

# BRIEF RESEARCH STATEMENT

GEORGE MOUTSOPOULOS

## GENERAL

My research focuses on string theory and supergravity. String theory provides a consistent description of quantum gravity. Supergravity is a supersymmetric extension of gravity, whose solutions provide consistent backgrounds for the quantum propagation of strings. Supergravity theories exist in various dimensions and they are, more often than not, connected by a web of various dualities and reductions. The mother theory of all these is eleven-dimensional supergravity, an extremely simple theory. As simple as it is, imposing supersymmetry reveals a plethora of elegant geometric structure. The connection between supersymmetry and geometric structure is a recurrent theme in my research.

My PhD was focused in ten and eleven dimensions, but I have consistently visited four and three dimensions. My current focus is on three-dimensional supergravity. These theories have a very rigid structure. For instance, in the ungauged case, the bosonic field content of 3d supergravity is a metric and a classified set of non-linear sigma models coupled to gravity. Although the equations of motion seem daunting at first, imposing supersymmetry is enough to reduce them and indeed find many interesting solutions.

Another recurrent theme of my research is that of dualities. T-duality is a fascinating example of a string theory duality. T-duality is a duality between strings living on circles of reciprocal radii. This allows for exotic constructions called T-folds. As a rough example, imagine we bend a cylinder whose ends have radii  $R$  and  $1/R$  and then bind its ends. This construction seems impossible for particle mechanics, e.g. how do the pointlike particles jump over the discontinuity  $R \mapsto 1/R$ ? However, it makes sense in string theory as a CFT orbifold, certain aspects of which can also be studied in three-dimensional supergravity. The higher-dimension space is an object beyond ordinary differential geometry. It introduces a specific notion of stringy “non-geometry”.

The study of symmetry and the geometry of supersymmetry but also finding a framework to study non-geometry in string theory are the main ingredients that motivate my research. In my PhD, I worked on the Killing superalgebras in supergravity [1, 2], which are a supersymmetric extension of the Killing vector Lie algebras, and the framework of doubled geometry [3], which is a framework for studying T-folds. Since then I have worked in diverse topics of theoretical physics, from the role of the NUT charge in the 4d  $\mathcal{N} = 2$  electromagnetic charge algebra [4] to the unusual asymptotics of certain 3d spacetimes [5], see also [6, 7, 8, 9, 10].

## FUTURE PLANS

My recent work in Bogazici University [10, 11] classifies supersymmetric solutions to the maximal and half-maximal supergravity theories in three dimensions. The outcome is an important result in the study of this theory: supersymmetric solutions can be classified and indeed a huge class of solutions can be found in closed form. There are also a number of extensions to this work. One would like

to know if the methods used can be extended into the gauged 3d theories. This is particularly important in order to embed the solutions into interesting higher-dimensional geometries. Another extension is to study the global properties of the solutions. It is an extension particularly suitable for a first-year PhD student under my supervision. In particular, one would describe the non-trivial monodromies, which are then related to the non-geometric features of higher-dimensional spaces. Other extensions emanating from [10, 11] are also possible.

A different but related problem is the description of the effective braneworld theories that source T-fold backgrounds. There is a lot of progress in understanding the bulk spacetime description of T-folds. One doubles the dimension of spacetime and works in the so-called doubled field theory, while imposing a second class differential constraint on all fields. On the other hand, the braneworld theories that source the T-folds are much less studied. In Hannover University, I studied precisely these theories [9]. Our focus there was on the form of the action (dynamics) and the consistent definition of non-geometric charge, e.g. from the couplings in the action. However, our work did not, and was not, expected to show the duality structure covariantly. It is already known that the WZW couplings form representations of the T-duality group, but how one can incorporate this and the kinetic DBI action into the doubled field theory formulation, e.g. in the spirit of [3], is not known. Investigating how braneworld theories can manifest U-duality and T-duality symmetry is a project that complements the solutions of [10] and is a continuation of [9].

Recently, we have completed in Bogazici University a project on 3d (2,0)-supersymmetric solutions [12, 13]. At the same time, in collaboration with Bern University, we are nearing the completion of a linear analysis of 3d (1,1)-supersymmetric logarithmic/critical theories. As evidenced in this research statement, the study of string theory and supergravity is a very fruitful industry, but also an intriguing field with lots of elegant structures beckoning to have light shed on them. More generally, theoretical high energy physics and quantum gravity is a continuously evolving field with the noble raison d'être our universe's very existence. I find the field very motivating and much of my research has been planned by myself. Furthermore, I am very much interested and look forward to contributing to and supporting an intellectually stimulating academic environment, where such questions can be addressed.

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MATHEMATICS DEPARTMENT, SOUTH CAMPUS, BOGAZICI UNIVERSITY, ISTANBUL, TURKEY