Galileo Galilei Institute Workshop

Low-dimensional Quantum Field Theories and Applications

1. Workshop organizers

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2. Scientific motivations

Exact methods in low-dimensional field theory and integrable systems have developed enormously over the last twenty years thanks to the fruitful exchanges with many areas of physics. They are at the heart of crucial developments in string theory as well as in statistical physics and critical phenomena. More recently they have opened the way to the comprehension of many fascinating experimental results coming from strongly interacting systems in condensed matter. Furthermore, they have stimulated the development of several mathematical subjects, like infinite-dimensional Lie algebras, algebraic geometry, topology, functional analysis etc. The importance of low-dimensional exact methods is widely recognized and they are expected to play a central role in the developments of all these fields.

Examples of research topics in this domain are: (a) two-dimensional conformal field theories, providing a vast family of exactly solvable models with interacting massless excitations; (b) Liouville theory, whose integrability at the quantum level is now well understood; (c) massive integrable field theories, that can be solved by the scattering-matrix approach and the associated form-factor expansion of correlation functions; (d) the thermodynamic Bethe ansatz for computing thermodynamic quantities at and outside thermal equilibrium; (e) lattice integrable models, such as the spin chains and the vertex models, and their interpretation as statistical sums of geometrical objects like loop gases and polymers.

These methods continue to be actively developed at the formal level providing novel ideas, solutions and interrelations. Technical progress is also stimulated by the challenges coming from the condensed matter applications and string theory, that will be briefly outlined below. An important topic of current activity is the study of non-trivial boundary conditions, both in conformal and massive integrable field theories and for lattice models. Another subject is the breaking of integrability that can be analysed by perturbing around a known integrable field theory and using the form-factor expansion and the semi-classical approximation. The (algebraic) Bethe ansatz is also being extended in several directions: for example a new relation has been recently found with the theory of ordinary differential equations. Finally, a relation between conformal theories and stochastic processes has been recently found as described below.

Concerning condensed matter systems, low-dimensional theories efficiently describe the phases of matter in mesoscopic systems, quantum Hall devices and ultra-cold atomic gases. The rapid experimental advances in the studies of these systems have led to an unprecedented direct access to phenomena dominated by quantum effects and strong correlations. These give rise to exotic non-perturbative effects such as spin-charge separation and fractionally charged excitations, that cannot be dealt with by standard (perturbative) theoretical approaches. Remarkably, many of the model Hamiltonians of interest in these problems turn out to be exactly solvable: it is now possible to use conformal invariance, quantum integrability and supersymmetry in experimentally motivated problems of quantum magnetism, mesoscopic physics and ultra-cold atomic gases.

Among the future studies of interest in this domain, one may quote: (a) the development of the Bethe ansatz to describe non-equilibrium properties and transport phenomena in quantum integrable systems beyond the Keldysh formalism; (b) the extension of the theories of the quantum Hall effect to the new Hall states formed by cold atoms in rapid rotation; (c) the computation of correlation functions in integrable field theories and lattice models that makes possible the precise comparison with the experimentally measured dynamical response in quantum magnets.

String theory is another major topic of application of low-dimensional exact methods. The worldsheet description of strings is provided by conformal field theory, whose exact results have been very useful over the years for string model building. The recent studies address the time dependent phenomena and will require and stimulate significant progress in non-rational and logarithmic conformal field theory. Remarkably enough, these theories also appear in the context of two-dimensional systems with disordered electrons: this is an example of the interdisciplinary research that can be carried on in the proposed workshop at the Galilei Institute.

In exploring the AdS/CFT correspondence, quantum integrability also appears in a different context. Indeed, the diagonalization of the dilatation operator in four dimensional supersymmetric gauge theory, measuring anomalous dimensions of conformal fields, can be related to the exact solution of a quantum spin chain. At the perturbative orders computed so far, these chains are integrable, raising the hope that the gauge theory itself might be integrable in the large N limit.

Finally, we mention the recent field of stochastic Loewner evolution that describes the random growth of curves and domains in two dimensions, such as those occurring in the problem of percolation. The statistical averages can be modelled by two-dimensional field theories that are conformal invariant. This field theoretic description of growth phenomena can reveal new relations between string theory, quantum gravity, probabilistic methods and non-equilibrium statistical mechanics.

The proposed Galilei Institute workshop is aimed to bring together experts in the domains of exact solutions, low-dimensional condensed matter and string theory and to develop interdisciplinary communication and collaboration.

3. Specific topics and key participants

The main topics of the workshop will be:

1. Quantum dynamics in mesoscopic systems and cold atoms.
2. Conformal field theory and topological quantum computation.
3. Correlations and entanglement in lattice models and field theories.
4. Sigma models on noncompact groups and logarithmic conformal field theory.
5. Stochastic Loewner evolution and growth processes.
6. Integrability in the AdS/CFT correspondence.

The list of invited participants will include:

Affleck [Vancouver], Abanov [Stony Brook], Altshuler [Princeton], Amico [Catania], Bauer [Saclay], Belavin [Landau], Bernard [ENS, Paris], Cardy [Oxford], Caux [Amsterdam], Chamon [Boston], Corrigan [York], P. Dorey [Durham], Doucout [LPTHE], Doyon [Oxford], Egger [Dusseldorf] Essler [Oxford], Fateev [Montpellier], Felder [Zurich], Fendley [Virginia], Fradkin [Urbana], Guzberg [Chicago], Kazakov [ENS,Paris], Korepin [Stony

Brook], Kostov [Saclay], Le Clair [Cornell], Ludwig [Santa Barbara], Lukyanov [Rutgers], Maillet [Lyon], Miwa [Kyoto], Mudry [Scherrer Inst.], Nepomechie [Florida], Nersesyan [ICTP], Nienhuis [Amsterdam], Rasetti [Turin], Ravanini [Bologna], Read [Yale], Reschetikin [Berkeley], Pearce [Merbourne], Polychronakos [New York], Schomerus [Hamburg], Schoutens [Amsterdam], Serban [Saclay], Sierra [Madrid], Sodano [Perugia], Staudacher [MPI, Potsdam], Zarembo [Uppsala], Teschner [Hamburg], Tsvelik [Brookhaven], Al. Zamolodchikov [Montpellier], A. Zamolodchikov [Rutgers].

4. Dates and Workshop Conference

The workshop will last 10 weeks, from September 1st to November the 7th, 2008. We would like to have about twenty researchers present every day and require a minimum period of stay of three weeks. The organizers Cappelli, Mussardo and Zuber will be in residence most of the time.

A one-week conference will be held on September 15-19 and will host up to 100 participants. It will be organized together with the European Science Foundation programme: "INSTANS: Interdisciplinary Statistical and Field Theory Approaches to Nanophysics and Low Dimensional Systems".