Nonlinear Fokker-Planck Equation and Associated Entropic Form for Charged Particles by Neglecting Thermal Noise

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A system of interacting charged particles, under overdamped motion, is considered by neglecting thermal effects. Its connection with nonextensive statistical mechanics is discussed, and particularly, its description by means of a typical nonlinear Fokker-Planck equation, derived by means of a coarse-graining procedure in the equations of motion. In contrast to particles interacting through short-range forces, the Coulomb interactions yield difficulties to the coarse-graining approach, particularly in both limits of very short and very large distances. Due to this, the analysis is restricted to a finite spherical region, between radius a and b ($b > a > 0$). The system is studied also by means of molecular dynamics numerical simulations, which show that the equilibrium-state probability distribution agrees well with the analytical solution of the Fokker-Planck equation. An effective temperature θ is introduced by means of a free-energy functional, $f = u - \theta s$, for which the H-theorem $[(df/dt) \leq 0]$ can be proved making use of the corresponding Fokker-Planck equation. It is shown that θ is directly related to the density, to the interactions among particles, as well as to the radius a and b and so, it can be varied accordingly. Due to the long-range character of the Coulomb interactions, common thermodynamic procedures (e.g., thermodynamic limit) become rather nontrivial tasks, and particularly, the resulting quantities depend on the form of the apparatus considered.

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