ABSTRACT

According to the AdS/CFT correspondence (holographic principle), certain classes of strongly coupled systems can be related to the weakly coupled theory of gravity. Although the microscopic theory of such systems is not always well understood, their macroscopic properties are well captured by some effective theories in the low-energy or long-wavelength limit. In this thesis, we attempt to understand the entanglement structure of specific states in such systems by computing the holographic entanglement entropy (HEE). For our analysis, we consider a relativistic hydrodynamic theory and a superconducting phase transition in a holographic setup.

We examine the behaviour of the HEE in near-equilibrium thermal states that are macroscopically described by some specific conformal relativistic hydrodynamic flows, which are dual to fluctuating AdS black brane via the fluid/gravity map. We consider two specific fluid configurations for our computation. Firstly, we explore the behaviour of the HEE and the holographic mutual information (MI) for a stationary fluid moving with a constant velocity in $d = 2, 3$, and 4 dimensions. We observe that the UV regulated HEE increases with the fluid velocity and tends to diverge as the velocity approaches its relativistic upper bound. Also, the MI vanishes at a critical velocity even when the separation between two subsystems is less than the critical value. Secondly, for the fluctuating fluid configuration, we analyse the HEE in the presence of a sound mode and observe intriguing features as it evolves towards equilibrium. Specifically, in $d = 4$, we encounter an additional UV divergence that is sub-leading to the 'area law', and it is controlled by dissipation.

Furthermore, we study the HEE of a holographic superconductor across its phase transition, which is dual to a charged hairy AdS black brane. We propose a novel mechanism for such superconductors, where the superconducting phase is obtained by forcing the condensation of a charged scalar through the source of an interacting uncharged scalar field. In this setup, we observe that the change in HEE near the phase transition follows a scaling law similar to the order parameter but with a different critical exponent.

Keywords: AdS/CFT correspondence, Gauge/Gravity duality, Holographic Entanglement Entropy, Relativistic Hydrodynamics, Fluid/Gravity correspondence, Holographic Superconductor, Holography and Condensed Matter Physics (AdS/CMT)