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Research Results

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My research interests are in gravitation, as related to string theory and supergravity. Much of my research has focused especially on higher-dimensional black holes, because the theories imply the existence of extra dimensions and motivate us to study gravity in a wider higher-dimesional framework. Meanwhile, the study of higher-dimensional black holes provides not only applications to important subjects, but valuable insights into the nature of the theory. For instance, four-dimensional black holes are known to possess a number of remarkable features, such as uniqueness, spherical topology, dynamical stability, and the laws of black hole mechanics. Many exact solutions of higher-dimensional black holes have been recently discovered. For higher-dimensional black holes, nevertheless, a lot of open problems remain because of their complexity and many degrees of freedom.

Killing-Yano symmetry in the Kerr spacetime

Killing-Yano symmetry has been studied as a fundamental hidden symmetry which plays a crucial role in black hole spacetimes. In the Kerr spacetime, the Hamilton-Jacobi equation for geodesics can be solved by separation of variables. This means that there exists an forth constant of geodesic motion known as Carter's constant, apart from constants associated with two Killing vectors and the Hamiltonian. The Carter's constant is generated from a rank-2 conformal Killing-Yano (CKY) tensor and the corresponding symmetry is called Killing-Yano symmetry. It can be further demonstrated that the CKY tensor generates two isometries. In this way, for the Kerr spacetime all the symmetries necessary for complete integrability of the Hamilton-Jacobi equation for geodesics can be generated by the CKY tensor, namely, the existence of the Killing-Yano symmetry.

Separability structure

During the several years that followed, I studied the Killing-Yano symmetries of the Kerr-NUT-(A)dS spacetimes. I have demonstrated that the existence of a non-degenerate rank-2 closed conformal Killing-Yano tensor (primary CKY) guarantees complete integrability of the Hamilton-Jacobi equation for geodesics. This means that given a primary CKY in any spacetimes, one can produce mutually commuting constants of geodesic motion and independent of the dimension number (where non-degenerate means that all eigenvalues of the CKY tensor are functions). The Kerr-NUT-(A)dS spacetimes are examples having such a structure.

Classification of spacetimes admitting the Killing-Yano symmetry

After that, I found a relaxed non-degeneracy condition and classified spacetimes admitting a general, possibly degenerate, rank-2 closed CKY. I further have provided the explicit form of the metrics, which are Kaluza-Klein metrics on the bundle over Kähler-Einstein manifolds whose fibers are Kerr-NUT-(A)dS spacetimes. This result also shows that the Kerr-NUT-(A)dS metrics are the only vacuum solutions admitting a primary CKY. In this sense, I have provided a kind of uniqueness theorem of the Kerr-NUT-(A)dS spacetimes in higher-dimensions.

Generalization of Killing-Yano symmetry

I have studied an extension of Killing-Yano symmetry in the presence of skew symmetric torsion. I have demonstrated that, when the torsion is an arbitrary 3-form, one obtains various torsion anomalies and they break separability of field equations. However, in spacetimes where there is a natural 3-form obeying the appropriate field equations, these anomalies disappear and the concept of generalized Killing-Yano symmetry becomes very powerful. For example, I have demonstrated that the Kerr-Sen black hole spacetime of heterotic string theory and the five-dimensional minimal supergravity black hole spacetime possess a generalized closed CKY tensor.