Recent progress in simulations of dense quantum plasmas and warm dense matter

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Presently we are witnessing dramatic progress in experiments with dense quantum plasmas where matter is being compressed to densities exceeding solid density. At the same time, accurate laser and x-ray based diagnostic tools have emerged that probe the properties of such warm dense matter. To understand these experiments and predict new ones poses a challenge to theory and simulations [1]. Promising tools include density functional theory (DFT), generalized quantum hydrodynamics (QHD), quantum kinetic equations (QKT, [2]), and quantum Monte Carlo (QMC, [3]). We will discuss some of the recent theory developments and present accurate results for the thermodynamic [4,5] and dynamic properties of the quantum electrons from QMC simulations, including the electron dynamic structure factor [6], dielectric function, plasmon dispersion [7], and momentum distribution [8]. We will also outline prospects of nonequilibrium simulations based on QKT [9, 10] and on QHD. For the latter we discuss how to improve the original equations to allow for reliable predictions [11, 12].

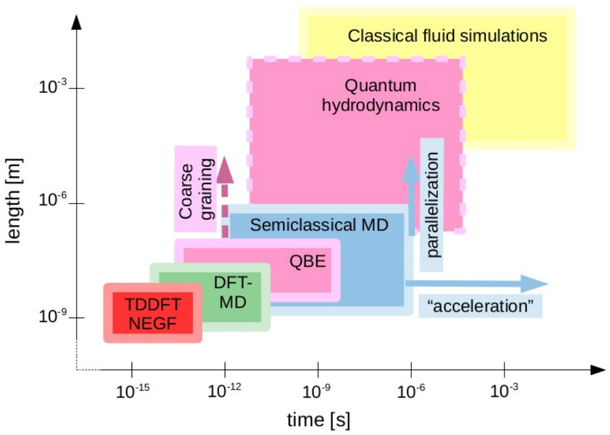

Figure: Schematic overview of computational methods for warm dense matter indicating their resolution of space and time scales. QBE: quantum Boltzmann equation, DFT: density functional theory, NEGF: nonequilbirium Green functions. From Ref. [1].

Warm dense matter is so complex that no single theory and simulation approach will be capable to describe all properties. Instead, a combination of methods that resolve small scales and accurately capture electronic correlations (but are computationally expansive) with coarse grained methods will be required to achieve predictive simulations in the future [1], as is sketched in the Figure.

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