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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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PEM026-P13 Room:Convention Hall Time:May 25 10:30-13:00

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