From inverse-cascade to sub-diffusive dynamic scaling in driven disordered Bose fluids

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Understanding the many-body dynamics of a quantum system following a quench is a fundamental challenge in physics. In this context, quantum gases quenched across a phase transition are particularly intriguing, as they exhibit a phenomenon known as "dynamic scaling" [1,2]. This refers to a self-similar evolution of correlation functions, characterized by dynamical exponents believed to be universal and with no counterpart in equilibrium statistical physics. This phenomenology is compelling, as it seems to extend the concept of universality class to quantum many-body systems far from equilibrium.

To delve deeper into this phenomenon and explore its universality against perturbations, I will discuss the dynamics of a 3D Bose gas quenched across the condensation transition, in the presence of both a spatial disorder and a periodic driving force. For vanishing drive and disorder, the dynamics exhibits an inverse particle cascade, characterized by universal dynamic scaling laws and exponents. Conversely, without interactions the interplay between drive and disorder leads to a novel form of sub-diffusive random walk in energy space—an effect recently observed experimentally [3].

Using a quantum kinetic framework, we have investigated the interplay between the sub-diffusive random walk and the inverse cascade under the simultaneous influence of drive, disorder and interactions [4]. I will show that this competition leads to three distinct dynamic regimes (figure 1): (i) an inverse cascade dominated by interactions overpowering the drive, (ii) a stationary phase where the sub-diffusive random walk and the inverse cascade reach a balance, and (iii) a sub-diffusive random-walk in energy space primarily governed by disorder and drive. I will show that these regimes can all be described by self-similar scaling laws, and discuss their universal properties [4].

References

[1] I. Chantesana et al., Phys. Rev. A, **99** (2019) 043620
[2] J.A.P. Glidden et al., Nature phys., **17** (2021) 457
[3] G. Martirosyan et al., Phys. Rev. Lett., **132** (2024) 113401
[4] E. Gliott et al., Phys. Rev. Lett., **133** (2024) 233403

Figure

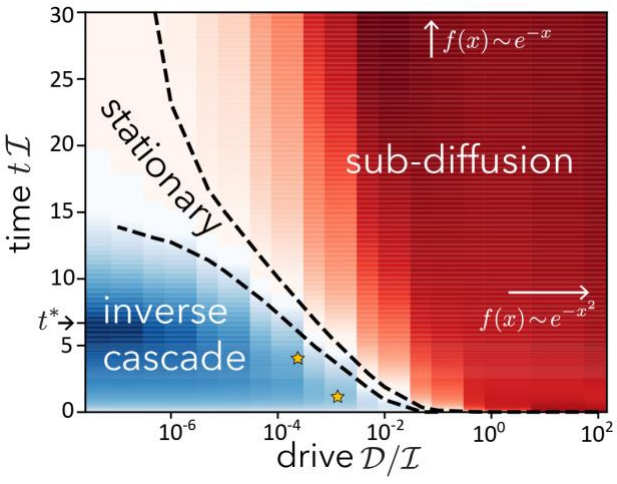

Figure 1: Dynamic phase diagram of a 3D Bose gas quenched across the BEC transition, under the combined action of interactions, periodic drive and spatial disorder (from [4]).