Anomalous "Superfluid" Response with Quantum Criticality of Two-Dimensional ^{4}He in a Triangular Lattice Potential

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The second layer of ^{4}He adsorbed on the surface of graphite shows an anomalous superfluid response that we have studied by the torsional oscillator method over the temperature range 1.5 mK to 3.5 K. This system is a realization of bosons moving in two dimensions subject to a triangular lattice potential, which here arises from the close packed lattice of the ^{4}He first layer. The superfluid density has a highly anomalous temperature dependence, at densities near that at which the second layer of ^{3}He adsorbed on graphite supports a two dimensional solid - a triangular super-lattice with respect to the underlying first helium layer. Both the inferred value of the superfluid density at $T = 0$, and the characteristic temperature T^* governing its temperature dependence, are strong functions of the second layer density. We report the scaling form of the superfluid density. The results suggest that the observed quantum critical behaviour belongs to the same universality class as that of the superfluid-insulator transition in the Bose-Hubbard model, in the clean limit.