

Modeling Turbulence in Space Plasmas

CHO, Jungyeon^{1*}

¹Chungnam National University

Space plasmas are magnetized and in turbulent states. I will briefly introduce properties of turbulence in a strongly magnetized medium. Turbulence in space plasmas is involved with various length scales. In general, different descriptions should be used for different scales. On large scales, plasma turbulence can be described in the framework of magnetohydrodynamics (MHD). In the first part of the talk, I will focus on MHD turbulence in the presence of a strong mean field. I will discuss energy cascade and structure of turbulence in this regime. On the other hand, on small scales near the proton gyro-scale, we cannot use MHD. In the second part of the talk, I will discuss how we can treat magnetized turbulence on small scales. I will also discuss properties and scaling relations of waves and turbulence in this regime.

Keywords: turbulence, MHD, waves, magnetic field

Nonlinear evolution of envelope-modulated Alfvénic turbulence in expanding accelerating solar wind plasmas

NARIYUKI, Yasuhiro^{1*} ; HADA, Tohru² ; TSUBOUCHI, Ken³

¹Faculty of Human Development, University of Toyama, ²E.S.S.T., Kyushu University, ³Tokyo Institute of Technology

It is well known that low-frequency Alfvénic turbulence is ubiquitously observed in solar wind plasmas. There is great interest in nonlinear evolution of the Alfvénic turbulence, since the observational studies clarified that the Alfvénic turbulence disappears with the increasing heliocentric distance and the fully-developed turbulence becomes dominant. Although most past studies on Alfvénic turbulence assume uniform background plasmas and magnetic fields, the effects of the inhomogeneity may not be negligible in the inner-heliosphere, in which several future spacecraft missions are planned. It is important that even if the wave reflection due to the inhomogeneity is negligible, the inhomogeneity of background plasmas and magnetic field may affect the nonlinear interaction among waves through contraction and reflection of the waves and the radial dependence of the background parameters such as the Alfvén velocity and the ion cyclotron frequency. In the present study, the nonlinear evolution of low-frequency, quasi-parallel propagating Alfvénic turbulence is studied by using the two-dimensional hybrid accelerating expanding box model. The dependence of the nonlinear evolution of Alfvénic turbulence on the effects of the inhomogeneity is discussed.

Keywords: solar wind, Alfvénic turbulence, ion kinetics

Development and Properties of Compressible MHD Turbulence in High-Beta Plasmas

JONES, Thomas^{1*} ; RYU, Dongsu² ; PORTER, David¹ ; EMMERICK, Andrew¹ ; CHO, Jungyeon³

¹University of Minnesota, ²Ulsan National Institute of Science and Technology, ³Chungnam National University

Many cosmic plasmas, including those in the solar wind and extra-galactic environments, are high beta = $P_g/P_B > 1$, so that as turbulence develops, magnetic stresses are, at least initially, weak. As the turbulence evolves, magnetic stresses become increasingly important on scales below the driving scales. Depending on the initial field strength and topology this evolution can take many large-scale eddy times to reach saturation. Even in subsonic turbulence, shocks can form and influence turbulence evolution and properties. We have carried out an extensive set of high resolution compressible MHD simulations of the evolution of such turbulence for a range of initial magnetic field strengths and topologies. Here we report on their properties and the astrophysical implications of those properties. This work is supported at the University of Minnesota by the US National Science Foundation and the Minnesota Supercomputing Institute.

Keywords: MHD Turbulence, High Beta Plasma

Instabilities and turbulence near the heliopause

POGORELOV, Nikolai^{1*} ; BOROVNIKOV, Sergey² ; ZANK, Gary¹ ; ZHANG, Ming³

¹Department of Space Science, University of Alabama in Huntsville, ²CSPAR, University of Alabama in Huntsville, ³Department of Physics and Space Sciences, Florida Institute of Technology

Recent observations from the Voyager 1 spacecraft show that it is sampling the local interstellar medium (LISM). This is quite surprising because no realistic, steady-state model of the solar wind (SW) interaction with the LISM gives the inner heliosheath width as narrow as 30. This includes such models that assume a strong redistribution of the ion energy to the tails in the pickup ion distribution function. We show that the heliopause (HP), which separates the SW from the LISM, is not a smooth tangential discontinuity, but rather a surface subject to Rayleigh-Taylor-type instabilities which can result in the LISM material penetration deep inside the SW. We also show that the HP flanks are always subject to a Kelvin-Helmholtz instability. The instabilities are considerably suppressed near the HP nose by the heliospheric magnetic field in steady-state models, but reveal themselves in the presence of solar cycle effects. We argue that Voyager 1 may be in one of such instability regions and therefore observing plasma densities much higher than those in the pristine SW. These results may be an explanation of the Voyager 1 early penetration into the LISM. We also show that there is a possibility that the spacecraft may enter the SW again before it finally leaves the heliosphere.

We demonstrate a spontaneous transition to chaotic behavior in the heliosheath region covered by the heliospheric current sheet. Additionally, we analyze the behavior of the heliopause in the heliotail and show that it becomes violently unstable beyond 1000 AU, which results in the interpenetration of the solar and interstellar plasma.

