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

PEM30-01 Room:503 Time:April 30 14:45-15:10

Kelvin-Helmholtz turbulence in space and astrophysical plasmas

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Solar wind interactions with magnetized or un-magnetized planets destabilize planetary boundaries such as the magnetopause of the Earth magnetosphere and the ionopause of Mars and Venus. The Kelvin-Helmholtz (K-H) instability arising at a velocity shear layer has been considered to be important for momentum transport of the solar wind across the boundary layers, and been a universal nature of the planetary interactions. Linear and nonlinear growths of the instability depend on background plasma and magnetic field configurations. At the Martian ionopause, where the ionospheric ion escape is expected by the K-H instability, a fast (~400 km/s), delute (~1 /cc) plasma flow directly interacts with a high density (10^4-10^5 /cc), low temperature (a few thousand K) plasma. The situation can be found similarly at the terrestrial magnetopause, where in-situ observations have often indicated growth of the instability and resultant transport of the solar wind plasma into the magnetosphere, in the sense that the K-H instability grows in a strongly inhomogeneous plasma.

In this presentation, we review nonlinear evolutions of the K-H instability in strongly inhomogeneous plasmas. The evolutions are characterized by the secondary instabilities such as the Rayleigh-Taylor instability and the magnetic reconnection, by which a coherent eddy structure are destroyed and the energy is transported to smaller scales. Recent kinetic plasma simulations have shown that electron-scale structures are spontaneously generated as a consequence of the secondary instabilitties (Karimabadi et al., 2013). The micro-scale structure accompanied with the MHD-scale evolution enhanced mixing of collisionless plasmas. It was also found that the spatial size of the turbulent area was quickly broaden when coupled with a coalescence of large scale K-H modes, that is, the inverse energy cascade (Matsumoto & Seki, 2010). When nonlinear mode coupling was considered the time scale of the inverse energy cascade can be even faster than the fastest growing mode of the K-H instability. These nonlinear features in micro and macro scales have large impact on plasma transport process in the solar wind - planetary interactions as well as in astrophysical plasmas.

Keywords: Kelvin-Helmholtz instability, turbulence, Earth's magnetosphere, Planetary atmosphere

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PEM30-02 Room:503 Time:April 30 15:10-15:30

Experimental Study on Turbulent Transport using ElectroHydroDynamics Convection Turbulence

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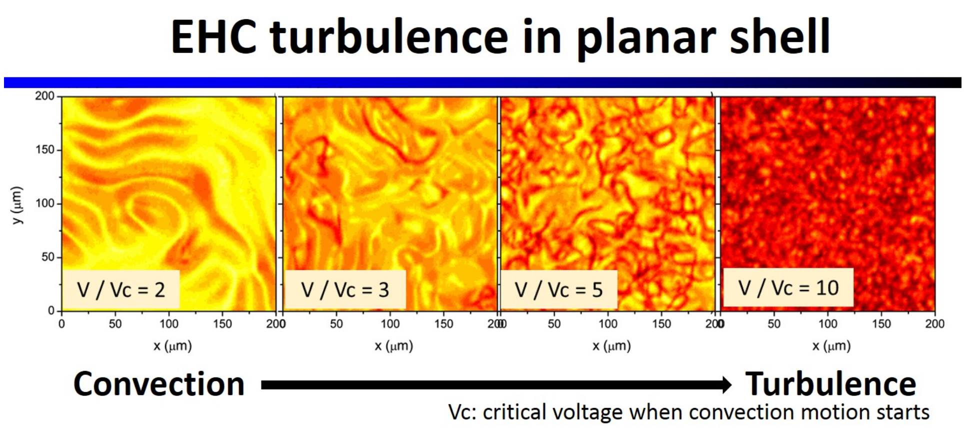
Turbulent transport is a very general subject in a wide area of physics research. The phenomena that we are interested in are very complex ones associated with structure formations in turbulence. It is well known that the Kolmogorov scaling appears in three-dimensional isotropic turbulence. However, it is less interested because nothing happens. In many cases of our interest, some structures appear in turbulence due to symmetry breaking such as temperature gradient, density gradient, intensity gradient of turbulence, rotation, velocity shear, magnetic field, etc. We have proposed a new experimental approach to turbulent transport using ElectroHydrodynamic Convection (EHC).

The EHC is a convection motion driven by the electric field in a liquid crystal, where the gravity and the temperature gradient in a Rayleigh Bernard convection (RBC) system can be replaced by the electric field alone. When the electric field is increased, the EHC becomes turbulent, which is the same feature as RBC with stronger buoyant force. Non-dimensional parameters characterizing EHC turbulence can be easily controlled with the biased voltage. The Rayleigh number is proportional to voltage squared and the Prandtl number is inversely proportional to the frequency of biased ac voltage, respectively. When the EHC turbulence experiment on a rotating table becomes possible in future, the Rossby number can be also controllable.

