Nonlinear Wave-Particle Interactions: Recently Developed Theoretical Results

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Test particles resonantly interacting with coherent, large amplitude waves have qualitatively different effects on charged test particles than the quasi-linear diffusion usually induced by small amplitude, broadband waves. The former model may be more germane than the latter for radiation belt electrons in the presence of intense chorus or electromagnetic ion cyclotron waves (EMIC) during disturbed conditions. Test particle and self-consistent simulations have identified several classes of behavior of test particles acted on by such waves, and analytical treatment has been developed to some degree. Recently, the theoretical description and corresponding analysis have advanced on several fronts.

Gyro-averaging near cyclotron resonance yields a low-dimensional Hamiltonian, which is often approximated to have the same form as for a plane pendulum. This yields standard phase bunching and phase trapping, which are associated with the breaking of the first adiabatic invariant I upon crossing a separatrix in phase space. Detailed expressions for the change in I, which retain dependence on wave-particle phase, have been developed [1], uncovering a narrow range of "positive phase bunching" even for this model. To remain valid at low values of the first adiabatic invariant, the pendulum model has been extended to a so-called second model of resonance [2, 3]. While the pendulum model has a single x-point and a single o-point, this second model exhibits either just one o-point or an x-point and two o-points. The transition can give "anomalous" phase trapping, distinct from separatrix crossing, and reproduces the behavior seen in more conventional versions of the equations of motion [4]. Here, these recent developments and applications to whistler mode [5] and EMIC waves [6] are reviewed.

References

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