Autoresonant Wave Dynamics in Vlasov-Poisson Systems

Lazar Friedland
Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem, 91909, Israel
email: lazar@vms.huji.ac.il

Abstract:

Autoresonance is an important nonlinear phenomenon, where a driven system is captured into resonance and stays phase-locked continuously despite variation of system's parameters. Since the first use in particle accelerators, new studies of autoresonance emerged recently in a broad range of fields in physics, few examples being plasmas, nonlinear optics, planetary dynamics, and superconducting Josephson junctions (see [1] for a short review). While the transition to autoresonance in an oscillatory one degree of freedom nonlinear systems is well understood, there remain many unsolved questions in autoresonant many degrees of freedom systems, the main issues being the thermal spread and collective phenomena. In this context, resonant phase space dynamics and space charge effects will be analyzed in chirped frequency driven, charged ensembles of particles (plasmas) described by the Vlasov-Poisson system of equations for particle distributions and self-electric fields. It will be shown that different nontrivial coherent nonlinear structures in this system can be conveniently formed and controlled by slow chirped frequency perturbations. In particular, for a range of parameters one can excite large amplitude fluid-type waves. In the small wave vector limit these waves are described by the KdV equation, so the aforementioned fluid modes comprise a realistic generalization of autoresonant KdV solutions [2,3]. In addition, by reversing the direction of variation of the driving frequency, one can form dissipationless nonlinear kinetic excitations (Bernstein-Green-Kruscal modes) associated with the holes in particles phase space. A simplest problem of this type can be dealt with by modeling the particle distributions via the water bag model. This case allows analysis of the autoresonant Vlasov-Poisson dynamics via the Whithams variation principle [4]. More general particle distributions can be treated within the multi-water bag model. Formation of different autoresonant coherent structures in the system will be illustrated in numerical simulations and the associated theory will be discussed.

References:

1. L. Friedland, Scholarpedia 4, 5473 (2009).
2. L. Friedland, A.G. Shagalov, Phys. Rev. Lett. 90, 074101 (2002).
3. I. Aranson, B. Meerson, and T. Tajima, Phys. Rev. A 45, 7500 (1992).
4. G. B. Whitham, Linear and Nonlinear Waves (John Wiley, New York, 1973).