Holography, Generalized Geometry and Duality

Monday 6 May 2019 - Friday 17 May 2019

Mainz Institute for Theoretical Physics, Johannes Gutenberg University

Scientific Programme

One of the strongest evidence for the existence of superconformal field theories is the explicit construction of their gravity duals through the AdS/CFT or Gauge/Gravity correspondence. Following this lead, many studies have focused on trying to find a way to systematically describe families of CFTs by identifying the corresponding classes of gravity duals. Analyzing the most general kind of supersymmetric solutions in supergravity theories has thus been the focus of much of the research activity in gauge/gravity duality over the past years.

5d fixed point theories, being intrinsically strongly coupled, are particularly hard to study by field theoretical methods. For this reason they represent an archetypical example where to apply the latest holographic techniques. The same holds true for four-dimensional field theories that do not have a perturbative Lagrangian description, as well as for conformal field theories in lower number of dimensions. Indeed, a large number of these were discovered using holographic methods. Precise calculations gave values for the field theoretical observables (central charge and other correlation functions), that have subsequently been checked with newly developed field theoretical methods. This led to the need for a classification of backgrounds with an AdS-factor.

Comprehensive analysis of supersymmetric AdS solutions of supergravity have been carried out in different dimensions and for different AdS spaces. Particularly interesting are the AdS solutions arising from compactifications of (2,0) or (1,0) conformal field theories in six dimensions living on the worldvolume of M5-branes. These conformal theories are themselves only partially understood. Studying their compactifications to lower dimensions is another way to learn about their properties.

Numerous studies have addressed the classification of AdS solutions arising by compactifying (2,0) theories. Compactification on 2d Riemann surfaces produces interesting N=2 theories in four dimensions, known as class S theories. Analogous solutions with N=1 have also been extensively explored. Despite some recent important progress in this direction there is still a plethora of open questions, including the role of punctures on the Riemann surface and the relation to non-Abelian T-duality.

Under certain circumstances, many field theories constructed in this way are effectively described in terms of chains of unitary gauge groups that can be engineered in different NS5- Dp brane systems. In this way, a description of the exotic six-dimensional conformal field theories can be obtained in terms of more familiar four- dimensional theories. Similarly, some of the field theories that flow to interacting five dimensional fixed point theories also emerge from NS5-D5 brane, or (p,q) five-brane systems.

Another important spin-off stemming from these ideas is to understand the space of supersymmetric AdS3 and AdS2 vacua of string and M-theory arising from wrapped branes and describing holographically RG flows across dimensions. In the AdS3/CFT2 context supergravity and brane considerations suggest an enormous variety of two-dimensional (0,2) superconformal CFTs. Some information about these theories can be extracted from Holography but there are certainly many unexplored venues on the field theory side. The same holds true for AdS2 vacua in string and M-theory where the holographic correspondence is even less understood. What is clear in these classes of examples is the important role played by extremization principles. These are lower-dimensional analogs of the well-known a- maximization and F-maximization and their role and application in a holographic context still remains under-explored.

A geometrical understanding of supersymmetry is very helpful in looking for AdS solutions, sometimes going as far as classifying them. The spinorial parameters of supersymmetry define tensors and forms called G-structures. The differential constraints that they obey are typically easier to solve than the original spinorial equations. Often these equations simplify further if one formally

collects the G-structures as representations of a generalized Lorentz group, which extends the ordinary one by including T-duality symmetries characteristic of string theory and to some extent of its low-energy supergravity approximations. One can also include string theory S-duality properties in the formalism, leading in certain dimensions to representations of exceptional Lie groups. These generalized or exceptional formalisms are however more than a tool to find solutions; they often capture various properties of their CFT duals, leading to geometrical methods to compute central charges and conformal dimensions. Generalized geometry may also provide the natural language for a general geometrical formulation of extremization principles.
Various classification results in different dimensions have been achieved with this method. They have led to several large and explicit classes of solutions, like the recent $AdS_7 \times M_3$ metrics in massive IIA, dual to field theories engineered in NS5-Dp brane configurations. These higher-dimensional cases have been the focus of much attention recently. Indeed, field theories in $d > 4$ are hard to find with traditional methods; moreover, as previously mentioned, many interesting field theories in $d = 4$ and lower can be obtained by compactification of a higher-dimensional theory on different spaces.
String Theory duality symmetries have also been successfully used to generate new supergravity backgrounds. Non-Abelian T-duality, the extension of (Abelian) T-duality to non-Abelian isometries, is a transformation between world-sheet field theories known since the nineties. Its character of solution generating technique has recently been mathematically proven under certain assumptions. However, contrary to Abelian T-duality, the generated solution is not equivalent to the original solution, but represents new physics. This opens up an interesting new avenue for the study of new CFTs through Holography.

Indeed, non-Abelian T-duality has gained a lot of momentum in recent years as an important new tool to generate new backgrounds (and put them in the context of Holography). More standard approaches, such as generalized complex geometry and integrable BPS equations, have missed classes of solutions that have been reached through non-Abelian T-duality. This technique has produced, for instance, the first known analytic AdS_6 supersymmetric solution to Type IIB supergravity. This background is likely to describe the 5d fixed point theory arising from a given (p,q) 5-brane web. A more general classification of AdS_6 solutions to Type IIB supergravity using integrability of the reduced BPS equations has followed.

In the context of Holography interesting new backgrounds have been constructed with CFT duals arising in the low energy limit of NS5-Dp brane intersections. This points at an interesting relation between AdS non-Abelian T-duals and compactifications of M5-branes.

In summary, this proposal is to put together the recently developed ideas on various aspects of conformal field theories (with different amounts of supersymmetry and in different dimensions), together with experience on U-dualities, non-Abelian T-duality and geometrical methods in supergravity theories to attack long-standing problems: the definition of new conformal field theories, the explicit calculation of their observables and, breaking conformality, the application of these ideas to realistic physical systems.

To achieve this purpose, the aim of this scientific program is to gather leaders in these interconnected areas of gauge/gravity duality, generalized geometry, dualities and field theories in different dimensions to share and discuss recent progress and interconnections between these topics. By bringing together physicists working on these different areas, this program will create synergies, promote opportunities for collaboration and stimulate advances in the wide applications of Holography, Generalized Geometry and Dualities to the study of Quantum Field Theories.

The fertile environment of the Mainz Institute for Theoretical Physics will certainly contribute to make this a very profitable scientific program.

The main focus points to be explored in depth during the program will include:
New examples of Holography
Wrapped branes and Holography
Non-Abelian T-duality and Holography
5d fixed point theories and Holography
Non-geometric backgrounds, generalized geometry and beyond

The subjects of this proposal are of truly international significance with research being conducted by groups spanning the globe. Since the original conjecture, the holographic correspondence has developed into many different directions, and now finds applications to disparate domains of physics. The recent years have also seen a lot of exciting progress in more fundamental aspects of the correspondence, such as the discovery of infinite new classes of supersymmetric AdS6 and AdS7 solutions and their field theory duals, and the use of non-Abelian T-duality (and other duality transformations) to generate new supergravity solutions and study the respective dual field theories. It thus looks particularly timely that researchers working on such fundamental aspects meet and exchange ideas on the current status of the basic principles of Holography. This program gives a unique opportunity to bring together researchers of the highest caliber to work intensively on these topics.