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Effects of non-WKB Alfvén waves on a multicomponent solar wind with differential ion flow

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We present multicomponent solar wind models self-consistently incorporating the contribution from dissipationless, monochromatic, hydromagnetic (with angular frequencies ω well below ion gyro-frequencies), toroidal Alfvén waves, which are coupled to the flow solely 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. We find that the non-WKB effects are significant, for the fast and slow solar wind solutions alike. Relative to comparable non-WKB waves, the WKB ones are more effective in accelerating the solar wind inside the Alfvén point, producing significantly enhanced ion fluxes and considerably reduced alpha abundance in the inner corona. Only when $\omega > 3.5 \times 10^{-3}$ (1.5×10^{-3}) $\mathrm{rad\ s^{-1}}$ can the waves in the fast (slow) winds be adequately described by the WKB limit. Moreover, while the Alfvén waves tend to reduce the magnitude of the proton-alpha speed difference $|U_{\alpha p}|$ in general, different mechanisms operate in two different regimes, separated by an $\omega_c \sim$ several $\times 10^{-5}\ \mathrm{rad\ s^{-1}}$. When $\omega > \omega_c$, the fluctuations are wave-like and tend to accelerate both ion species, thereby losing most of their energy in doing work on ion flows; whereas when $\omega < \omega_c$, a quasi-static behavior results: the fluctuations may act to accelerate the slower flowing ion species but decelerate the faster moving one in a large portion of the computational domain, and only a minor fraction of the wave energy flux injected at the base is lost. The fluctuations with the lowest frequency are no less efficient in reducing $|U_{\alpha p}|$ than the WKB waves: in the slow solar wind solutions, they may be able to quench a significant $|U_{\alpha p}|$ with base amplitudes as small as $4\ \mathrm{km\ s^{-1}}$. The consequences of this

ω_c on the velocity fluctuation spectra of protons and alpha particles, which are likely to be obtained by future missions like Solar Orbiter and Solar Probe, are discussed.