Strings and string signatures

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INTRODUCTION

Neither the Standard Model (SM) nor the Minimal Supersymmetric Standard Model (MSSM) provide a general framework for all the interactions we know of, namely gravity cannot be described by a perturbative local quantum field theory. One candidate for such a unified framework is given by string theory, which turned out to be a finite quantum theory of gravity in ten respectively eleven dimensions.

Members of our group are involved with work in all the various directions in string theory. The research involves the questions of how the SM arises as a solution, how string theory can be tested at the LHC, whether the AdS/CFT correspondence helps to understand non-perturbative QCD and the strongly coupled regime of condensed matter systems and what kind of cosmological scenarios arise. Furthermore some basic and mathematical properties of superstring amplitudes as well as new non-commutative and non-associative structures of non-geometric closed string backgrounds have been explored. Finally, also the relation between strings and black holes within the scenario of large number of species and the so called black hole N-portrait have been investigated, whereas this research has been done in collaboration with Gia Dvali.

RECENT WORK

1. Universal String Signatures at the LHC: If the fundamental string mass scale is in the TeV range and the universal string coupling constant is small, string theory becomes testable at the LHC. More precisely in D-brane constructions the mass scale of fundamental strings can be as low as few TeV provided that space–time extends into large extra dimensions. We discuss the phenomenological aspects of this weakly coupled low mass string theory related to experimental searches for physics beyond the Standard Model at the LHC. In such D-brane constructions, the dominant contributions to full-fledged string amplitudes for all the common QCD parton subprocesses leading to dijets are completely independent of the details of compactification, and can be evaluated in a parameter-free manner. This fact leads to concrete predictions of string theory. In fact, the ATLAS and CMS collaborations were directly referring to our work in their publications on the search for new physics at the LHC.

In a series of paper we have also investigated the phenomenological properties with D-brane models with additional U(1) Z'-gauge bosons and also with additional Higgs fields, which are rather generic features for this class of string compactifications. Specifically, we have discussed the possible signatures of stringy Z'-gauge bosons at the Tevatron and at the LHC as well as their cosmological implications, and we discussed the vacuum stability of string models with extra Z'-gauge bosons and extra singlet Higgs fields in view of the recent LHC discovery of the SM Higgs particle and its mass.

2. New structures for non-geometric strings: String theory is expected to be a consistent theory of quantum gravity. Employing T-duality, it has become clear during the last years that also a non-geometric frame exists.

During the last years, we were following an intense research program on unraveling the nature and the mathematical structure of these non-geometric string theories. Being a new branch of the space of string theory compactifications, a clearer understanding might also lead to new developments in string phenomenology. Various questions were raised and consequently different approaches were followed.

By performing an explicit quantization with the respective boundary conditions, some indication was provided that not only open strings but also closed strings in a non-geometric background see a kind of non-commutative and even non-associative geometry.

As a second major field of activity, we were investigating whether one can formulate not only a compactified but already a ten-dimensional description of the physics of such non-geometric string theories. Here the frameworks of generalized geometry and double field theory are very useful.

Utilizing a field redefinition motivated via the Buscher rules of T-duality, a leading order ten-dimensional action was derived for non-vanishing Q- but vanishing R-flux. Employing double field theory, this was extended also to the case of non-vanishing R. Making explicit the winding coordinate dependence of ordinary diffeomorphisms, it was possible to write this action in terms of quantities familiar from differential geometry, like generalized connections and curvature tensors. Finally, brane solutions of the new ten-dimensional actions were constructed. These are called Q-branes resp. R-branes, as they are the microscopic sources for the non-geometric fluxes. Intersections of those branes lead to various 6-dimensional, supersymmetric, non-geometric backgrounds of the type IIA/B superstrings.

3. Strings, gravity, large species scenario and black holes: In collaboration with G.Dvali we addressed the question how string compactifications with D-branes are consistent with the black hole bound, which arises in any theory with number of particle species to which the black holes can evaporate. For the Kaluza-Klein particles, both longitudinal and transversal to the D- branes, it is relatively easy to see that the black hole bound is saturated, and the geometric relations can be understood in the language of species-counting. We next addressed the question of the black hole evaporation into the higher string states and discover, that contrary to the naive intuition, the exponentially growing number of Regge states does not preclude the existence of semi-classical black holes of sub-stringy size. Our analysis indicated that the effective number of string resonances to which such micro black holes evaporate is not exponentially large but is bounded by $N = 1/g_s^2$, which suggests the interpretation of the well-known relation between the Planck and string scales as the saturation of the black hole bound on the species number.

We revised within the the framework of the Black Holes Quantum N- Portrait the semi-classical black hole bound on the number of particle species $N_{species}$. We showed that unlike the bound on global charge, the bound on species survives in the quantum picture and gives rise to a new fundamental length-scale, $L_{species} = \sqrt{N_{species}} L_P$, beyond which the resolution of species identities is impossible. This scale sets the size of the lightest quantum black hole in the theory, called Planckion. A crucial difference between the gravitational and non-gravitational species emerges. For gravitational species, the lightest black holes are exactly at the scale of perturbative unitarity violation, which is a strong indication for self-UV-completion of gravity. However, non-gravitational species create a gap between the perturbative unitarity scale and the lightest black holes, which must be filled by some unitarity-restoring physics.