Machine learning quantum phases: toward autonomous phase discovery

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Understanding quantum phases of matter has long relied on physicists' intuition and mathematical tools such as symmetry and topology. Remarkably successful as these approaches have been, they provide no systematic way to explore a Hamiltonian space whose organizing principle is not known in advance. In this talk, I will introduce a fully autonomous system for quantum phase discovery that couples auto-differentiable Hamiltonian solvers, an autoencoder in which phases emerge as clusters in the latent space, and an active feedback loop that steers the search toward previously unseen phases. Finding a new phase thus becomes a geometric problem: gradient descent in the latent space drives the Hamiltonian parameters toward regions no cluster yet occupies. Because ground states are computed only along the trajectory, the cost scales with the length of the path rather than with the volume of parameter space. Tested across four Hamiltonians and three solvers, the phase discovery system recovers conventional symmetry-breaking transitions and nontrivial topological order on an equal footing. It resolves all five phases of a transverse-field XXZ chain and all eight phases of a generalized cluster-state chain, including symmetry-protected topological phases, in an eight-dimensional parameter space. Our results establish autonomous, gradient-driven exploration of Hamiltonian space as a practical route to discovering quantum phases without prior theoretical input.