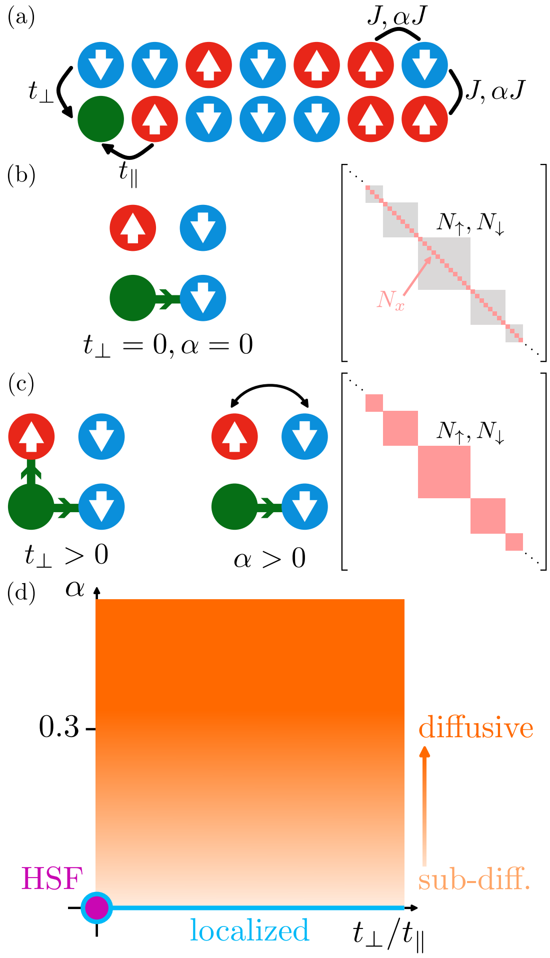
Dopants in quantum spin lattices: from quantum simulators to high precision numerics

The motion of dopants in magnetic spin lattices has received tremendous attention for at least four decades due to its connection to high-temperature superconductivity. Despite these efforts, we are far from thoroughly and controllably understanding their behavior, especially out-of-equilibrium and at nonzero temperatures. In this talk, I will explain to you a major development in our grasp of these systems based on sophisticated large-scale matrix-product-state calculations [1]. We investigate the non-equilibrium dynamics of dopants in antiferromagnetic XXZ two-leg spin ladders. In the Ising limit, we show that the dopant is *localized* at any nonzero temperature due to an emergent disordered potential, with a localization length controlled by the underlying correlation length of the spin lattice. This greatly generalizes the localization effect discovered recently in Hilbert-space fragmented mixed-dimensional models [2,3]. In the presence of spin-exchange processes, both the dopant and the spin diffuses with important qualitative and quantitative differences, however. We substantiate these findings by showing that the dynamics shows self-similar scaling behavior, which strongly deviates from the Gaussian behavior of regular diffusion. Finally, we show that the diffusion coefficient follows an Arrhenius relation at high temperatures, whereby it exponentially decreases for decreasing temperatures.



[1] M. Yang et al., Phys. Rev. B **112**, 165129 (2025).

[2] K. K. Nielsen, Phys. Rev. Res. **6**, 023325 (2024).

[3] K. K. Nielsen, SciPost Phys. Core **7**, 054 (2024).