In the first step of the EHC turbulence experiment, particle transport in homogeneous EHC turbulence without rotation (symmetric case) was evaluated with a particle tracing technique. The small particles put in the liquid crystal can visualize local flow velocity in the EHC turbulence and the particle transport can be evaluated by the orbit tracing of particles. The diffusive nature (random walk process, the Hurst number ˜0.5) of particle transport was observed in the EHC turbulence. The effective diffusivity increases with the Rayleigh number with the power index of ˜0.85. These results are very similar to turbulent transport properties in viscos fluids (Navier-Stokes system).

The details of EHC turbulence experiment in laboratory frame without symmetry breaking and three experimental plans will be discussed. One is an investigation of non-uniformity effects on turbulent transport with inhomogeneity of turbulence intensity (spatial gradient of the Rayleigh number). Second one is an investigation of rotation effect on turbulent transport. These experiments on turbulent transport may reveal some general effects of symmetry breaking of scalar field and vector field, respectively. The last one is a laboratory simulation of the convection zone in stars and/or planet atmosphere with three-dimensional geometry identical to the real geometry (rotating spherical shell with radially driven convection). The radially-driven turbulence in rotating spherical shell have never realized in laboratory. Using ECH turbulence, turbulence can be driven in the radial direction with radial electric field. The convective zone in the Sun is the first target because of relatively large Rossby number˜0.1-1.

Keywords: turbulent transport experiment, symmetry breaking, EHC, liquid crystal



PEM30-03 Room:503 Time:April 30 15:30-15:45

Investigation of magnetic flux transport on the solar surface based on satellite data and auto-tracking technique

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Spatial displacement of patch structure on the solar surface is investigated based on satellite data and auto-tracking technique.

Magento-convection system on the solar surface is thought to be important not only as a cause of various solar activities but also as an actual observable magneto-convection on the stellar surface. One important issue is how magnetic flux is transported there. In global scale, the transport of magnetic field is treated as a diffusion now. However it is not clear that diffusion treatment is appropriate in magneto-convection system. The aim of this study is to understand if the diffusion treatment of magnetic field transport in global scale is good or not.

I investigate the dependence of mean-square displacement on elapsed time by using auto-tracking technique, which is thought to be one of the critical characteristics for global-scale description of transport.

The longest magnetogram data obtained by Hinode/FG is used. In that data, number of tracked patches is enough for statistical study, more than 40000. The obtained dependence show a different character above and below the point of L~10^4 km. Below that scale, it has a power-law dependence with an index of ~-1.4, namely super-diffusion scheme. However, in the larger scale, the power-law dependence becomes ~-0.6, namely sub-diffusion scheme. These characters can be explained by the network flow pattern qualitatively. Below the network scale, patch is transported by constant flow (~0.3km s^{-1}) from center of network cell to edge of the cell addition to the large (~1km s^{-1}) perturbing flow of granulation. On the other hand, above the network scale, patches experience the trapping around stagnation point of network flow, which makes displacement of patch shorter than that only by diffusion motion.

Keywords: the Sun, magnetic field, convection, diffusion, feature recognition

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PEM30-04 Room:503 Time:April 30 15:45-16:00

Dynamic structure of convective motion depending on the height with line profile originating at solar photosphere

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On the solar surface, there are bright cellular patterns which are called granules, separated by narrow dark regions named intergranular lanes. These spatial patterns result from surface convection. The surface convection induces the magnetic field dynamics and it is considered as an energy source of corona heating problem. Therefore, it is important to understand a convective motion in revealing the mechanism of corona heating problem. However, the smallness of its spatial structure prohibits us from resolving granular patterns in the observation. Furthermore, though the vertical structure is important in convection mechanism, it is difficult to observe it because there are few methods for a direct observation of solar interior. In this study, we investigate the height dependence of the vertical velocity and its spatial correlation with granular pattern based on the analysis of spectrum obtained by Solar Optical Telescope (SOT) on board the Hinode satellite. SOT/Spectropolarimeter (SP) obtains the spectrum including the Fe I 630.13/630.25nm lines, which corresponds the solar photosphere. The high spatial resolution of SP enables us to obtain spectra in granule and intergranular lanes separately. In addition, the seeing free condition in space observation enables the long time observation with high resolution, in this study, which is difficult for ground base observation. Consequently, we can remove the 5-min oscillation, which affects the radiative intensity and Doppler velocity, and then reduce errors of the analysis.

