Exotic Quantum Phases of ^{3}He and ^{4}He in Two Dimensions

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The first three monolayers of ^{3}He and ^{4}He adsorbed on graphite are model systems for two-dimensional (2D) quantum liquids and solids which provide us new physics not usually seen in three dimensions (3D). I will discuss several examples including exotic ground states of the commensurate solids of both the isotopes in the second layer (C2 phase) by introducing recent experiments and theories. The second layer is perhaps the most intriguing system since there the kinetic energy, confining potential and particle correlations are comparable each other. The C2 phase is barely stabilized in the presence of a small potential corrugation at a relative density close to 4/7 with respective to the first layer. It has a significantly low density and hence the much higher delocalized nature than solid He in 3D. In the case of ^{3}He-C2 phase, the gapless quantum spin-liquid state of nuclear spins ($S = 1/2$) emerges below 1 mK unlike the antiferromagnetically ordered phase in bcc ^{3}He. The strong frustration caused by the triangular lattice structure and competing ring exchange interactions is responsible for the emergence of such an unusual state. Similar states are now discussed in electronic spin systems such as quasi-2D organic materials and transition metal oxides with frustrated lattices. An even more exotic quantum state is the supersolid phase expected in the C2 phase of ^{4}He. Torsional oscillator (TO) experiments using Grafoil substrate by three different groups show superfluid-like frequency shifts below 200 mK in this 2D bosonic solid. A new TO experiment using a better graphite substrate in terms of platelet size is now undergoing which would clarify if the tiny frequency shifts so far observed are of bulk superfluidity. Note that here He atoms localize choosing the particular density fraction and arrangement among others, which means that the C2 phase is a solid in a lattice space with spontaneous symmetry breaking.

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