The Fascinating Helium Atom

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Abstract. Despite having being discovered more than a century ago, and extensively studied both experimentally and theoretically, the Helium atom never ceases to reveal intriguing properties in its many manifestations: from the isolated atom to small clusters to large droplets and the bulk.
In this talk I report our recent findings of two aspects of helium.
The nodes of even simple wave functions are largely unexplored. However, motivated by their importance to quantum simulations of Fermionic systems, we studied the properties of the nodes of several atoms and molecules. We have found unexpected symmetries in the nodes the Helium atom. We find that in both ground and excited states some nodes of He have simple forms. In particular, the nodes have higher symmetry than the wave functions they come from. Given the importance of symmetry in physics, it is of great interest to understand the source of these new symmetries.
Focusing on Helium capability to form small clusters, we have studied the stability of mixed ^{3}He/^{4}He clusters in different angular momentum and spin states by variational and diffusion Monte Carlo methods. The clusters $^3He^4He_M$ (L=0, S=1/2) and $^3He_2{}^4He_M$ (L=0, S=0) are known to be stable for M>1, while to bind two ^{3}He in an S=1 L=1 state we found the minimum number of ^{4}He is four. This type of coupling between the two fermions is similar to that exhibited by cooper pairs in superfluid ^{3}He. Interestingly four bosons are also sufficient to support the S=0 L=1 state. When only one fermion atom is present, we studied the minimum number of ^{4}He necessary to give a stable cluster, for different L>0 states.