In this study, we focus on line profile of Stokes I originating in quiet region. Vertical velocity of convection is obtained from the Doppler shift of the line profile. We also analyze the wavelength structure of the line profile. Because of the dependence of absorption coefficient on wavelength, the intensity at different wavelength position reflects the structure at different height. The intensity at the line center reflects the structure in the higher layer, while the intensity at the line wings reflects the structure in the lower layer. We found that the difference of convective velocity between upper and lower level are typically 300 m s-1. At some locations, it exceeds 1km s-1. Taking into account that the speed of sound is approximately 7km s-1, it means that there are remarkable acceleration or deceleration around the solar surface. Further, there is a tendency between convective motion and acceleration, that granular region has upward motion with deceleration and intergranular region has downward motion with acceleration. In the presentation, we will discuss about the description of typical convective structure on the solar surface and what happens where has the different structure.

Keywords: sun, convection, spectrum, phtosphere

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PEM30-05 Room:503 Time:April 30 16:15-16:30

Particle acceleration and magnetic field generation in the relativistic jet-plasma interactions

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The aim of the current work is to analyze particle acceleration and magnetic field generation related to propagation of a relativistic electron-ion jet front into an unmagnetized ambient electron-ion plasma. We have focused on the earliest evolution in shock formation. The analysis is on the basis of a three-dimensional relativistic electromagnetic particle-in-cell (PIC) code. The results demonstrate that the Weibel instability is responsible for generation of strong small-scale magnetic fields and subsequent particles acceleration. In agreement with previous studies the majority of the particles acceleration occurs behind the jet front. Initially, the incoming electrons respond to field fluctuations growing as a result of the Weibel instability. Therefore, the electron channels are generated and the total magnetic energy grows linearly due to the mutual attraction between the channels, and downstream advection of the magnetic field fluctuations. When the magnetic fields become strong enough to deflect the much heavier ions, the linear growth rate of instability decreases as a result of oppositely directed electron-ion currents and topological change in the structure of magnetic fields. The Ion channels are then merged and magnetic energy increases more slowly at the expense of the energy stored in ion stream. It has been clearly illustrated that the ion channels develop through a larger scale in the longitudinal direction, while extension of the electron filaments is limited. Hence, the ions channels are the sources of deeply penetrating magnetic fields. Our results are in valid agreement with those reported in the literature.

Keywords: Relativistic jets, Particle acceleration, Magnetic field generation, Weibel instability

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PEM30-06 Room:503 Time:April 30 16:30-16:45

Magnetohydrodynamic evolutions of the Richtmyer-Meshkov instability in astrophysical and laboratory plasmas

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The Richtmyer-Meshkov instability (RMI) in magnetohydrodynamics is of great interest in many fields such as astrophysical phenomena, laboratory experiments, and inertial confinement fusion. The RMI occurs when an incident shock strikes a corrugated contact discontinuity. A strong shock wave traveling through the density inhomogeneity of magnetized interstellar medium is a promising site of the RMI. This astrophysically common event plays a key role in determining the dynamics of supernova remnants and gamma ray bursts. Recent laboratory experiments are designed to test the magnetic field amplification due to the RMI by the use of laser-induced shock waves. In inertial confinement fusion, the RMI excited at several capsule interfaces amplifies the perturbations that seed the Rayleigh-Taylor instability. For the fast ignition approach, the utilization of an external magnetic field to guide the fast electrons is discussed proactively and sheds light on the impact of magnetohydrodynamic (MHD) instabilities during the implosion.

The inclusion of a magnetic field brings two important consequences into the RMI, which are the amplification of an ambient field and the suppression of the unstable motions. The magnetic field can be amplified by the stretching motions at the interface associated with the RMI. A strong magnetic field inhibits the nonlinear turbulent motions of the RMI. The vorticity generated by the interaction between a shock front and a corrugated contact discontinuity is the driving mechanism for the RMI. For the cases of MHD parallel shocks, the role of the magnetic field is to prevent the deposition of the vorticity on the interface, and stabilize the RMI.

We have investigated that the critical strength of a magnetic field required for the suppression of the RMI numerically by using a two-dimensional single-mode analysis. For the cases of magnetohydrodynamic parallel shocks, the RMI can be stabilized as a result of the extraction of vorticity from the interface. A useful formula describing a critical condition for magnetohydrodynamic RMI is introduced and is successfully confirmed by direct numerical simulations. The critical field strength is found to be largely dependent on the Mach number of the incident shock. If the shock is strong enough, even low-beta plasmas can be subject to the growth of the RMI.

