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ANR: DIADEMS ; StrongInt

Field theory and continuous symmetries are two cornerstones of modern theoretical particle physics. These two domains were complementarily used since a long time, but their merging really appeared in the 80's, with two-dimensionnal conformal field theories, used in string theories. String theory is the most serious candidate for a unified theory of particle physics, including gravity. String/field theories and study of symmetries constitute the core of the subjects developped in the phy-math team.

An important place is given to infinite dimensional algebras (and / or deformed ones), appearing as mathematical properties (symmetry) of physical systems. In particular, integrable systems are central in the studies of the phy-math group. They are among the main topics of theoretical physics that have experienced fundamental developments in the last twenty years. Integrability is imposed in quantum field theory for the development of non-perturbative methods for the calculation of physical quantities. This concept applies to any system, classical or quantum, possessing enough conservation laws for all physically relevant quantities to be calculated exactly. These conservation laws are associated with symmetries, but these symmetries can be hidden and their determination is a challenge for mathematics. The phy-math group is a pole internationally recognized in the field of integrable systems. He produced many works on integrable systems in dimension 2, as the study of statistical mechanical models and / or condensed matter, especially spin chains models, the general treatment in field theory of diffusion in the presence of a factorized impurity, or of theories defined on one-dimensional graphs. Relations with string theories are also strongly considered (see below).

Recently, there have been remarkable developments in string theories, such as Witten's twistor approach, Bern-Kosower-Dixon method for perturbative calculation to large orders, or Alday-Maldacena proposal for the description dual scattering amplitudes. They have led to great progress in the calculation of scattering amplitudes, avoiding the traditional calculation of

Feynman diagrams. Most of these results took place in maximally supersymmetric Yang-Mills theories (N = 4 SYM). These theories are very similar to QCD, with whom they share many important properties. The group is a leader in the calculation of scattering amplitudes of these theories.
The famous conjecture of correspondence between conformal field theories in four dimensions and string theories is now in an ``experimental'' phase. This conjecture predicts equivalence between operators in conformal field theories (e.g. SYM N = 4) on the one hand, and the excited states of a superstring propagating in a curved background (of anti-de Sitter type). In its original form, the AdS / CFT conjecture applied to the quasi-classical string (relatively well studied) and the conformal field theory in the strong coupling regime, that is virtually inaccessible by current methods. Recently, this correspondence has been completely reversed after the discovery that the two theories are probably based on very similar principles of integrability: integrable systems of the type of Heisenberg spin chain were found in the N = 4 SYM theory and also from the quasi-classical string side. This allowed, for the first time, to compare quantitative predictions (and not only qualitative ones, as early in the AdS / CFT) of string theory and perturbative results in conformal field theories.

More formal studies of field theories and functional integrals are also conducted within the phy-math group. They relate in particular non-Abelian Chern-Simons theories and Deligne-Beilinson cohomology.

In addition, the phy-math group leads numerous studies on exact solutions in general relativity: for example, new black hole solutions and black membranes were obtained as part of dilatonic theories of gravity inspired by string theory.

To sumarize, the main research areas studied by the group are:

- Integrable models, (deformed) symmetries and their physical applications
- Gauge theories, string theories, dualities and super Yang-Mills theories
- Field theories, Chern-Simons theories, Deligne-Bellinson cohomology
- General relativity and dynamics of black holes