DAMOP12-2012-000402

Abstract for an Invited Paper
for the DAMOP12 Meeting of
the American Physical Society

In situ probing of two-dimensional quantum gases[1]

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Experiments on ultracold gases offer unique perspectives to unveil many-body phenomena near phase transitions described by paradigmatic condensed matter models. In this talk, I will present new insight from spatially-resolved, in situ images of ultracold atoms confined in a two-dimensional (2D) trap, with a focus on critical regions of continuous phase transitions. In situ imaging of a monolayer of 2D gas reveals precise atomic density distributions, providing advantages in studying equilibrium thermodynamics, transport properties, as well as density fluctuations and spatial correlations away from thermal equilibrium, many of which are difficult to resolve in conventional bulk measurements. Using samples prepared at various temperatures and atomic interaction strengths, we confirm scale invariance and universality of weakly interacting 2D gases near the Berezinskii-Kosterlitz-Thouless transition, and verify the theory describing its critical behavior. Density-density correlations and static structure factors are also extracted, revealing intriguing quantum behavior of underlying many-body phases. By loading a 2D gas into a square lattice potential, we induce the superfluid-Mott insulator quantum phase transition, and observe the emergence of quantum criticality at low temperatures. Our study reveals different time scales for global mass transport and statistical evolution, opening up new prospects to investigate dynamical criticality near quantum phase transitions.

[1]This work was performed at the University of Chicago under the supervision of Prof. Cheng Chin.