background level of the decimeter radio waves from the center part of our Galaxy. To search for the pulse shape, then, 1200000 times of period coherent accumulations of time series data, i.e. box-car method, have been applied, after the coarse decision of the pulse periods by applying FFT method. For this purpose, the data during 21 days observations are utilized. To carry out the box-car method, the periods for analyses have been swept with step of 4/100000 of the center periods for search. The obtained wave forms are evaluated defining the index which gives identification of the quality of the detected pulse forms distinguished from background noise.

Because of the extremely low signal to noise ratio with the order of 0.01% of the background noise level, comparison of the analyzed results with those for time series of pseudo random numbers has been made. Consequently it is verified that the results for decimeter pulses are confident; we can utilize them to investigate the deviation of the period to compare with that of decameter radio wave pulses.

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PEM026-P07 Room:Convention Hall Time:May 25 10:30-13:00

A new numerical method for simulating the solar wind Alfven waves: Development of the Vlasov-MHD model

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A novel scheme of plasma simulation, particularly suited for computing the one-dimensional non-linear evolution of parallel propagating solar wind Alfven waves is presented. The scheme is based on the Vlasov and the MHD models, for solving the longitudinal and the transverse components, respectively. As long as the nonlinearity is not very large (so that the longitudinal and transverse components are well separated), our Vlasov-MHD model can correctly describe evolution of finite amplitude quasi-parallel Alfven waves, which are typical in the solar wind, both in the linear and nonlinear stages. The present model can be applied to discussions of phenomena where the quasi-parallel Alfven waves play major roles, for example, the solar coronal heating and solar wind acceleration by the Alfven waves propagating from the photosphere.

Keywords: Vlasov simulation, solar wind, Alfven wave

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PEM026-P08 Room:Convention Hall Time:May 25 10:30-13:00

Development of a new multi-fluid code for the Io-Jupiter system based on the semi-discrete central scheme

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Subcorotation of Iogenic plasma in the Io plasma torus has been understood as electric drift by a perpendicular electric field with respect to the Jovian magnetic field. A part of the radially integrated potential has been considered to be imposed along the magnetic field lines. The purpose of this study is to clarify where and how the actual the electric fields arise in the Io-Jupiter system. Here, we take notice of the importance of the electron convection term in the generalized Ohm's law. We applied a semi-discrete central scheme to extended MHD equations which include the electron convection term and prescribe the dynamics of one or two ion species, and investigated the role of the electron convection term in a one-dimensional model of the Io-Jupiter system.

We find that the parallel electric field arising from the electron convection term works like negative pressure. For the cases of steady state discontinuities, the sum of the electric force arising from the electron convection term and a steepening effect due to the ion convection term balance with the ion pressure gradient. An electrostatic potential difference across a discontinuity equals the electron kinetic energy obtained from a transition through the discontinuity. The electron convection term enables us to describe a situation in which a parallel electric field and parallel electron acceleration coexist, which is impossible for ideal or resistive MHD.

Each ion sound mode becomes unstable if the parallel current density exceeds some threshold associated with the individual ion temperature. If the sound mode of the cold ions is unstable and that of the hot ions is stable with the specific current density, the growth of the unstable sound mode saturates after a while. At this stage cold ions gather around the high density region since the negative pressure arising from the electron convection term exceeds the pressure of the cold ions. The discrete parallel electric field forms at the boundary of the high- and low-density regions and prevents cold ions from going through the field. Although the growth rate of the ion sound mode does not reproduce that of the actual Debye-scale ion acoustic mode, the process of the wave growth and saturation would approximate that of the Debye-scale current driven instability in the large spatial and temporal scales.

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PEM026-P09 Room:Convention Hall Time:May 25 10:30-13:00

Implementation of a fast Poisson solver into MHD and PIC simulations

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Poisson equation appears in various situations in numerical simulations of space plasmas. For example, the electrostatic potential in the ionosphere is obtained by solving the Poisson equation with the field-aligned current given by the global MHD simulation of the magnetosphere.

The equation is generally solved by iterative solvers. Successive Over-Relaxation (SOR) and Conjugate Gradient (CG) methods are of well used solvers, but the number of iterations increases as $N^{3/2}$ as the system size (NxN) increases. Thus a fast Poisson solver is necessary in a large-scale numerical simulation.

In this presentation, an implementation of Multigrid poisson solver into a MHD simulation code and its application to the global MHD simulation are shown. The solver is implemented in order to remove the monopole of the magnetic field that arises due to the numerical discretization. This enables us to examine a large scale global MHD simulation with keeping div(**B**) negligibly small. The multigrid solver is also applied to the PIC simulation code in which Maxwell equations are solved implicitly. This enables us to simulate under larger c/v_{the}=$omega_{pe}$/$OMEGA_{ge}$/sqrt(beta) parameters with a large time step.

