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We explore the universal properties of interacting fermionic lattice systems, mostly focusing on the development of pairing correlations from attractive interactions. Using renormalization group we identify a large number of fixed points and show that they correspond to resonant scattering in multiple channels. Pairing resonances in finite-density band insulators occur between quasiparticles and quasiholes living at different symmetry-related wavevectors in the Brillouin zone. This allows a BCS-BEC crossover interpretation of both Cooper and particle-hole pairing. We show that in two dimensions the run-away flows of relevant attractive interactions lead to charged-boson-dominated low energy dynamics in the insulating states, and superfluid transitions in bosonic mean-field or XY universality classes. Analogous phenomena in higher dimensions are restricted to the strong coupling limit, while at weak couplings the transition is in the pair-breaking BCS class. The models discussed here can be realized with ultra-cold gases of alkali atoms tuned to a broad Feshbach resonance in an optical lattice, enabling experimental studies of pairing correlations in insulators, especially in their universal regimes. In turn, these simple and tractable models capture the emergence of fluctuation-driven superconducting transitions in fermionic systems, which is of interest in the context of high temperature superconductors.

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