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Buckley Prize Talk: Bosons on the Boundaries: The magnetic field driven superconductor-insulator quantum phase transition

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Experiments probing the competition between superconductivity and disorder in two-dimensional (2D) thin-film systems have provided fascinating glimpses into the physics of superconductor-insulator (S-I) quantum phase transitions (QPTs). This talk will address the use of externally applied magnetic fields to tune through the S-I transition of amorphous composite indium oxide (α-InOx) thin films prepared at different stages of disorder. Air-stable α-InOx films are particularly advantageous for these studies: the disorder parameter as measured by the sheet resistance can be reproducibly controlled during deposition and the films are uniformly homogeneous out to macroscopic length scales. Temperature-dependent resistance and current-voltage measurements confirm the power-law decay of the order-parameter correlation function appropriate to a Kosterlitz-Thouless description of phase transitions in 2D systems. Accordingly, the superconducting phase transition temperature Tc is related to the unbinding of vortex-antivortex pairs either by temperature and/or disorder. The application of magnetic fields unveils fundamentally different physics in which, rather than a vortex unbinding transition, a field-tuned QPT emerges with the signature of a disorder-dependent critical field Bc that identifies the delocalization and Bose condensation of field-induced vortices. The concomitant pronounced divergence in resistance, which becomes increasing sharp as the temperature is lowered, marks the boundary between a superconductor harboring both Bose condensed Cooper pairs and localized vortices and an insulator harboring both Bose condensed vortices and localized Cooper pairs. The data for this putative QPT are well described by finite temperature scaling theory with critical exponent values accurately determined. At higher fields there is a second critical field where the transverse resistance appears to diverge, signaling the unbinding of pairs with the superconducting energy gap simultaneously going to zero and localized single electrons dominating to form a Fermi glass insulator.