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Holographic Scaling and Dynamical Gauge Effects in Disordered Atomic Gases[1]

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Quantum systems with strong disorder, and those far from equilibrium or interacting with a thermal reservior, present unique challenges in a range of physical contexts, from non-relativistic condensed-matter settings, such as in study of localization phenomena, to relativistic cosmology and the study of fundamental interactions. Recently, two related concepts, that of the entropy of entanglement, and the controversial suggestion of entropic emergent gravity, have shed insight on several long-standing questions along these lines, suggesting that strongly disordered systems with causal barriers (either relativistic or those with Lieb-Robinson-like bounds) can be understood using holographic principles in combination with the equivalence between quantum vacuua thermal baths via the Unruh effect. I will discuss a range of experiments performed within a strong, topologically disordered medium for neutral atoms which simultaneously introduces quenched disorder for spin and mass transport, and provides simple mechanisms for open coupling to various types of dissipative baths. Under conditions in which a subset of quantum states are continuously decoupled from the thermal bath, dark state effects lead to slow light phenomena mimicking gravitational lensing in general relativity in a characterizable table-top disordered medium. Non-equilibrium steady-states are observed in direct analogy with the evaporation of gravitational singularities, and we observe scaling behaviors that can be directly connected to holographic measures of the information contained in disorder. Finally, I will show how a dynamic-gauge-field picture of this and similar systems can lead to a natural description of non-equilibrium and disordered phenomena, and how it provides some advantages over the Harris and Luck criteria for describing critical phenomena. Connections between out-of-equilibrium dynamics and some long-unresolved issues concerning the existence of a gauge-boson mass gap in certain Yang-Mills models will also be discussed, as will dynamic gauge effects in experimental many-body systems.

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