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Frustration in spin models with cavity-mediated interactions

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Ultracold atoms confined in transversely pumped optical cavities experience cavity-mediated interactions, which can give rise to phenomena such as crystallization [1] that are otherwise difficult to realize using ultracold atoms. We show that for atoms with three or more internal levels, the spin-dependent cavity-mediated interactions are long-ranged and sign-changing, like the RKKY interaction; therefore, ensembles of such atoms subject to frozen-in positional randomness can realize spin systems having disordered and frustrated interactions [2]. We map the problem of spins with cavity-mediated interactions onto a variant of the Hopfield associative-memory model. Using this mapping we argue that if the spins are coupled to sufficiently many cavity modes, the cavity-mediated interactions give rise to a spin glass. We then discuss how spins in cavities can emulate models of interacting bosons subject to purely “off-diagonal” disorder, which exhibit Mott glass and random-singlet glass phases [3] (hitherto unrealized using ultracold atoms). We discuss how the realizable glassy phases can be detected through their slow dynamics, as well as their imprint on the correlations of the light emitted from the cavity. Finally, we discuss the robustness of the predicted glassy physics in the presence of driving and dissipation.

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