Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

PEM34-01 Room:503 Time:May 1 11:30-11:55

Frontier of space plasma observations expanding from interplanetary space to interstellar medium

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The Sun emits the super-sonic plasma flow, called the solar wind, to form the heliosphere in the ambient interstellar medium. The spatial scale of the heliosphere is about 100 AU. Since interesting physical phenomena such as the solar wind formation, excitation and propagation of shocks, acceleration of energetic particles arises through interaction between plasma and fields in the heliosphere, it is used as an experiment site to make various observational studies of the space plasma. Remote sensing measurements of the solar wind with the interplanetary scintillation (IPS) method are one of those studies. The obtained IPS data revealed the global distribution of the solar wind drastically changes its global distribution over short- and long-timescales being closely associated with the solar activities (Tokumaru, 2013).

At present, marked progress occurs in the heliospheric sciences, being driven by new observational facts. One of progress has been brought about by exploration of heliospheric boundary region by Voyager-1, 2 (V1,V2) and IBEX spacecraft (Gurnett et al., 2013, McComas et al., 2009). The V1 encountered the termination shock (TS) at 94 AU in 2004, and reached the heliopause at 120 AU in 2012, then entered the interstellar medium. The V2 encountered the TS at 87 AU in 2007, being expected to reach the heliopause in a few years. The IBEX revealed the large-scale ribbon structure surrounding the heliosphere from imaging observations of energetic neutral atoms (ENAs). In order to interpret those observations, information on 3-diminensional (3D) structure of the heliospheric boundary region is needed. Since IPS observations mentioned above give global distribution of the solar wind in the inner heliosphere, 3D structure of the heliospheric boundary region can be determined precisely by MHD simulation based on the IPS data. The IPS-based MHD simulation data are provided to both Voyager and IBEX teams to make collaborative studies of the heliospheric boundary region.

Another driver for progress in the heliospheric science is arrival of the peculiar solar activity. The level of the current solar cycle is 100 years low, and IPS observations revealed that significant changes including marked drop of the solar wind density and different distribution of fast and slow solar winds occurs in this cycle (Tokumaru et al., 2009, 2010, 2012). These facts are important not only for studies of the heliospheric boundary region and influence on the planetary magnetospheres (i.e. the space weather), but also for elucidating enigma of the solar wind acceleration mechanism. Besides, observations during the current peculiar activity provide a clue to understand a hidden process for cooling of the Earth's climate during the Maunder minimum in the 17th century.

The V2 encounter for the interstellar medium which is expected to occur within a few years will enable detailed investigation of plasma environment in the local interstellar cloud surrounding the heliosphere. Furthermore, the heliopshere is immersed in the low-density (but high-beta) region called the local bubble, whose plasma properties have been investigated from radio observations using pulsars (Spangler, 2009). In the future, space plasma study for the integrated region ranging from the heliosphere to the local bubble will significantly advance by using in situ and remote sensing observations.

Keywords: solar wind plasma, interplanetary scintillation, heliosphere, interstellar medium, solar cycle

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PEM34-02 Room:503 Time:May 1 11:55-12:15

Scale hierarchy and self-organization in magnetospheric plasma

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Inhomogeneous magnetic field gives rise to interesting properties of plasmas which are degenerate in homogeneous (or zero) magnetic fields. Magnetospheric plasmas, as observed commonly in the Universe, are the most simple, natural realization of strongly inhomogeneous structures created spontaneously in the vicinity of magnetic dipoles. In this talk, we describe the experimental results form a "laboratory magnetosphere" RT-1, and theoretical modeling of its spontaneous confinement.

The RT-1 device produces a magnetospheric plasma by a levitated superconducting magnet. Stable confinement (particle and energy confinement time = 0.5 s) of high-beta (local electron beta >0.7); electron temperature >10 keV) plasma has been demonstrated (which are promising characteristics for an innovative concept of advanced fusion; it is also applicable as a particle trap for experimental particle physics or atomic physics). The radial profile of the electron density n(r) is highly peaked. Fitting the data by a function $n(r) = n_0 r^{-p}$,we estimate $p=2.8\pm0.4$ for a wide range of operating parameters. Multiplying n(r) by the magnetic flux tube volume, we can estimate the particle number N(r) in a unit magnetic-flux tube. While n(r) is a steep increasing function towards the center of the dipole magnetic field, N(r) is a decreasing function, hence interchange modes are stable. Whereas the simple kinetic model predicts a flat distribution of N(r) [1], the model of grand-canonical equilibrium explains the observed equilibrium state [2].

Theoretically, we can describe the self-organized confinement of the magnetospheric plasma as a grand-canonical equilibrium in a "foliated phase space" of magnetized particles [3]. What makes the distribution function fundamentally different from the conventional Boltzmann distribution is the topological constraints on the phase space which limits the actual domain where the particles can occupy; the adiabatic invariants pose such constraints. Taking into account the constancy of the magnetic moment and the parallel action, we obtain a foliated phase space of coarse-grained variables, on with the invariant measure is distorted by the inhomogeneous magnetic field. The grand-canonical equilibrium has an inhomogeneous density when it is immersed in the laboratory flat space. Hence, the creation of a steep-density clump is a natural consequence of equipartition in the magnetic-coordinate phase space.

