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

PEM33-01 Room:503 Time:May 1 09:00-09:25

Effects of cosmological infall of galaxies: its discovery, plasma physical implications, and verification with ASTRO-H

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Clusters of galaxies are a system consisting of hundreds of galaxies that are gravitationally bound together. About 10% of the mass of each cluster is in the form of X-ray emitting hot plasmas, called Intra-Cluster Medium (ICM), that constitute the most dominant form of known baryonic components in the universe. The ICM is tenuous, hot, and magnetized, and is hence considered as the most ideal classical plasma ever known.

At central regions of many clusters, the ICM was considered to cool over the Hubble time by emitting X-rays, and lose its pressure. Then, the ICM would flow from outer to inner regions, and enhance the radiative cooling by raising the density. This catastrophy, called cooling flows, were long thought to be actually taking place, as X-ray observations kept discovering its evidence.(3) the energy is then transported to the cool ICM phase via Alfven waves and reconnection, (4) the two ICM phases are kept thermally stable by a mechanism known in Solar corona; and (5) the moving galaxies will gradually fall to the potential center as they transfer their dynamical energies to the ICM (Makishima et al., Publ. Astro. Soc. J. 53, 401, 2001). We have been striving to observationally enhance this novel scenario.

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Through observations of clusters of galaxies with the 4th Japanese X-ray satellite ASCA launched in 1993, we found that the cooling flows are not taking place anywhere, even though the ICM ubiquitously shows mild temperature decrease towards the cluster center: there must be some unknown plasma heating source. We have hence proposed a novel plasma physical scenario; (1) the central galaxy has a magnetosphere, where the cooler plasma is confined and insulated from the surrounding hot ICM; (2) other galaxies, all moving in the cluster space, will receive resistance from the ICM and excite MHD turbulence therein; (3) the energy is then transported to the cool ICM phase via Alfven waves and reconnection, (4) the two ICM phases are kept thermally stable by a mechanism known in Solar corona; and (5) the moving galaxies will gradually fall to the potential center as they transfer their dynamical energies to the ICM (Makishima et al., Publ. Astro. Soc. J. 53, 401, 2001). We have been striving to observationally enhance this novel scenario.

Recently, we have obtained crucial evidence supporting (5). That is, we studied 34 clusters with various redshifts (0.1-0.9) with X-ray and optical wavelength. Then, galaxies in nearby clusters were confirmed to be much concentrated than the ICM, while these two components are nearly co-spatial at distant clusters (Gu et al., Astrophys. J. 767, id 157, 2013). That is, galaxies in each luster have been falling, on the Hubble time scale, to the center. This result not only provides the long-sought heating mechanism of the ICM and strengthen our hypothetical view, but means the discovery of a very large energy flow that has not been known. Furthermore, it can explain many other puzzles with clusters of galaxies.

We are now developing, under an extensive international collaboration, the innovative X-ray satellite ASTRO-H, to be launched in 2015. With ASTRO-H, we will be able to detect X-ray Doppler effects which is caused when moving galaxies drag the ICM around them, and study possible particle acceleration phenomena as a consequence of energy loss by galaxies.

Keywords: galaxies and their clusters, intra-cluster medium, X-ray emission, magnetoplasma effects, ASTRO-H satellite

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PEM33-02 Room:503 Time:May 1 09:25-09:45

Direct measurement of the plasma momentum in a magnetic nozzle helicon plasma for electric propulsion

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The ion and electron energy distribution functions of a low-pressure, current-free helicon plasma in a magnetic nozzle configuration are experimentally investigated by electrostatic Langmuir probes including a radiofrequency compensated probe and a retarding field energy analyzer; the ions are electrostatically accelerated by a spontaneous potential drop of a double layer and/or ambipolar electric field, and only the energetic electrons can overcome the potential structure. The results indicate that the accelerated ions are spontaneously neutralized by the energetic electrons. These findings propose that the source system is applicable to an electrodeless and neutralizer-free plasma thruster.

