ランダウ減衰の非可逆性
Irreversibility of Landau damping

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ランダウ減衰はプラズマ運動論の中で基本的な素過程のひとつであり、ほとんど全てのプラズマ物理の教科書でくわしく扱われている。しかしながら、その正確な意味については、いくつかの誤解があり、教科書の記述もまちまちである。講演者は2015年度秋のSGEPSS講演会でランダウ積分路に関する混乱について報告したが、今回はその可逆性について議論する。
多くの教科書では、ブラソフ方程式に衝突項がないため、無衝突プラズマで起こる現象は可逆であると解説している。そして、その例としてランダウ減衰をあげ、プラズマエコーによって波動を再現できることから、情報が失われていないという議論をしている。しかしながら、「可逆」という言葉を字義通り、つまり「時間逆転をした過程が実際に起こりうる」という意味に解釈すると、プラズマエコーは可逆の証拠ではない。プラズマエコーが先におこり、それを放置しておくと初期状態にもどるような現象は起こらないからである。
講演では近年の統計力学の知見をもとに「不可逆」の意味を考え、ランダウ減衰も普通の不可逆現象と本質的に同じ意味で不可逆であることを示す。この観点からみると、プラズマエコーでは散逸が起こってないのではなく、実空間の散逸と同じタイムスケールで速度空間内の散逸が起こっているため、一見情報が失われてないようにみえると説明できる。

キーワード：ランダウ減衰、プラズマ波動、無衝突プラズマ
Keywords: Landau damping, Plasma waves, Collisionless plasma

温度異方性を考慮したMHDによる無衝突降着円盤の成層シミュレーション
Stratified Simulations of Collisionless Accretion Disks by Kinetic MHD with Anisotropic Pressure

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An accretion disk is one of the most ubiquitous astrophysical structure in the universe. In particular, the accretion disk around a supermassive black hole, such as Sgr A* in our galactic center, is thought to consist of a collisionless plasma, in which the gas is so hot and dilute that the mean free path of charged particles become larger than a scale size of the accretion disk. Particle-in-cell and Vlasov simulations are typical numerical approaches to investigate such a collisionless system. In the case of the accretion disk, however, the fact that the scale size of the disk and the kinetic scale of particles are different by orders of magnitude makes it impossible to apply the kinetic simulation techniques to this problem directly due to the limit of computational resources. To study the large-scale dynamics of collisionless accretion disks, therefore, the so-called kinetic magnetohydrodynamics (MHD), which can take into account some of kinetic effects, is required.

In this study, we pay attention to the effect of anisotropy of the thermal pressure. Including an anisotropic pressure tensor can modify the nature of the magnetorotational instability (MRI), which has been considered to play an important role for the angular momentum transport in accretion disks. We carried out series of kinetic MHD simulations using a *stratified* shearing box model, for the purpose of investigating the impact of pressure anisotropy on large scale dynamics of collisionless disks.

In the case of the standard MHD simulations with an isotropic pressure in a stratified domain, it is known that the disk threaded by a weak magnetic field is eventually filled with MRI-driven turbulence, which provides a sufficient rate of the angular momentum transport. This MRI-driven turbulence is considered to be responsible for production of a large-scale toroidal magnetic field observed in the stratified simulations, through some underlying disk dynamo process. We found that, once the effect of the anisotropic pressure is included, the resultant saturation level of the small-scale MRI-driven turbulence reduces to one third of that in the isotropic case with respect to the magnetic energy, due to the anisotropy with $P_{\perp}>P_{||}$ generated by the MRI itself. On the other hand, the magnetic energy contained in large-scale structure gets much smaller roughly by one order of magnitude, which implies that the dynamo action might not work efficiently in the collisionless disks. In our talk, we will discuss the dynamical behavior in more detail and try to give a theoretical explanation to the reduction of the turbulence and suppression of the disk dynamo.

