“Scale Invariance and Universality in Two-Dimensional Bose Gases”

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The collective behavior of a many-body system near a continuous phase transition is insensitive to the details of its microscopic physics. Characteristic features near the phase transition, called critical phenomena, are that the thermodynamic observables follow generalized scaling laws. The Berezinskii-Kosterlitz-Thouless (BKT) phase transition in two-dimensional (2D) Bose gases presents a particularly interesting case because the marginal dimensionality and intrinsic scaling symmetry result in a broad fluctuation regime which manifests itself in an extended range of scale-invariant and universal behavior. We study this universal behavior by probing the density profiles and fluctuations of ultracold cesium atoms in a 2D optical trap at various temperatures and interaction strengths across the BKT phase transition. We report the observation of a global invariance of scale and a universal description of 2D gases under proper power-law scaling with respect to the thermal de Broglie wavelength and the 2D interaction strength. The extracted universal thermodynamic functions confirm the wide BKT critical regime, provide a sensitive test to Monte Carlo calculations, and point toward a growing density-density correlations in the critical regime. We show that universality can be used as a powerful tool to study critical phenomena and outline future efforts to explore quantum criticality near the superfluid-to-Mott insulator transition in a 2D optical lattice, where the phase transition is driven by quantum fluctuations at absolute zero temperature.