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Weakly Turbulent Nonlinear Wave-Particle Interactions in Space and Astrophysical Plasmas

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Abstract

Weakly nonlinear and incoherent interactions among waves and plasma particles can be described by perturbative nonlinear kinetic theory known in the plasma physics literature as the weak turbulence theory. The basic methodology will be briefly outlined and application of the weak turbulence theory to electron beam-plasma interaction problem will be discussed. The theoretical framework starts from simple Vlasov-Poisson equation, which is extended to Klimontovich-Poisson system of equations. Then electromagnetic generalization of Vlasov-Possion to Vlasov-Maxwell equation is discussed, which is finally generalized to Klimontovich-Maxwell system. The discussion will be of a review of existing literatures [1, 2, 3, 4, 5]. The increasing complexity in the theoretical development will be briefly explained at the conceptual level. The application of the theory to actual space plasma problem will be emphasized.

In the context of space physics, the weak turbulence analysis of electron beam-plasma interaction pertains to two prominent examples. One is the physical origin of nonthermal electron distribution function observed in space. It is well known that the solar wind electron distribution function can be empirically fitted with the celebrated kappa distribution function [6], but its origin was not understood. The weak turbulence theory of electron beam-plasma interaction and ensuing Langmuir turbulence can naturally explain the generation of electron kappa distribution function [7]. The stationary kappa distribution function for the electrons that forms as a result of interaction with saturated Langmuir turbulence spectrum may be equivalent to the non-extensive statistical equilibrium state [8, 9].

Another application is on the radiation generation during the course of electron beam-plasma interaction process. The emission of electromagnetic radiation at the plasma frequency and/or its harmonic(s) is known in the literature as the plasma emission, and it is the fundamental process responsible for the solar type II and type III radio bursts [10]. Many theories have been developed in the literature since the decade of 1950s [5], but complete theoretical/numerical demonstration of plasma emission starting from the electron beam-plasma instability process has not been done until recently [11]. The plasma emission result when Langmuir turbulence energy is partially converted to electromagnetic radiation via nonlinear processes. This talk will overview the latest development on this research topic.

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