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Novel quantum phases of interacting fermionic atoms

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Recent developments in ultracold atomic gases have revitalized interest in some basic qualitative questions of quantum many-body theory, because they promise to make a wide variety of conceptually interesting systems, which might previously have seemed academic or excessively special, experimentally accessible. I will describe a set of simple, idealized model systems that seem to surprisingly display new states of quantum matter. One such system is a two component fermi gas of mismatched fermi surfaces and of different masses. Our study shows it has a new kind of pairing state—breached pair superfluidity—other than the well known states of BCS and Larkin-Ovchinnikov-Fulde-Ferrell (LOFF). I will discuss when the state becomes stable and suggest ways of possible experimental realization, including a theoretical design of optical sublattices with different tunnelings (thus a spin-dependent Hubbard model). The state also contains novel signature of superfluidity in the momentum distribution of particles, which is directly observable as a first-order effect. In the presence of a steeper confining trap potential which strongly breaks the translational symmetry, our work in progress indicates that another competing new state—angular crystalline superfluid—seems to become energetically favorable.