Dynamics of interacting fermions under spin-orbit coupling

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Quantum statistics and symmetrization dictate that identical fermions do not interact via s-wave collisions. However, in the presence of spin–orbit coupling (SOC), fermions prepared in identical in-ternal states with distinct momenta become distinguishable. The resulting strongly interacting system can exhibit exotic topological and pairing behaviours, many of which are yet to be observed in condensed matter systems. Ultracold atomic gases offer a promising pathway for simulating these rich phenomena, but until recently have been hindered by heating and losses. Here I will report our ability to enter a new regime of many-body interacting SOC in a fermionic optical lattice clock (OLC)[1,2,3], where the long-lived electronic clock states mitigate unwanted dissipation. Using clock spectroscopy, we observe the precession of the col-lective magnetization and the emergence of spin-locking effects arising from SOC-induced exchange interactions. The many-body dynamics are well captured by a collective XXZ spin model, which describes a broad class of condensed matter systems ranging from superconductors to quantum magnets. Furthermore, I will discuss how harness-ing the interplay between interactions and SOC in the state of the art 3D lattice clock can prolong inter-particle spin coherence, transforming the dephasing effect of spin-orbit coupling into an en-tangling process. We find that even with realistic experimental imperfections it may possible to gen-erate ~12-14 dB of spin squeezing in ~1 second with 10^2-10^3 atoms. Our investigations exemplifies a new paradigm of using driven, non-equilibrium systems to overcome current limitations in quantum metrology

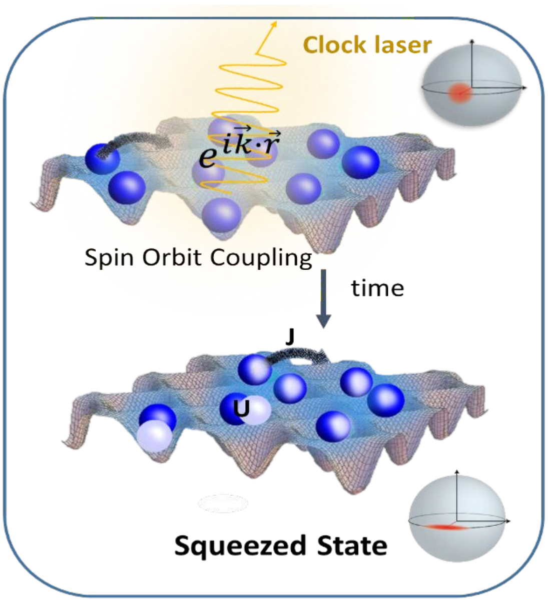

Figure 1: the Harnessing spin-orbit coupling and interactions in an optical lattice clock can be used to generate useful quantum correlated states

[1] Bromley S L *et al* 2018 Nature Physics. **14** 399
[2] Kolkowitz S *et al* 2016 Nature. **541** 66
[2] Wall M L *et al* 2016 PRL. **116** 035301