Effects of Non-WKB Alfven Waves in Accelerating the Multicomponent Solar Wind

B. Li1 and X. Li2
1 *School of Space Science and Physics, Shandong University at Weihai, Weihai 264209, China*
2 *Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth SY23 3BZ, UK*

We examine the interaction between finite-wavelength (non-WKB) Alfven waves and multi-component stellar winds, adopting the solar wind, by far the best studied outow from stars, as an example. While stellar winds tend to be modeled by using a single-uid approach where different species are not distinguished, observational evidences abound that show beyond a few tenths of solar radius above the solar surface the solar wind becomes too tenuous to provide a strong Coulomb coupling between its major species, namely electrons, protons and Helium nuclei (alpha particles). Di_erent species in the wind will respond in different ways to electromagnetic fields, such as those associated with the low-frequency hydromagnetic waves. Alfven waves, a salient feature in the solar wind uctuation spectrum, have been of particular interest for decades, given their capability to accelerate and heat the solar wind ions. Usually the short wavelength (WKB) approximation is used for mathematical simplicity, which however is questionable if one attempts to examine the wave-flow system in the solar corona, considering the large Alfven speed there and the relatively long wave period (hour or longer). Therefore we adopt a non-WKB approach in describing dissipationless, monochromatic, hydromagnetic (with angular frequencies well below ion gyro-frequencies), toroidal Alfven waves in a multicomponent solar wind, where the waves and ion ows are coupled through the wave-induced ponderomotive forces. Protons and alpha particles are treated on an equal footing, and the wavelength is not assumed small compared with the spatial scales at which the solar wind parameters vary. In addition to presenting a self-consistent description for the wave propagation, we also construct three-uid solar wind models where the flow parameters and wave properties are mutually consistent. We compare the WKB and non-WKB results, thereby deducing the signiffcance of a non-WKB treatment. In particular, we examine the efficiency of waves inaltering the alpha abundance in the solar corona and the proton-alpha particle speed difference in interplanetary space. We also discuss the relevance of our treatment to the development of Alfvenic turbulence in interplanetary space, and to the acceleration of winds from solar-like stars.
Keywords: Solar wind; Solar magnetic fields; MHD waves; Stellar winds