Integrability, Symmetry and Quantum Space-time

Reporting

Project Information

ISAQS

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Final Report Summary - ISAQS (Integrability, Symmetry and Quantum Space-time)

String theory is the prime candidate for a consistent theory of quantum gravity. It should therefore be able to address fundamental questions such as the origin and structure of spacetime. The key to an understanding of these deep problems is to uncover the symmetry principles that underlie string theory and to gain control of its nonperturbative regime. This project, "Integrability, Symmetry And Quantum Spacetime" (ISAQS) was motivated by some of the recent progress in string and Yang-Mills theory on the one hand, and the discovery of the long sought after description of multiple coincident branes in M-theory on the other.

The primary scientific goal of ISAQS was to uncover new techniques in the theory of integrability that will be useful for the understanding of the integrability of string theory, as well as to discover and study new symmetry principles of string theory, so as to obtain better control and new insights about the quantum structure of space-time at high energies or small scales. Our scientific objectives came under 3 workpackages:

Integrability of String Theory: To understand the appearance and role of integrability in string theory. This can give new techniques to calculate the spectrum of states in string theories, and through gauge/gravity duality such developments might allow us to determine the full spectrum of field theories such as N = 4 Super-Yang-Mills (SYM), as well as giving information about scattering amplitudes and their relation to Wilson loops.

Techniques of Integrability: With renewed interest in, and new examples of, integrability in string theory contexts, it should be very productive to generalise techniques such as the thermodynamic Bethe-Ansatz and nonlinear integral equations so that these powerful methods can be applied in more general contexts, such as four-dimensional SYM theory. We also searched for new examples of integrable systems by exploring the classes of possible boundary conditions and defects which can be included in known models.

Membranes and New Symmetry of String Theory: The understanding of other extended objects, known as branes, in string theory has lead to many of the recent developments in our understanding of string theory and its applications. In particular D-branes provide a direct link to gauge theories such as N = 4 SYM. However, relatively little was known about branes in M-theory until recent developments for the M2-brane. We developed models to describe M-branes and explored the novel symmetries of the worldvolume field theories.

This project has brought together leading researchers with broad, complementary expertise in order to tackle these issues. Several exchanges have taken place between the EU partner organisations at Durham University, UK; the University of York, UK; Humboldt University, Berlin, Germany; and the Albert Einstein Institute, Potsdam, Germany, and the two third country partner organisations at CQUeST, Seoul, Korea and YITP, Kyoto, Japan. There has also been collaboration with researchers at the external organisation National Tsing Hua University, Taiwan. This has enabled exchange of knowledge and collaborations to be initiated and developed. The result has been good progress in all three workpackages described above. The exchanges also provided excellent opportunities for early stage researchers to broaden their expertise and interact with experts at several other institutes.

Members of the ISAQS project have published many papers. Some important results obtained are:

An improved understanding of the integrability of N = 4 SYM and of the role and significance of Yangian symmetry in string theory.

New results for scattering amplitudes and correlation functions in planar N = 4 SYM, in part using integrability.

The description and classification of boundaries and defects in integrable systems.

The exploration and analysis of the recently discovered Mathieu Moonshine including the discovery of an overarching symmetry.

The description of non-Abelian tensor gauge fields on multiple M5-branes, and the construction of self-dual-string solutions in non-Abelian M5-brane theory.

The discovery of a string origin of a novel Quantum Nambu geometry.

Naturally some developments have led to new opportunities related to our original goals, for example much of the focus on M-branes moved from M2-branes to M5-branes, and the study of N = 4 SYM expanded to consider a wider variety of topics in this rapidly developing area. In addition to exchanges which took place throughout the four years of the programme, we held three workshops including a summer school. This gave additional opportunities to present results and exchange ideas, particularly giving early stage researchers excellent opportunities to interact with leading experts from outside their own institutions. The links between members of the project from the EU and Asia will continue well beyond the end of this project, and in turn this will lead to other exchanges and collaborations between the countries. Indeed several early stage researchers from CQUeST visited Durham and AEI after the end date of this project.

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