# Mini-Symposium on String Theory and $M$-Theory

CHAIR: Michael R. Douglas

Duiliu-Emanuel Diaconescu
Jaume Gomis
Chris M. Hull
Albrecht Klemm
José M. F. Labastida
Marcos Mariño
Nikita Nekrasov
Christoph Schweigert
Angel M. Uranga

**Duiliu-Emanuel Diaconescu**
Institute for Advanced Study, Princeton
*K-theory from M-theory*
**Wednesday, 12.30 – 13.00, Room B**

I report on joint work with Gregory Moore and Edward Witten —"$E_8$ Gauge Theory, and a Derivation of $K$-Theory from $M$-Theory". It has become clear in recent years that type II string theories contain nonperturbative objects —called D-branes— which support gauge fields. From a more abstract point of view, D-brane charges are classified by $K$-theory classes of the space-time manifold $X$. Since D-branes are charged under Ramond-Ramond fields, E. Witten and then G. Moore and E. Witten proposed a $K$-theoretic interpretation of Ramond-Ramond fluxes themselves. This is more striking, as the RR fields are states in the perturbative closed string spectrum which a priori have no connection with vector bundles and $K$-theory. In the present work, we show that this proposal is consistent with $M$-theory. The main idea is a detailed comparison of the leading terms in the long distance partition function of $M$-theory and IIA string theory. The analysis relies heavily on index theory and homotopy theory techniques. It is found a precise agreement which confirms the internal consistency of $M$-theory, as well as the validity of the $K$-theoretic formalism in string theory.

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**Jaume Gomis**
Caltech University
*D-branes in nongeometric phases of string theory*
**Tuesday, 12.00 – 12.30, Room B**

Recent progress in string theory hinges upon our improved understanding of its nonperturbative states. The microscopic description of some of these states, called D-branes, is given in terms of space-time submanifolds where open strings end. This geometric description, even though it is very powerful, it is inadequate for generic points in the moduli space of solutions of string theory. Many solutions of string theory do not have a clear geometric description and a more algebraic approach to the classification of D-branes is required. Boundary conformal field theory and $K$-theory are the primary tools in such a classification effort. We describe the D-brane spectrum of solutions of string theory that at a particular point of moduli space correspond to a Calabi-Yau compactification and which at another point do not have a geometric description. We use mirror symmetry and conformal field theory techniques to compare the D-brane spectrum at these two points in moduli space and make connections using our results with the McKay correspondence and $K$-theory.

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**Chris M. Hull**
Queen Mary and Westfield, London
*String theory, duality and geometry*
**Tuesday, 11.30 – 12.00, Room B**

Recent developments in string theory and $M$-theory have profound implications for the nature of space and time at short distance scales and require new ideas in geometry to incorporate them. Some of these developments are surveyed and their implications discussed.

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**Albrecht Klemm**
Humboldt-Universität zu Berlin
*Mirror symmetry, topological strings and D2-branes*
**Thursday, 11.30 – 12.00, Room B**

Recent developments in the description of virtual fundamental classes on the moduli spaces of holomorphic maps into Calabi-Yau manifolds enable us to solve the topological A-model by localization techniques at all string loops. By mirror symmetry this solves the holomorphic ambiguity in the topological B-model. The interpretation in terms of D-branes gives a reformulation of the rational Gromov-Witten invariants in terms of integral invariants associated to a Lefshetz decomposition of the cohomology of D2-brane moduli spaces. The results are also relevant for computing the black hole entropy in 5d and the calculation of exact couplings in effective $N = 2$ theories in 4d.

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**José M. F. Labastida**
Universidad de Santiago de Compostela
*Knot invariants and Chern-Simons theory*
**Wednesday, 11.30 – 12.00, Room B**

A brief review of the development of Chern-Simons gauge theory since its relation to knot theory was discovered in 1988 is presented. The presentation is done guided by a dictionary which relates knot theory concepts to quantum field theory ones. From the basic objects in both contexts the quantities leading to knot and link invariants are introduced and analyzed. The quantum field theory approaches that have been developed to compute these quantities are reviewed. Perturbative approaches lead to Vassiliev or finite type invariants. Non-perturbative ones lead to polynomial or quantum group invariants. In addition, a brief a discussion on open problems and future developments is included.

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**Marcos Mariño**
Rutgers University
*Topological quantum field theory and four-manifolds*
**Wednesday, 12.00 – 12.30, Room B**

I review some recent results on four-manifold invariants which have been obtained in the context of topological quantum field theory. I focus on three different aspects: (a) the computation of correlation functions, which give explicit results for the Donaldson invariants of non-simply connected manifolds, and for generalizations of these invariants to the gauge group $SU(N)$; (b) compactifications to lower dimensions, and connections to three-manifold topology and to intersection theory on the moduli space of Riemann surfaces; (c) four-dimensional theories with critical behavior, which give some remarkable constraints on Seiberg-Witten invariants and new results on the geography of four-manifolds.

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**Nikita Nekrasov**
Institute of Theoretical and Experimental Physics, Moscow
*On some mathematical aspects of $M$-theory*
**Tuesday, 12.30 – 13.00, Room B**

Existence of the ground states in certain supersymmetric quantum mechanics, quantization of the volume-preserving diffeomorphisms and gauge theories on the non-commutative spaces are some examples of the mathematical problems arising in the seacrh for the mysterious eleven-dimensional vacuum of the string theory, called $M$-theory. In my talk, after a brief introduction into $M$-theory, I will try to give a review of the several aspects of each of these subjects, with the emphasis on their relevance for $M$-theory.

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**Christoph Schweigert**
Université Paris VI
*D-brane conformal field theory and bundles of conformal blocks*
**Thursday, 11.30 – 12.00, Room B**

The spaces of conformal blocks form a system of vector bundles over the moduli space of complex curves with marked points. We discuss various aspects of these spaces; in particular, we present conjectures about the dimensions of sub-bundles. As a corollary of these conjectures, we obtain a Verlinde formula for non-simply connected structure groups like $PGL(n, C)$.

As an application, we discuss conformal field theories on surfaces with boundary and show how the subbundle structure of the conformal blocks controls the structure of symmetry breaking boundary conditions. Such boundary conditions naturally appear in the description of string propagation in the background of a D-brane.

Joint work with J. Fuchs.

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**Angel M. Uranga**
CERN, Genève
*From quiver diagrams to particle physics*
**Thursday, 12.00 – 12.30, Room B**

Recent scenarios of phenomenologically realistic string compactifications involve the existence of gauge sectors localized on D-branes at singular points of Calabi-Yau threefolds. The spectrum and interactions in these gauge sectors are determined by the local geometry of the singularity, and can be encoded in quiver diagrams. We discuss the physical models arising for the simplest case of orbifold singularities, and generalize to non-orbifold singularities and orientifold singularities (a generalization naturally arising in string theory). Finally we show that relatively simple singularities lead to gauge sectors surprisingly close to the standard model of elementary particles.

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