

Research project objectives/Research hypothesis

Physical processes responsible for the energy release and transport in the solar atmosphere have so far been evaluated within a framework of single-fluid MHD. As the lower layers of the solar atmosphere contain large amount of neutrals, and the energy travels through these layers, the processes need to be re-assessed by taking into account more realistic 2-fluid models of plasma; it is necessary to examine how energy can be transported from the low atmospheric layers and transferred through the solar atmosphere, and how efficiently this energy can heat the solar chromosphere and corona. Two-fluid effects appear to be important for the quantification of the supply of energy, momentum and mass into the overlying chromosphere and corona, and therefore they are strictly associated with the longstanding solar physics problem, namely, the heating of the solar chromosphere and coronal heating as well as the solar wind acceleration.

Research project methodology

We propose to significantly extend our current research efforts by developing innovative 2-fluid models and use them to perform more realistic simulations of the solar atmosphere. To reach these goals, we plan to

(a) adopt a novel self-consistent 2-fluid model (Wójcik 2017, Wójcik et al. 2017c) for characterizing weakly ionized plasma in the photosphere and chromosphere and collision-less plasma in the solar corona. Because of the ability of 2-fluids, in comparison to MHD, to represent a wide range of scales (from full-scale to ion scale), and to study waves potentially in a real case scenario, the present project will focus solely on this promising approach. Braginskii (1965) was the first to derive a consistent 2-fluid formulation, considering ions and electrons, the effect of the magnetic field on the transport properties, while neglecting chemical reactions. Recently, Meier (2012) and Leake et al. (2013) proposed a 2-fluid model considering ions and neutrals as separate fluids, including chemical reactions (ionization, recombination) and anisotropic effects in the plasma heat conduction due to the magnetic field. The Leake et al. (2013) model is already implemented in the JOANNA code (Wójcik 2017), in its 2D and 3D Cartesian variants, and validated by performing a number of tests (<http://kft.umcs.lublin.pl/dwojcik/>) as well as simulating 2-fluid solar spicules (Kuźma et al. 2017b);

(b) perform extensive parallel simulations of the solar atmosphere with the use of the JOANNA code. We will investigate wave propagation through the solar atmosphere in 2D and 3D computational domains spanning from the photosphere to the corona by combining all the above mentioned models. The target problem is the consistent quantification of the energy flux of waves that are generated in the bottom layers of the atmosphere and that evolve through the transition region to the corona, contributing to the nascent solar wind.

Expected impact of the research project on the development of science

This proposal addresses in the pioneering and break-through ways the cardinal and remaining unsolved issues of chromospheric and coronal heating (Srivastava et al. 2017) as well of origin of the solar wind (Kuźma et al. 2017c) within the framework of 2-fluid models which were not considered to that extend so far. Their presence is indispensable to realistically model the solar atmosphere which requires the innovative numerical modeling with the use of JOANNA, a state-of-the art numerical code (Wójcik 2017). As a result, the impact of the overall improved modeling capabilities proposed by this project in the field of solar physics supposed to be break-through, leading to important new insights into all above-mentioned key processes of heliophysics. For instance, the results obtained so far with the JOANNA code (Wójcik 2017) showed that 2-fluid effects play an important role in a development of spicules (Kuźma et al. 2017b). The outcome, in terms of resulting modeling and numerical tools, will allow for potentially advancing the state-of-the-art not only in solar and space physics but also in a wide range of plasma-related problems (fusion, space weather, etc.).