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Spin- and atom-interactions in multimode cavity QED RONEN KROEZE, YUDAN GUO, Stanford University, JONATHAN KEELING, School of Physics and Astronomy, University of St. Andrews, BENJAMIN LEV, Stanford University — Optical cavity QED provides a versatile platform with which to explore quantum many-body physics in driven-dissipative systems. Multimode cavities are particularly apt for exploring beyond mean-field physics. After previously having demonstrated strong, tunable range, photon-mediated, atom-atom interactions, we now present three other recent experimental advances. Firstly, we have endowed these interactions with a sign-changing feature. In a confocal cavity, Gouy phase effects result in non-local, sign-changing interactions, and enriched symmetries. We demonstrate this using holographic detection of the cavity emission, after crossing a superradiant, self-organization phase transition. In the same context of a non-equilibrium Dicke-like phase transition, we realize joint spin-spatial (spinor) organization of a two-component Bose-Einstein condensate, as driven by spinor-spinor interactions. Lastly, we present results on dynamical spin-orbit coupling, where a chiral spin spiral emerges. Uniquely, it is quantum fluctuations that drive this spin-orbit coupling, enabling studies of dynamical gauge fields. Together, these advances enable us to explore exotic, strongly correlated systems such as quantum liquid crystals, driven-dissipative spin glasses, and quantum neural networks.

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