Contribution ID: **50** Contribution code: **P1.26** Type: **Poster**

Effect of Maxwell Stress on Electromagnetic ITG Turbulence Investigated Using a Simple Fluid Model

A two-species (one main ion and electrons) fluid model for describing ion temperature gradient (ITG) turbulence in a Z-pinch magnetic geometry has been derived from gyrokinetics. Firstly, we carry out a mass ratio expansion ($\sqrt{m_e/m_i} \ll 1$) similar to the procedure introduced in \cite{Schekochihin_2009}. It is then followed by small $k_\perp \rho_i$ expansion, where $k_\perp$ is the typical wavenumber perpendicular to the mean field line and ρ_i is the ion gyroradius. Since we study ITG in the long wavelength limit $k_\perp \rho_i \ll 1$, it requires shifting the driving scale of ITG also to long wavelength, leading to the cold-ion assumption, which is used in electrostatic ITG fluid models studied previously\cite{ivanov_schekochihin_dorland_field_parra_2020,ivanov_schekochihin_dorland_2022}. The novelty of the model being presented here is that it retains electromagnetic effects and aims to provide a physical mechanism by which the ITG turbulence transitions from a low transport, zonally dominated state to a high transport, fully turbulent state. The low transport (usually at low β) states are often accompanied by strong zonal flows. However, as β is increased, Maxwell stress starts to erode the zonal flow, setting a threshold β above which the turbulence can no longer support a strong zonal flow and hence produces relatively large transport. Studying this model is an attempt to address the issues people are having with many local gyrokinetic simulations for ITG, where they find divergent heat fluxes resulting from including finite β effect\cite{nonzonal}. Our fluid model seems to support the idea that gyrokinetic simulations of electromagnetic ITG could be producing physical results, namely that the heat fluxes are indeed large due to weak zonal flows.

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Session Classification: Poster session: 01