キーワード：降着円盤、無衝突プラズマ、MHDシミュレーション
Keywords: accretion disk, collisionless plasma, MHD simulation

磁気回転不安定性の非線形段階でパラサイト不安定性が駆動する乱流の波数スペクトルの異方性について
Anisotropic wave number spectra of turbulence driven by parasitic instability in the nonlinear stage of MRI

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The magneto-rotational instability (MRI) (Balbus & Hawley, 1991) is one of the most important phenomena in accretion disks and causes turbulence driving the mass accretion in the disks. Goodman & Xu (1994) suggested that the magnetic field structure cased by the MRI cascades into turbulence through the evolution of the parasitic instability, which is related to the Kelvin-Helmholtz instability and magnetic reconnection. Pessah (2010) suggested the wave vector and growth rate of parasitic instability are strongly related to both magnetic diffusivity and fluid viscosity. These facts indicate that the artificial diffusivity, which is necessary in an MHD simulation scheme for treating the discontinuity and shock, should be as low as possible in the ideal MHD simulation of MRI-driven turbulence.
We have originally developed the MHD simulation code by employing the MHD scheme suggested by Kawai (2013). This scheme focuses on resolving the turbulence much accurately, and treats the discontinuity by adding the artificial diffusivity only to the vicinity of discontinuity (Localized Artificial Diffusivity method). We carry out the three-dimensional ideal MHD simulation by the developed code with net vertical magnetic field in the local shearing box disk model. We use 256x256x128 grids in the simulation system. We analyze the simulation results for the evolution of the MRI and the simultaneous enhancement of the parasitic instability.
Simulation results in the present study show that the MRI grows in the time scale of a few orbital periods and saturates at 2.8 orbital period. We find that a channel flow is formed through the evolution MRI and that the parasitic instability grows concurrent with the MRI, resulting in the turbulence spectra of both magnetic field and velocity in the simulation system. We confirm the strong enhancement of the parasitic instability at the timing of the saturation of the MRI and its anisotropic wave number spectra of turbulence appeared when the first channel flow is broken down. The anisotropic wave number spectra observed in the simulation result are consistent to the previous analytical studies. Additionally, we reveal that the magnetic field and velocity vectors enhanced by the MRI do not change in time from the same specific angle in the horizontal plane, but the waves enhanced by the parasitic instability in the subsequent channel break down does not show such a clear anisotropic wave number spectra as we find in the first channel flow. It could be because the turbulent flow breaks the laminar channel flow in the subsequent channels as Latter et al. (2009) suggested. We study the formation process of the anisotropic turbulence by analyzing the simulation results in detail.

キーワード：磁気回転不安定性、パラサイト不安定性、MHDシミュレーション
Keywords: Magneto-rotational instability, Parasitic instability, MHD simulation