Momentum of the plasma flow is one of essential physical parameters dominating the particle acceleration in both laboratory and space. Especially their interaction with magnetic fields have been significant subject associated with natural plasmas (astrophysical jets, magnetospheric physics, solar dynamics, aurora dynamics, etc.) and artificial plasmas (thermonuclear fusion devices, electric propulsion systems, plasma devices for material processing, etc.). The plasma momentum is equal in magnitude and opposite in direction to a thrust imparted from a plasma thruster for the electric propulsion device. The direct measurement of the thrust imparted from a magnetic nozzle helicon plasma thruster is successfully measured by using a pendulum thrust balance immersed in vacuum, where the thrust components arising from the presence of the physical boundaries and magnetic nozzle are also independently measured by attaching each component to the thrust balance. Further a laboratory experiment of a helicon plasma thruster is established to control only a plasma cross-field diffusion in a rapidly-divergent magnetic nozzle while maintaining a constant plasma injection into a magnetic nozzle. The thrust component due to a plasma pressure force inside the source cavity is constant and that due to the magnetic nozzle increases when inhibiting the cross-field diffusion in the nozzle. The latter force is well explained by an electron-diamagnetic-induced plasma momentum derived from two-dimensional momentum equations and approaches the theoretical limit derived from a one-dimensional model assuming an ideal magnetic nozzle with no plasma loss. Further a new source system approaching the ideal magnetic nozzle and the recent progress of the thruster performance will also be shown. It is noted that the above-described phenomena are occuring in current-free source system. These insights into the plasma thruster dynamics might include a common physics relating to the plasma acceleration in a non-uniform magnetic field in both the laboratory and space.

Keywords: plasma momentum, magnetic nozzle, helicon plasma, electric propulsion

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PEM33-03 Room:503 Time:May 1 09:45-10:00

Laboratory in-situ experiments for plasma wave-particle interaction in linear magnetized plasma machine

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Wave-particle interactions are thought to play important roles to generate MeV electrons in the radiation belt. " Wave-Particle Interaction Analyzer (WPIA) " , which derives energy flaxes between wave and particle from simultaneous measurements of an electric field and particle velocity vector, has been developed to observe the interaction between wave and particle in space plasma. We have been conducting laboratory in-situ experiments of plasma wave-particle interaction.

We have carried out the laboratory simulation using the Q$_T$-Upgrade Machine in Tohoku University, which is linear magnetized plasma machine. The Q$_T$-Upgrade Machine consists of a vacuum chamber of 0.2 m in diameter and 4.5 m in length, and plasma sources, which generates high-temperature electrons using electron cyclotron resonance (ECR) and low-temperature thermal electrons. Thus, an electron temperature gradient (ETG) is formed in the apparatus by superimposing low temperature thermal electrons on the high temperature electrons of the ECR plasma. Moon et al. [Rev. Sci. Instrum., 2010] reported that low-frequency fluctuations of drift-wave mode with a frequency of 7 kHz were excited with ETG mode of 0.5 MHz. We focus on the low-frequency fluctuations and simultaneously measures an electric field vector (**E**) and current vector (**J**). Energy flaxes between wave and particle can be calculated from inner products of **E** and **J** vectors. For the simultaneous measurements, we have developed a combination probe, which is a combination of Mach probe for ion flow measurements and Twin probe for electric field measurements. Three-dimensional vector are measured by turning and moving the probe in the chamber.

In this presentation, we will report the performance of the combination probe, the phase relationship between the electric field fluctuation and the current fluctuation, and transient response of fluctuation growth in detail.

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PEM33-04 Room:503 Time:May 1 10:00-10:15

Weibel instability mediated collisionless shock generation using large-scale laser systems

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Collisionless shocks are considered to be sources of high-energy particles or cosmic rays, and occur when a coulomb mean-free-path is longer than the shock-front thickness. In such plasmas wave-particle interactions and collective effects play an essential role in the shock formation. In addition to local observations of spaces plasmas by spacecraft and global emission measurements of astrophysical plasmas, a laboratory experiment can be an alternative approach to study the formation of collisionless shocks.

In this paper, we investigate the formation of Weibel-instability mediated collisionless shocks in counter-streaming plasmas produced by large-scale laser systems. Kato and Takabe investigated the collisionless Weibel shock in two-dimensional PIC simulation using the injection method [1]. A scaling-law derived in simulation revealed that high-density (electron density $\sim 10^{20}$ cm^{-3}), high-flow velocity ($\sim$1000 km/s) plasmas are required to produce the collisionless Weibel shock. In order to achieve these plasma parameters, a MJ-class high-power laser system or the word largest laser, the NIF laser (LLNL, USA), is required. Before starting the NIF experiment, we conducted OMEGA laser (LLE, USA) experiment and measured plasma parameters such as electron and ion temperatures, electron density, and flow velocity of counter-streaming plasmas using collective Thomson scattering, and current filaments produced by the Weibel instability using proton-radiography.

