Current Progress

Background

Recent progress on higher dimensional black holes reveals there is a vast number of black hole phases, surprisingly 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 black hole horizons admit a simple universal structure in this limit. This has allowed us to develop new powerful analytical approaches to reformulate and solve black hole dynamics in a novel perturbative expansion.

(i) Large D analysis of the linear dynamics of black holes

Firstly, I and collaborators started from the linear analysis of higher dimensional black holes. 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 quasi-normal modes (QNM) are one of the basic properties of the black hole. I and collaborators studied the QNM of several higher dimensional black holes. Especially, we studied:

- Instability of black strings (Gregory-Laflamme instability)
- Instability of rotating black holes (i.e. Myers-Perry black holes)
- Quasi-local modes of (A)dS Schwarzschild black holes

We obtained the analytic formulas of dispersions for each black holes written in the inverse dimension expansion. Including higher order corrections, the formulas reproduce the numerical results well up to the relevant order of 1/D.

(ii) Black hole dynamics in the large D limit

Our works revealed that the large D limit is a good approximation not only for the linear order analysis, but also for the nonlinear analysis of the Einstein equation. For this, we used our discovery that, in 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 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. By studying the effective equation for the horizon membrane, I and collaborators studied the analytic form of several non-uniform solutions.

Especially, we studied:

- Phase diagram and critical dimension for the non-uniform black string (NUBS)
- Dynamical evolution of the NUBS. NUBS is shown to be the end point of the Gregory-Laflamme instability in the large D limit
- Dynamics of charged black holes