R008-P05
ポスター 2 ：11/25　AM1/AM2 （9:00-12:00）

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Instabilities and microstructures in magnetic island in collisionless magnetic reconnection

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Collisionless Magnetic reconnection is an important process for abrupt releasing magnetic energy, accompanying with the change of magnetic field topological structure. Through the reconnection, magnetic islands occupied by high energy plasma are often formed. Understanding the physics occurring in magnetic islands is crucial to resolve the mechanisms of energy transfer and particle acceleration through magnetic reconnection.

In a number of the past numerical simulations, microstructures in the magnetic island have been discussed. Lu et al. (2011) conducted two-dimensional PIC simulation in an ion-electron plasma and found regular structures of out-of-plane magnetic field in a magnetic island. In the PIC simulation done by Swisdak et al. (2008), we confirmed similar structures in positron-electron plasma. Inner structures of a magnetic island is also observed in hybrid simulation (mi/me=∞). Walia et al. (2022) showed that the outflow emitted from an X point gives rise to pressure anisotropy of plasma. The pressure anisotropy in a magnetic island can cause regular structures through the excitation of microinstabilities. Lu et al. (2011) demonstrated that the regular structures of out-of-plane magnetic field have a wavevector perpendicular to the current sheet as well as that parallel to it. They explained that the structure having the perpendicular wavevector is due to Weibel instability driven by local electron temperature anisotropy, while the structure having the parallel wavevector is due to nonlinear effects. However, details of the nonlinear effects are not clear. In this study, we discuss the possibility that the coupling between Weibel instability and another electrostatic instability, such as two-stream instability or ion acoustic instability, causes the regular structures.

We conduct 2d PIC simulation (in the x-y plane) of proton-electron plasma, the initial configuration is two Harris current sheets settled in anti-parallel with a background population. We successfully observed similar fluctuations observed by Lu et al. (2011). According to the local distribution function, both electron and proton anisotropies are raised in magnetic island. Based on the estimate of temperature of particles, ion acoustic instability is very likely to exist. We obtain the solution of low frequency electrostatic waves propagating along the outflow direction in the current sheet with finite growth rate by numerical linear analysis. We will show the analytical and numerical solutions of the dispersion relation in the magnetic island.