単位球内部MHD流体の流れを伴う緩和状態
MHD Relaxation with Flow in a unit Sphere

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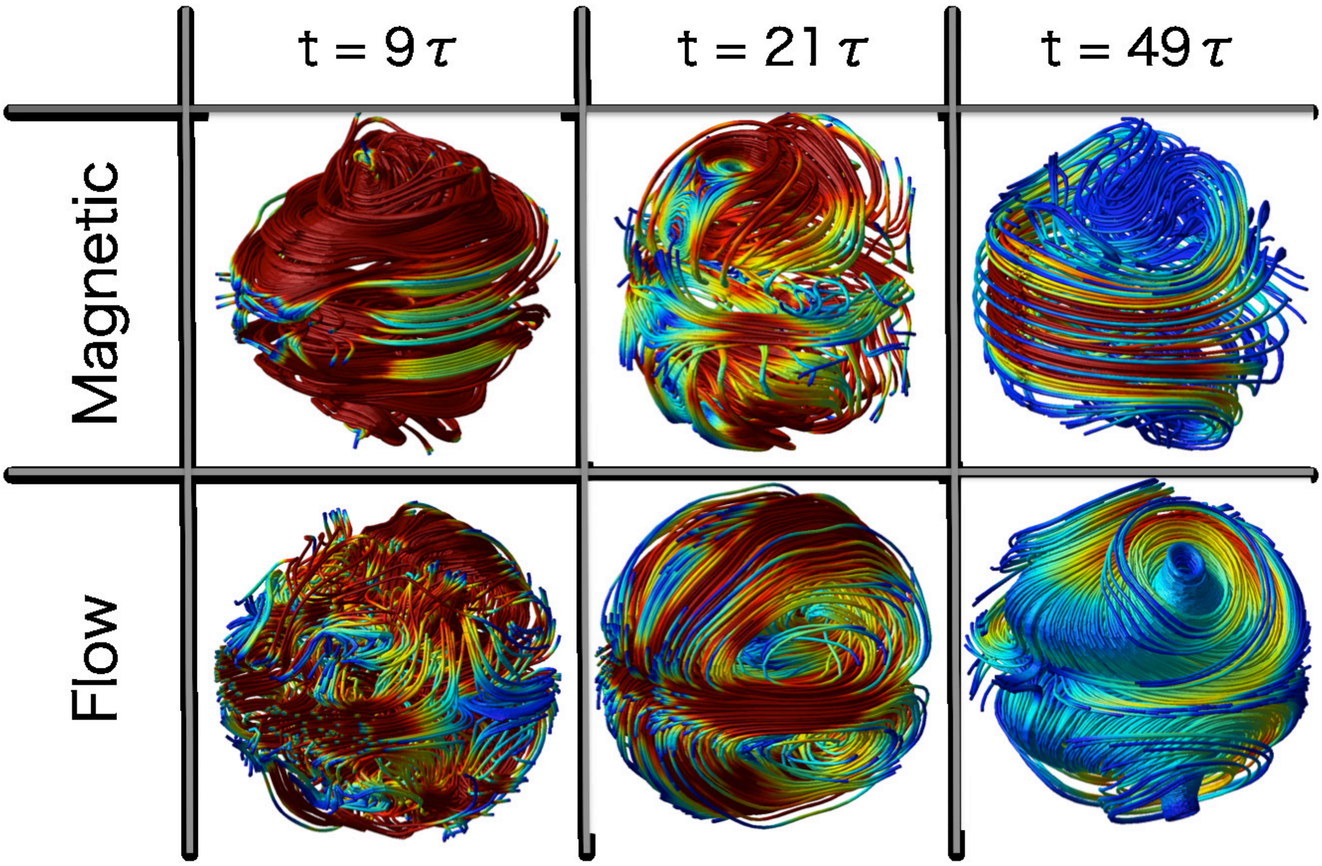
磁気流体力学（magnetohydrodynamics,MHD）モデルでのプラズマの緩和理論がWoltjerとTaylorによって構築され、 実験結果の定量的な説明を含めて大きな成功を納めてきた。この理論（Woltjer-Taylor理論）では、磁気ヘリシティが保存する条件下において 磁気エネルギーと比較して磁気ヘリシティの保存性が良いという仮定の下、磁気エネルギー最小の状態が最終状態になる理論である。この最終状態では流れのエネルギーはない（つまり流れはゼロ）と仮定されている。我々は、単位球内部に閉じ込められたMHD流体の、流れのある緩和状態を計算機シミュレーションで調べた。球の境界条件として、完全導体壁境界条件、stress-free境界条件、断熱壁境界条件を採用した。この場合、全エネルギーに加えて全角運動量が系の保存量となる。 初期条件として経度方向のみのリング状のトロイダル磁場を与え、流れは全領域でゼロとした。初期状態として与えた磁場によるローレンツ力が働くことで、流れが駆動され、その後の緩和過程を観測する。レイノルズ数Reと磁気レイノルズ数Rmはともに Re = Rm = 8600となった。 その結果、緩和状態では正方形の各頂点にそれぞれ渦が配置された特徴的な流れが見られた。

キーワード：磁気流体力学、自己組織化、MHD緩和、Yin-Yang-Zhong格子
Keywords: magnetohydrodynamics, self-organization, plasma relaxation, Yin-Yang-Zhong grid



ヘリコンプラズマ放電過程のシミュレーション
The simulation of helicon plasma discharge

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Helicon plasma is a high-density and low-temperature plasma generated by the electromagnetic helicon wave (i.e., bounded whistler wave) excited in the plasma. It is considered useful for various applications. The helicon plasma discharge is a very complex system that involves many physical processes: the wave propagation and mode conversion to the electrostatic TG wave (determined by the wave dispersion relation), collisional and non-collisional wave damping, plasma heating, and ionization/recombination of neutral particles which in turn renews the dispersion relation. While the steady state of the helicon plasma is relatively well understood, there remain some important unsolved questions, such as how the discharge grows, how the helicon and the TG waves influence the plasma density and the electron temperature, and how their spatial profiles are determined. We have constructed a self-consistent model of the discharge growth that takes into account the wave excitation, electron heat transfer, and diffusion of particles. We discuss some quantitatively different states arising due to different choices of plasma parameters.

