Geometric optical knots as sources of gravitational fields

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We propose a new perspective in which gravitational fields arise not from conventional matter-energy sources, but from topologically structured configurations of light. In this preliminary investigation, we consider the possibility that optical knots—topologically nontrivial ray configurations—can induce curvature in space-time in a manner analogous to how energy-momentum sources enter Einstein's field equations. Drawing inspiration from knotted electromagnetic fields such as Hopfions, and guided by insights from Abelian Chern–Simons theory in (2+1) dimensions, we outline a research program aimed at understanding whether knotted ray bundles may serve as effective sources of gravity. While no detailed model is presented here, we motivate the idea that the gravitational field might not be fundamental, but rather a topological byproduct of self-organized light configurations.

Keywords: *geometrical optic, knot, gravitational field.*

The classical theory of gravitation, as encoded in Einstein's general relativity, describes gravity as the curvature of space-time induced by the presence of mass and energy. In this framework, light rays follow null geodesics shaped by the geometry of space-time. However, the theory itself does not explain the origin of this curvature — it assumes the geometry is shaped by matter fields through the Einstein field equations. General relativity explains how space-time curvature arises when energy and momentum are present, but it does not explain why energy and momentum should produce curvature in the first place.

In contrast, recent developments in topological field theory and knot theory, particularly in electromagnetism and fluid dynamics, suggest that topological structures in field configurations may play a more fundamental role in shaping physical phenomena. For instance, in electromagnetic theory, Ranada and others have constructed stable, finite-energy solutions in vacuum — such as Hopfions — whose field lines are knotted and linked, yet free of sources. The phrase "free of sources" means that the field solution does not originate from external charges or currents — in other words: the field arises not from conventional sources such as electric charge, mass, or current, but purely from the internal structure of the field itself.

This raises a provocative question: could space-time curvature, and therefore gravity itself, emerge from the topological properties of light rather than from mass-energy?

In this preliminary work, we explore the idea that geometric optical knots — that is, ray trajectories in the eikonal approximation that form closed, topologically nontrivial structures — may act as effective sources of gravity. Unlike standard matter fields, these knots do not require mass but instead carry energy and topological invariants, potentially enough to influence or define curvature.

The guiding insight is to reinterpret gravitational interaction not as a fundamental force, but as a manifestation of complex topological configurations in the underlying field content, specifically light. From this viewpoint, the bending of light is not caused by gravity — it is gravity. In other words, topological behaviour of light — especially in the form of knotted, self-entangled rays — is not the consequence of gravity, but the very mechanism that gives rise to what we perceive as gravitational interaction. The bending of light is not merely an effect of gravity — rather, it is the very manifestation of gravity itself.

This inversion of perspective motivates an inquiry into the role of light's geometry, not just as a probe of space-time, but as a generator of its structure. Though speculative at this stage, this viewpoint suggests an intriguing path toward unifying optics, topology, and geometry in a new gravitational paradigm.

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