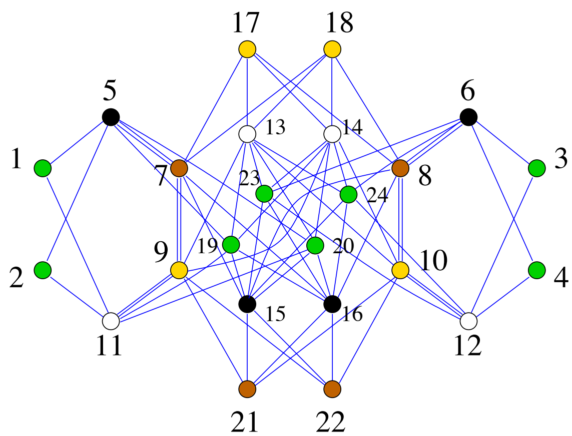
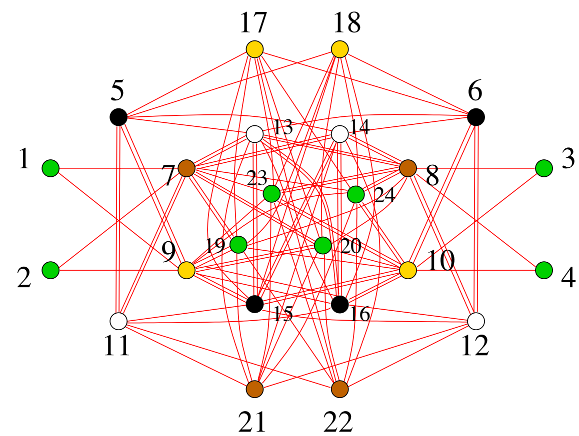
SPhT

RAPPORT D'ACTIVITÉ JUIN 2000 - MAI 2002





Cover : These graphs encode the spectrum of a 2D conformal field theory endowed with a $SU(5)$ current algebra in the presence of boundaries. The vertices are in one-to-one correspondence with the consistent boundary conditions. The number of blue (resp. red) edges between vertices a and b gives the multiplicity of representation $\underline{5}$ (resp. $\underline{10}$) with boundary conditions a and b on the two sides of a strip (See Models and Structures, sect. 3.1).

GENERAL CONTENTS

INTRODUCTION

This report presents an overview of the activities of the Service de Physique Théorique (SPhT) for the period June 2000-May 2002. It has been prepared in view of the biennial evaluation of the laboratory which will be carried out in December by our External Scientific Committee (CSE).

As was the case in the previous report, the scientific activities of the laboratory have been organized in three parts which reflect the major themes of research at SPhT: quantum field theory and mathematical physics; nuclear physics, particle physics and astrophysics; statistical physics and condensed matter physics. This division corresponds to the way the laboratory is structured. While it offers some administrative convenience, this structure is not meant to be rigid: the budget is roughly equally distributed among the three groups (which are of comparable sizes), but there are no independent group budgets, and the major decisions, concerning for instance long term visitors and postdocs, are taken at the level of the "conseil scientifique" (CS) of SPhT (after discussion within the groups). Also, the frontiers between the groups are permeable, as is attested by many contributions to this report.

The regular meeting of SPhT, which traditionally had been coupled with the evaluation, took place in October 2001, at Benodet (Brittany). A few physicists from other laboratories (SPP, SPEC and Insitut Curie) were invited to give a talk. The director of the "Direction des sciences d la matière" (DSM) could also attend the meeting for one day, and he gave a general presentation of DSM activities. This meeting was the occasion for mutual presentations of our scientific activities as well as for general discussions involving in particular some prospective. Such prospective discussions complement those occurring regularly within the SPhT CS, and the recommendations of our External Scientific Committees. While it is very difficult to predict what will be the most exciting topics in theoretical physics in five or ten years from now, a few directions emerge in which we feel the need to strengthen our activities in the near future: cosmology at the frontier with particle physics, mathematical aspects of string theory, and physics problems inspired by biology. At the same time, the survival of certain traditional activities of SPhT, like nuclear structure, is a source of concern.

The exchange of ideas and techniques between physicists is ultimately the main justification for a large laboratory of theoretical physics such as SPhT. Aside from our regular seminars (a seminar of general theoretical physics every other week, and weakly specialized ones), we have continued our "matinées thématiques", half days of presentations on a given theme by SPhT physicists. Once a year, the PhD students present their work to the rest of the laboratory. Several times a year, the "journal of SPhT" highlights recent activities or important events concerning SPhT. But new ways to maintain a high level of communication within the laboratory have to be invented regularly. Thus we shall be initiating this year a new formula: a monthly seminar in which several SPhT members will present their latest work as short contributions.

We are also continuing our efforts to strengthen our relations with other laboratories, in particular with the experimental laboratories of DSM. Thus for instance visits of SPEC have been organized, and have been highly appreciated. With SPEC, common working groups exist, in particular in statistical physics of disordered systems, and in condensed matter physics. Strong relations continue to be developed with DAPNIA, with which common publications have been realized. Our efforts to attract visitors to SPhT have continued; unfortunately one sees little progress (if any) to simplify their access to the laboratory. Our Friday lectures have become a well established tradition and some of these lectures are part of the program of the "Ecole doctorale de physique" of Paris. Another tradition of SPhT are the "Journées Claude Itzykson", held regularly in June. Thanks to grants from various European networks and Marie-Curie fellowships, the number of postdocs has significantly increased. Efforts have also been made to attract more PhD students.

Since the last evaluation four CEA physicists have retired and either left the laboratory or have become "CEA scientific advisors". Three new CEA positions were offered to young physicists, and two to senior physicists who will join the laboratory in October. While scientific excellence remains the main selection criterion, we pay continuous attention to guarantee critical sizes to various activities; this is certainly visible in condensed matter physics, and in string theory. The arrival of a substantial number of young physicists over the last few years has started to produce profound changes in the laboratory. Efforts are made to encourage them to take initiatives, and some do indeed. One of them has obtained support for coordinating the project "La cosmologie: un laboratoire pour la physique des particules", which involves young physicists from various laboratories of the Paris area (ACI from Ministère de la recherche).

The association of SPhT with CNRS as a "Unité de recherche associée" (URA) became effective on 01/01/2001. It has provided the laboratory with new resources, directly from CNRS, and indirectly. Getting "official" recognition from CNRS was well appreciated and contributed positively to the general atmosphere of the laboratory. However I cannot help but express concern that no new junior CNRS position was attributed to SPhT over the last two years.

In closing this introduction, I wish to thank in advance the members of the CSE for having accepted their task. I thank also those who took part in the elaboration of the present document. Such a report represents a fair amount of work, but we found that the effort put in the synthesis of our scientific activities and of the material presented in the various annexes, is worth doing every other year. The synthesis of individual contributions were realized by Denis Bernard and Philippe Di Francesco for the part "Models and Structures: mathematical physics", by Jean-Yves Ollitrault for the part "Cosmology, physics of particles and nuclei", and Henri Orland for the part "Statistical physics and condensed matter". Alain Billoire coordinated the preparation, and together with Marc Gingold took care of the final editing.

Jean-Paul BLAIZOT

MODELS AND STRUCTURES: MATHEMATICAL PHYSICS

This chapter gathers research activities along five main directions:

(i) *Quantum chaos and dynamical systems.* This subject is a longstanding tradition at the SPhT. Recent results concern the extension of the exact WKB method that has been previously formulated here. Progress has also been made in the description of the wave functions of chaotic quantum systems. Renormalization techniques have been applied to the analysis of dynamical systems.

(ii) *Combinatorial statistical physics.* This theme emerged more recently. It mainly deals with elaborating tools from statistical models — whether integrable or not — with applications to combinatorial problems. As exemplified by results obtained at SPhT, this physically inspired approach leads to unexpected mathematical conjectures. The recent activities have broadened the spectrum of applications to random graphs, optimization and localization problems.

(iii) *Integrability: from structures to applications.* The SPhT has been deeply involved in developing techniques of conformal field theory and integrable model systems. Progress is still made in particular for open systems with boundary conditions, in connection to strings and branes physics. Advances have been made towards finding new exciting physical or mathematical applications of these techniques ranging from the remarkable link between integrability and exact WKB quantization to two-dimensional disordered systems. Another traditional subject at SPhT concerns random matrices, for which new correlations of eigenvalues have been computed and better connections to integrability have been formulated.

(iv) *Gravities and string theories.* String theory at SPhT was pursued along two directions. One involves Matrix model techniques applied either to the description of two-dimensional strings in black hole backgrounds or to the quantization of branes. The other probes non-perturbative effects such as the vacuum structure within the context of M-theory. Work has also been done towards quantization of Einstein gravity using loop variables.

(v) *Quantum field theory.* This is an established tradition at SPhT. The results obtained lately concern its foundations, in flat or curved spaces, but also applications to second-order phase transitions in statistical systems.

Contents

1 Quantum chaos and dynamical systems

The study of the one-dimensional Schrödinger equation with arbitrary polynomial potential has undergone a major development in the form of new exact WKB methods of solution, now yielding a host of new results on the spectrum and wave functions. In the same spirit, semi-classical asymptotic analysis has been applied to stochastic dynamical systems and even to the famous mathematical problem of the zeros of the Riemann Zeta function.

We also present advances in the understanding of spectra and wave functions of quantum dynamical systems displaying chaotic behavior.

