Strong correlations from two complementary approaches: Gravity and randomness

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**ABSTRACT**

In condensed matter physics, strongly correlated systems remain a central challenge and exhibit emergent phenomena such as unconventional superconductivity, Mott insulating behavior, and the fractional quantum Hall effect (FQHE). Furthermore, it is widely regarded that interaction effects are particularly important in flat band systems, heavy fermion compounds, and strange metals. Conventional approaches—such as band theory, perturbative quantum field theory (QFT), and Fermi liquid theory—typically assume weak coupling, and fail to capture non-perturbative strong correlation effects. While numerical approaches—like quantum Monte Carlo (QMC) and density matrix renormalization group (DMRG)—are powerful, they are computationally expensive and limited by system size, and they often provide a "black box" result without offering analytic insight into the underlying mechanism. Thus, we need rigorous non-perturbative effective theories. In this talk, I will introduce two theoretical frameworks to tackle these problems. One is "bottom-up holography" that captures strong correlations via gravitational duals. The other is the "G–Σ formalism" that is a rigorous saddlepoint approximation of an effective field theory written in terms of auxiliary bi-local fields.