Keywords: MHD instability, astrophysical plasmas, laboratory plasmas

PEM30-07 Room:503 Time:April 30 16:45-17:00

Gyrokinetic simulation of multi-scale plasma turbulence

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As is well known, spatio-temporal scales of plasma phenomena are characterized by multiple scale-lengths. As the scale-separation may not necessarily hold, multi-scale phenomena have been regarded as a common subject in the space and laboratory plasma studies. Magnetic reconnection is discussed as one of the examples. On the other hand, turbulence involves macro- and micro-scale structures simultaneously, and shows the fluctuation spectrum in a wide wavenumber range. Here, we discuss plasma turbulence with multiple scale-lengths, focussing on turbulent transport in magnetic fusion plasma.

By means of the gyrokinetic simulation, we have investigated transport phenomena in case with the electron temperature gradient (ETG) turbulence and the trapped electron mode (TEM) driven by a density gradient, where two scale-lengths characterizing the turbulence are involved. If both the two modes are unstable, after development of the ETG turbulence with a short spatio-temporal scale, the TEM instability grows with a long spatio-temporal scale. We have found an interesting case where the TEM drives a shear (zonal) flow with a longer spatio-temporal scale by which ETG and TEM fluctuations are regulated. The obtained result implies a possibility of turbulent transport reduction with a different driving source with a help of cross-scale interaction through zonal flows.

Furthermore, we have carried out a large-scale gyrokinetic simulation of multi-scale turbulence including the ion temperature gradient mode, where a turbulence spectrum from ion to electron scales as well as its dynamical evolution is studies. In the presentation, we will discuss characteristics of the multi-scale plasma turbulence and related transport.

*This work is based on collaboration studies with Y. Aasahi (TiTech), S. Maeyama, M. Nakata, Y. Idomura (JAEA), A. Ishizawa, M. Nunami, and H. Sugama (NIFS). Under supports for the research collaborations, the numerical simulations are carried out by utilizing Plasma Simulator (NIFS), Helios (IFERC-CSC), and K (AICS, Riken). This work is also partly supported by by the MEXT grant for HPCI Strategic Program Field No.4, and by grants-in-aid of MEXT.

Keywords: turbulence, transport, kinetics, simulation

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PEM30-08 Room:503 Time:April 30 17:00-17:15

Plasma heating by nonlinear development of a finite amplitude whistler wave

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A two-dimensional, three-velocity (2D3V) particle-in-cell simulation has been done in order to study nonlinear development of a finite amplitude and long wavelength R-mode wave propagating parallel to the mean magnetic field, where the fluctuation energy is 10% of the mean magnetic field and the wavelength is about the ion inertial length. The simulation has shown that the bulk motion associated with the finite amplitude wave triggers the modified-two-stream instability that generates electrostatic field in the quasi-perpendicular direction. The electrostatic field scatters ions in the perpendicular direction and electrons in the parallel direction. About 70% of fluctuation energy of the initially imposed R-mode decreases in one gyro-period of ion. The dissipation through the modified-two-stream instability in the two-dimensional system is more effective than the parametric instability in the one-dimensional system. Further the simulation found that quasi-perpendicular-propagating electromagnetic fluctuations are enhanced through the nonlinear development of the R-mode. Discussion will focus on both the plasma heating and the nonlinearly enhanced fluctuations propagating quasi-perpendicular directions.

Keywords: Whistler wave, Solar wind, Nonlinear development, Plasma heating, Particle-in-cell simulation

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PEM30-09 Room:503 Time:April 30 17:15-17:30

A theoretical model of nonlinear Alfven waves in expanding accelerating solar wind plasmas

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During about forty years, a lot of studies have discussed the linear and nonlinear dynamics of Alfven waves in solar wind plasmas. Although the uniform plasmas are assumed in most past studies, the effects of the inhomogeneity of background plasmas cannot be negligible in the inner heliosphere, in which several future spacecraft missions are planned. In the present study, a nonlinear evolution equation of envelope-modulated Alfven waves is derived from the magnetohydrodynamic accelerating expanding box model by using the reductive perturbation method. The effects of the acceleration of solar wind to nonlinear evolution are discussed in detail.

Keywords: solar wind, Alfvenic turbulence

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PEM30-P01 Room:Poster Time:April 30 18:15-19:30

Alfven wave resonance in density profile structure and the effect for nonlinear phenomenon

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Wave transport in plasma (e.g. Alfven wave) is a universal phenomenon for astrophysical fluid which is effected by electro-magnetic force. Presence of

density structure in plasma causes these wave reflection, and prevents smooth transport for one direction. However, it is known that if the density structure is like square well form, Alfven wave is trapped in the structure and wave reflection does not occur. It seems that this wave trapping is a ordinary case and concerns with physical phenomenon, because density valley usual exist in plasma. For example, it is pointed out that Alfven wave energy is dissipated at low-density area which is located in surface of the sun, and this mechanism is relate to coronal heating.