1.1 Exact asymptotic methods for the Schrödinger equation and dynamical systems (A. Voros)

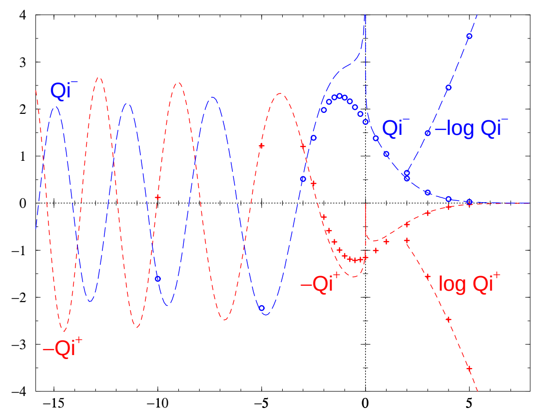
Analytical solution of the 1D Schrödinger equation with general polynomial potential

An exact WKB resolution method for the 1D stationary Schrödinger equation $[-\hbar^2 \mathrm{d}^2/\mathrm{d}q^2 + V(q) - E]\psi = 0$, with a *general polynomial* potential $V(q)$, has been developed over the past few years. New explicit results have been exhibited for *binomial* potentials, $V(q) = uq^N + vq^M$, especially for their spectral determinants at zero energy: $D(v) = \det(-\mathrm{d}^2/\mathrm{d}q^2 + q^N + vq^M)$, studied as entire functions of v (taking $N > M$, and $u = \hbar = 1$, without loss of generality), with emphasis on three cases [T00/194, T01/146]:

a) $V(q) = q^4 + vq^2$, the classic symmetric anharmonic oscillator: several special values, infinitely many algebraic identities, and exact functional relations of quartic type have been found for $D(v)$, together with asymptotic $v \to \infty$ properties of Airy type. No such exact result existed for this quantum problem before.

b) $V(q) = q^{2M+2} + vq^M$, $M > 0$ *even* (supersymmetric potentials): $D(v)$ and its zeros (the generalized [v-]eigenvalues) have been completely computed in terms of Gamma functions; this infinite sequence of solvable problems thus fully generalizes the case of the harmonic oscillator ($M = 0$).

c) $V(q) = q^{2M+2} + vq^M$, $M > 0$ *odd* (never studied before): an exact formula $D(v) = \mathrm{Cst}\cos[\pi v/(2M+4)]$ has been derived, implying an elementary exact quantization condition for the v-eigenvalues.



The two spectral determinants of the symmetric quartic anharmonic oscillators at zero energy, $\mathrm{Qi}^{\pm}(v) = \det(-\mathrm{d}^2/\mathrm{d}q^2 + q^4 + vq^2)$ $(-/+$ correspond to negative/positive-parity eigenfunctions). Those are entire functions behaving very much like the Airy function and its derivative, and for which many exact relations can be obtained. (Dots mark numerically computed points, dashed lines plot large-v asymptotic formulae also obtainable from exact WKB theory.

The exact Bohr—Sommerfeld formulae which underlie the above formalism have also been recognized as a kind of Bethe-Ansatz equations, which solve the general 1D Schrödinger problem in just the same sense as integrable models in 2D statistical mechanics (see also Sect. 3.2 below). There remains to truly explain this observed structural coincidence, as well as to prove the convergence of iterative resolution schemes based on those relations (bootstrap solution of the exact Bohr–Sommerfeld formulae, and thermodynamical Bethe Ansatz). Plenty of new research thus lies ahead!

Asymptotics of high order noise corrections

We have continued an exact asymptotic study of a stochastic dynamical system, namely a discrete Langevin equation perturbed by a (Gaussian) noise, (the noise strength is taken as small parameter). Formerly, only the trace of the evolution operator $\mathcal{L}$ itself could be analyzed this way. Now the results have been generalized to all traces of powers (i.e. iterates) $\mathcal{L}^n$: their noise expansions also diverge factorially, and the precise large-order behaviors have been expressed through periodic-orbit expansions for different operator traces, thus yielding a new instance of resurgence in asymptotics [T00/140, T00/181].

Zeta functions for the Riemann zeros

A family of Hurwitz-like Zeta functions built as Dirichlet series over the Riemann zeros (i.e. the zeros $\{\frac{1}{2} + \mathrm{i}\tau_k\}$ of the Riemann zeta function) has been studied: namely, $Z_v(\sigma) = \sum_{k=1}^{\infty}[{\tau_k}^2 + v]^{-\sigma}$. These have been continued as meromorphic functions to the whole complex σ-plane, and many of their analytical features (their polar structure, countably many special values, asymptotic results) have been explicitly determined, using semiclassical spectral techniques [T01/033].

1.2 Renormalization group analysis for dynamical systems of atomic physics (C. Chandre)

We applied renormalization methods to describe the loss of stability of a charged particle in an infinite square-well potential driven by an external (linearly polarized monochromatic) electric field. This work showed the applicability of renormalization techniques to atomic physics which provide the most accurate estimates of critical thresholds. The further developments are applications to ionization of Rydberg atoms driven by strong microwave fields [T00/128, T00/175].

1.3 Quantum chaos (S. Nonnenmacher)

Quantized chaotic dynamics

Quantized chaotic maps on a compact phase space naturally give rise to a sequence of $N \times N$ unitary matrices, with $N \sim Cte/\hbar$ assumed large. We want to understand the spectrum of these large matrices.

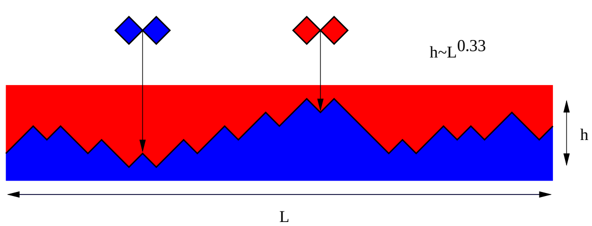
A long-standing conjecture concerns the short-range correlations of the eigenvalues, which for a generic chaotic map are expected to satisfy random matrix (Wigner–Dyson) statistics; this is the case for instance for the correlations of the spectral determinant. We have studied this problem in the framework of finite-dimensional quantum maps, and expressed the spectral determinant pair correlation function as a "discrete nonlinear σ model". In order to obtain a generic result, we have averaged over the quantum maps, and then attempted to solve this model through a saddle-point expansion [T01/100].

2 Combinatorial statistical physics

Equilibrium statistical mechanics has always been related in one way or another to the combinatorics of counting states or configurations. We see here the emergence of new techniques applied to various such combinatorial problems, from random walks to random lattices, eventually leading to asymptotic solutions of yet unsolved classical combinatorial problems.

2.1 Even visiting random walks (M. Bauer, D. Bernard and J.-M. Luck)

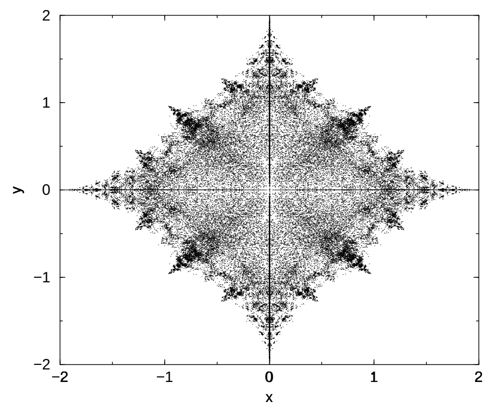
The counting of random walks subject to constraints is interesting in connection to many problems. One example is the Chalker–Coddington model for the quantum Hall effect, which imposes phase coherence to electrons. Another example is the modeling of deposition-evaporation of complex (i.e. non-monomer) objects. We concentrate here on a one-dimensional problem with dimers (this amounts to exclude walks that do not visit all the sites an even number of times) and give a thorough analysis of its physical properties by using the connection with disordered systems (random iteration of maps). We derive exact enumerative recursion relations. The analogy with an exactly solvable model, the random mirror model, is exploited to obtain the leading singularities of the relevant physical quantities, leading to precise asymptotic formulæ [T01/001].



Dimer deposition-evaporation processes

2.2 Complex spectra of random matrices (H. Orland)

Non-Hermitian random Hamiltonians occur in various problems such as vortex line pinning in superconductors, growth models in population biology, even-visiting random walks, etc. The complex spectrum of a non-Hermitian tridiagonal random matrix model is studied. Using the Dyson–Schmidt equation, the spectrum is shown to consist of a non-enumerable set of lines in the complex plane. Each line is the support of the spectrum of a periodic Hamiltonian, obtained by the infinite repetition of any finite sequence of the disorder variables [T02/047].



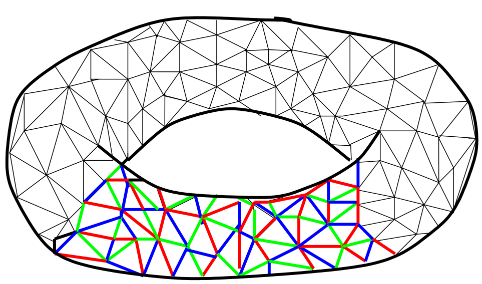
Typical spectrum of a complex random matrix

2.3 Geometrically constrained statistical models on random planar graphs (J. Bouttier, P. Di Francesco, E. Guitter and I. Kostov)

The relation between 2D critical phenomena on regular lattices and their "gravitational" versions on random graphs is now well established in the form of the celebrated KPZ formula, allowing for a precise identification of phase transitions and critical exponents. The techniques used for solving regular lattice models and random ones are very different and surprisingly random graph models are sometimes easier to handle, thanks to matrix model formulations. In the case of geometrically constrained models (such as fully-packed loop models), attention must be paid to the class of random surfaces considered which may alter drastically the observed critical properties. We have here an example of application of ideas borrowed from the study of physical systems to the solution of tough mathematical puzzles: the three-color, meander and hard square problems.

