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Non-diffusive pitch-angle scattering of a distribution of energetic particles by coherent whistler waves

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A recent study and a companion talk [1] showed that an exact rearrangement of the relativistic particle equation of motion under a coherent circularly-polarized electromagnetic wave leads to an equation describing the motion of the "frequency mismatch" parameter ξ under a pseudo-potential $\psi(\xi)$. When the particle undergoes a so-called "two-valley motion" in ξ-space, it experiences large changes in ξ and thus its pitch-angle because ξ is a function of the particle's velocity parallel to the background magnetic field. This single-particle analysis is extended [2] to a distribution of relativistic particles. First, the condition for two-valley motion is derived with parameters relevant to magnetospheric contexts. Single-particle simulations verify that particles which satisfy this condition indeed undergo large pitch-angle fluctuations. Second, assuming a relativistic Maxwellian particle distribution, the fraction of particles that undergo two-valley motion is analytically derived and is numerically verified by Monte-Carlo simulations. A significant fraction (1% - 5%) of the distribution undergoes two-valley motion for typical magnetospheric parameters. For sufficiently fast interactions where a uniform background magnetic field and a constant wave frequency can be assumed, the widely-used second-order trapping theory [3] is shown to be an erroneous approximation of the present theory.

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