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New tools for far-from-equilibrium quantum spin dynamics inspired by ultracold molecule experiments KADEN HAZZARD, JILA, MICHAEL FOSS-FEIG, JQI, BRYCE GADWAY, BO YAN, STEVEN MOSES, JACOB COVEY, DEBORAH JIN, JUN YE, ANA MARIA REY, JILA — We describe new numerical techniques based on a type of cluster expansion and analytic solutions for treating far-from-equilibrium dynamics in quantum many-body spin models. Specifically, we apply them to dynamics following a quantum quench that is routinely implemented in experiments with Ramsey spectroscopy. For many observables, these new approaches converge extremely rapidly compared to existing techniques, which are unable to converge using any feasible computational resources. We describe the theoretical methods and our understanding of their superior convergence. These calculations are motivated by recent experiments with ultracold molecules in optical lattices [Yan *et al.*, Nature **501**, 521 (2013)] and trapped ions [Britton *et al.*, Nature **484**, 489 (2012)], which are described by spin models with long-range interactions in appropriate limits. We will compare theoretical predictions with experimental observations in these systems. We expect the novel methods developed to describe ultracold matter to also have applications to solid state systems, for example in the dynamics of nitrogen-vacancy centers in diamond or energy transfer in complicated molecules.

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