Mathematics > Probability

Large deviations for cluster size distributions in a continuous classical many-body system

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An interesting problem in statistical physics is the condensation of classical particles in droplets or clusters when the pair-interaction is given by a stable Lennard-Jones-type potential. We study two aspects of this problem. We start by deriving a large deviations principle for the cluster size distribution for any inverse temperature $\beta\in(0,\infty)$ and particle density $\rho\in(0,\rho_{\rm{cp}})$ in the thermodynamic limit. Here $\rho_{\rm{cp}} >0$ is the close packing density. While in general the rate function is an abstract object, our second main result is the Γ-convergence of the rate function towards an explicit limiting rate function in the low-temperature dilute limit $\beta\to\infty$, $\rho \downarrow 0$ such that $-\beta^{-1}\log\rho\to \nu$ for some $\nu\in(0,\infty)$. The limiting rate function and its minimisers appeared in recent work, where the temperature and the particle density were coupled with the particle number. In the de-coupled limit considered here, we prove that just one cluster size is dominant, depending on the parameter ν. Under additional assumptions on the potential, the Γ-convergence along curves can be strengthened to uniform bounds, valid in a low-temperature, low-density rectangle.

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