Spreading of information in out-of-equilibrium quantum systems with variable-range interactions

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We review our recent work on the spreading of information in out-of-equilibrium quantum systems with short- and long-range interactions. In these systems, the propagation of any quantum signal is bounded by so-called Lieb-Robinson bounds. It creates a causality cone, which is ballistic for short range interactions and super-ballistic for long-range interactions. Recently, bounded propagation of correlations has been reported for ultracold atomic gases in optical lattices and quantum simulators of lattice spin systems based on artificial ion traps. The latter show significant deviations from expectation based on the Lieb-Robinson bounds.

We show that the causality cone features a double structure whose scaling laws can be related to a set of universal microscopic exponents that we determine. When the system supports excitations with a bounded group velocity, we find that the correlation edge moves ballistically, with a velocity equal to twice the maximum group velocity, while the dominant correlation maxima propagate with a different velocity that we derive. When the maximum group velocity diverges, as realizable with long-range interactions, we show that the correlation edge has a slower-than-ballistic motion. The motion of the maxima is, instead, either faster-than-ballistic, for gapless systems, or ballistic, for gapped systems. Our results have fundamental consequences on information spreading in correlated quantum systems and shed new light on existing experimental and numerical observations, for which our analysis provides a unified picture.

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