Kinetic frustration in doped magnets encoded with Rydberg atom arrays

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Doping an antiferromagnetic Mott insulator is central to our understanding of a variety of phenomena in strongly-correlated electrons, including high-temperature superconductors where the binding of charge carriers play a pivotal role. To describe the competition between tunneling of hole dopants and antiferromagnetic spin interactions, theoretical and numerical studies often focus on the paradigmatic t-J model. We have implemented a doped quantum magnet using our Rydberg tweezer platform [1]. We utilize coherent dynamics between three Rydberg levels, encoding spins and holes, to implement a tunable bosonic t-J model. This implementation provides microscopic control over lattice geometry, interaction range, and energy scales, enabling access to regimes that are challenging for conventional solid-state or cold-atom platforms.

Building on this capability, we use the engineered t-J Hamiltonian to investigate binding phenomena in frustrated lattices [2]. We demonstrate that kinetic frustration alone can induce robust bound states between mobile dopants (holes) and spin excitations (magnons), even in the absence of attractive interactions. We developed a new spectroscopic method [3] to provide the first direct measurement of the binding energy of these composite objects. Combined with our spatial resolution, we characterize the formation, mobility, and internal structure of these composite objects and elucidate the mechanism by which binding emerges.

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[2] M. Qiao *et al.*, *arXiv*:2510.17183 (2025).
[3] R. Martin *et al.*, *arXiv*:2602.17600 (2026).

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