The solution of the three-color problem on planar graphs

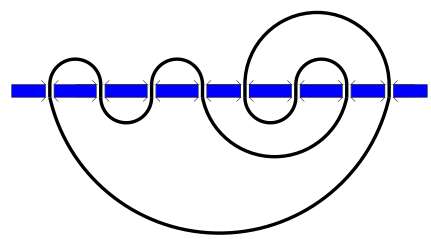
Baxter's three-color problem on a regular hexagonal lattice is one of the classical examples of solvable lattice models. The partition function of this model is equal to the number of ways of coloring the links of the lattice with three different colors, A, B and C, so that no links that meet at a vertex carry the same color. The problem is equivalent to a special version of the $O(2)$ model, whose partition function is given by a gas of fully packed loops on the hexagonal lattice, having two different flavors. It is known for almost a decade that the three-color problem on a random planar graph model can be reformulated as the large-N limit of a special matrix model. This matrix model, involving three coupled random matrices, could not be solved by the traditional methods. Its exact solution was obtained in [T00/074] and it was found that the number of three-colorings of an infinite random graph is 0.9843 per vertex.



Tri-coloring a random triangulation

Fully-packed loop models on random surfaces and meanders

The two-dimensional loop gas (or $O(n)$ model where configurations are made of self-avoiding loops on a lattice, with a fugacity n per loop) is known to have three different critical lines, corresponding to dilute, dense and fully-packed situations. All three may be solved in the continuum by use of Coulomb gas techniques. The latter however is more subtle in the sense that its degrees of freedom crucially rely on colorability properties of the underlying lattice. By carefully implementing this fact, we have been able to identify the universality class of compactly folded polymers by solving the fully-packed loop model on *bicolored* random surfaces. This in turn allows to predict various configuration exponents of meanders, i.e. configurations of a closed non-self-intersecting road crossing a river through a given number of bridges [T00/108].



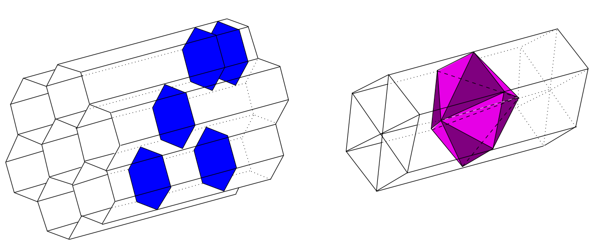
Meanders: enumerate all circuits crossing a river through a given number of bridges.

Hard objects on random bi-colorable lattices

We addressed in [T02/007] the general problem of hard objects on random lattices in order to emphasize the crucial role played by the colorability of the lattices in the crystallization transition. Noting that the naive (colorless) random-lattice version of the hard-square model is unable to reproduce the crystalline phase observed on the regular square lattice, we have shown how to restore this phase by considering the same model on *bicolored* random lattices. Solving this model exactly by use of multimatrix models, we have shown moreover that the crystallization transition point lies in the universality class of the Ising model coupled to 2D quantum gravity, thus settling the nature of the transition of the yet unsolved hard square model. We have then extended our analysis to a new two-particle exclusion model, whose regular lattice version involves hard squares of two different sizes. The exact solution of this model on bicolorable random lattices displays a phase diagram with two (continuous and discontinuous) crystallization transition lines meeting at a higher order critical point, in the universality class of the tri-critical Ising model coupled to 2D quantum gravity.

2.4 Statistical models of semi-random lattices and Lorentzian gravity (P. Di Francesco and E. Guitter)

Semi-random lattices denote generically lattices with a number, say D, of random directions and a number, say d, of regular ones. Such lattices interpolate between purely random lattices ($d = 0$), such as those used as discretizations of quantum gravity, and purely regular ones ($D = 0$). In particular, when $d = 1$, semi-random lattices provide discrete models of the so-called Lorentzian gravity in which the time direction is regular while the space ones are random. We have developed various tools to generate such lattices, and to study their statistics.



(a) (b)

A model of 1+2 gravity: hexagonal plaquettes are randomly placed in a network of parallel tubes (a). The dual is a random 1+2D tetrahedral complex paved by means of the dodecahedral tiles (b) dual to the hexagons.

Semi-random lattices in $1 + d$ *dimensions*

In the case of only *one* random direction ($D = 1$), we have established a very general inversion formula which reduces the statistics of $(1 + d)$-dimensional semi-random lattices to that of hard (non-overlapping) objects on the regular d-dimensional space. This allows for an exact solution of a variety of models, including critical and multicritical models of Lorentzian lattices built out of tiles of various shapes, and with arbitrarily large fractal dimension. This also gives the first solution of a three-dimensional Lorentzian gravity problem in the form of a $(1+2)$-dimensional tetrahedral complex, equivalent to two-dimensional hard hexagons. These results are gathered in [T01/042] where we also establish a general connection between semi-random lattices and directed-site lattice animals.

Generalized Lorentzian gravity in $1+1$ *dimensions*

We have generalized the original model of $(1 + 1)$-dimensional Lorentzian triangulations so as to include a certain class of outgrowths ("baby universes" in the language of gravity), with fugacity β. By computing various thermodynamic scaling functions, we have shown that the model possesses a transition point at $\beta = 1$ below which its continuum limit is described by a 1D quantum Calogero Hamiltonian [T00/145].

2.5 Spectral properties of random graphs and combinatorial optimization (M. Bauer and O. Golinelli)

Two years ago, we reported on our study of quantum transport properties for free particles moving on a graph and its relation with the spectral properties of the incidence matrix of the graph, taking the standard random graph model as an example. Since that time, our understanding has progressed, and we have obtained surprising results showing the richness of the simplest possible model. We have been able to give a complete analysis of zero energy states: we have counted their total number, and given a combinatorial description of a family of localized eigenvectors. It turns out that the localized eigenvectors exhaust all zero-energy states except in a finite interval of values for the disorder parameter. So a conducting phase separates two insulating phases. At the boundaries, critical fluctuations govern the physics. Inside the conducting phase, a third phase transition, of geometric origin, takes place. We have related it to a phase transition in the complexity of one of the standard combinatorial optimization problems, the matching problem [T00/087, T00/088, T01/017].

3 Integrability: from structures to applications

Integrability, as practiced at SPhT, is developed to tackle non-perturbative phenomena. This requires understanding and elaborating the fundamental structures that underly the integrability principle, but also testing them on physical problems. In the recent years, we have extended our understanding of conformal theory and random matrix models, in particular in the context of 2D quantum gravity. This now provides fruitful applications to ordinary differential equations, conformal maps, low-energy QCD as well as localization transitions.

3.1 Graphs and conformal field theories (J.-B. Zuber)

Former studies on boundary conditions in rational conformal field theories (RCFT) had shown that the multiplicities that appear in the decomposition of the Hilbert space in the presence of boundary conditions onto irreducible representations of the Virasoro or of the relevant chiral algebra form a non-negative integer valued matrix representation ("nim-rep") of the fusion algebra and they may be conveniently encoded into graphs (for a review, see [T00/072]). The construction of this nim-rep has been recently carried out explicitly in the non-trivial case of conformal theories with a $sl(N)$ current algebra where the left sector is twisted with respect to the right one by the complex conjugation [T02/013].

This line of thought has been continued and enriched in the light of recent work by Adrian Ocneanu in a more abstract setting, thus giving to the latter an explicit physical realization. On the one hand, it has been shown that the introduction of "twisted" boundary conditions is a natural and fruitful extension of the former considerations on boundary conditions. It is natural as it corresponds in the language of statistical mechanics to the introduction of defect lines or "seams". It is fruitful as it provides a new way of probing the content (spectrum and couplings) of a RCFT. The multiplicities that appear in the decomposition of the corresponding Hilbert space form now an integer valued representation of the *double* fusion algebra and the graphs that encode them may be called Ocneanu graphs. On the other hand, the multiplicities in the presence of boundaries and/or twists, subject to consistency constraints, are also the combinatorial data required to construct a quantum algebra, introduced by Ocneanu under the name of "double triangle algebra", mathematically a weak Hopf C^* algebra. This algebra appears to be the fundamental quantum algebra of the RCFT, as (i) it incorporates in a natural way the truncation of its representations inherent to a RCFT; (ii) it enables one to construct generalized chiral vertex operators, which are appropriate to describe the bulk-boundary couplings; and (iii) it also contains in its $3-j$ and $6-j$ (recombination) coefficients all the information on the operator product algebra of the conformal theory and on the Boltzmann weights of the associated integrable lattice models [T00/137, T00/190, T00/188, T00/189, T01/022, T01/087].

3.2 Integrable systems and ordinary differential equations (P. Dorey and R. Tateo)

The articles [T00/094] and [T00/136] are on the subject of a "correspondence", previously discovered between two distinct areas of mathematical physics, which links an approach to the theory of ordinary differential equations, with the functional-relations treatment of integrable models as initiated by Baxter. The first article [T00/094] concerns the extension of the correspondence to Bethe Ansatz systems associated with the Lie algebra $SU(n)$, finding that they are related to higher-order ordinary differential equations. The second one [T00/136] provides a relatively elementary review of this whole area, including previous examples of the correspondence.

3.3 Integrable structure of conformal maps (I. Kostov)

Recently, it has been realized that conformal maps exhibit an integrable structure: conformal maps of compact simply connected domains bounded by analytic curves provide a solution to the dispersionless limit of the 2D Toda hierarchy. As is well known from the theory of solitons, solutions of an integrable hierarchy are represented by τ-functions. The dispersionless limit of the τ-function emerges as a natural object associated with the curves. The τ-function for simple analytic curves is studied in its connection to the inverse potential problem, area preserving diffeomorphisms, the Dirichlet boundary problem, and matrix models [T00/080].

3.4 Random matrices and integrable systems (B. Eynard, M.L. Mehta and J.-M. Normand)

Random matrices are powerful tools for many problems in physics, ranging from condensed matter physics (quantum chaos, mesoscopic conductors, crystal growth,...) to high energy physics (QCD, string theory, quantum gravity), and statistical physics (statistical physics on random fluctuating surfaces). The reason of this success is "universality". The statistical distribution of the spectrum of large random matrices is universal. These universal functions are solutions of integrable differential systems. The link between random matrices and integrability, is by itself very interesting, and can bring a wealth of new results in both domains.

