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The role of whistler-mode waves in electron scattering: Comparison of Parker Solar Probe observations with particle tracing simulations

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The discovery of large-amplitude narrowband whistler-mode waves at frequencies of tenths of the electron cyclotron frequency in large numbers both at ~1 AU by STEREO S/WAVES and inside ~.3 AU by the Parker Solar Probe Fields Suite provides an answer to longstanding questions about scattering, energization and of solar wind electrons, and regulation of the heat flux. Simultaneous observations of whistler waves by the Fields Suite and of electrons by the Solar Wind Electrons Alphas and Protons (SWEAP) Investigation provide strong evidence for pitch angle scattering of strahl-energy electrons by narrowband whistler-mode waves at radial distances less than ~0.3 AU. These narrowband large amplitude whistler-mode waves are, therefore, the most likely candidates for regulating the electron heat flux and scattering of strahl electrons into the halo. Using a full 3d particle tracing code, we have examined interactions of electrons with energies from 0 eV to 2 keV with whistler-mode waves with amplitudes of 20 mV/m and propagation angles from 0 to 180 degrees to the background magnetic field. Interactions with wave packets and single waves are both modeled based on observations at ~0.3 AU and 1 AU. The simulations demonstrate the key role played by these waves in rapid scattering and energization of electrons. In addition to modeling the interactions with core and strahl energy electrons, we also investigated the interaction with more energetic electrons. Results for both energy ranges provide evidence for nonlinear effects, indicating that quasi-linear methods are not adequate for modeling the role of whistlers in the evolution and transport of solar wind electrons.

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