Ebysus, a Multi-Fluid Multi-Species (MFMS) code: Application to magnetic reconnection in the solar atmosphere

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The solar atmosphere is composed of many species with a large number of ionization levels. Depending on the region considered, the plasma can be partially or fully ionized, weakly or strongly magnetized, weakly or strongly collisional, allowing for thermal non-equilibrium processes and chemical reactions. Recent observations of the IRIS mission (De Pontieu et al. 2014) have confirmed that the solar atmosphere is a complex environment involving a wide range of unsteady processes occurring at different temporal and spatial scales.

In this context, we have developed a new code Ebysus (see Martinez-Sykora et al., 2019), by expanding the state-of-the-art single-fluid radiative MHD code Bifrost (Gudiksen et al. 2011). Ebysus solves a full MultiFluid MultiSpecies (MFMS) system of equation for any species and/or ionized/excited level as desired separately. Following Wargnier et al. 2020, an accurate description of the collisions for multicomponent plasmas in solar atmosphere conditions, consistent with the kinetic theory, has also been developed and implemented in the code. The code includes non-equilibrium (NEQ) ionization, recombination, excitation and de-excitation for any species, momentum exchange, electric forces due to velocity drift between different ionized species, thermal conduction and radiative losses. The whole numerical strategy has been tested and the modules needed for this proposal are fully implemented.

First, we will present the model and its numerical strategy. We will then focus on realistic magnetic reconnection (MR) events and perform numerical simulations in several conditions representative of different layers of the solar atmosphere. In particular, we will demonstrate the role of the drift velocities between different species on the reconnection rate and the formation of plasmoid instabilities, which leads to a high energy release. These instabilities play a significant role in the dynamics of chromospheric jets, as observed by IRIS (Rouppe et al. 2017). This strategy will be a crucial point in understanding MR events that occur during UV bursts or flares.