Random matrices and orthogonal polynomials

We were interested in the probability density of determinants of random matrices, which may be (1) real, (2) complex, (3) quaternionic, (4) real symmetric, (5) complex Hermitian, or (6) quaternionic self-dual. The case (1) was solved since 1954, cases (5) and (6) since 1998 and case (4) since 2000. The methods used were either by induction or through the eigenvalues. The determinant of a matrix is not only the product of its eigenvalues but its norm is also the product of its singular values. So going through its singular values, rather than its eigenvalues, gives a general derivation of the probability density of a determinant in the three cases (1), (2) and (3) [T00/101]. The probability density is in general a Meijer's G-function.

The three cases (4), (5) and (6) have been extensively studied. In random matrix theory they are called GOE, GUE and GSE (G for

Gaussian; O, U and S respectively for orthogonal, unitary and symplectic; and E for ensemble). We calculated the moments of the characteristic polynomial in these three ensembles in two different ways. Comparing the resulting expressions for the same moment one gets remarkable identities, one between an $n \times n$ determinant and an $m \times m$ determinant, and another between the pfaffian of a $2n \times 2n$ antisymmetric matrix and a sum of $m \times m$ determinants [T01/016].

Orthogonal polynomials are familiar for a century or so. In particular, the characteristics and location of their zeros are known. Skew-orthogonal polynomials and bi-orthogonal polynomials have been studied more recently. Skew-orthogonal polynomials are orthogonal with respect to an anti-symmetric scalar product. Two kinds of anti-symmetric scalar products are known to be useful. Bi-orthogonal polynomials are orthogonal with respect to a non-local weight. Under certain conditions on the weight function $w(x,y)$ they are almost uniquely defined by

$$\int\int w(x,y)P_j(x)Q_k(y)\ dx\ dy = \delta_{jk}.$$

What can one say about the zeros of the set of polynomials $P_j(x)$ or the set of polynomials $Q_j(x)$? In general, their zeros are not real and do not lie in the respective supports of $w(x,y)$, as is the case with orthogonal polynomials. However, we have shown that under some specific conditions on the weight $w(x,y)$ the zeros of $P_j(x)$ or $Q_j(x)$ are all real and lie in the respective supports of $w(x,y)$ [T01/086].

Large n asymptotics of skew-orthogonal polynomials for non-Hermitian random matrices

Non Hermitian matrices represent physical systems with time reversibility, or with broken spin invariance. There are two types: orthogonal ensembles and symplectic ensembles. The statistical properties of the spectrum of such matrices also become universal when the matrices become large. The statistical properties (correlation functions for instance) can be computed in terms of some skew-orthogonal polynomials, and some large n asymptotics were needed to understand the large n universal statistical properties. A method for finding the large n asymptotics of the skew-orthogonal polynomials was developed [T00/170].

The two-matrix model and duality in integrable differential systems

We studied the two-matrix model (two random Hermitian matrices coupled linearly), particularly in relationship with differential systems. The two-matrix model was introduced to represent statistical physics systems on a random lattice with matter, as for instance the Ising model. It is known that the two-matrix model has a much larger universality class than the one-matrix model, and therefore is more general. The statistical properties of the two spectra can be computed from some bi-orthogonal polynomials. These two families of polynomials obey some systems of differential equations. The family associated to the first matrix and the family associated to the second matrix obey systems of different sizes. We have proven that the two systems of differential equations are dual to each other, and that they have the same spectral curve [T01/047, T01/123]. This duality had never been observed before (only guessed in some limits), and it plays a very important role in the universality of the statistical spectral properties.

3.5 Applying random matrices to QCD (G. Akemann and S. Nonnenmacher)

Random matrix models (RMM) find very nice applications in low-energy QCD with broken chiral symmetry. The reason is that in a particular finite-volume limit the partition function of the Goldstone particles, the pions, reduces to a finite group integral over the Goldstone manifold which is equivalent to a large-N chiral random matrix model. One can either study directly the finite group integral, for example to deduce the dependence of the chiral condensate or other quantities on the QCD vacuum angle θ. Here, we find a first order phase transition at $\theta = \pi$ for an arbitrary gauge theory (Dashen's phenomenon). On the other hand one can study the equivalent RMM describing the spectral correlations of QCD Dirac operator eigenvalues. These eigenvalues are closely related to the phenomenon of chiral symmetry breaking. We have introduced a new class of critical RMM with real critical exponents, which permit to study the chiral phase transition. For QCD with non-vanishing chemical potential the Dirac eigenvalues are complex. We introduced a corresponding chiral RMM with complex eigenvalues and determined all spectral correlation functions [T01/141, T02/037].

We have also considered a toy model of strong-coupling lattice QCD, which we map onto an effective theory of baryons and mesons through an exact algebraic transformation, called the color-flavor transformation. The obtained effective action is then treated in the large-N_c limit, by identifying its stationary configurations. We treat in detail the model in 1+1 dimensions (both analytically and numerically), obtaining both topological and non-topological configurations for the meson field [T01/139].

3.6 Localization transitions in two dimensions (D. Bernard, N. Regnault and D. Serban-Teodorescu)

Recent observations have underlined the existence of localization-delocalization transitions in two dimensions whose behaviors differ from generic Anderson localizations to mention but a few examples : investigations of the quantum Hall transition, of dirty superconductors, of localization in systems with degenerate Fermi surfaces, ... We have extended our analysis of these problems using tools borrowed from renormalization group transformations and conformal field theories. These works fit in the more general theme of understanding, and developing techniques for disordered two dimensional systems. We formulate a classification of the related problems of random Dirac fermions, showing in particular that it is slightly finer than that of random matrices [T01/128]. We tackled these localization problems by trying to implement renormalization group techniques to their field theory formulations. We in particular pointed out singularities in these perturbative renormalization group flows but conjectured scaling relation between the typical amplitude exponent and the typical point contact conductance exponent [T01/127]. These analyses were based on recently proposed all order β functions which we tested in few simpler situations [T01/029]. We have also studied these problems using a large N approach, which yields, in a controlled way, to the description of these problems in terms of σ models on super-groups. As expected on symmetry grounds, in this limit the effective action is that of a σ model on a symmetric superspace [T02/003]. This in particular allowed us to point out the existency of a transition in the nature of the localization phenomena as N varies from small to large values [T01/046].

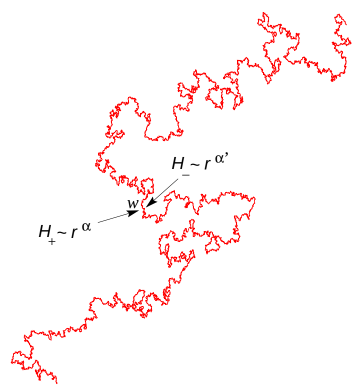
3.7 Discrete thermodynamical Bethe Ansatz (M. Bergère)

We generalize the thermodynamical Bethe Ansatz to the case of a discrete spectrum. We show that the grand partition function of the Calogero–Moser model can be reproduced from a thermodynamical Bethe Ansatz à la Yang and Yang where the integral over the continuous momenta is replaced by a discrete sum over the discrete levels of the energy spectrum of the system.

We extend successfully our result to the case of the Lieb and Liniger model in a harmonic well and in the case of two particles where the eigenfunctions are explicitly known. However in the case of N particles where the solution is only known perturbatively, our Ansatz fails beyond the first order of perturbation [T01/041].

3.8 Graphs and conformal field theories (B. Duplantier)

In the review [T02/088], the exact multifractal spectrum $f(\alpha)$ of the harmonic measure (or electrostatic potential, or diffusion field) near any conformally invariant fractal in two dimensions is derived from conformal invariance and quantum gravity. It gives the Hausdorff dimension of the set of points where the potential varies with distance r to the fractal frontier as r^{α}. Higher multifractal spectra, functions of several α variables, are also derived. First examples of random fractals are a random walk, i.e., a Brownian motion, a self-avoiding walk, or a critical percolation cluster. The generalized dimensions $D(n)$ as well as the multifractal functions $f(\alpha)$ are all identical for these three cases. The external frontiers of a Brownian motion and of a percolation cluster are thus *identical to a self-avoiding walk* in the scaling limit. The multifractal function $f(\alpha, c)$ of the electrostatic potential near any conformally invariant fractal boundary, like a critical $O(N)$ loop or a Potts cluster, is solved as a function of the central charge c of the associated conformal field theory. The dimensions D_{EP} of the external perimeter (a *simple* curve, i.e., without double points), and D_{H} of the hull of a critical scaling curve, or cluster, obey the *superuniversal* duality equation $(D_{\mathrm{EP}}-1)(D_{\mathrm{H}}-1)=\frac{1}{4}$, independently of c. This shows that a simple conformally scaling curve has at most dimension $\frac{3}{2}$. The equivalence to scaling process SLE_{κ} (stochastic Löwner evolution of parameter κ) is given, in which the latter appears as the frontier of a critical cluster. The consequence of the above mentioned duality is a duality there between κ parameters, $\kappa\kappa'=16$, relating simple curves ($\kappa \leq 4$) as frontiers of non simple ones ($\kappa' \geq 4$).



Double distribution of harmonic potential H near a simple scaling curve (here a self-avoiding walk (SAW)), in terms of distance r to point w. The local exponents on both sides of point w are α and α'. The Hausdorff dimension of such points along the SAW is $f_2(\alpha, \alpha')$.

