Spontaneous avalanche dephasing in large Rydberg ensembles

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Realizing efficient many-body quantum simulators requires an exquisite control over the coherence and the interactions between many particles. Rydberg atoms are emerging as a strong candidate [1] for achieving the coherent control of large interacting systems. However recently there has been concerns [1] due to the observation of giant inhomogeneous dephasing in large ensembles [2,3]. Hence the current difficulties encountered for realizing Rydberg dressing for atomic ensembles of ~ 100 atoms or more [1]. We provide experimental evidence confirming the hypothesis [3] that this phenomenon is due to the avalanche-like onset of off-diagonal dipole-exchange interactions, fueled by blackbody transitions. Using several time-resolved spectroscopic methods in a neatly controlled ensemble of ultracold Rydberg atoms held in a 3D optical lattice, we present the first dynamical description of this highly-correlated, many-body avalanche dephasing process. We also present ways to mitigate the decoherence in the context of current experiments, which should be immediately useful to the community. Finally, we argue that the avalanche process is an instance of interesting highly-correlated many-body excitation growth, which should also be studied for its own sake.

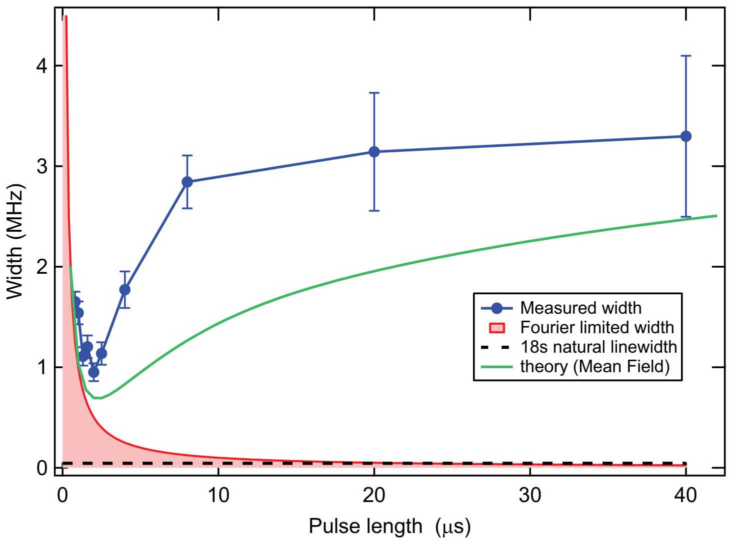

Figure 1. Observed broadening (blue) vs. excitation time. Fast excitations hinder the buildup of opposite-parity states: the dephasing is reduced. The natural linewidth (dashed line) cannot be recovered due to Fourier broadening (red). Mean-field approaches (green) are slower than the experiment, showing the high degree of correlations.

[1] M. Saffman, J. Phys. B **49**, 202001 (2016).
[2] J.A. Aman *et al.*, PRA **93.4**, 043425 (2016).
[3] E.A. Goldschmidt *et al.*, PRL **116**, 113001 (2016)