Geophysical Research Abstracts,
Vol. 11, EGU2009-5954, 2009
EGU General Assembly 2009

Finite-wavelength Alfvén waves and proton-alpha particle differential speed in the solar wind

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The complex solar wind plasma comprises the electrons, protons, and a non-negligible flux of alpha particles. The differential speed between the protons and alpha particles is prominent in the fast solar wind, and may also be so in the slow one. Alfvén waves, which abound in the in situ solar wind measurements, are widely accepted as being responsible for accelerating the solar wind. From the theoretical perspective, usually the short-wavelength WKB approximation is adopted to describe the interaction between these waves and ion flows. However, the WKB approximation may not hold in the inner corona in view of the large Alfvén speeds there. In this presentation we examine the interaction of the finite-wavelength (non-WKB) Alfvén waves with ion fluids, paying special attention to the wave effect on the proton-alpha differential speed. We show that with decreasing frequency the waves demonstrate a transition from a genuinely wave-like to a quasi-static behavior, with the critical frequency f_c being $0.5 \sim 1 \times 10^{-5}$ Hz. Whichever category the waves belong to, they tend to reduce the proton-alpha speed difference. We also demonstrate that in the super-Alfvénic regions of the solar wind, in the presence of Alfvénic fluctuations, an apparent break should exist around f_c in the velocity fluctuation spectrum for alpha particles, provided that the spectrum for protons is smooth. Such a break is entirely a linear property, and has nothing to do with the non-linearities that may also shape the fluctuation spectra. Introducing realistic ion thermal anisotropies will not make the apparent break disappear. Direct samples from the Solar Orbiter and Solar Probe will make the observational test of this prediction possible.