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What regulates the dynamical evolution of the expanding solar wind?

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Understanding the physical processes of how the solar wind evolves in the interplanetary medium is an outstanding issue in heliospheric-physics community. In view of the currently operating and upcoming inner heliosphere missions, NASA's Parker Solar Probe and ESA's Solar Orbiter, it is timely to discuss the current status of solar wind research particularly relevant to the dynamic and thermodynamic evolution of the solar wind.

Since the speed of the super-Alfvenic solar wind practically reaches a maximum constant value beyond a few tens of solar radii, a typical example of physical quantities describing the thermodynamic evolution of the solar wind might be the temperature of plasma and its anisotropy. Measurements in situ of solar wind temperature anisotropy have revealed that the adiabatic moments of the magnetized plasmas deviate significantly from the prediction of the double-adiabatic theory [1,2], implying that there may be other physical processes essentially acting on the expanding solar wind. It is commonly believed that the thermodynamic property of the solar wind evolution results from a combination of physical processes including the double-adiabatic expansion, Coulomb collisions, turbulent and/or cyclotron heating, and kinetic plasma instabilities. Those are the intrinsically multi-scale physical processes that are simultaneously coupled to each other, resulting in a significant contribution to the overall energetics of the expanding solar wind through interplanetary space [3].

In the present study, we address the fundamental question of how the intricate multi-scale coupling between global dynamics and local kinetic processes affects the thermodynamic property of the solar wind. We develop an expanding box model based on the velocity moment-based quasilinear kinetic analysis that includes the above-mentioned physical processes. By incorporating the local kinetic processes, such as the turbulent heating and microinstabilities, into the large-scale description in the present model, we describe how the solar wind temperature anisotropy evolves in interplanetary space and discuss the importance of the multi-scale nature of the solar wind [4-8]. The theoretical results may help us understand the observational features of not only the previous space missions including WIND and Helios but also the currently operating Parker Solar Probe.

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