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.

Current Achievements

I have studied on **the large D limit** of General Relativity, to elucidate the theoretical aspects of black holes in higher dimensions**.** Recent works initiating from the paper by I and collaborators reveal that this limit allows drastic simplifications of the Einstein's equation.

(i) Large D Effective Theory

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 $\mathcal{O}(D)$, 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, the analytic properties of various black hole solutions are studied.

Blob approximation

The nonlinear dynamics of black holes have the small length scale of $\mathcal{O}(1/\sqrt{D})$, which cannot be captured within the leading order effective theory on the compact horizon. Instead, by scaling up around the rotating axis by $\sqrt{D}$, those compact solutions can be studied as Gaussian 'blobs' in the black brane setup in exchange for the global geometry. Using the blob approximation, we studied various deformed solutions such as black bars, ripples, dumbbells and flowers. We also studied the blob-blob collision to understand the black hole collision in higher dimensions.

(ii) Topology-changing solution at Large D

Above Large D Effective theory approach breaks down when the horizon has the large variation of $\mathcal{O}(D)$ along the horizon. The critical solution between two solution families with different horizon topologies is a typical example, in which the spacetime is expected to have the conical waist close to the pinching point. However, the entire spacetime solution around the critical phase has been a long-standing puzzle. 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, a known Ricci flow solution (King-Rosenau) turns out to give the closed form formula for the topology-changing spacetime.