Scattering and energization by large-amplitude whistler-mode waves in the evolution of solar wind electron distributions and Hamiltonian analysis of resonant interactions

T. Vo, C. Cattell, A. West, and R. Lysak
University of Minnesota - Twin Cities, Minneapolis, MN 55455

Whistler-mode waves have often been proposed as a plausible mechanism for pitch angle scattering and energization of electron populations in the solar wind. Theoretical work suggested that whistler waves with wave vectors parallel to the interplanetary magnetic field must counter-propagate (sunward) to the electrons for resonant interactions to occur. However, recent studies reveal the existence of obliquely propagating, high amplitude, and coherent waves consistent with the whistler-mode. Initial results from a particle tracing simulation demonstrated that these waves were able to scatter and energize electrons. However, that simulation was limited and did not examine a broad range of electron distributions. We adapt the original particle tracing code for the solar wind with wave parameters observed by STEREO satellites the Parker Solar Probe (PSP) and study the scattering and energization in core, halo and strahl electrons.

Simulations are run to record the response of a wide initial phase space volume with uniform waves and wave packets. Using a Hamiltonian analysis, resonant responses at different harmonics of the cyclotron frequency are included in the simulation. A numerical integration scheme that combines the Hamiltonian analysis and the relativistic 3d particle tracing deployed on a high performance cluster enables accurate mapping and large-scale statistical studies of phase space responses. Observations of electron distributions from WIND and PSP at 1 AU are used for normalization. This enables extrapolations for core, halo, and strahl electrons evolution with the numerical Green's function method. Results provide evidence for pitch angle broadening of the strahl and energization of core and halo electrons. This model can also provide results that are applicable to a number of different wave-particle interactions in the heliosphere for comparison to in-situ measurements. Comparisons to observed electron distributions will be made. We also compare to recent theoretical studies of electron interactions with whistlers.