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Engineered spin-orbit coupling in ultracold quantum gases

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Ultracold quantum gases are an ideal medium with which to explore the many-body behaviour of quantum systems. With a century of research in atomic physics at the foundation, a wide variety of techniques are available for manipulating the parameters that govern the behaviour of these systems, including tuning the interactions between particles and manipulating their potential energy landscapes. In recent years, the ability to generate "artificial gauge fields"has made it possible to simulate, experimentally, the effects of electromagnetic fields among these uncharged particles. Using the same techniques, which selectively transfer momentum from light to atoms, a correlation between the internal state and the motion of the atoms, known as "spin-orbit coupling,"has also be realised in several quantum gas systems. The relationship between spin and motion is quite general: experiments in quantum gases have used it to perform experiments that mimic both Dirac equation (with high-energy phenomena) and the spintronics (with small power consumption). One promising avenue for quantum simulations with spin-orbit coupled systems is to study the competing effects of this coupling and interparticle interactions. To do this, potassium-39 systems are well-suited: they have widely tunable interactions and technically feasible spin-orbit coupling schemes. Unlike conventional solid state systems, both interactions and spin-orbit coupling are tunable, and predictions suggest that the character of the low-temperature ordered systems will depend strongly on these parameters, giving states that have both superfluid and magnetic character.
Further, these experiments will allow for the study of non-equilibrium behaviour of the interacting, spin-orbit coupled system, including measuring behaviour at the condensation transition and low-temperature dynamics.

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