Current Progress

Background

Recent progress on higher dimensional black holes reveals the existence of a vast number of black hole phases, different from the four dimensional gravity. In D = 5, there found many explicit solutions with various horizon topologies, i.e. Myers-Perry black holes, black rings, black Saturns, etc. The discovery of these solutions greatly owes to the solution generating technique specific to D = 5 stationary spacetime. On the other hand, in D > 5, the only known explicit solutions for the vacuum Einstein gravity are Myers-Perry solutions which have the sphere topology. Due to the difficulty in directly solving the Einstein equation with less symmetries, the approximation techniques should be used.

Large D limit of General Relativity

Currently, my research goal is investigating **the Large D limit of General Relativity.** Recent works initiating from the paper by me and collaborators reveal that this limit is a powerful analytical approaches to reformulate the black hole dynamics in a simplified form.

(i) Black hole Dynamics at Large D

- **Linear Analysis**
  Firstly, I and collaborators started from the linear analysis of higher dimensional black holes. Through the studies on the linear properties of various black holes/branes, such as (in)stability, quasi-normal mode (QNM), we identified several key elements of black hole dynamics in the large D limit. In particular, the decoupling of the near-horizon dynamics from the asymptotic region greatly simplifies the perturbation equation, and therefore admits the analytical treatment. The analytic formulas for dispersions for various black holes obtained in the inverse dimension expansion. Including higher order corrections, the formulas reproduce the numerical results well up to the relevant order of 1/D expansion.
- **Large D Effective Theory**
  The large D limit remains to be a good approximation also in the non-linear regime in the General Relativity. The key feature is that, at the large D limit, the near horizon dynamics are decoupled from the far region if the variation along the horizon is not so large as O(D), which makes the near horizon spacetime varies dominantly in the radial direction. Due to this gradient hierarchy, the radial dependence can be integrated out in advance, and therefore the remaining equation reduces to the effective membrane equation for the collective degrees of freedom on the horizon, which has one less inhomogeneity than the original system. Solving the effective equation for the horizon membrane, I and collaborators studied the analytic properties of several non-uniform solutions, such as
  - Phase diagram, critical dimension for non-uniform black strings (NUBS)
  - NUBS as the end point of the Gregory-Laflamme instability of uniform Strings at the large D

(ii) Topology-changing solution at Large D

Above Large D Effective theory approach breaks down when the horizon has the large variation of O(D) along the horizon. The critical solution between two solution families with different horizon topologies is the typical example, in which the spacetime is expected to have the conical waist close to the pinching point. With a nonconventional scaling limit, the large D limit leads to the Ricci flow, which describes the topology-change of the horizon at the large D.
For the black hole/string transition in the Kaluza-Klein spacetime, the known Ricci flow solution (King-Rosenau) leads to the closed form formula for the topology-changing spacetime.