Nonlinear Kinetic Turbulence Theory

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Abstract

Plasmas may be considered collisionless if one is interested in phenomena that evolve in time scales much shorter than time scales of binary collisions. For such cases, the Vlasov-Maxwell system of equations may be employed, which is a nonlinear partial differential equation, customarily solved under different degrees of approximation. Under the linear approximation one obtains the dispersion relations, but for time evolution of the system one needs to nonlinear effects. The lowest order approach is the quasilinear theory. The next step in this chain of approximations is the weak turbulence theory, which incorporates nonlinear effects of lowest order, that is, the quadratic nonlinearity. The weak turbulence theory was largely developed between the late 1950s and the decade of 1970s. In more recent years the present author resumed further development of the weak turbulence theory. However, until recently, the formal developments and numerical analyses thereof have not taken into account the collisional interaction between plasma particles. The reason had been that the time scale of collective processes should be shorter than the time scale associated with binary collisional processes. However, in some of the applications that have been made, it was shown that nonlinear effects continue to operate far beyond the time scale of the instability saturation and nonlinear mode coupling, to the extent that an asymptotically steady state, or quasi-equilibrium state, of the turbulent system becomes of relevance. Specifically, it was demonstrated that the plasma in such a "turbulent equilibrium" state is associated with a background of electromagnetic radiation and the inverse power-law velocity distribution function called the "kappa" distribution. It is therefore pertinent to raise the question of whether collisional processes can play a role in these processes of long-time evolution or not, even in tenuous turbulent systems. In addition, there are space plasma phenomena whose explanation requires the presence of beams of particles under the influence of collisional processes. The prime example may be the emission of X rays via bremsstrahlung, by electrons traveling in the solar chromosphere. There is evidence that suggests that the generation of Langmuir waves due to the presence of a beam may affect the velocity distribution of the X ray generating electrons. It is therefore deemed necessary that the long time evolution of the beam-plasma system, and possibly other physical systems, may have to be reconsidered by taking into account not only the wave-particle and wave-wave interactions, but also the collisional interactions as well. In the present lecture, the generalized theory of plasma kinetic theory in the context of weak turbulence ordering that includes both collective and collisional effects will be outlined.