Universal Prethermal Dynamics in Quantum Magnets and Fracton Fluids

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Describing the emergence of universality in far-from-equilibrium regimes of many-body quantum systems is a current frontier in physics. One key challenge in non-equilibrium regimes is that the system can explore a large fraction of phase space, therefore identifying relevant degrees of freedom across many length and energy scales is challenging. In these lectures I will focus on isolated many-body systems that are initially quenched from an initial excited states and describe how universality can emerge in an intermediate-time but long-lived prethermal regime. Our main goal will be to identify the relevant degrees of freedom and compute the universal scaling exponents in the prethermal regime, with a special focus on magnetic spin systems and `fractonic' fluids.

In the first lecture, I will set the stage by reviewing the universal non-equilibrium dynamics of weakly-interacting bose gases, which have been extensively studied both theoretically and experimentally. We will begin the discussion by identifying all the possible excitations that may exist at different energy densities. Using kinetic theory for weakly-interacting particles, we will discuss the non-thermal solution associated to wave-turbulence and compute the universal scaling exponents. We will end the lecture by providing a holistic picture of thermalization in bosonic gases.

In the second lecture, we will add an additional layer of complexity by considering spin models with a global SU(2) symmetry. We will find the effective theory describing excitations at intermediate energy scales and derive a kinetic model for such excitations. I will show that, in the special case of d=2, the systems exhibits unusually slow thermalization due to the existence of slow modes with quasi-long-range character, giving rise to rise to a universal self-similar regime with anomalous scaling exponents.

In the third lecture, we will discuss `fractonic' models which contain kinematic constraints, such as dipole moment conservation. We will use a hydrodynamic approach to study dynamics close to the thermal state, and consider cases with and without momentum conservation. For momentum-conserving fracton fluids, we will find that the hydrodynamic description is intrinsically unstable and leads to a higher-dimensional analogue of the Kardar-Parisi-Zhang (KPZ) universality class.