キーワード：ヘリコンプラズマ、ヘリコン波、TG波、自己無撞着放電モデル
Keywords: Helicon plasma, Helicon wave, TG wave, Self-consistent discharge model

デカメータ波電波によるわが銀河系中心部ブラックホール・バイナリー検出の再検証
Confirmation of the proposal of five sets of binary of super massive black holes in the central region of our Galaxy

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デカメータ電波パルスの観測に基づき銀河系中心部における超巨大ブラックホールは天文学界の定説となっているような単数ではなく、多数のブラックホール群よりなり、少なくとも５組以上のブラックホール・バイナリーのシステムを形成してることを提唱してきた。それらは、公転周期が Gaa-Gab系、Gac-Gae系、Gad-Gag系、Gaf-Gah 系およびGai-Gaj系においてそれぞれ、2300sec,1200sec,810sec,528sec 及び450sec で、それぞれのバイナリ— を構成する各BHの自転周期は Gaa, 171.6 sec; Gab 119.6 sec; Gac,100.8 sec; Gad,72.4 sec; Gae, 62.8 sec; Gaf, 54.0 sec; Gag, 46.0 sec; Gah, 44.0；Gai, 26.0 sec ; およびGaj, 23.6 sec と得られてきた。これらのパラメータの導出は受信されるデカメータ信号に対してFFT解析を施し、結果となる、諸特徴周期を手掛かりとして、周期相関集積法（ボックス・カー法）を適用して、パルス波形の検出と合わせてより詳細な周期を決定する手法によっている。現時点で自転周期1secはBH質量として5000太陽質量に相当する。 ここで、本研究はこれまで得られた結果の確かさを、厳密に検証する時期にはいっていて、今回は基本ステップであるFFT解析結果の検証を以下３点についておこなった。即ち、１）BHバイナリーの根拠としている公転周波数（公転周期の逆数）をその基準にしている側帯波スペクトルの有意性をランダム雑音の場合との対比から明確にすること、２） 銀河系中心部の出現とブラックホールバイナリー、群の存在の根拠とするFFTコード出現の対比を明確にすること、３）現在までに得られた５組のブラックホールバイナリーの諸周期情報から逆に信号源を組み立てたシミュレーションにより観測結果との一致性を評価すること、である。 検証の結果、第１）検証項目については特徴ある側帯波スペクトルは多数のBHバイナリー系からの相互干渉によって一部1/3の率で本来のピークを外れるが、ランダム雑音では一致と外れの場合が1/2 づつで、観測結果は有意に公転運動にもとづく周波数変調を示すと結論された。第２）検証項目は、銀河中心を直視出来ない観測時点にもブラックホールバイナリー、群の存在の根拠とするFFTコードが出現することが判明した。しかしこれは問題のFFTコードが銀河中心部に存在する５組のブラックホールバイナリーに起源を持つことを否定するものでなく、逆にデカメータ波電波が電離層により蜃気楼をつくることの証明となった。第３の検証項目はシミュレーションによって得られたFFT結果は観測によって得られているBHバイナリー群のFFTコードと主要点において一致していて、本研究において進めてきた、我が銀河系中心部の超巨大ブラックホールが５組以上のブラックホール・バイナリーのシステムを形成しているとの提唱の根拠が確認された。

キーワード：ブラックホールバイナリ—、銀河中心、デカメータ波電波
Keywords: Black Hole Binary, Galaxy Center, Decameter Radio Wave

実験室宇宙物理学における協同トムソン散乱計測に向けた数値実験
Numerical simulation of collective Thomson scattering in laboratory astrophysics

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We have performed the laboratory experiment on collisionless shocks by using high power laser in collaboration with the Institute of Laser Engineering (ILE) at Osaka university for the past few years. To measure the local plasma quantities in the shock transition region, collective Thomson scattering (CTS) measurement is utilized. The CTS is the scattering of low frequency incident electromagnetic waves by collective oscillations of plasma electrons. The spectrum of the scattered waves enables us to infer the local plasma quantities like electron density, electron and ion temperature, valence of ions, etc, as a function of local position along the path of the incident probe laser light.

