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Mean Force Kinetic Theory[1]

SCOTT BAALRUD, University of Iowa

Traditional plasma kinetic theories can be derived from the BBGKY hierarchy by expanding either in terms of the range or strength of interactions, as in the Boltzmann or Lenard-Balescu theories, respectively. Either infrared or ultraviolet divergences arise as a consequence. These are resolved by invoking concepts of weak Coulomb coupling, such as Debye shielding or the distance of closest approach in a binary collision. Because these theories rely on ad hoc arguments, it is difficult to attempt generalizations to other important situations such as moderate or strong Coulomb coupling or strong magnetization. This work presents a new closure of the BBGKY hierarchy based on a single expansion parameter. It does not depend explicitly on the strength or range of interactions, which avoids the usual divergences. Rather, it is based on enforcing that the exact equilibrium limit is maintained at all orders of the hierarchy. The resulting kinetic equation shows that particles effectively interact via the potential of mean force and that the range of this force determines the size of the collision volume. The resulting collision operator is the same as the effective potential theory proposed in [1] based on a physical argument. In addition to providing a systematic derivation of this collision operator, the new theory [2] includes an additional term that is shown to be associated with the excess (non-ideal) component of the pressure and internal energy in the hydrodynamic limit. Tests of the transport and equation of state properties predicted by this theory are provided from a combination of molecular dynamics simulations and experiments in both ultracold plasmas and warm dense matter. These show that the theory provides an accurate extension of the plasma kinetic theory well into the strongly coupled regime. [1] Baalrud and Daligault, Phys. Rev. Lett. 110, 235001 (2013). [2] Baalrud and Daligault; arXiv:1904.09208 (2019).

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