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

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

Plasmoid-induced turbulence in 3D magnetic reconnection

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

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

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

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

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

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

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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. These nonlinear behaviors of MRI, such as generation of turbulence or accretion due to the strong turbulent viscosity, are mainly studied by numerical simulations under MHD approximation which assumes the plasma as a single component fluid.

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

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

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

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PEM26-03 Room:102B Time:May 22 14:15-14:30

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

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

Keywords: solar wind, proton temperature anisotropy, Alfvenic turbulence

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

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

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

Keywords: sun, convection, numerical calculation

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

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

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

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

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

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

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

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

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

Keywords: sun, photosphere, convection, magnetic field

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PEM26-06 Room:102B Time:May 22 15:00-15:15

Magnetospheric sources and mechanisms of Region 2 field-aligned currents

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

Keywords: Magnetosphere, Field-aligned current, MHD simulation

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PEM26-07 Room:102B Time:May 22 15:30-15:45

Plasma particle simulations on spacecraft wake effects on electric field measurements

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

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

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

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

Keywords: Electric field sensor, Spacecraft wake, PIC simulation

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PEM26-08 Room:102B Time:May 22 15:45-16:00

Dissipation of electromagnetic energy at relativistic shocks

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

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

Keywords: shock, electromagnetic wave, relativistic

PEM26-09 Room:102B Time:May 22 16:00-16:15

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

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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, ions were observed in the deep wake by a Japanese spacecraft SELENE (KAGUYA) which is orbiting the moon in a polar orbit around 100km altitude. A key mechanism of this phenomenon is thought to be scattering of SW ions at the lunar dayside surface by an interaction between the Interplanetary Magnetic Field (IMF) and a lunar magnetic anomaly. In the present study, we examine entry processes of ions into the wake due to the interaction between IMF and the magnetic anomaly via a full-kinetic Vlasov simulation.

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

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