ABSTRACT

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Thesis Title: "Behaviour of Particles in Closed Timelike Orbits and Massive Gravity Wormholes"

Einstein's General Relativity comes with a disturbing yet fascinating time reversal pathology in the form of closed timelike curves (CTCs), which create challenges for the initial value Cauchy problem. These paths violate chronology, disrupting determinism, distinct from curvature singularities which disrupt physical laws. Despite attempts to eliminate CTCs through quantum theories and modified spacetime models, their full resolution remains elusive. While research in this area is more than half a century old, there are still missing ingredients to accommodate a concise description to effectively address this phenomenon, such as the properties of particles that may traverse these curves, limitations of backward time jumps, and the effect of spacetime horizons, among others. In this thesis, a number of these properties are addressed, particularly the formation of closed timelike curves and closed timelike geodesics (CTGs) in terms of zero and non-zero angular momentum of particles are explored within axisymmetric spacetime solutions. These particles are mainly considered to be neutral; however, for the Kerr-Newman spacetime with a charged source, particles with varying charge are also taken into account. The constructive analysis of spacetime diagrams for geodesic motion provides the geodesic confinements, which are applied to estimate the nature of particles, the role of confinement radius and the effect of horizons in the CTCs, along with the expression of backward time jump in CTGs.

Wormhole, on the other hand, is another phenomenological outcome of GR that offers hypothetical shortcuts through spacetime, enabling travel between distant regions or even different universes. It is potentially capable of violating causality by acting as a CTC when the special relativistic Twin paradox is applied on it. To extensively connect the CTCs with wormholes, the geodesic motion of particles and their visualization in wormhole embedding are presented, which create the possibility of CTG formation in the asymptotic geometries of either side of wormhole's throat. Since the recent discovery of the supermassive black hole shadow and the direct detection of gravitational waves, considerable attention has been focused on detecting other exotic objects and objects that may mimic black holes, thereby enhancing the importance of wormholes. Simultaneously, investigations conducted by LIGO-VIRGO have placed potential limitations on the graviton mass, further increasing the significance of the massive gravity theory. Thus, the formation of static and evolving wormholes in dRGT massive gravity has been explored, revealing the presence of a repulsive gravity effect potentially induced by massive gravitons. Subsequently, under these circumstances, hydrostatic stability analysis of wormhole formation is also conducted. Moreover, traversable wormholes require the presence of exotic matter at the throat to keep them open for traversability. In recent times, several studies have delved into non-exotic matter wormholes. Therefore, a thorough examination has been proposed to investigate traversability and the nature of matter contents at the throat, suggesting a significant possibility of non-exotic matter wormholes in massive gravity, with some evolving from non-exotic to exotic matter.

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