Applications of AdS/CFT to strongly correlated matter: from numerics to experiments

Chagnet, N.

Summary

By their very nature, strongly coupled systems are both some of the most interesting while simultaneously being some of the least understood systems in physics. Without the help of perturbation theory and other common tools, physicists have had to be creative in order to probe and learn more about strongly coupled systems. To that end, the AdS/CFT correspondence, which is at the heart of this thesis, has shown tremendous promise and success in helping elucidate the physics of various systems such as the quark gluon plasma or strongly correlated electronic metals found for instance in cuprate high-T_c superconductors.

This thesis brings about new numerical insights on this type of system in chapter 2, using complex black hole models and high-performance computing. The results of such simulations demonstrate a rich variety of behaviors; the black holes with a spatially undulating horizon are shown to behave like a relativistic fluid in a periodic potential for which a universal effective hydrodynamic theory is presented in chapter 3. The extent to which this model can explain the transport properties of such strongly-coupled system dual to these black holes is an indicator that electrons in cuprates might behave more like a fluid than like billiard balls in a traditional metal. Such black hole models require extreme care and analysis in order to be properly defined as we discuss in chapter 4.

As a general mathematical duality, AdS/CFT can be applied to a wide range of theories and models. Among the most intriguing questions it can help answer, the problem of finding a configuration of fermions in a stable gravitational and electromagnetic potential in AdS space has remained elusive for the better part of a decade. In chapter 5, we improve on the previous models and make some significant progress towards a final resolution to this question. Another recent burning question has been to understand the entanglement patterns of such strongly coupled systems, as it has been theorized that measuring their long-range entanglement properties could be a meaningful probe of their unique physics. One such measure which has garnered a lot of interest is complexity, a continuum generalization of the ubiquitous computer science notion. In chapter 6, we expand on the proper definition of such notion for conformal field theories and bring about a direct connection to the geometry of the dual Anti-de Sitter spacetime.

The common theme between these results is the predictive power of seemingly unrelated computations of gravitational solutions when interpreted through the lens of a dual lower-dimensional strongly coupled quantum system. These *holographic* theories provide generic examples of computationally tractable strongly-interacting systems which are otherwise unreachable with conventional methods.