The CTS measurement has been widely used so far to measure experimental as well as space plasmas. However, details of the scattering theory are complex. In particular the theory of the CTS in a non-equilibrium plasma has not been established. In this study we build the numerical simulation system of virtual CTS applicable to the measurement system in the ILE experiment. A local non-equilibrium plasma near a shock is reproduced by using standard full particle-in-cell (PIC) simulation. The time-series data of electron density obtained from the PIC simulation is used to solve a wave equation of the scattered waves separately. Since the frequencies of the scattered waves as well as the incident probe light are much higher than the plasma frequency, the wave equation should be solved with the temporal resolution much higher than that in the PIC simulation. Furthermore, the measurement system at ILE is essentially two dimensional. We will report preliminary results of the virtual CTS simulation with realistic parameters in the ILE experiment.

キーワード：協同トムソン散乱、実験室宇宙物理学、数値実験
Keywords: collective Thomson scattering, laboratory astrophysics, numerical simulation

マジックCFL法を用いた相対論的衝撃波の長時間計算

Long-term PIC simulations of relativistic shocks using the magic CFL method

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Mitigating so-called the numerical Cherenkov instability (NCI) has been a critical issue in studying particle accelerations at relativistic collision-less shocks by means of the particle-in-cell simulation. We have studied the stability property of the NCI in relativistic plasma flows employing particle-in-cell simulations. Using the implicit finite-difference time-domain method to solve Maxwell equations, we found that the nonphysical instability was greatly inhibited with a Courant-Friedrichs-Lewy (CFL) number of 1.0 (Ikeya and Matsumoto, 2015). The present result contrasts with recently reported results (Vay et al., 2011; Godfrey and Vay, 2013; Xu et al., 2013) in which magical CFL numbers in the range 0.5–0.7 were obtained with explicit field solvers.
Using the newly found stability property of the NCI, we successfully solved long-term evolutions of relativistic collision-less shocks. For relativistic, un-magnetized shocks in pair plasmas, we found that magnetic field turbulence generated by the Weibel instability saturated at much larger levels than those found in the previous studies. As results, particles’ maximum energy increased linearly in time with the energy spectral slope $\gamma^{-1.8}$, which compares with the previously-reported relation as $\gamma_{max} \propto \sqrt{t}$ with $\gamma^{-2.4}$.

キーワード：PICシミュレーション、相対論的衝撃波、粒子加速
Keywords: PIC simulation, relativistic shocks, particle acceleration

ケルビン・ヘルムホルツ不安定性におけるジャイロ粘性効果
Evaluating gyro-viscosity in the Kelvin-Helmholtz instability by kinetic simulations

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In the present paper, the gyro-viscous term[W. B. Thompson, Pep. Prog. Phys. 24, 363-424 (1961)] is evaluated by using a full kinetic Vlasov simulation result of the Kelvin-Helmholtz instability (KHI). The average velocity (velocity field) and the pressure tensor are calculated from a high-resolution data of the velocity distribution functions obtained by the Vlasov simulation, which used to approximate the gyro-viscous term according to Thompson (1961). The direct comparison between the pressure tensor and the gyro-viscous term shows a good agreement. It is also shown that the off-diagonal pressure gradient enhanced the linear growth of the KHI when the inner product between the vorticity of the primary velocity shear layer and the magnetic field is negative, which is consistent with the previous Finite-Larmor-Radius(FLR)-MHD simulation result, but not with the previous kinetic simulation results. This result suggest that it is not enough for reproducing the kinetic simulation result to include the gyro-viscous term only in the equation of motion in fluid simulations.