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[2] Z. Yoshida et al., Plasma Phys. Control. Fusion 55 (2013), 014018.
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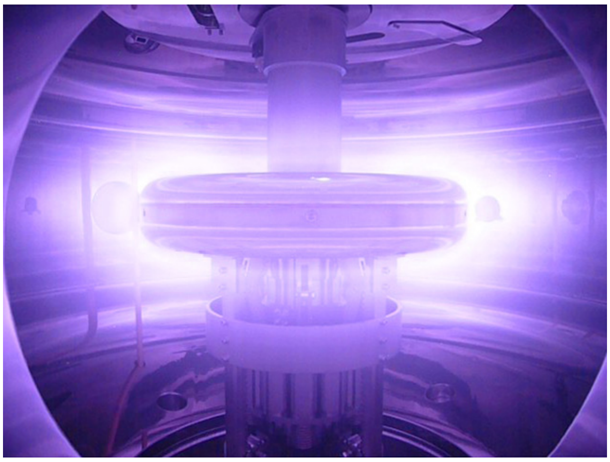
Keywords: inward diffusion, adiabatic invariant, foliation, high-beta plasma, dipole magnetic field, non-neutral plasma



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PEM34-03 Room:503 Time:May 1 12:15-12:30

Solar wind plasma entry into the wake behind an unmagnetized obstacle

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Plasma entry into a wake downstream of a non-magnetized obstacle in the supersonic flow of the solar wind is studied by using a two-dimensional, electromagnetic particle-in-cell simulation. Importance of negative charging of the downstream-side surface of the obstacle is examined by comparing the simulation results of 3 different ratios 8, 16, 32 of the obstacle size to the Debye length.

Keywords: wake, solar wind, surface charging, electron thermal speed, Debye length, particle-in-cell simulation

PEM34-04 Room:503 Time:May 1 12:30-12:45

Global Vlasov simulation of a small body with a magnetic anomaly with the K-computer

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The interaction between a plasma flow and a small dielectric body with a weak intrinsic global magnetic field is studied by means of a five-dimensional (5D) full electromagnetic Vlasov simulation with two configuration spaces and three velocity spaces. In the present study, entry processes of ions into the nightside wake tail are examined. The simulation result shows that the bow shock and the magnetopause are formed on the dayside. However, most of solar-wind ions are reflected at the dayside magnetopause and are picked up by the interplanetary magnetic field. Then, a small part of the reflected ions are taken into the deep wake tail near the body by the E cross B cycloid motion. The present result, in which the spatial resolution is low and the Debye-scale charge separation on the dayside surface is not solved, is obtained by using a recent cluster computer system. Currently we are performing a 5D high-resolution global Vlasov simulation by using the K-computer. The direct comparison between the low- and high-resolution runs would show importance of fully kinetic global simulations.

Keywords: simulation, plasma, small geophysical body, magnetosphere, Vlasov code, K computer

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PEM34-05 Room:503 Time:May 1 14:15-14:30

Dependence of Jovian Magnetopause Location on Solar Wind Dynamic Pressure

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Past observations revealed that the probability density distribution of Jovian magnetopause stand-off distance has double-peak. The probability between two peaks is very low. Thus the stand-off distance of Jovian magnetopause changes from the peak distance to the other peak by solar wind dynamic pressure. However, the scatter plot of stand-off distance versus solar wind dynamic pressure was nearly on one line. But the solar wind dynamic pressure was considered by magnetic pressure in the Jovian magnetosphere, due to the absence of the solar wind monitor at the Jovian orbit. We approached the double-peaked distribution by using the calculated solar wind parameters via MHD equations whose input parameters are based on the observation at Earth's orbit. Referring the propagated solar wind parameters, we investigated the location of Jovian magnetopause observed by the Galileo spacecraft. We found that the peaks of the distribution seem to be a result of probability density distribution of solar wind dynamic pressure. The very low probability stand-off distance between the peaks seemed to be caused by unusual distribution of solar wind dynamic pressure.

Keywords: Jovian Magnetopause, Solar Wind Dynamic Pressure

PEM34-06 Room:503 Time:May 1 14:30-14:45

Pickup ion acceleration via multiple reflection between two successive CIRs

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Interstellar neutral particles, during their propagation inside the heliosphere, become ionized by the charge exchange with the solar wind (SW) plasma. The interplanetary magnetic field picks up these newborn ions, called "pickup ions" (PUIs), and carries them away into the outer heliosphere with SW. The gyrating velocity of PUIs around the magnetic field is equivalent to the SW flow speed, hundreds of km/s, which is much faster than the SW thermal velocity. This property enables PUIs to be accelerated more efficiently at the shock than the thermal SW particles. Thus PUIs are considered to be the dominant source of anomalous cosmic rays (ACRs) generated at the heliospheric termination shock.

