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# Turbulent energization of ions in warm collisionless plasmas – hybrid simulation study

Yana Maneva (1), Adolfo Vinas (2), and Stefaan Poedts (1)

(1) CmPA, KU Leuven, Leuven, Belgium (yana.maneva@wis.kuleuven.be), (2) NASA Goddard Space Flight Center, Greenbelt, MD, USA

Turbulent waves and structures are ubiquitous and indispensable part of the solar wind throughout the Heliosphere and have crucial contribution to the energization of particles in the warm collisionless plasma near the Earth, especially in regions where strong wave activity is observed. Wave-based turbulent energization of protons and minor ions in the undisturbed solar wind can occur through resonant and non-resonant wave-particle interactions and related wave absorption, particle scattering and diffusion in phase space. The efficiency of the ion heating depends on the characteristics of the waves carrying energy at the ion scales, such as polarization, direction of propagation and spectral properties of the fluctuations. The observed solar wind turbulence includes different types of waves at all scales, starting from the large-scale fluid regime and reaching towards the small electron scales, where the magnetic fluctuations are ultimately dissipated. Although the spatial and temporal scales of these fluctuation are separated by few orders of magnitudes, they can still exchange energy due to large and small-scales turbulent cascades. Trying to model part of the solar wind turbulence at the ion scales we assume a superposition of non-resonant Alfvén waves, which follow Kolmogorov-type spectral slope by construction. Such waves are frequently observed in situ in the solar wind, and yet their specific role for the energization of minor ions remains unclear. We perform 2.5D hybrid simulations with fluid electrons, kinetic ions and minor ions to study the effects of turbulent energization of minor ions by initial broad-band spectra, consisting of parallel and oblique forward propagating Alfvén waves. The numerical model is driven by observations of the solar wind plasma parameters at 1AU and takes into account the differential streaming between the protons and the minor ions. For the chosen spectral range of the external initial wave spectra we observe preferential energization for the minor ions and strong parallel heating for both ion species. The minor ions are subject to significant perpendicular heating, whereas the protons are cooled in transverse direction at all propagation angles.