Keywords: PIC simulation, MHD simulation, Poisson equation, Multigrid, SOR method

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PEM026-P10 Room:Convention Hall Time:May 25 10:30-13:00

The HLLD approximate Riemann solver in Lagrangian coordinate system

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The magnetohydrodynamic (MHD) equations are the most important equations to describe macroscopic dynamics of plasmas. Since the ideal MHD equations are nonlinear hyperbolic conservation laws, discontinuous solutions such as fast / slow shocks are often generated in nonlinear simulations. Therefore, shock capturing schemes for MHD have been increasingly developed in last decades. In particular, several approximate Riemann solvers [1,2] have been successfully proposed and applied for physical simulation studies since mathematical properties of hyperbolic conservation laws are reflected within those numerical schemes. In those schemes, well-behaved numerical solutions are obtained integrating exact or approximate solutions of the Riemann problem at cell faces over each cell volume in fixed Eulerian grids. However, some problems such as strong shock interactions are difficult to solve on a uniform Eulerian grids although those may be suitable for Lagrangian-type schemes. In this paper, we find an approximate solution of the Riemann problem for MHD in Lagrangian coordinates due to a Lagrangian-type approximate Riemann solver for MHD. Since the MHD equations can be rewritten in another conservative form of the equations in Lagrangian mass coordinates [3], we can apply an HLL-type approximation in Eulerian grids that is constructed based on conservation laws over the Riemann fan. Particularly, we obtain an HLLD-type approximate Riemann solution [2] where the physical state is assumed to be divided by five-waves in Lagrangian mass coordinates. Mathematical properties of the approximate solution are discussed in detail.

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Keywords: MHD, shock capturing scheme, Lagrange coordinates, conservation laws, HLLD approximate Riemann solver

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PEM026-P11 Room:Convention Hall Time:May 25 10:30-13:00

Experimental Study of Plasma Acceleration Using Rotating Electric Field for Electrodeless Plasma Thruster

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Electric propulsion system has a large specific impulse and is suitable for a long term space mission such as a space exploration. Some space missions using electric propulsions have been successfully conducted. However, in conventional electric propulsion systems, the discharge and acceleration electrodes are exposed to the plasma and the electrode deterioration restricts the life time of electric propulsion systems. To overcome this difficulty, we have been studying a electrodeless electric propulsion system using the helicon plasma source. In this study, the electromagnetic plasma acceleration concept called Lissajous acceleration is focused. In this acceleration concept, the plasma is accelerate3d by the Lorentz force generated by an applied rotating electric field and applied magnetic field. Plasma acceleration experiments have been conducted for validating the acceleration concept, and the experimental results will be presented.

Keywords: helicon plasma, electrodeless electric propulsion, rotating electric field

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PEM026-P12 Room:Convention Hall Time:May 25 10:30-13:00

Two-Dimensional Hybrid-PIC Simulation of Solar Wind Plasma Flow around Magnetic Sail

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Magnetic sail is a propellant less propulsion system proposed for an interplanetary space flight. The thrust force is produced by the interaction between magnetic field artificially generated by superconducting coils in a spacecraft and a solar wind. Thrust performance of such spacecrafts utilizing solar wind energy can be higher than that of conventional electric propulsion thrusters. Thrust force of a magnetic sail is characterized by the ratio of representative length of magnetosphere and ion Larmar radius at the magnetopause. In the case of ion inertial scale, namely, representative length which is shorter than ion Larmar radius, the simulation model including ion inertial effect must be selected in order to evaluate accurate thrust performance of magnetic sail. Based on the above, We examined the solar wind plasma behavior and thrust of a magnetic sail by two-dimensional X-Y Cartesian, hybrid particle-in-cell (PIC) simulations.

As simulation results, it is found that interplanetary magnetic field (IMF) affects the structure of shock wave around the spacecraft. This is because the solar wind flow is changed by the position of magnetic reconnection points which depend on the direction of IMF. Furthermore, high thrust force acting on the spacecraft can be obtained when IMF becomes perpendicular to the solar wind. The lift force is generated on the spacecraft when IMF becomes not perpendicular but parallel to the solar wind. Although there still exist many phenomena to be clarified and many problems to be overcome in order to realize the system, the magnetic sail is surely worth examining in more detail.

Keywords: Magnetic Sail, Magnetosphere, Hybrid-PIC Simulation

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Research and development of next generation electrodeless plasma thrusters

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Electric thruster is a form of spacecraft propulsion that uses electric energy to accelerate plasma propellant. Due to its large specific impulse, the electric thrusters are suited for long duration operations such as missions to outer planets. On the other hand, the performance of many of the conventional electric thrusters is severely limited by electrode wastage. In order to overcome this difficulty, we have initiated the HEAT (Helicon Electrodeless Advanced Thruster) project to pursue research and development of completely electrodeless plasma thrusters. In the presentation, we first briefly describe the background and the targets of the project, and then introduce the concepts of electrodeless plasma production using the so-called helicon waves (i.e., bounded whistler waves) and the electrodeless plasma acceleration via externally applied time-varying electromagnetic fields. In particular, we discuss some details on the three plasma acceleration schemes we consider: the Rotational Magnetic Field (RMF), the Rotational Electric FIeld (REF), and the Ponderomotive Acceleration (PA) schemes, and compare their thrust based on a scaling argument. Although the helicon plasma is collisional and dissipative, it actually shares many intrinsic features with space plasmas, implying that there are realistic possibilities that SGEPSS members make substantial contributions in the field of electric thrusters. We will stress importance of future collaborative interaction between the two fields.

Keywords: helicon plasma, electric thruster, electrodeless thruster