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Development of a new multi-fluid code for the Io-Jupiter system based on the semi-discrete central scheme

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Subcorotation of Iogenic plasma in the Io plasma torus has been understood as electric drift by a perpendicular electric field with respect to the Jovian magnetic field. A part of the radially integrated potential has been considered to be imposed along the magnetic field lines. The purpose of this study is to clarify where and how the actual the electric fields arise in the Io-Jupiter system. Here, we take notice of the importance of the electron convection term in the generalized Ohm's law. We applied a semi-discrete central scheme to extended MHD equations which include the electron convection term and prescribe the dynamics of one or two ion species, and investigated the role of the electron convection term in a one-dimensional model of the Io-Jupiter system.

We find that the parallel electric field arising from the electron convection term works like negative pressure. For the cases of steady state discontinuities, the sum of the electric force arising from the electron convection term and a steepening effect due to the ion convection term balance with the ion pressure gradient. An electrostatic potential difference across a discontinuity equals the electron kinetic energy obtained from a transition through the discontinuity. The electron convection term enables us to describe a situation in which a parallel electric field and parallel electron acceleration coexist, which is impossible for ideal or resistive MHD.

Each ion sound mode becomes unstable if the parallel current density exceeds some threshold associated with the individual ion temperature. If the sound mode of the cold ions is unstable and that of the hot ions is stable with the specific current density, the growth of the unstable sound mode saturates after a while. At this stage cold ions gather around the high density region since the negative pressure arising from the electron convection term exceeds the pressure of the cold ions. The discrete parallel electric field forms at the boundary of the high- and low-density regions and prevents cold ions from going through the field. Although the growth rate of the ion sound mode does not reproduce that of the actual Debye-scale ion acoustic mode, the process of the wave growth and saturation would approximate that of the Debye-scale current driven instability in the large spatial and temporal scales.