Unification of Fundamental Forces of Nature by Modern String Theory

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We outline the key features of the Standard Model of particle physics comprising electromagnetic, strong, and weak forces. It represents a consistent and experimentally confirmed quantum field theory of these elementary interactions. On the other hand, in this concept gravitational forces still resist a consistent description as a quantum theory.

With regard to the latter, we focus on the key features of String Theory, which is a consistent quantum theory of extended objects – strings. We elucidate, how it can unify the established quantum field theories of elementary particles with quantum gravity. We review, how String Theory sheds light on important fundamental questions of theoretical physics, such as the quantum structure of black holes or the geometric background of the Standard Model. We highlight recent developments in the geometric domain of String Theory, where the string coupling constant can be large, i.e. the so-called F-theory. We outline the key geometric features of F-theory that lead to a consistent construction of the Standard Model with three families of quarks and leptons, as confirmed by collider experiments. We also highlight subsequent systematic explorations of the landscape of three-family Standard Models as well as future directions for studies of such constructions via machine learning algorithms.