[1] T. N. Kato and H. Takabe, The Astophys. J. Lett. 681, L93 (2008).

Keywords: collisionless shock, weibel instability, large-scale laser experiment

PEM33-05 Room:503 Time:May 1 10:15-10:30

Experimental study on collisionless shocks with high-power laser system "Gekko-XII"

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Collisionless shocks play significant roles in particle acceleration, for example, in Earth's bow shock and Supernova remnant shocks. In collisionless shocks, collisions between particles can not account for the formation mechanism and particle?field interactions are essential. Therefore, the shock thickness is much smaller than ion-ion mean free path and a large electromagnetic field exists at the vicinity of the shock. Laboratory experiments with high-power laser systems can be alternative to observations or in-situ measurements by satellites. Collisionless shocks have been produced and investigated in counter-streaming laser-produced plasmas. To investigate collisionless shocks, the measurements of an electric or magnetic field and of fundamental plasma parameters are required. Shocks have been measured by optical diagnostics such as interferometry, shadowgraphy, optical pyrometry, and Thomson scattering to obtain the fundamental plasma parameters: density, temperature, charge state, and flow velocity. We will present recent results from series of our experiments on collisionless shocks with Gekko-XII laser system.

Keywords: collisionless shock, laser, plasma, diagnostics

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PEM33-06 Room:503 Time:May 1 10:30-10:45

Current status and issues of a study on collisionless shocks by using laser experiment

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Collisionless shocks are ubiquitous in various space and astrophysical environments like a termination shock of a stellar wind, planetary bow shocks, supernova remnant shocks, etc. Recently, collisionless shocks have been able to be experimentally generated by using high power laser facilities. One of the advantages in an experimental study is that both the global and the local structures of the phenomenon are simultaneously accessible in principle, which is inherently difficult in-situ or remote sensing observations in space. However, the shocks produced in the laser experiments and the method for measuring them are quite different from those in space. A majority of the shocks produced in laser experiments are unmagnetized shocks. The methodology for measuring their local quantities in the transition region has not been established.

On the other hand, basic structures and dissipation mechanisms in an unmagnetized shock have not been well understood theoretically. So far high Mach number electrostatic shocks are thought to be generated by the counter streams of two non-identical plasmas. In this study microstructures of such electrostatic shocks are studied by using a full particle-in-cell simulation. In addition, characteristics and issues of currently adopted method of measuring local quantities in shock transition region, known as Thomson scattering measurement, are also discussed.

Keywords: collisionless shock, laser experiment, numerical simulation

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PEM33-07 Room:503 Time:May 1 11:00-11:15

Electromagnetic Field Excitation in Magnetized Plasmas by External Electrodes: 1D PIC Simulation Studies

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We perform one-dimensional particle-in-cell (PIC) simulation of external electromagnetic field excitation into magnetized plasmas. We consider two models for the electromagnetic field excitation: electrostatic excitation by electrodes and electromagnetic excitation by current antenna. Here, the external electrodes are placed outside plasma region, background magnetic field is perpendicular to the one-dimensional direction, and the externally applied field frequency is chosen in a range below the lower-hybrid frequency. For both models, we will discuss the electromagnetic field excitation processes by varying the externally applied field frequency and the plasma radius.

Keywords: external electromagnetic field, external electrodes, magnetized plasmas, electric thruster, electrodeless electric thruster

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PEM33-08 Room:503 Time:May 1 11:15-11:30

Numerical simulation of satellite potential control using charged particle beam emission

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It is known that a satellite is charged by plasma in space.

Satellite charging on surface is a cause of discharge and malfunction electric equipment, and affect plasma diagnostics by the satellite potential accelerate ambient plasma, therefore a satellite is designed to mitigate surface charging. However, a perfect mitigation of satellite charging is difficult.

Thereby, a charging mitigation technique using electron emitter and ion emitter is often adopted. Satellite charging will be caused due to collisions with charged particles in plasma. In general, surface potential is determined by the balance of inflow current and outflow current. It becomes a positive value in the sunshine, and a negative value in the shade. The potential balance point can be controlled using charged particle beam emission.

We investigate a feasibility of satellite potential control under various environments using numerical simulation.

Keywords: satellite charging, spacecraft charging, charged particle beam