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# A closure model of magnetohydrodynamic equations for collisionless plasmas

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The ideal magnetohydrodynamic (MHD) equations describing macroscopic behaviors of collisionless plasmas are completed by considering the so-called moment-closure problem, since the local equilibrium assumption is not valid in high temperature plasmas. It is well known that the CGL (Chew-Goldberger-Low) model, where the parallel heat flux is presumed to be zero, predicts lower criteria of temperature anisotropy for the mirror instability than that of linear analysis of the Vlasov equation (by a factor of 6). It is also noted in association with the temperature anisotropy in the magnetosheath. In order to resolve the problem in the CGL model, Kulsrud proposed a kinetic MHD equations where two components of the pressure tensor (p_¥perp, p_¥parallel) are directly given by second-order moments of a drift kinetic equation [1]. In the Kulsrud's approach, the fluid and kinetic equations are derived by (1/e)-ordering and gyrophase averaging of the Vlasov equation, and are coupled with each other to be solved. Here, it is called the kinetic MHD equations.

It has been desired to find a closure model for the kinetic MHD equations, since they are too complicated to be applied to numerical simulations although the derivation is strict and valid. Thus, we consider a closure model as follows, according to the idea of the nondissipative closure model for the ion temperature gradient mode turbulence [2];

q_{¥perp 1} + p_{¥perp 0} U_z
= a_{i¥parallel} C_{p¥perp} p_{¥perp 1} + p_{¥parallel 0} C_{U1} U_x

q_{¥parallel 1} + 3p_{¥parallel 0} U_z
= a_{i¥parallel} C_{p¥parallel} p_{¥parallel 1} + p_{0¥parallel} C_{U2} U_x .

Here, C_{p¥perp}, C_{p¥parallel}, C_{U1}, and C_{U2} are real-valued, and determined so as to reproduce the two conditions; the relation between the heat flux (q_{¥perp 1}, q_{¥parallel 1})^t and the pressure (p_{¥perp 1}, p_{¥parallel 1})^t given by the kinetic MHD equations and the linear dispersion relation (where the subscript 1 denotes fluctuations). Applying the closure model to (q_{¥perp 1}, q_{¥parallel 1})^t in equations for (p_{¥perp 1}, p_{¥parallel 1})^t given by second-order moments of the kinetic equation, we have found a set of fluid equations which preserves the time-reversibility for unstable modes and gives the same dispersion relation as that from the kinetic analysis.

[1] R.M.Kulsrud, Handbook of Plasma Physics, vol.1, Chapt.1.4, (1983).
[2] H.Sugama, T.-H.Watanabe, and W.Horton, Phys. Plasmas, vol.8, 2617 (2001).

Remarks: This is a collaboration work with Dr.H.Sugama (NIFS) and Prof.W.Horton (U.Texas, IFS).