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Gyrokinetic simulations for understanding self-organization and turbulent transport in magnetospheric plasmas

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Plasmas confined in a dipole trap may exhibit peculiar transport property: Particles diffuse against the density gradient to create centrally peaked profiles of the density and temperature, which contradicts the conventional understanding of the relaxation process whereby particles spread out to homogenize the profile. The inward diffusion phenomena (the inward pinch) are both observed in planetary magnetospheres and experimental devices, such as RT-1 [1] and LDX [2]. The basic understanding of self-organized structures and transport properties of magnetospheric plasmas helps achieving high-performance fusion devices [3]. The dipole trap is also considered as an excellent candidate for the storage of antimatter and electron-positron pair plasmas--a laboratory experiment is under development [4].

Recent theories [2,5,6] suggest that the inward pinch phenomenon is understood as a relaxation process in distorted phase space induced by strongly inhomogeneous dipole magnetic fields. Yoshida et al argued that, because of the conservation of the magnetic moment, random diffusion which tends to homogenize the density occurs in each flux tubes yielding the density profile in a laboratory frame. Sato et al formulated a diffusion process under geometric constraints and demonstrated that random diffusion in the dipole configuration leads to the formation of sharp density gradients.

The other possible explanation of the mechanism of the inward pinch is turbulent transport due to microscopic instabilities. Kobayashi et al performed a gyrokinetic flux-tube simulations along the dipole field and studied turbulent transport due to the so-called entropy mode driven by the pressure gradient [7,8]. They showed that there exists a parameter window where particles are transported up the gradient. In this scenario, transport due to turbulent mixing drives the plasma profile towards a marginal stable state.

In this study, we aim at constructing a self-consistent theory of the self-organization and transport processes in magnetospheric plasmas. We perform gyrokinetic simulations of turbulent transport driven by pressure gradients in a dipolar magnetic field using GS2 and study the effects of the magnetic field structures and self-consistently gnerated turbulent fluctuations. We compare the characteristics of fluctuations obtained from the gyrokinetic simulations and from experimental observations in RT-1.

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