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Quantum melting and superfluidity of molecular hydrogen clusters

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Clusters of parahydroge comprising between 10 and 50 molecules have been extensively studied by computer simulations based on the continuous-space Worm Algorithm, which allows one to go down to temperatures as low as a few hundredths of a K. These clusters display an intriguing interplay of liquid- and solid-like behavior as a function of both temperature and cluster size. In this sense, their physics is far richer than that of helium clusters. An intriguing phenomenon predicted by our simulations is *quantum melting*, whereby clusters in some size range (roughly between 22 and 30 molecules) are observed to go from rigid, solid-like, to essentially structureless and liquid-like as the temperature is lowered, due to the onset of quantum exchange cycles involving all the molecules in the cluster. At low temperature these clusters turn superfluid; their local superfluid response has been analyzed, and found to be essentially uniform throughout the system in the $T \to 0$ limit, even in clusters with a pronounced shell structure. In particular, exchanges involving molecules in the inner and outer shells are shown to be underlying the superfluid response. This system can also allow one to gain insight into the relationship of the superfluid properties with Bose condensation, and aspect that has been thoroughly investigated.