At linear phase, we can understand analytically the property of Alfven wave transport on square well density profile. Therefore, we can also understand the condition that wave trapping and no reflection occurs. At this phase, the flow is well-regulated and steady state, and compressibility effect (e.g. pressure or density vary) doesn't appear because Alfven wave is essentially transverse wave. However, as the wave injection continues, the amplitude increases and nonlinear effect turns important. At this phase, the flow is complicated due to trapped wave's collision, and square well density profile can not keep the form. As a result, the resonance condition will change voluntarily. This density profile is universal in the plasma gas, so above physical mechanism is important for understanding plasma phenomenon.

In our numerical simulation, we pay attention voluntarily structural change due to linear phase shift to nonlinear phase. Consequently, the linear phase resonance condition directly affects the time evolution in nonlinear phase. We will introduce the result.

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PEM30-P02 Room:Poster Time:April 30 18:15-19:30

The effect of the ion gyro motion to nonlinear processes of the Kelvin-Helmholtz instability

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Nonlinear evolution of the Kelvin-Helmholtz instability (KHI) at a transverse velocity shear layer in an inhomogeneous space plasma is investigated by means of a four-dimensional (two spatial and two velocity dimensions) electromagnetic Vlasov simulation. When the rotation direction of the primary KH vortex and the direction of ion gyro motion are same, there exists a strong ion cyclotron damping. In this case, spatial inhomogeneity inside the primary KH vortex is smoothed and the secondary Rayleigh-Taylor instability is suppressed. The ion gyro motion also suppresses the formation of secondary vortices in the spatial scale smaller than the ion gyro radius, when the rotation direction of the vortex and the direction of ion gyro motion are same. As a result, the secondary instabilities take place at different locations in the primary KH vortex, where the rotation direction of the secondary vortex and the direction of ion gyro motion are opposite. These results indicate that secondary instabilities occurring in the nonlinear stage of the primary KHI at the Earth's magnetospheric boundaries might show dawn-dusk asymmetries.

Keywords: the Kelvin-Helmholtz instability, Vlasov simulation, space plasma, nonlinear processes, secondary instabilities

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PEM30-P03 Room:Poster Time:April 30 18:15-19:30

Magnetohydrodynamic and Radiation Hydrodynamic Simulations of Tidal Disruption Events by a Supermassive Black Hole

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Gas clouds or a star approaching a supermassive black hole can be disrupted by its tidal force. Such tidal disruption events enable us to observe the luminosity variations and state transitions triggered by the increase of the accretion rate, and give us hints to understand the transitions between different types of active galactic nuclei. Furthermore, the interval between the state transitions restricts the angular momentum transport rate, which determines the time scale of viscous evolution of an accretion disk. In 2014, tidal disruption flares are expected in two objects. One is the Galactic center supermassive black hole Sgr A∗. A gas cloud named G2, whose mass is three times of the Earth mass is now approaching Sgr A∗, and its pericenter passage will be in March, 2014. Since the distance from the black hole is well inside the radius of the accretion disk around Sgr A∗, the tidally disrupted gas cloud will interact with the accretion disk. We carried out three-dimensional magnetohydrodynamic simulations of this interaction by applying a MHD code CANS+ based on the HLLD scheme. We found that the accretion rate increases more than 10 times during this outburst, and that magnetically driven jets are ejected. Increase of the X-ray and radio luminosity takes place within 1 month after the passage. The second object we expect an outburst is Swift J1644+57, which showed extremely high energy outburst in March 2011. This object locates at the center of a galaxy at redshift z=0.35. The energy released in this outburst indicates that the outburst was triggered by a disruption of a star. The luminosity of this source exceeded the Eddington luminosity for a 1-million solar mass black hole for period longer than a year but the X-ray luminosity decreased 100 times in August 2012. This darkening can be interpreted as the transition from a supercritically accreting slim disk state to a sub-critically accreting standard disk state. We carried out radiation hydrodynamic simulations of this event and showed that mass of the stellar debris is accumulating in the outer disk. When the surface density of the outer disk exceeds the threshold for the transition from a standard disk to a slim disk, the disk mass will accrete supercritically onto the black hole. Numerical results indicate that the luminosity of Swift J1644+57 may exceed the Eddington luminosity again in 1-2 years from the darkening.

Keywords: accretion disk, MHD, radiation hydrodynamics, black hole, tidal disruption, state transition