Research Plan

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We plan to investigate how the presence or absence of spacetime singularities alters the physical properties of black holes and cosmological evolution based on quasi-topological gravity. Quasi-topological gravity is an extension of general relativity that can naturally admit regular black holes as exact solutions, and has therefore attracted considerable attention in recent years. Our research program consists of two tightly connected directions:

(A) Quasi-topological gravity, regular black holes, and inflationary cosmology

Within general relativity, the standard cosmological picture traces the origin of the Universe back to the Big Bang singularity. In addition, a period of early-time accelerated expansion (inflation) is widely regarded as essential for reconciling the observed homogeneity, isotropy, and near scale-invariant primordial fluctuations with causal microphysics. In conventional model building, inflation is typically implemented by introducing an *ad hoc* scalar degree of freedom (the inflaton). This approach, however, often relies on nontrivial tuning of the inflaton potential, and the underlying field has not been directly identified observationally.

Our group has shown that, in quasi-topological gravity, the Big Bang singularity can be resolved through higher-curvature effects associated with regular black hole, and that an inflationary phase can arise *without* introducing an inflaton (manuscript in preparation). Building on this result, we will (i) derive robust predictions for cosmological observables within this framework, and (ii) quantify their departures from the standard cosmological model. This project is a collaboration with Riko Yoshimoto (Nagoya University) and Pablo Cano (University of Murcia).

(B) Dynamical formation and evaporation of regular black holes

As emphasized in the research background, black holes are expected to evaporate via Hawking radiation, yet the end state of evaporation remains an open problem. To address this question in a singularity-free setting, it is crucial to construct a coherent description that covers the entire evolution from formation to evaporation. We will therefore study dynamical spacetimes in which a regular black hole forms from the gravitational collapse of a scalar field and subsequently evaporates, aiming to characterize the possible endpoints of regular black hole evaporation within quasi-topological gravity.

Moreover, by combining these dynamical constructions with the global structure analysis developed in our previous work [2], we will determine the corresponding Penrose diagrams and investigate key spacetime properties—such as causal structure and (un)predictability. This project is also a collaboration with Pablo Cano (University of Murcia).