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Dynamical spin-orbit coupling of a quantum gas in a cavity[1]

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Quantum simulation with ultracold atoms has been enriched by techniques using laser-induced atomic transitions to create synthetic gauge fields, including spin-orbit coupling (SOC). These synthetic fields can generate exotic phase diagrams with paradigmatic topological states. We describe how we realize SOC in the context of cavity quantum electrodynamics, where ultracold atoms are trapped inside an optical resonator in a way such that the atoms interact strongly with the electric field inside the cavity. SOC-generating Raman transitions are created using one external classical field plus the intracavity quantum field. Owing to the cavity initially being in a vacuum state, and being spontaneously populated by the atoms superradiantly scattering light from the external beams, the SOC is rendered dynamical. We observe emergent SOC through spin-resolved atomic momentum imaging and temporal heterodyne measurement of the cavity-field emission. These reveal that the spin-orbit coupled state is a spinor-helix polariton condensate with a spontaneously broken Z_2 symmetry. Extending these results to dynamical gauge fields may enable coupled light-matter systems to generate Meissner-like effects, topological superfluids, and exotic quantum Hall states.

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