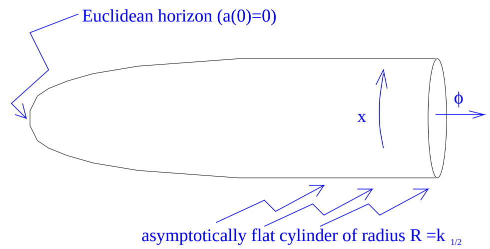
Finally, for a conformally invariant scaling curve which is simple, higher multifractal functions have been derived, like the universal function $f_2(\alpha, \alpha')$ which gives the Hausdorff dimension of the points where the potential jointly varies with distance r as r^{α} on one side of the curve, and as $r^{\alpha'}$ on the other. The general case of the potential distribution between the branches of a star made of an arbitrary number m of scaling paths is also treated, leading to universal multifractal spectra $f_m(\alpha_1, \alpha_2, \cdots, \alpha_m)$.

4 Gravities and string theories

String theory is a promising approach for understanding quantum gravity. In this respect, we have developed aspects of two-dimensional string theory, with a particular emphasis on its connection to matrix models as well as non-perturbative properties of M-theory. We have also followed an alternative path known as loop quantum gravity.

4.1 2D String theories in a black hole background (I. Kostov and S. Alexandrov)

It is well known that the two-dimensional bosonic string theory can be exactly solved, after being reformulated as a large N matrix quantum mechanics. Its solution is however known only in the simplest case of a translation-invariant background. On the other hand, the most interesting problems in string theory involve non-trivial backgrounds. For example, the quantum mechanics of a 2D black hole can be formulated as a 2D string theory in a special background, characterized by a curved geometry of the target space. A first step in attacking this problem is made in [T00/123], where the matrix quantum mechanics is solved in the presence of a source of winding modes. This result is potentially related to the Euclidean black hole due to a conjecture by V. Fateev, A. and Al. Zamolodchikov, relating the black hole background to condensation of vortices (winding modes around Euclidean time) on the world sheet of the string. Since the vortices are related by duality to the vertex operators, the result can be also interpreted as the exact solution of the sine-Gordon model coupled to quantum gravity, the so-called sine-Liouville string theory. The integrable structure of Toda lattice hierarchy, characterizing this model is further studied in [T01/075], where it was shown that the solution obtained in [T00/123] is determined by imposing a constraint ("string equation") relating the two Lax operators.



"Cigar" geometry of the 2D Euclidean black hole

Recently a matrix model for 2D string theory in a black hole background was suggested. It was shown that it is described by the Toda lattice hierarchy. Using this integrable structure expressed in the set of Hirota equations for the partition function of the model, the one- and two-point correlators of the vortex (winding) operators in the spherical limit were calculated [T01/034].

4.2 Loop quantum gravity (S. Alexandrov)

Loop quantum gravity is a nonperturbative and background independent approach to the quantization of general relativity. In its standard form it is based on a formulation of gravity in terms of a $SU(2)$ connection, where the $SU(2)$ gauge group is obtained after a partial gauge fixing of the initial local Lorentz symmetry. In this framework the kinematical Hilbert space of quantum gravity has been constructed and the spectra of some geometrical operators have been calculated. However, the obtained results have raised some problems.

Recently, a Lorentz covariant formulation of general relativity has been developed, where no gauge fixing was used. Taking it as the starting point for the loop quantization, the spectrum of area operator, measuring the area of a surface in a given state, was rederived [T01/035]. It was expressed through quadratic Casimir operators of $SO(3,1)$ and $SO(3)$. Remarkably, the unphysical Immirzi parameter, which unfortunately contributes to the result obtained in the conventional approach based on the $SU(2)$ gauge group, does not appear.

It was then shown that the obtained spectrum corresponds to the only Lorentz connection which diagonalizes the area operator and transforms correctly under all diffeomorphisms [T01/104].

Using these results, a model for the Hilbert space in the Lorentz covariant approach to loop quantum gravity was suggested [T02/030]. It was derived from the assumption that all area operators should be simultaneously diagonalizable. In this model several important problems of covariant loop quantization were solved. The resulting structure suggests that a connection with other approaches to quantum gravity like the spin foam approach should exist.

4.3 Strings and M-theories (F. Sugino and P. Vanhove)

IIB Matrix Model

Recent developments in string theory involves various proposals for nonperturbative construction of string theory in terms of matrix models. In perturbation theory, string theory has infinitely many degenerate vacua, which correspond to arbitrary conformal field theories on the string world-sheet. It has been believed that nonperturbative effects resolve the degeneracy as in the case of QCD θ-vacuum and select a single vacuum corresponding to our world.

Among matrix models for nonperturbative string theories, the IIB matrix model (Ishibashi, Kawai, Kitazawa and Tsuchiya, 1996) has the simplest form — the zero-volume limit of ten-dimensional super Yang–Mills theory. We first considered bosonic Yang–Mills and 4D super Yang–Mills integrals, which are the zero-volume limit of D-dimensional bosonic Yang–Mills theory and four-dimensional $\mathcal{N}=1$ super Yang–Mills theory. For these matrix models (including the IIB matrix model), we cannot use standard perturbative expansions, but we have applied the Gaussian approximation method, and found that our results qualitatively coincide with the known numerical results [T00/165, T01/057]. Next, we applied this method to the IIB matrix model proposing a systematic improvement of the approximation. Because the IIB matrix model contains Majorana–Weyl fermions, the fermion determinant is a complex number and the standard Monte Carlo technique cannot be applied due to the notorious phase problem. Thus, our new analytical approach is expected to be quite meaningful, in particular for the IIB matrix model. We examined spontaneous symmetry breaking (SSB) of $SO(10)$ symmetry of the IIB matrix model in the Gaussian expansion method. We calculated up to the 3rd order, and found the SSB of the $SO(10)$ symmetry to $SO(4)$, which is the first analytical evidence that our 4-dimensional space-time is generated from the 10-dimensional one by nonperturbative dynamics of string theory [T01/117].

Structure of M-theory

The structure of eleven dimensional supergravity is largely unknown. E. Witten strongly stressed the necessity of R^4-corrections for a correct quantization of the 4-form field strength of the theory. Its 3-form potential is conjectured to be a Cheeger–Simons form but a complete understanding is still missing. The minimal and rigid structure of the supersymmetry algebra in eleven dimensions raise hopes that a complete construction of the R^4-deformed algebra will provide answers to these questions. We showed in [T00/116, T00/117] that part of the R^4-corrections does not affect the geometry of M-theory leaving open the question for the other class of R^4-terms. A more general case is attacked in [T01/138], where we show the impossibility to write an effective action matching the superstring S-matrix elements within the linearized approximation to the superspace formalism for type IIB supergravity.

Membrane and U-duality

Quantization of the M2-brane or the M-theory membrane is a difficult unsolved problem. Membrane world-sheet instantons can be derived from U-duality symmetries. In [T01/068] we showed how much the world-volume theory of the membrane differs from the one of a string. We used a membrane matrix model description, obtained by dimensional reduction on a 3-torus of the $\mathcal{N}_{10} = 1$ super-Yang—Mills theory. We showed that the matrix model description does not have exact quasi-classics in contrast to matrix string models. Using cohomological methods, the partition function of the membrane matrix model was computed and the measure of summation predicted by U-duality was successfully derived.

Closing open strings

Open strings can break and emit closed string but not the opposite. Sen conjectured that an unstable vacuum containing only open string degrees of freedom decays into a stable vacuum with only closed string degrees of freedom. An infinite set of non-renormalizable interactions in the effective action of open string is necessary for capturing the complete closed strings moduli space. In [T01/063] we considered open strings theory in the classical background of a supersymmetric $SO(8)$ Yang—Mills instanton. The symmetries of this background singled out the F^4-operator in the open string effective action. In the zero-size limit all the energy of the system goes into a flat D1-brane and the quantum fluctuations are closed strings which we characterized by their sigma-model. For the two-dimensional fermions, the $SO(8)$ symmetry group of the normal bundle to the string becomes a gauge group identified with the $SO(8)$ group of the Yang—Mills instanton. This is very reminiscent of the Jackiw–Rebbi construction of fermionic zero modes in the background of $SU(2)$ monopoles.

5 Quantum field theory

Field theory was traditionally developed at the SPhT to analyze phase transitions by use of the renormalization group; we discuss here some advances in this direction. We have also gathered works of a more mathematical and fundamental character about general principles and geometry in quantum field theory in Euclidean, Minkowski or curved space-times.

5.1 Trace anomaly in four dimensions (R. Guida)

The general form of the stress-tensor three-point function in four dimensions was obtained by solving in momentum space the Ward identities for the diffeomorphism and Weyl symmetries. Several properties of this correlator have been discussed, such as the renormalization and scheme independence and the analogies with the anomalous chiral triangle. At the critical point, the coefficients of the Weyl and Euler terms in the four-dimensional trace anomaly have been related to two finite, scheme-independent amplitudes of the three-point function. Off-critical sum rules for the imaginary parts of these amplitudes have been derived, that express the renormalization-group flow of the anomaly coefficients between pairs of critical points. Although these sum rules are similar to that satisfied by the two-dimensional central charge, the monotonicity of the flow, i.e. the four-dimensional analogue of the c-theorem, remains to be proven [T00/131, T01/027].

5.2 Renormalization group (C. Bervillier)

We wrote a critical review [T01/009] on exact renormalization group equations applied to scalar field theory. The emphasis was put on reparametrization invariance which induces the presence of a redundant operator with vanishing renormalization group eigenvalue for most of the physically relevant fixed points. We also presented a summary [T00/178, T00/097] of works on nonasymptotic critical behaviors. This lead us to formulate them in such a way that the crossover from classical to Ising-like critical behavior is transparent [T02/006].

5.3 Axiomatic quantum field theory (J. Bros)

Quantum field theory in Minkowski space

In [T01/118], we have discovered non-perturbative properties at large times of QFT's in a thermal background. These asymptotic properties, which depend on the interacting field model, differ basically from the perturbative recipes of current use.

