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New Perspectives for Warm Dense Matter Theory: from Quantum Monte Carlo to Temperature Diagnostics

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Warm dense matter (WDM)—an extreme state that is characterized by extreme densities and temperatures—has emerged as one of the most active frontiers in plasma physics and material science. In nature, WDM occurs in astrophysical objects such as giant planet interiors and brown dwarfs. In addition, WDM is highly important for cutting-edge technological applications such as inertial confinement fusion and the discovery of novel materials. In the laboratory, WDM is studied experimentally in large facilities around the globe, and new techniques have facilitated unprecedented insights into exciting phenomena like the formation of nano diamonds at planetary interior conditions [1]. Yet, the interpretation of these experiments requires a reliable diagnostics based on accurate theoretical modeling, which is a notoriously difficult task [2]. In this talk, I give an overview of recent ground-breaking developments in this field [3,4], which will allow for the first time to rigorously treat the intricate interplay of Coulomb coupling with thermal excitations and quantum degeneracy effects. Moreover, I show how cutting-edge quantum Monte Carlo simulation techniques will help to decisively improve density functional theory (DFT) simulations of WDM, thereby opening up unprecedented perspectives and new paradigms such as the experimental and theoretical study of nonlinear effects [5,6]. Finally, I will present a new idea to extract the exact temperature from an X-ray Thomson scattering experiment without any models or simulations [7].

[1] D. Kraus et al., Nature Astronomy 1, 606-611 (2017)
[2] M. Bonitz et al., Physics of Plasmas 27, 042710 (2020)
[3] T. Dornheim et al., Physics Reports 744, 1-86 (2018)
[4] T. Dornheim et al., Physical Review Letters 121, 255001 (2018)
[5] T. Dornheim et al., Physical Review Letters 125, 085001 (2020)
[6] Zh. Moldabekov et al., Journal of Chemical Theory and Computation 18, 2900-2912 (2022)
[7] T. Dornheim et al., arXiv:2206.12805

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