Contribution ID: **47** Type: **Talk**

Ebysus, a multi-fluid multi-species code: application to upper chromospheric magnetic reconnection with Helium-Hydrogen mixture

Monday, 27 February 2023 14:10 (13 minutes)

Our understanding of magnetic reconnection (MR) under chromospheric conditions remains limited. Recent observations have demonstrated the important role of ion-neutral interactions in the dynamics of the chromosphere. Furthermore, the comparison between spectral profiles and synthetic observations of reconnections suggest that single-fluid MHD approaches appear to be inconsistent with observations. Indeed, collisions and multi-thermal aspects of the plasma, hydrogen and helium ionization effects play a major role in the energy balance of the chromosphere.

This work investigates multi-fluid/multi-species (MFMS) effects on MR in upper chromospheric conditions. We compare an MFMS approach based on a helium-hydrogen mixture with a two-fluid MHD model based on hydrogen only. We study the evolution of the MR and compare the two approaches including the decoupling of the particles, the evolution of the heating mechanisms, and the composition.

The simulations have been performed in the same numerical code Ebysus (Wargnier et al. 2022) which can solve any MFMS model for any species and/or ionized/excited level as desired. A numerical strategy based on a partitioned implicit-explicit orthogonal Runge-Kutta method has been considered. This algorithm allows an optimization of the timestep while estimating the error of the various terms involved in these models and guaranteeing reasonable computational costs.

Our results show that the presence of helium species leads to more efficient heating mechanisms than the two-fluid case. The different dynamics between helium and hydrogen species could lead to chemical fractionation and enrichment of helium. This could be of significance for recent observations of helium enrichment in switchbacks or CMEs.

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Session Classification: Chromosphere

Track Classification: Chromosphere