Aspects of Type II Superstring Theory

Supersymmetric D-branes, T-duality, and Holographic Thermalization

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Abstract:
String theory contains the required elements to provide for a framework in which quantum gravity and quantum gauge theories can peacefully co-exist. In this sense, one can consider string theory as a candidate theory unifying all (known) fundamental interactions. In type II superstring theory, the (massless) oscillations of the closed strings account for the gravitational degrees of freedom, while the gauge interactions are linked to the presence of D-branes. D-branes are solitonic objects whose undulations can be described in terms of boundary conditions of open strings ending on the D-brane.

In a first line of research we study the geometric properties of D-branes wrapping subspaces on bihermitian or generalized Kähler geometries, by investigating the boundary conditions of an open string ending on the D-brane. By developing an $\mathcal{N} = 2$ boundary superspace formalism, the open string boundary conditions can be written in such a form that the geometric properties of D-branes on bihermitian geometries can be easily read off. We find that D-branes on generalized Kähler geometries can be characterized in terms of symplectic geometry (or Poisson geometry for the most generic cases). The classification and characteristics of the D-branes on generalized Kähler manifolds are closely related to the structures and symmetries present on the open string worldsheet.

An important and characteristic aspect of string theories is the equivalence between two seemingly different string theories through T-duality: a first string theory compactified on a circle of radius R contains the same physical information as a second string theory compactified on a circle of radius $1/R$. T-duality extends to compactifications on more general spaces, such as bihermitian manifolds. We formulate the procedures to dualize a D-brane on a generalized Kähler manifold and apply them to D-brane configurations constructed by hand such that we obtain more involved D-brane configurations. Using these methods (construction by hand and by T-duality) we find a variety of D-branes on four dimensional spaces which allow a bihermitian geometry (namely T^4, $T^2 \times D$, and $S^3 \times S^1$).

A second line of research studies the thermalization properties of strongly coupled field theories using the techniques of the gauge/gravity duality. According to the holographic dictionary (a corner stone of the gauge/gravity duality) we can compute nonlocal field theory probes (such as equal-time two-point functions, Wilson loops and the entanglement entropy) in a d dimensional strongly coupled gauge theory by determining the dual geometric objects (geodesics, minimal area surfaces and minimal volumes) in the $d+1$ dimensional gravity background. We present methods to assess the progress towards thermality in strongly coupled field theories brought far from thermal equilibrium by a sudden and homogeneous injection of energy. The methods consist in investigating the time evolution of the various nonlocal probes in a thermalizing strongly coupled field theory, by computing their geometric duals following the holographic dictionary. We observe that the UV momentum modes of two, three and four dimensional strongly coupled field theories (with a gravity dual) thermalize faster than the IR momentum modes, suggesting a top-down thermalization scenario. The thermalization rate of the entire system is set by the entanglement entropy (the 'slowest' probe), implying that thermalization occurs at the speed of light.