Surprisingly, N-body mechanics can describe several basic, yet non trivial, phenomena of plasmas [1, 2]. In particular, it provides a short and simultaneous derivation of Debye shielding and of Landau damping. Furthermore, it brings a deeper understanding of the corresponding physics [1]. For instance, while Coulombian deflections are traditionally viewed as the cause of a disorder leading to collisional transport, the new approach shows the cooperative action of these deflections to produce order too: after one plasma period typically, this action makes the plasma to behave as a dielectric, and Debye shielding to set in. Paradoxically, the Vlasovian description turns out to be right thanks to what is usually called "collisions". The new approach also makes intuitive how a particle can be shielded by all other ones, while contributing to shielding them all.

Technically, the new approach is elementary. The intuitive explanation of Debye shielding stems from a calculation applying Picard iteration technique to the equations provided by Newton’s second law for N electrons coupled by their Coulomb potential in a periodic box with a neutralizing background. Debye shielding and Landau damping are simultaneously recovered by applying Laplace transform to the same set of equations where Coulomb potential is linearized about the ballistic orbits of electrons. No probabilistic argument and no partial differential equation are used. The continuous velocity distribution is introduced after particle dynamics has been taken into account, and not before, as occurs in the kinetic approach.

The N-body approach also provided the first description of collisional transport incorporating all impact parameters without any ad hoc cut-off [2]. As a result, while the N-body dynamics has always been the ultimate reference in plasma textbooks, it is now a practical tool. Furthermore, Laplace’s dream was not a mere utopia, since classical mechanics can genuinely describe non trivial aspects of the macroscopic dynamics of a many-body system.

References