キーワード：計算機シミュレーション、ケルビン・ヘルムホルツ不安定、非MHD効果
Keywords: Computer simulation, Kelvin-Helmholtz instability, Non-MHD effect

Compressible fluid effects in plasmoid-dominated turbulent reconnection
Compressible fluid effects in plasmoid-dominated turbulent reconnection

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Traditionally, two basic models of magnetic reconnection have been discussed in the framework of resistive magnetohydrodynamics (MHD): Fast Petschek reconnection and slow Sweet--Parker reconnection. However, the former requires a localized profile of the electric resistivity. The latter is free from such an assumption, but it is too slow to explain reconnection events in the plasma universe.
 Recently, it has been found that Sweet--Parker reconnection switches to plasmoid-dominated turbulent reconnection due to the generation of secondary plasmoids. As a result, the reconnection rate remains moderately fast (R ~ 0.01) in realistic parameters, in which the conventional Sweet--Parker reconnection is too slow. This transition is analogious to a transition from a laminar flow to a turbulent flow in fluid dynamics.
 Both Sweet--Parker and plasmoid-dominated models usually assume the incompressibility as a first step to understand the mechanism. At present, the role of the compressibility in these systems remains unclear.
The compressible fluid effects are pronounced in a low-beta plasma, in which the typical speed of the system or the typical Alfven speed exceeds the local sound speed. As extreme examples of compressible effects, recent MHD simulations revealed various shock-structures in low-beta reconnection (Zenitani & Miyoshi 2011, Zenitani 2015).
 In this contribution, we will report our initial results on the basic properties of plasmoid-dominated turbulent reconnection in a low plasma beta. We discuss the role of the compressible parameters on the global reconnection rate and fine structures around the plasmoid islands. We will also discuss numerical issues in our HLLD/HLLC type MHD code.

キーワード：磁気リコネクション、磁気流体、乱流
Keywords: Magnetic reconnection, MHD, Turbulence

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The role of Hall magnetic field in large-scale magnetic reconnection dynamics and structure

The role of Hall magnetic field in large-scale magnetic reconnection dynamics and structure

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A Hall magnetic field of magnetic reconnection is generated by the electron-ion dynamics in the diffusion region. There are many studies on the effect of the Hall magnetic field for the reconnection rate around the diffusion region. However, in this study, we investigate the roles of the Hall magnetic in the dynamics and structures of reconnection jets and plasma sheet boundary layers, along which the Hall magnetic field propagate away from the diffusion region in large-scale magnetic reconnection systems. That makes it possible to discuss the Hall magnetic field strength generated in various conditions of magnetic reconnection.

キーワード：磁気リコネクション、ホール磁場
Keywords: magnetic reconnection, Hall magnetic field

磁気リコネクションに対する拡散過程の影響
Impact of diffusion processes on magnetic reconnection

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Magnetic reconnection intrinsically contains a hierarchical structure ranging from the fully kinetic scale to the magnetohydrodynamic (MHD) scale. In order to identify the essential physics necessary to model the reconnection, numerical simulations have been conducted with a variety of codes from kinetic codes to conventional resistive MHD codes (Birn et al. 2001). They have shown that only the MHD simulation with uniform resistivity fails to trigger fast reconnection, indicating that resistive MHD would be insufficient to model it.
The role of resistive dissipation on the reconnection has been extensively investigated in the framework of MHD. Recent theoretical and numerical studies have proposed a dynamic model dominated by plasmoids for sufficiently small resistivity beyond a classical static model. The resulting reconnection rate seems to be independent of the resistivity that may account for actual phenomena, although it does not necessarily settle the difference from the kinetic model. Meanwhile, the impact of other dissipation processes should be discussed. This study especially focuses on viscosity and heat transfer.
Viscosity controls the dissipation scale of vortex. Resistive MHD assumes it to be zero, meaning that the vortex dissipation scale is negligible small compared with the current dissipation scale. However, the ratio of the scale of vortex to current can be much larger than unity in actual environments, and it affects the dynamics. Finite heat transfer is frequently observed in association with the reconnection. It can also affect the dynamics through increasing compressibility.
In order to investigate the effect of viscosity and heat transfer on the nonlinear evolution of the reconnection, we conduct two-dimensional fully-compressible visco-resistive MHD simulations coupled with thermal conduction. We discuss that viscosity and thermal conduction considerably modify the dynamics from a resistive model. Large viscosity excites a broad vortex that enables the efficient transfer of upstream magnetic field to the reconnection region. The resulting reconnection rate increases with viscosity provided that thermal conduction is fast enough to take away the viscous heating energy. This is indicative of the importance of viscosity and heat transfer to model the reconnection against the conventional resistive MHD. We also investigate the dependence on resistivity to determine key parameters (specifically, Reynolds numbers and Prandtl numbers) governing the visco-resistive reconnection coupled with thermal conduction. Comparison with the kinetic model will be discussed.

