



## Wave-Particle Interactions in the Second Standard Model of Resonance

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Interactions with resonant waves have a major effect on the dynamics of radiation belt electrons. Small or moderate amplitude broadband waves can be treated successfully with quasi-linear theory, but large amplitude, narrowband waves require a nonlinear treatment. Both whistler mode and ion cyclotron waves can take this form. To go beyond representative, direct test particle simulations, a standard approach derives a pendulum-like Hamiltonian near isolated resonances, which leads to analytical estimates for particle behavior referred to as phase bunching and phase trapping. However, it has become recognized that this approach can fail for particles with low pitch angle, most obviously because of predictions of adiabatic invariant decrease below zero. This applies to both the average change and the change for most phase angles, although a detailed analytical treatment shows that not all energy and pitch angle changes are negative, even for the pendulum model.

Recent work has improved on this situation with a slightly more accurate version of the Hamiltonian, denoted a "second standard model of resonance," which recovers the pendulum Hamiltonian in most cases but is modified in such a way as to keep the first adiabatic invariant positive and qualitatively reproduces "anomalous phase trapping" seen in test particle simulations. Geometrically, the novel feature is a second o-point and associated trapping region, as well as a single x-point and separatrix in the appropriate phase plane. Here we investigate several unresolved aspects: the fidelity of the modified Hamiltonian to the directly obtained gyro-averaged equations motion; "positive phase bunching" at intermediate levels of wave amplitude; and the corresponding treatment for EMIC waves.