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Ensemble Theory for Stealthy Hyperuniform Disordered Ground States

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Disordered hyperuniform many-particle systems [1] have been receiving recent attention because they are distinguishable exotic states of matter poised between a crystal and liquid that are endowed with novel thermodynamic and physical properties. It has been shown numerically that systems of particles interacting with "stealthy" bounded, long-ranged pair potentials (similar to Friedel oscillations) have classical ground states that are, counterintuitively, disordered, hyperuniform and highly degenerate. The task of formulating an ensemble theory that yields analytical predictions for the structural characteristics and other properties of stealthy degenerate ground states in d-dimensional Euclidean space is highly nontrivial because the dimensionality of the configuration space depends on the number density and there is a multitude of ways of sampling the ground-state manifold, each with its own probability measure for finding a particular ground-state configuration. A new type of statistical-mechanical theory had to be invented to characterize these exotic states of matter. I report on some initial progress that we have made in this direction [2]. We show that stealthy disordered ground states behave like "pseudo"-equilibrium hard-sphere systems in Fourier space. Our theoretical predictions for the structure and thermodynamic properties of the stealthy disordered ground states and associated excited states are in excellent agreement with computer simulations across dimensions. [1] Torquato and F. H. Stillinger, Local Density Fluctuations, Hyperuniform Systems, and Order Metrics, Physical Review E, 68, 041113 (2003); [2] S. Torquato, G. Zhang, and F. H. Stillinger, Ensemble Theory for Stealthy Hyperuniform Disordered Ground States, Physical Review X,5, 021020 (2015).