In [T01/119], we make use of the analyticity of general four-point functions in the complex angular momentum variable (previously obtained) and of the general Bethe–Salpeter structure of QFT in order to exhibit the concept of "pole-particle in the sense of Regge" as a logical consequence of the general principles of QFT. The present proof is restricted to fixed negative values of t in the $t-$channel.

Finally, as a response to a stream of research stating that particles with non-Lorentz invariant dispersion laws could be produced in possible non-renormalizable QFT's (with wild local singularities) violating Lorentz invariance although they would preserve microcausality and energy-positivity, we have shown in [T01/120] that microcausality and energy-positivity in all frames imply Lorentz invariance of dispersion laws. This is a nice application of the constraints of complex geometry in several variables.

Quantum field theory in curved spacetime

We have developed an appropriate framework for a general theory of quantized fields on the anti-de Sitter spacetime, in which the peculiarities of complex geometry are thoroughly exploited [T01/121].

COSMOLOGY, PHYSICS OF PARTICLES AND NUCLEI

This chapter describes our recent works in the fields of cosmology, particle physics and nuclear physics. Through these activities, we share common interests with our experimental colleagues from DAPNIA (Département d'astrophysique, physique des particules, physique nucléaire et instrumentations associées) in Saclay.

Some of the traditionally strong activities at SPhT are illustrated by three review articles published in Physics Reports, about the large-scale structure of the universe [T01/142], the thermodynamics of gauge theories [T01/005], and chiral symmetry in hadronic systems [T01/030].

A recent trend, already noted in the previous activity report, is the cross-fertilization between cosmology and high-energy physics, with some twenty research articles at this interface in the last two years. One may quote, among others: the idea that dark matter may not be as weakly interacting as previously thought; a general study of the growth of small perturbations in the context of higher-dimensional theories; a possible explanation of the smallness of the cosmological constant through violation of Lorentz invariance in the gravity sector. In the field of observational cosmology, a three-point correlation has been detected for the first time using gravitational lensing experiments; its non-Gaussian features arise from the dynamics of the gravitational instability, thus opening the way to a better determination of cosmological parameters.

Particle physics beyond the standard model is represented by a wide diversity of works. New developments in this field are triggered by progress on both experimental and theoretical sides. For instance, the first unambiguous observation of neutrino oscillations leads, through a "bottom-up" analysis, to an identification of several possible patterns for their masses and mixing angles, which could be discriminated by observing lepton number violating decays such as $\tau \to \mu\gamma$. On the other hand, the "de-construction" of supersymmetric theories, inspired by recent advances in higher-dimensional theories, leads to a parameter-free prediction for the mass of the Higgs boson.

Particle physics is naturally linked to current experimental programs. High-energy lepton-hadron collisions at HERA (Hamburg) and nucleus-nucleus collisions at RHIC (Brookhaven) probe a new regime of strong interactions, the so-called "saturation regime", where partons are so densely packed that they overlap. Several important results have been obtained in this field, among which an explanation of the "geometric scaling" of structure functions observed at HERA. These works tend to bridge the gap between particle physics and high-energy nuclear physics. While research at SPhT focuses on strong interactions, it may be relevant also to electro-weak physics: quantitative predictions have been made for the diffractive production of the Higgs boson at Tevatron and LHC, which appears promising due to its low background. In the more specific field of heavy-ion collisions, new methods of analyzing azimuthal correlations by means of a cumulant expansion have been devised, which are already applied by the major experimental collaborations in the field.

Finally, recent progress has been achieved in the understanding of nuclear structure, a traditional activity at SPhT, through an unprecedented microscopic study of pairing correlations in spherical and deformed nuclei.

Contents

1 Cosmology and astro-particle physics

This section gathers a wide variety of works addressing fundamental questions in cosmology, from the nature of dark matter to the variation of the fine-structure constant with time.

Analytical approaches to the problem of structure formation by gravitational instability have become a traditional activity at SPhT. Recent progress in this field is described in Sec. 1.1. Sec. 1.2 focuses on a related, though more phenomenological question: how can the large-scale structure of the universe be inferred from astrophysical observations? The works described in the remaining sections are at the intersection between cosmology and particle physics. Sec. 1.3 studies the growth of small perturbations, eventually leading to the large-scale structure of the universe, in the context of "brane cosmologies" inspired by string theory (see Sect. 2.3). Works presented in Sects. 1.4 and 1.5 shed new light on two fundamental problems in cosmology: the "dark energy" suggested by recent experiments, and the nature of "dark matter". Finally, Sect. 1.6 discusses other astrophysical observations which might tell us about "new" physics.

1.1 Gravitational Dynamics

The observed structures in the present universe result from the gravitational collapse of tiny irregularities in the primordial universe. Important contributions to the study of this dynamics came from SPhT in the last few years, and it is still actively studied, in the quasi-linear and in the strongly non-linear regime.

1.1.1 Theoretical methods (F. Bernardeau, P. Valageas)

The formation of large structures under the influence of gravitation has been studied at SPhT using analytical methods based on perturbation theory. Results obtained in this domain are described in a long review paper for Physics Reports [T01/142] . In [T01/089], the perturbative approach was applied to the collisionless Boltzmann equation, rather than to the equations of hydrodynamics (Euler equation). One recovers the usual results obtained from the hydrodynamical description, i.e. shell-crossing requires non-perturbative tools.

Using an alternative approach, we have developed a steepest-descent method to derive the probability distribution (pdf) of the density contrast within spherical cells in the quasi-linear regime [T01/093]. This allows us to recover in a more rigorous fashion most of the results obtained by standard perturbative expansions and to correct them for the high-density tail. Another advantage of this method is that it can also be applied to non-Gaussian initial conditions [T01/094] and to rare events in both the linear and non-linear regimes [T01/095]. Moreover, it enables one to compute the error on the pdf measured in numerical simulations due to the set-up of the initial conditions at a finite red shift (rather than at $z_i \to \infty$) [T01/150]. Finally, in [T01/130] we describe how divergences appear beyond a finite order in perturbation theory for initial conditions with no small-scale cutoff. This is related to the fact that on small scales, the density field is non-linear and cannot be described by perturbative means, which leads to "anomalous" exponents in perturbative expansions performed at larger linear scales.

1.1.2 Evolution of large-scale structures (R. Schaeffer, P. Valageas)

In the past years, we developed an analytical approach of large-scale structure formation. We are thus able to calculate the number of objects of given mass and size from the density field in the non-linear regime, the latter being determined by the initial conditions at very early times. This can be done within a dynamical range that goes much beyond the possibilities of numerical simulations. It provides a unified description for objects whose density compared to the average density of the universe may reach 10^6, or may be as low as 1/100. One can thus describe with very few parameters objects which seemed to bear little or no relation: galaxy clusters, groups, galaxies, dark Lyman-α absorbers, and predict their evolution backwards in red shift. This is directly linked with current observations done at the HST (Hubble Space Telescope), the KECK telescope and the VLT (Very Large Telescope).

We have studied the spatial clustering of these various objects and the fraction of matter they contain [T00/092]. Our results agree with observations and show that hierarchical scenarios provide a good model for structure formation and can describe a wide range of objects (which span at least seven orders of magnitude in mass). Next, we have studied the secondary cosmic-microwave-background (CMB) anisotropies generated by the inhomogeneous reionization of the universe [T01/013]. Our analytical results agree with numerical simulations and suggest that the signal could be detected by future interferometers (Atacama Large Millimeter Array: ALMA). Besides, we were able to distinguish the contributions arising from different processes and to conclude that one cannot discriminate reionization by stars from a quasar-driven scenario. Finally, in [T01/151] we have shown that the density-temperature phase diagram of cosmological baryons can be understood in very simple physical terms as it expresses the various processes which occur in any hierarchical scenario. This yields robust model-independent results which agree with numerical simulations. In particular, the intergalactic medium is seen to be formed by two distinct phases.

1.2 Gravitational lensing

1.2.1 Gravitational lenses: mapping the dark matter in the universe (F. Bernardeau, P. Valageas)

One of the outstanding results of observational cosmology in this period has been the detection of the so-called "cosmic shear", weak gravitational lensing effects induced by the large-scale structures of the universe: distant images are distorted by the fluctuations of the gravitational potential along the line-of-sight. This is a direct probe of the large-scale density field objects, including dark matter.

The first report of such a detection was done by the group of the institut d'astrophysique de Paris with which we have an ongoing collaboration. This result was the first step of a scientific program, developed in collaboration with the Astrophysics Department of Saclay (SAp), aiming at mapping the large-scale structure of the universe over few hundred square degrees. Eventually our goal is to take advantage of these surveys to test the mechanisms at play for the formation of the large-scale structures and to determine some of the cosmological parameters [T01/073, T01/155]. An important result for these studies has been obtained recently with the first detection in the available survey of the shear three-point correlation function [T01/144], following theoretical and numerical investigations [T01/143].

In this same context, further theoretical results have been obtained that complement previous investigations. In [T00/091], we study gravitational lensing in both the quasi-linear and highly non-linear regimes. In both cases our analytical predictions for the probability distribution (pdf) of the distortion agree well with numerical simulations. Our method shows how one could recover the pdf of the density field from such observations. Another work [T00/155] consolidates the semi-analytical models used to describe the intermediate regime (in between the nonlinear regime and the quasi-linear one) for which theoretical insights are very difficult to obtain.

1.2.2 The cosmic microwave background (CMB) (K. Benabed, F. Bernardeau)

Somewhat related to the previous topics is the exploration of the lensing effects on the properties of the CMB, and more particularly on its polarization. We have shown that the detection of such effects would permit to put constraints on the (cosmological) vacuum energy density (that determines the overall size of the optical bench on which those effects are measured) or to detect the signature of a quintessence field [T01/045] (see Sect. 1.4.1). These investigations have been selected to be part of the scientific core program of the European satellite *Planck-surveyor*.

