

Current Progress

Background

Recent progress on higher dimensional black holes reveals there are a vast number of black hole phases, unexpected from the four dimensional spacetime. In $D = 5$, there found various explicit solutions as Myers-Perry black holes, black rings, black saturns, etc. for now. The discovery of these solutions greatly owes to the solution generating techniques which were only found for $D = 5$ stationary spacetime. On the other hand, in $D > 5$, the only known explicit solutions are Myers-Perry solutions. Since it is difficult to directly solve the Einstein equation and obtain an explicit solution with less symmetries, some approximation techniques should help us.

Large D Limit of General Relativity

In some gravitational phenomenon in higher dimensions, it is known that there exists a certain limit when we take the *dimension* D sufficiently large. I and collaborators have studied this large D limit in more detail and formulated the large D expansion method in more generic way.

Large D analysis of the linear dynamics of black holes

The quasi-normal modes (QNM) are one of the basic property of the black hole. I and collaborators studied the QNM of several higher dimensional black holes. In the large D limit, the perturbation equation is simplified and therefore admits the analytical treatment. Especially, we studied:

- Instability of black strings (Gregory-Laflamme instability)
- Instability of rotating black holes (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 $1/D$.

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 nonlinear analysis of the Einstein equation. In the large D limit, the near horizon dynamics and the dynamics in the region decouples 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 and the gradient in other directions can be ignored, and therefore the equation decouples into the radial part and the others. After the radial dependence is solved, the remaining equations reduce to the differential equation with one less inhomogeneity, which makes the analysis of the non-uniform solution easier. The black hole horizon act as a hypothetical 'membrane' which follows its effective equation of motion in the large D limit. By studying the effective equation for the horizon membrane, I and collaborators studied the analytic form of several non-uniform solutions. We could show the critical dimension in the non-uniform black string (NUBS) analytically.

Studying the evolution of the effective equation, we showed that NUBS is dynamically stable and it is actually the end point of the Gregory-Laflamme instability in the large D limit.