Modeling of Long-Range Frequency Sweeping Phenomena

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The nonlinear evolution of Alfvén waves driven unstable by energetic particles in toroidal magnetic confinement devices is known to exhibit holes and clumps in the fast particle distribution function, associated with frequency sweeping of the wave [1]. These coherent phase space structures, comprised of resonant fast particles trapped in the wave fields, can be viewed as long living Bernstein-Greene-Kruskal (BGK) modes [2], and they reveal interesting behavior in the presence of relaxation mechanisms such as dynamical friction (drag) and velocity space diffusion [3]. In this contribution, we model the evolution of such BGK modes using a 1D bump-on-tail model. The idea is to solve the equations in the moving reference frame of an isolated BGK wave, which allows for frequency sweeping range comparable to the initial linear mode frequency. The mode frequency sweeping rate is much smaller than the bounce frequency of the particles trapped in the wave field, enabling an adiabatic description of the resonant particles. The system can therefore be described efficiently by resolving only time scales larger than the trapped particle bounce period. This numerical approach generalizes the previous analytical solution [2] in that it covers particle trapping in the wave field and incorporates fast particle velocity space diffusion and drag.

References

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