キーワード：磁気リコネクション、磁気流体シミュレーション、拡散
Keywords: Magnetic reconnection, MHD simulation, Diffusion

ホイッスラー乱流中での運動論スケール静電波動の励起について: 粒子シミュレーション
Enhancement of kinetic scale electrostatic fluctuations in decaying whistler turbulence: Particle-In-Cell simulations

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Solar wind observations show that larger cascade rates of turbulence lead to steeper power-law magnetic spectra at kinetic scales. This suggests that larger fluctuation amplitudes at kinetic scales lead to some nonlinear properties more efficiently. Our previous research showed that the modified two stream instability in a monochromatic finite amplitude whistler wave contributes the nonlinear dissipation of the wave at kinetic scales. This result suggests that kinetic instabilities can enhance the dissipation at electron and ion scales. The wave driven instability occurs with larger wave amplitudes more efficiently, so this process could be a contributor for the steep power-law spectrum at kinetic scales. Here two-dimensional electromagnetic particle-in-cell simulations in magnetized, homogeneous, collisionless electron-ion plasma demonstrate the forward cascade of whistler turbulence at ion scales. The simulation show that whistler turbulence cascades into electron scales, and show a spectrum break around the scale of the electron inertial length. Around the scale related to the break point, electrostatic fluctuations appear at several points intermittently. The electrostatic fluctuations are expected to be driven by ion acoustic instability driven by localized electric current in whistler turbulence. We will discuss the instability driven dissipation of whistler turbulence at kinetic scales and heating of both electrons and ions.

キーワード：プラズマ乱流、ホイッスラー波、粒子シミュレーション
Keywords: plasma turbulence, whistler wave, Particle-In-Cell simulation

相対論的衝撃波におけるプリカーサー
Precursor Waves in Relativistic Shocks

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The origin of high energy cosmic rays has been a long-standing problem in astrophysics. Many particle acceleration mechanisms such as Fermi shock acceleration in relativistic jets and magnetic reconnection in pulsar/magnetor magnetosphere have been proposed so far, however, there is no plausible model to explain such energetic particles. Recently Chen et al. (2002) proposed the particle acceleration by the ponderomotive force of a large amplitude Alfvén wave as a model of ultra-high energy cosmic rays, based on the wakefield acceleration process (Tajima and Dowson 1979). Since then the mechanism attracts interests in astrophysical field. In relativistic shocks, the generation of large-amplitude precursor electromagnetic waves is discussed by synchrotron maser instability (Hoshino and Arons 1991). Lyubarsky (2006) suggested the precursor waves excited in the relativistic shock front induces the electrostatic field, and argued that it may be responsible to the particle acceleration. Hoshino (2008) extended the previous studies and demonstrated the efficient particle acceleration by the incoherent wakefields induced by the large-amplitude precursor electromagnetic waves in the upstream region of a relativistic shock wave by using one-dimensional Particle-In-Cell (PIC) simulation.

However, the efficiency of the particle acceleration by the wakefield mechanism is sensitive to the nature of the precursor electromagnetic waves, because the ponderomotive force is known to strongly depend on the wave amplitude and the wave coherence. In this study, we argue the precursor waves in relativistic shocks by using the two-dimensional PIC simulation. Since relativistic shocks are mainly controlled by “sigma parameter” which is the ratio of the Poynting flux and plasma flow energies, the amplitude of the precursor wave depends on sigma parameter. For instance, in our simulations, the amplitude of the precursor wave gets smaller and the wave coherency of the precursor wave gets lower as sigma parameter decreases, and the amplitude dependence on sigma parameter in two-dimensional simulations is different from that in one-dimensional simulations. Furthermore, the previous one-dimensional simulations could not investigate the wave coherency of the precursor wave. We must take account of the wave coherency when considering the wakefield acceleration because the wave coherency of the precursor wave, which is required for the ponderomotive force, is essential to the wakefield acceleration. In this presentation, we compare two-dimensional simulations to one-dimensional simulations and report our results.

