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Multi-fluid generalization of the Braginskii model

Confronting numerical simulations with observational studies
is necessarily based on an underlying theoretical description, which describes the dominant physical processes that are being numerically simulated and observationally analyzed. We consider several generalizations of the well-known fluid model of Braginskii (1965). We use the Landau collisional operator and the moment method of Grad. We focus on the 21-moment model that is analogous to the Braginskii model, and we also consider a 22-moment model. Both models are formulated for general multi-species plasmas with arbitrary masses and temperatures, where all the fluid moments are described by their evolution equations. The 21-moment model contains two "heat flux vectors" (3rd and 5th-order moments) and two "viscosity-tensors" (2nd and 4th-order moments). The Braginskii model is then obtained as a particular case of a one ion-electron plasma with similar temperatures, with de-coupled heat fluxes and viscosity-tensors expressed in a quasi-static approximation. We provide all the numerical values of the Braginskii model in a fully analytic form (together with the 4th and 5th-order moments). For multi-species plasmas, the model makes calculation of transport coefficients straightforward. Formulation in fluid moments (instead of Hermite moments) is also suitable for implementation into existing numerical codes. It is emphasized that it is the quasi-static approximation which makes some Braginskii coefficients divergent in a weakly-collisional regime.

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