PLASMAS: FROM WEAKNESS TO STRENGTH

Gabor J. Kalman

ABSTRACT

Plasma physics is a relatively new discipline. While it started with the study of plasmas, which now we would describe as " weakly coupled ", it soon developed a branch which is now referred to as the physics of strongly coupled plasmas, or in somewhat more general terms, of strongly coupled Coulomb systems. Weak coupling and strong coupling in this context signify whether the kinetic energy or the potential energy dominates in the system. I will follow this development, by emphasizing the early ideas and notions that have become seminal in the establishment of the study of strongly coupled plasmas. Foremost amongst these is the Non-linear Fluctuation-Dissipation Theorem (NLFDT) that generalizes Kubo's pioneering work to establish profound connections between quadratic response functions, perturbed correlations and equilibrium three point fluctuations. In searching a theoretical description of the dynamics of strongly coupled plasmas, in the absence of a small perturbation parameter one has to reject perturbation theory as a viable approach and rather seek an avenue that leads to the introduction of an, albeit approximate, self-consistency requirement for the dynamical variables of the system. The NLFDT , combined with kinetic theory, provides a way to create such a self-consistency generating algorithm, while observing all the relevant sum rules. I will review the advantages and disadvantages, lack of simplicity being one of them, of this approach. Thus attempting to attack the problem from a alternate point of view seems to be justified. Rather than relying on the exploitation of the mathematical structure of the dynamical equations, one can construct a somewhat *ad hoc* physical model, based on the most relevant features of strongly coupled plasmas. These are, first, the temporary localization and oscillation of the particles in the local, fluctuating potential traps due to the "other" particles, and, second, the strong correlations between the locations of the potential traps. All these considerations lead to a formalism that has become known as the Quasi-Localized Charge Approximation (QLCA). The QLCA has been applied, in conjunction with Molecular Dynamics computer simulations carried out by the Wigner Centre, to a number of 3-dimensional and 2-dimensional plasmas and plasma-like systems, such as Yukawa and electric and magnetic dipole systems, with considerable success. A number of remarkable differences between the dynamics of the weakly and strongly coupled variants of these systems will be pointed out.