THE ENERGY OF QUANTUM COULOMB LIQUID IN WHITE-DWARF CORES

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Using the Metropolis method to compute quantum path integrals (PIMC), the energy of the one-component plasma, composed of fully-ionized atomic nuclei and uniform incompressible charge-compensating electron background, is calculated. The range of temperatures under study corresponds to a strongly-nonideal Coulomb liquid, i.e. the parameter $\Gamma = (Ze)^2/(aT)$ varies from 1 to 175. (In this case, Ze is the ion charge, a is the ion-sphere radius, T is the temperature.) The range of densities considered represents the fully-ionized internal layers of white dwarfs: the ion parameter $r_s = a/a_0 \geq 1200$. (In this case, a_0 is the ion Bohr radius.) At these densities, ions can be treated as distinguishable, but the effects of ion motion quantization are significant and are accounted for from the first principles. At $r_s = 1200$, the results obtained reproduce those of [1]. At $r_s \gtrsim 10^5$, the well-established results for *classic* strongly-nonideal Coulomb liquid are asymptotically reproduced. The error of the present calculation (statistical plus systematic) is significantly lower than that of [1]. The energy dependence on temperature obtained can be easily differentiated with respect to temperature. This allows one to determine reliably the specific heat of quantum strongly-nonideal Coulomb liquid, which is an indispensable ingredient for modeling cooling of white dwarfs. On top of that, the latent heat, which is another crucial parameter in the theory of white dwarfs, is calculated in the same density range and its dependence on density due to quantum effects is analyzed. It is shown that the approach to calculation of thermodynamic functions of quantum strongly-nonideal Coulomb liquid in the interiors of white dwarfs prevailing in the literature (the classic expression plus the first quantum correction from the Wigner–Kirkwood expansion) may result in noticeable errors in the specific heat and latent heat values.

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1. Jones M.D. and Ceperley D.M. // Phys. Rev. Lett. 1996. V. 76. No. 24. P. 4572.