1.3 Perturbation theory in brane cosmologies (P. Brax, A. Riazuelo)

Brane cosmologies are based on the idea that our four-dimensional universe is in fact a surface (a "brane") embedded in a higher (typically, five-) dimensional spacetime (see Sect. 2.3). A few years ago, it was realized that standard cosmology could be recovered at low energy in brane models, which triggered a lot of activity in this field. However some modifications to the usual four-dimensional gravity are to be expected. One of the main challenges at this moment is to compute the CMB anisotropies in this class of models. This is a difficult problem, as one must solve the five-dimensional equations for the cosmological perturbations. In our work, we have derived all the necessary equations for this purpose. Although this was already done in some specific contexts, our work is more general and could in principle be adapted to any model of cosmological interest [T02/040].

More specific brane models have been considered, where $N = 2$ supergravity in the bulk is broken on the brane. We have investigated models where an accelerated universe is obtained [T00/153, T01/056]. The coupling to matter on the brane [T01/032] and the cosmological perturbations in the long wave-length limit have been studied. In particular the Newton constant is seen to vary on cosmological time-scale since nucleosynthesis. The low energy field theory of these models and in particular the radion mode have been investigated leading to scalar-tensor theories with a large Brans–Dicke parameter [T02/008, T02/009].

1.4 The dark energy of the universe

Famous recent astrophysical observations (of supernovae and cosmic microwave background) suggest that a significant part (some 70%) of the energy density of the universe would be under the form of a homogeneous component with negative pressure, often referred as "dark energy", which could correspond to a nonvanishing cosmological constant. This triggered several recent works at SPhT.

1.4.1 Quintessence (P. Brax, A. Riazuelo)

The energy density of the "dark energy" is of order 10^{-47} GeV^4, which is extremely small in comparison with the Planck scale. The motivation for quintessence is to provide a dynamical explanation for such a small but non zero energy. It relies on the hypothesis that this energy is under the form of a slow rolling scalar field. The energy density of the universe would then be explained by the small value of the potential energy of the quintessence field now.

In a first series of works, we have proposed [T00/130, T01/044] a supergravity scenario leading to potentials of the required type, an inverse power law decrease followed by a steep exponential increase. Such models could be tested experimentally by studying lensing effects on the cosmic microwave background (see 1.2.2).

Another recent work studies some cosmological consequences of quintessence [T02/011]. It focuses on the case where the scalar field was non minimally coupled to the metric. This leads in particular to a variation of Newton's constant with time. As a consequence, the Chandrasekhar mass also varies with time. This modifies the interpretation of the supernovae light curve, which is the most crucial observation in favor of the presence of dark energy. In this work, we have been able to set limits on the amplitude of the coupling between the quintessence field and the metric.

1.4.2 Dimming of supernovae by axion–photon oscillations (C. Grojean)

Another recent work takes the point of view that neither a cosmological constant nor a rolling quintessential scalar field are natural dark energy components in regards of their quantum instability. One must then find alternative explanations to observations, which do not involve any "dark energy". The key observation here is the Hubble diagram of high red shift supernovae (SNe). It reveals that they are fainter than expected from the standard luminosity-red-shift relationship in a matter-dominated decelerating universe.

In [T01/126] we elaborate on a model proposing an alternative explanation in which the SNe dimming is explained by photon–axion oscillations in the intergalactic medium: quantitatively, the 0.44 magnitude increase in the SNe luminosity is due to the loss of one third of the photons into an equilibrium population evenly divided between the two photon polarizations and the axion. A χ^2 analysis of the data allows to conclude that this model is as viable as the standard cosmological model with dark energy.

1.5 Interacting dark matter (A. Riazuelo, R. Schaeffer)

Although we definitely know that 90% to 99% of the matter in the universe is dark, its nature is still unknown. The standard lore is that most of this dark matter is not composed of baryons, but rather of a new, yet undetected, particle. In the framework of supersymmetry, this particle could be the lightest supersymmetric partner. However, this long-standing hypothesis of weakly interacting massive particles (WIMPS) is in crisis. It is unable to predict the correct small-scale clustering in the universe, in particular the number of small galaxies and the density profile in the central part of large galaxies.

Although ad-hoc solutions based on purely astrophysical considerations may be invoked to handle each of these problems, it may be that the dark matter is after all not as weakly interacting as was believed. We have studied the limits that astrophysical observations can put [T00/183] on the allowed strength of such interactions. More specifically, we have studied limits on the dark matter-photon [T01/147] (and in a near future on the dark matter-neutrino) cross section. This approach allows in turn for a general classification of all possible kinds of dark matter, exhibiting new possibilities including in particular strongly interacting ones. This form of matter could also in certain circumstances reproduce the observations of the structure of the galactic halos and of the number of dwarf galaxies better than the standard, non interacting dark matter.

1.6 Other directions in astro-particle physics

1.6.1 Gravitational lensing and search for new physics (F. Bernardeau)

The exploration of the phenomenological aspects of cosmic string lensing properties has been pursued for different types of string geometries [T00/159]. We have also explored the observational consequences of abnormal large-scale gravity laws, such as those expected in some scenarios of brane cosmology for the statistical properties of the large-scale mass distribution in the universe [T00/169].

1.6.2 Variation of the fine structure constant with time (C. Grojean)

A recent analysis (Webb *et al.*) of quasar absorption spectra at red shift $z \sim 0.5$–3.5 indicates that the fine structure constant α is changing with time: $(\alpha_{\rm now} - \alpha_{\rm past})/\alpha_{\rm now} = (.71 \pm .18)\, 10^{-5}$. While the possibility that the fundamental constants are time-dependent has been considered already a long time ago (starting with P. A. M. Dirac), it is not clear how this result fits into the current field-theoretic picture of elementary particle physics. In the standard model (SM), all the coupling constants run with energy. Since the temperature of the universe changes with time, this implies that the effective values of the couplings are also changing. This effect, however, cannot be used to explain the data, since α does *not* run at energies below the electron mass $m_e \approx 500$ KeV, corresponding to red shifts of order 10^7. Thus, it appears that the time variation of α reported cannot be explained without appealing to physics beyond the standard model. In [T02/038], we consider the possibility that such a variation could be induced by a second order phase transition which occurs at late times ($z \approx 2-4$) and involves a change in the vacuum expectation value of a light scalar with mass of the order of the temperature at the time of the transition (10^{-3}eV).

2 Particle physics beyond the standard model

The first evidence for physics beyond the standard model came recently with the observation of neutrino oscillations, showing that neutrinos have non-zero masses. The constraints imposed by existing data on models based on the seesaw mechanism are discussed in Sect. 2.1. Recent works on supersymmetric theories, which are at the root of the search for "new physics", are presented in Sect. 2.2: they address fundamental questions as well as the experimental search for supersymmetric particles at collider experiments. Finally, the phenomenology of higher-dimensional theories, which has stimulated a huge activity throughout the world in recent years, is discussed in Sect. 2.3.

2.1 Physics of neutrinos and flavor violation (S. Lavignac, I. Masina, C. Savoy)

With the results of the super-Kamiokande (1998) and SNO (2001) experiments, neutrino physics has entered a new era. The now well-established oscillations of solar and atmospheric neutrinos strongly suggest that neutrinos have non-zero masses and non-trivial mixing angles, like quarks. However the origin of neutrino masses is presumably different, and the most convincing explanation of their smallness is the so-called "seesaw" mechanism, which involves heavy right-handed neutrinos and requires a violation of lepton number, as predicted by many extensions of the standard model. Another striking difference with quarks is the presence of two large mixing angles in the lepton sector, associated with atmospheric and solar neutrino oscillations, respectively. In [T02/015], the patterns of seesaw parameters that can reproduce the observed large mixing angles with the least amount of tuning were identified without assuming any a priori high-energy structure. Interestingly enough, these patterns have a simple physical interpretation in terms of the couplings of the right-handed neutrinos, and point towards non-trivial flavor symmetries. Each pattern gives rise to specific relations among neutrino oscillation parameters, which lead to testable constraints on the third mixing angle θ_{13}.

Oscillation data are definitely not sufficient to identify the mechanism responsible for neutrino masses. Other experiments like searches for neutrinoless double beta decay and for rare processes such as $\mu \to e\gamma$ or $\tau \to \mu\gamma$ are necessary. In [T01/066], the possibility of discriminating between different supersymmetric seesaw models by improving the experimental sensitivity to these lepton flavor violating decays has been studied. As a result of this analysis, a classification of models according to their predictions for the branching ratios of $\mu \to e\gamma$ and $\tau \to \mu\gamma$ has been obtained. The decay $\tau \to \mu\gamma$ has been found to be a particularly promising tool to probe the fundamental seesaw parameters, and especially to identify the origin of the large atmospheric angle.

2.2 Supersymmetry

Supersymmetric theories are studied by several physicists at SPhT, whose recent works address both fundamental theoretical questions, and phenomenological issues closely related to present experiments. On the more fundamental side, a long-standing problem is to understand how to make contact between a low energy four-dimensional effective string theory and the minimal supersymmetric standard model (MSSM). This demands to find a mechanism responsible for supersymmetry (SUSY) breaking and predict the so-called *soft SUSY breaking terms*. This issue is addressed in Sec. 2.2.1 in the context of type I string models, where it is shown that dilaton and moduli can be stabilized by gaugino condensation. Consequences for CP violation are discussed in Sec. 2.2.2. Another generic problem of SUSY theories, that of multiple vacua, is studied in Sect. 2.2.3. Finally, Sects. 2.2.4 and 2.2.5 are devoted to phenomenological consequences of R-parity violating extensions of the MSSM in high-energy physics and cosmology.