However, the well-known diffusive shock acceleration (DSA) process alone is insufficient to raise the PUI energy up to the ACR range, typically in the order of MeV. This is because the primary PUI energy (10 keV at most) is still too low to be injected into DSA, where at least hundreds of keV is necessary. Therefore, some preacceleration should take place inside the heliosphere before SW and PUI reach the termination shock. Interplanetary shocks are the most possible source for it. In the present study, we focus on the shocks driven by the interaction of the fast SW with the ahead-flowing slow SW. The regions bounded by these shocks are called corotating interaction regions (CIRs); forward shock in the slow SW side and reverse shock in the fast SW side.

We demonstrate how particles are accelerated at this CIR system by performing hybrid simulations. The simulation results show that more efficient acceleration is identified in the PUI reflected at the shock than in those transmitted through the shock. The acceleration takes place while the PUI stays close to the shock surface. This situation is similar to the shock-drift or surfing acceleration mechanism. However, our results indicate that the acceleration is not dominant in the component transverse to the magnetic field, i.e., the direction of motional electric field. Rather, the net acceleration is confirmed in the field-aligned component. The mechanism will be discussed in terms of the characteristic of the Lorentz force balance acting on PUIs.

The periodic boundary condition applied in the present simulation virtually allows the successive appearance of two CIRs. After the reflected PUI travels the "inter-CIR" space, it encounters the shock of another CIR, where the reflection again takes place. While one reflection increases the PUI energy only a few times, this multiple reflection process yields the most energetic PUI with its maximum energy up to 100 keV, probably enough for the injection into DSA. Recent CIR observations have confirmed the presence of the energetic PUI in the solar wind between two CIRs, which may prove the present results.

PEM34-07 Room:503 Time:May 1 14:45-15:00

Study on The Difference Between Proper-Motion of Balmer hydrogen line emission and Non-Thermal X-Ray emission in SNRs

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Balmer line emission (Hα) by neutral hydrogen and X-ray synchrotron emission by accelerated electrons are observed from some supernova remnants (SNRs), which are thought as accelerators of galactic cosmic rays (CRs). From these observations, the cosmic ray acceleration eciency is estimated. According to the theory of diusive shock acceleration (DSA), electrons are accelerated around the shock front, and emit the synchrotron radiation. Measurement of proper motion of the synchrotron X-rays gives the shock velocity. At the same time, we can estimate the post shock temperature from the line width of Hα emission, because neutral hydrogen collide with downstream hot protons and exchange their charge, so that the hot neutral component arises.

In the specific case of a SNR RCW86, measured expansion speed of Hα filament is about 1200km/s(Helder et al. 2013), while 6000km/s in X-rays (Helder et al. 2009). It is expected that the emission regions of the Hα and the synchrotron X-rays are dierent. However, they are overlaid in the same line of sight.

In this study, using three dimensional magnetohydrodynamics (MHD) simulations, we consider propagation of super

nova blast wave shock in realistic inhomogeneous interstellar medium. Interaction between the upstream density inhomogeneity and the shock wave causes rippled shock structure and uctuation of local shock velocity. We show that our synthetic observations of the MHD simulation data are consistent with actual observation results for RCW86.

Keywords: supernova remnants, shock wave, cosmic ray

PEM34-08 Room:503 Time:May 1 15:00-15:15

Magnetohydrodynamic Simulations of the Interaction of a Jet with Interstellar Neutral Hydrogen Clumps

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An astrophysical jet transfers the energy released near the gravitating object and interact with the interstellar medium. When the jet propagates in the interstellar medium interacting with its environment. We carried out magnetohydrodynamic simulations of the jet propagation in neutral hydrogen (HI) clumps taking into account the interstellar cooling. At the initial state, HI clumps are assumed to be in thermal equilibrium. As the clumps are compressed by the bow shock ahead of the jet, the shocked cloud is heated up but since the density enhancement increases cooling rate, the cloud is subsequently cooled down. As a result, cold, dense sheath is formed around the jet. The enhanced density triggers the cooling instability and prompts the formation of the cold, dense gas.

We studied the dependence of numerical results on the volume filling factor of the HI clumps. We found that when the volume filling factor is large, the propagation speed of the jet is slow and arc-shaped cold dense region is formed. When the volume filling factor is small, propagation speed does not decrease so much and dense cloud distribution is more elongated. The distribution of the cold, dense gas and the length of the jet propagation speed depend on the filling factor.

We report the application of this model to molecular clouds toward the stellar cluster Westlund 2 and TeV γ-ray source HESS J1023-575 observed by NANTEN2 and Mopra telescope. HESS J1023-575 is located between these molecular clouds. The shape of molecular cloud on the right of HESS J1023-575 is like an arc and molecular clouds on the other hand distribute linearly. The difference of the filling factor can explain the difference of the shape of these molecular clouds.

Keywords: jet, interstellar medium, magnetohydrodynamics