キーワード：プラズマ、衝撃波、粒子加速
Keywords: plasma, shock, particle acceleration

運動論的アルヴェン波ダイナミクスのためのモーメント分離解法
Moment extracted method for solving kinetic Alfven wave dynamics

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Kinetic Alfven waves (KAW), which play crucial roles in a variety of phenomena in space plasmas, involve multiple space- and time-scales. For example, the wavelength along the field line may extend to the system size, while the perpendicular wave numbers are characterized by the ion gyro-radius or the electron skin depth. The characteristic time is given the wave frequency or the electron transit time. Thus, drift kinetic or gyrokinetic simulations of low-frequency plasma dynamics including the KAWs often suffer from a sever Courant condition for explicit time-integrators or a poor convergence of iteration in implicit methods.
To overcome the numerical inefficiency, we have developed a new scheme for solving the KAW dynamics including drift kinetic electrons. In the new scheme, the low-order moments of electron distribution function are calculated separately from the drift kinetic equation for electrons. It enables us to easily implement implicit time-integrators and/or the semi-Lagrangian scheme while keeping the numerical stability and the conservation property. Some applications of the moment extracted formulation will be discussed.

キーワード：アルヴェン波、シミュレーション、ジャイロ運動論
Keywords: Alfven waves, simulation, gyrokinetics

アルヴェン波の非線形発展における見かけの温度を含む平衡速度分布の効果
Effects of the equilibrium velocity distribution function with the apparent temperature on nonlinear evolution of Alfven waves

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Finite amplitude Alfvenic fluctuations are ubiquitously observed in the solar wind plasma. When we model the low-frequency phenomena of the solar wind plasma using one-fluid magnetohydro-dynamic (MHD) system, the fluctuations and the non-equilibrium components of ions are mixed into the pressure tensor (e.g., Chen et al, 770, 125 (2013); Nariyuki et al, POP, 22, 124502 (2015)). It is noteworthy that the local equilibrium velocity distribution function in the one-fluid MHD system can include the effects of the fluctuations as the apparent temperature. In the present study, nonlinear evolution of Alfven waves with the background (equilibrium) VDF including the apparent temperature is discussed by using the classical theoretical method such as the reductive perturbation method. If the isotropic equilibrium VDF is assumed, the apparent temperature can appear as the linear term in the triple-degenerated derivative nonlinear Schrodinger (TDNLS) system. The relationship between the apparent temperature and the Reynolds stress is also discussed.

キーワード：アルヴェン波、太陽風、磁気流体
Keywords: Alfven waves, solar wind, MHD

Expanding box model of quasilinear theory including the anisotropy-driven instabilities and collisional dissipation

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Measurements in situ of proton temperature anisotropy were found to be bounded by the marginal stability conditions of the kinetic instabilities driven by proton temperature anisotropies. This implies that these instabilities are indeed active and play an important role in limiting the range of temperature anisotropies observed in the expanding solar wind. However, the vast majority of the observed data distribution in the parameter space, denoted by proton temperature anisotropy and parallel beta, are found near isotropic state instead of being near the instability thresholds, so that they could not be explained by the local kinetic instability alone. Since the solar wind itself expands in inhomogeneous interplanetary space, the solar wind expansion would lead to a development of excessive parallel temperature anisotropy. Moreover, the binary particle collisions are thought to contribute to the temperature isotropization of the solar wind plasma. In order to understand the measured proton properties in the solar wind, various kinetic processes responsible for the global dynamics, such as the solar wind expansion and binary collisions, and the local kinetic instabilities should be taken into account. In the present work, we employ quasilinear theory of the expanding box model to investigate how the solar wind expansion and the instability driven collisionless dissipation as well as the collisional dissipation affect the dynamic evolution of the solar wind proton.

Keywords: solar wind proton, temperature anisotropy-driven kinetic instability, expanding box model of quasilinear theory, collisional dissipation

乱流場の中の宇宙線輸送
Cosmic ray transport in a turbulence field

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乱流場中の宇宙線（高エネルギー荷電粒子）輸送は、天体物理学や数理科学の観点から重要な問題であり続けている。とくに乱流が大振幅の磁気流体乱流の場合、非ガウス的な統計的性質があらわれる。本発表では、これをモデル化するフラクタル輸送拡散方程式の数値解を紹介する。衝撃波フェルミ加速についても言及する。

キーワード：宇宙線、輸送、非ガウス過程
Keywords: cosmic rays, transport, non-gaussian process