Keywords: ISM: kinematics and dynamics, ISM: magnetic fields, solar wind, Sun: heliosphere, turbulence

Wave reflection-driven accretion in active solar-type star winds

SUZUKI, Takeru^{1*} ; TERANISHI, Yasumasa¹

¹Nagoya University

In MHD simulations for winds from active solar-type stars by Suzuki et al.(2013), intermittent but long-time accretion phenomena were observed even though the Poynting flux associated with Alfvén waves is directed outward. In this talk, we present the detailed mechanism how this counter-streaming accretion takes place. Alfvén waves generated from a stellar surface are stochastically trapped in a transient density hole, and the magnetic pressure with the waves further dig the density hole. Eventually, this hole works as an efficient mirror against out-going Alfvén waves. As a result, out-going waves are reflected and the reflected component excites counter streaming flow.

Keywords: Wave, MHD, stellar wind, accretion

Physical Picture of 2-1/2D Driven Collisionless Magnetic Reconnection

CHENG, Chio^{1*} ; INOUE, S.² ; ONO, Y.³ ; HORIUCHI, R.⁴

¹Plasma and Space Science Center, National Cheng Kung University, Taiwan, ²Graduate School of Engineering, University of Tokyo, Japan, ³Department of Advanced Energy, University of Tokyo, Japan, ⁴National Institute of Fusion Science, Japan

The physical picture of how electrons and ions flow, how the electric and magnetic fields change, and how particles gain energy will be presented for the 2-1/2D collisionless driven magnetic reconnection. The 2-1/2 dimensional collisionless reconnection studies are performed using the particle simulation PASMO code [1] and theoretical analysis. In particular, we will provide the physical mechanism of how the poloidal current (including the Hall current in the downstream region) is generated and how the electrostatic potential is produced in the poloidal plane. The physical picture of how the quadrupole magnetic field and electrostatic potential are generated in the 2-dimensional (poloidal) plane is different from the one presented by Uzdensky and Kulsrud.[2]

[1] H. Ohtani and R. Horiuchi, Plasma Fusion Res., 4, 024 (2009)

[2] D. A. Uzdensky and R. M. Kulsrud, Phys. Plasma, 13, 062305 (2006)

Keywords: magnetic reconnection, numerical simulation, space plasma, laboratory experiment

Turbulence and shocks in high-beta plasmas

RYU, Dongsu^{1*}

¹Department of Physics, UNIST

High-beta plasmas are common in astrophysical environments, such as the intracluster medium (ICM) of galaxy clusters and the interplanetary medium (IPM) of the solar system. Observations and theoretical arguments suggest that the plasmas in such environments are in the state of turbulence, where highly nonlinear and complex physics is involved. Here we report high-resolution simulations to study the turbulence in high-beta plasmas. Along with the properties of the turbulence, we discuss the role of shocks and the energy dissipation.

Keywords: turbulence, shock wave, high-beta plasma

Acceleration and Diffusion of Cosmic Rays in Supernova Remnants in a Multi-Phase interstellar Medium

ROH, Soonyoung^{1*} ; INUTSUKA, Shu-ichiro² ; INOUE, Tsuyoshi³

¹Graduate School of Science, Nagoya University, ²Graduate School of Science, Nagoya University, ³Department of Physics and Mathematics, Aoyama Gakuin University

Supernova remnants (SNRs) are one of the most powerful cosmic phenomena and are thought to be the dominant source of Galactic cosmic rays (CRs). A recent report by Funk et al. (2013) has shown an unequivocal signature of pion-decay in the gamma-ray spectra of SNRs. This provides strong evidence that high-energy protons are accelerated in SNRs. On the other hand, Fukui et al. (2012) showed that pion-decay from protons dominates in emission from SNR RX J1713 based on the spatial correlation of gamma-rays and molecular line emission. The actual gamma-ray emission from pion-decay should depend on the diffusion of CRs in a multi-phase interstellar medium with molecular clouds (Inoue et al. 2012). In order to quantitatively describe the diffusion of high energy CRs from acceleration sites, we have performed test particle numerical simulations using a three-dimensional magnetohydrodynamics (MHD) simulation data cube provided by Inoue et al. (2012). In this presentation, we analyze a realistic diffusion coefficient of cosmic rays in simulated SNRs, and discuss the possible implications for X-ray and gamma-ray observations.

Keywords: Supernova Remnants, Diffusion of Cosmic Rays, Acceleration of Cosmic Rays, Pion-decay

Superdiffusion in turbulence and shock acceleration

YAN, Huirong^{1*}

¹Kavli Institute of Astronomy & Astrophysics, Peking U

Cosmic ray (CR) transport and acceleration are determined by the properties of turbulent magnetic field. We use the models of magnetohydrodynamic turbulence that were tested in numerical simulation, in which turbulence is injected at large scale and cascades to small scales. I shall address, in particular, the cross field transport of CRs. I shall demonstrate both analytically and numerically that particles are superdiffusive on small scales. We consider both super- and sub-Alfvenic cases. In the sub-Alfvenic case, the transport in the perpendicular direction is proportional with M_A^4 , consistent with our earlier analytical prediction. Implication for shock acceleration is discussed and we show that the difference between acceleration at perpendicular shock and parallel shock is marginalized in the presence of superdiffusion.

Keywords: turbulence, superdiffusion, particle, shock, acceleration, transport