f(R) gravity with spacetime torsion

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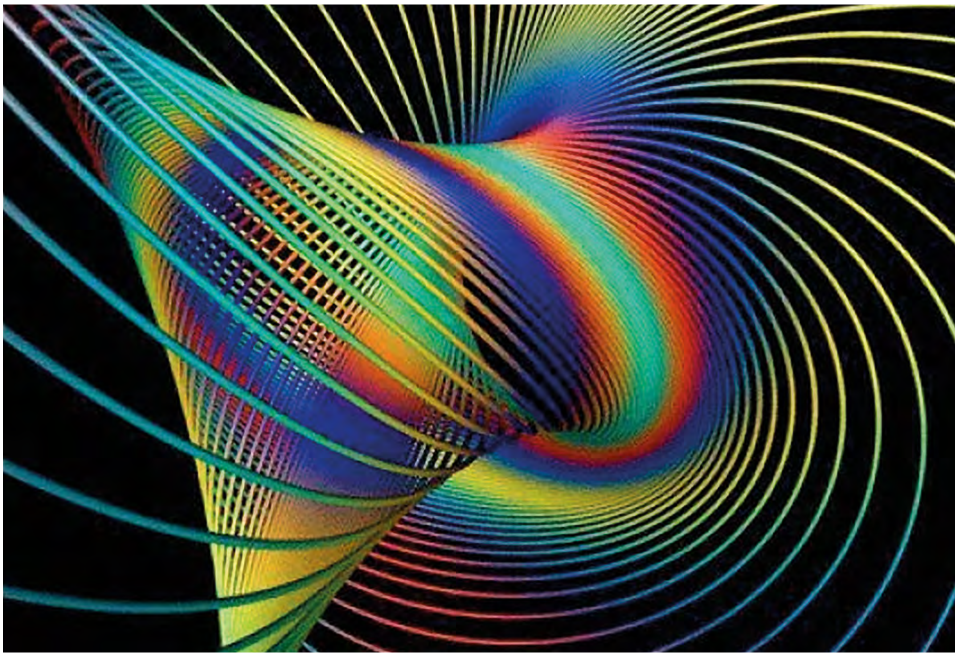
Despite a huge success of Einstein's General theory of Relativity, it has various limitations and there have been many modifications beyond Einstein's gravity to obtain a satisfactory resolution to these limitations.

One of the modified gravity theories is f(R) theory of gravity which is a higher curvature gravity theory. In f(R) theory we consider the action to be nonlinear in R which was considered linear in R in the usual Einstein Hilbert action (this action helps us to obtain Einstein eqn. which relates spacetime curvature to matter and energy). The f(R) gravity theory earned the most attention in the arena of higher-curvature gravitational theories, as the f(R) theory can naturally unify the early inflationary phase of the universe with the dark energy era. When we write f(R) action in Jordan frame one can obtain an action which contains a scalar tensor theory where scalar field appears with a potential that depends upon the f(R) taken under consideration. This implies that the degrees of freedom that we added in terms of higher powers of R in f(R) are being mapped into a scalar field with a potential. Now, if we include spacetime torsion in this action and again try to obtain the f(R) action in Jordan frame we may see some new kind of interaction between the scalar field and the tensor field. Torsion is the antisymmetric part of the affine connection. Spacetime torsion is a hypothetical property of spacetime that suggests it might not just bend and warp, but also twist(as depicted in the figure 1). While it's a complex concept, it offers intriguing possibilities for understanding the universe at its most fundamental level. In this work we obtain the f(R) action including spacetime torsion in Jordan frame to analyze where the additional degrees of freedom added in terms of torsion tensor go. In the resulting action the higher degrees of freedom manifest itself as a scalar field which couples with the massless antisymmetric tensor field (or equivalently, with the torsion field) through derivative kind of coupling. Furthermore, such interaction between the scalar and the torsion fields comes with a derivative coupling, and thus introduces a momentum-dependent interaction vertex factor—which may have interesting phenomenological implications both in cosmology as well as in particle physics. To particularly show the cosmological implications we have found the Friedmann equations in this scenario. From these equations it can be noticed that the during the end of the inflationary period this coupling term become significant as the scalar field gains acceleration. In particular it can be anticipated through the results that the antisymmetric term produces the deceleration effect which is proportional to the square of its derivative. Also during the reheating, the scalar field decays to other forms of matter fields through its couplings. Due to presence of such coupling terms, there is a resultant production of the massless antisymmetric tensor field along with the radiation fluid from the scalar field energy density. Such a cosmological era should have interesting effects on the propagation of primordial GWs and even on the dark matter scenario where the antisymmetric field may act as the dark matter candidate. The detailed studies of such possibilities will be studied in some future work. ■



▲ Torsion Field: Einsein's Metric Torsion Tensor allows a spin-field to twist spacetime.

References

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