2.2.1 Supersymmetry breaking in effective string models (G. Servant)

When trying to link low-energy effective string theory with the MSSM, a recurrent problem comes from the fact that the supergravity scalar potential of the low energy theory, which is a function of the dilaton and other moduli fields describing the geometry of the compact space, is flat in some directions. It is crucial to lift these flat directions, in other words to give a vacuum expectation value (*vev*) to the dilaton and moduli. In particular, the dilaton fixes the gravitational and gauge couplings while other moduli fix the size of the extra dimensions. More generally, the *soft SUSY breaking* parameters such as scalar masses, gaugino masses, tri-scalar couplings, and therefore the SUSY spectrum, depend on the *vev* of moduli.

A usual way to fix these moduli is to introduce some non-perturbative dynamics. For instance, a hidden gauge group entering a strong coupling regime leads to gaugino condensation, generating new contributions to the scalar potential of the theory. These non-perturbative contributions lift the flat directions and fix the *vev* of the dilaton and moduli. This mechanism has been extensively studied in the heterotic string. However, there was no such study in Type I string. Among the attempts to describe four-dimensional chiral theories in the framework of string theory, a new class of four-dimensional models were constructed, known as *Type IIB orientifolds* (*i.e.* Type I string). They offer new perspectives for phenomenology (*e.g.* low string scale allowed by the D-p brane structure). In [T00/118], we computed the scalar potential which generically emerges in these constructions and considered the effect of gaugino condensation on dilaton stabilization and the structure of soft-breaking terms. Our main observation is that dilaton and moduli can be stabilized by a single gaugino condensation in contrast with the usual *racetrack models* (multiple gaugino condensations required for stabilization). A crucial role is played by the twisted moduli associated with the fixed points of the orientifolds. These new fields not only modify the Kähler potential but also appear in the gauge kinetic functions leading to unusual properties of the non perturbative dynamics of these gauge theories.

2.2.2 CP violation and the SUSY/string CP problem (G. Servant)

In [T00/179], we studied CP violation in these models. CP violation in the standard model (SM) is not enough to account for the baryon asymmetry of the universe and new sources of CP violation beyond the SM are welcome. On the other hand, they have to satisfy strong experimental constraints. The SUSY/string CP problem is to understand why CP violating phases in the soft SUSY breaking sector of the MSSM are suppressed (but non zero). This requires a detailed study of CP breaking in intimate connection with SUSY breaking. The computation of the above potential allowed us to extract the structure of soft SUSY breaking terms as well as CP breaking terms. We showed how CP violation in the Cabibbo–Kobayashi–Maskawa matrix can appear as a result of the dynamics of moduli and on the other hand be suppressed in the soft SUSY breaking sector.

2.2.3 Vacuum degeneracies (P. Brax, C. Savoy)

Supersymmetric gauge theories generically have many supersymmetric vacua corresponding to different patterns of gauge symmetry breaking. This degeneracy leeds to problems in many applications. It can be lifted by the introduction of supersymmetry breaking to build more realistic models. The massless states associated to a continuum of vacua in the supersymmetric limit define the low energy degrees of freedom of the theory. They can be systematically determined by a study of the gauge invariant holomorphic polynomials in the complex scalar fields. Then, very powerful results in algebraic geometry can be translated into simple algorithms to determine the minima of the effective potential. Several fundamental questions can be addressed in this framework such as the question of confinement, the puzzling property of duality between different gauge theories and the role of the so-called syzygies (algebraic relations among the holomorphic invariant polynomials that are the composite (super)fields describing the low energy limit of a confined theory). We have written a short review about this [T01/040].

In realistic supersymmetric models where some gauge symmetry breaking is needed at scales much above the electroweak one, the presence of many vacua has to be efficiently controlled in order to obtain the right physics. Thus, if the parameters of the theory are chosen to yield a vacuum with a given residual symmetry (for instance the standard model gauge symmetry), it coexists with other vacua possessing larger symmetries into which it could tunnels or which could be cosmologically preferred. This is due to the fact that only holomorphic invariant polynomials are relevant to define a supersymmetric model. It is possible to characterize the larger residual symmetries associated to these spurious classical solutions and those which, on the contrary, can only be approximately enforced by a fine-tuning of the parameters. A systematic study of the $SO(10)$ symmetry breaking to determine the favored patterns from the point of view of the gauge coupling unification illustrates the two situations. This has interesting consequences for the scale of lepton number violation and neutrino masses [T02/034].

2.2.4 Single superpartner production at the Tevatron (G. Moreau)

In the minimal supersymmetric standard model (MSSM), supersymmetric particles must be produced in pairs. The R-parity violating extension of the MSSM offers the opportunity to produce single supersymmetric particles. In collaboration with physicists from DAPNIA, we have studied single gaugino production at Tevatron Run II and its experimental signatures. These analyzes allow to probe the masses of supersymmetric particles beyond the present experimental limits [T00/112].

2.2.5 R-parity violation and the cosmological gravitino problem (M. Chemtob, G. Moreau)

The cosmological gravitino problem stems as a direct consequence of the gravitational strength of the gravitino interactions. The very weak coupling of gravitinos with the matter and gauge particles causes their early thermal decoupling and their late disintegration during the time evolution of the universe since the Big Bang. The early decoupling entails the risk of an excessive abundance of gravitino cosmic relic particles, while the decay products emitted after the nucleosynthesis era threaten to distort the cosmic abundance of light nuclei.

Aside from inflation, one simple resolution of the problem is to enhance the gravitino decay rate. If the gravitinos are heavier than the lightest supersymmetric particles, the condition that these disappear before nucleosynthesis sets a lower limit on their mass of order $m_{\tilde{G}} > O(10)$ TeV. If the gravitino is the lightest supersymmetric particle, it is absolutely stable unless one takes the R-parity odd interactions into account.

A study of the gravitino three-body disintegration modes into quarks, leptons or a combination of quarks and leptons, according to the reaction scheme $\tilde{G} \to f_i + f_j + f_k$, has been developed on the basis of the tri-linear interactions violating R-parity. The comparison of the calculated gravitino decay rate with the universe expansion rate is used to determine the conditions under which the gravitino relics decay before the nucleosynthesis era. By taking into account the present constraints on the tri-linear R-parity violating coupling constants, and assuming that the gravitino and scalar superpartner masses do not exceed ≈ 10 TeV, we find that the gravitinos could easily have decayed before the present epoch but not earlier than the nucleosynthesis epoch [T01/082].

2.3 Extra dimensions

String theory is so far the only candidate to reconcile general relativity with quantum physics. It has currently has three important ingredients: extra dimensions, supersymmetry and branes. The discovery of p-branes (extended objects spanning (p+1)-space-time dimensions) in string theory has motivated the phenomenological study of "brane-world" scenarios, in which the standard model fields (i.e. ordinary matter) are localized on a 3-brane embedded into a higher-dimensional space-time ("bulk") where gravitational fields propagate.

Such theories could have interesting consequences for cosmology and particle physics. Some of their cosmological consequences have already been discussed in Sect. 1.3. In the field of high-energy physics, these theories resulted in a critical re-thinking of some long standing puzzles by using a new set of ideas and tools. This is illustrated in Sects. 2.3.1 and 2.3.2, where a definite prediction is given for the Higgs mass within de-construction models. Sect. 2.3.3 addresses the cosmological constant problem from the "brane-world" point of view, while Sect. 2.3.4 proposes an original solution to this problem. More formal aspects of these theories are studied in Sect. 2.3.5 and Sect. 2.3.6.

2.3.1 De-construction of supersymmetric theories (C. Grojean)

Recently, it was argued that it might be possible to translate many higher dimensional effects into a purely 4D construction by using a set of 4D theories which in the IR reproduce the dynamics of extra-dimensional theories. These theories are also useful tools to regulate the higher dimensional theories, and even give a UV completion of them. In [T01/098], we give a fully 4D implementation of a higher dimensional mechanism for supersymmetry breaking (gaugino mediation), using a 4D $\mathcal{N} = 1$ SUSY model which at low energies is equivalent to a latticized version of these higher dimensional models. We demonstrate that 4D $\mathcal{N} = 1$ supersymmetry plus gauge invariance (with properly chosen matter content) is enough to ensure the existence of additional supersymmetries in the continuum limit. This phenomenon of enhanced supersymmetry generation is related to the behavior of these models at low energies in a purely

4D context, in which $\mathcal{N}$=1 SUSY is enhanced to $\mathcal{N}$=2 on the moduli space, without the fine-tuning of parameters.

2.3.2 A prediction for the Higgs mass (C. Grojean)

In [T02/022], we present a class of four-dimensional models, with a non-supersymmetric spectrum, in which the radiative corrections to the Higgs mass are not sensitive to the UV completion of the theory, at least at the one loop level. At one loop, Yukawa interactions of the top quark contribute to a *finite* and *negative* Higgs squared mass which triggers the electroweak symmetry breaking, as in softly broken supersymmetric theories, while gauge interactions lead to a logarithmic cutoff dependent correction that can remain subdominant. Our construction relies on a *hard* supersymmetry breaking localized in the theory space of *de-construction* models and predicts, within a renormalizable setup, analogous physics as five-dimensional scenarios of Scherk—Schwarz supersymmetry breaking. The electroweak symmetry breaking can be calculated in terms of the de-construction scale, replication number N (the number of copies of the $SU(2)$ gauge group), top-quark mass and electroweak gauge couplings. For $m_{\rm top} \sim 170$ GeV, the Higgs mass varies from 158 GeV for $N = 2$ to 178 GeV for $N = 10$.

2.3.3 The cosmological constant problem (C. Grojean, S. Lavignac)

Several recent works address the cosmological constant problem (i.e. the almost perfect vanishing of the cosmological constant compared to high energy scales such as the Planck scale) from a brane-world perspective. As already mentioned in Sect. 1.3, it has been shown that four-dimensional gravity could be recovered even if some of the extra dimensions are non-compact, up to corrections consistent with the current experimental tests of gravity.

It has also been suggested that some particular set-up involving a bulk scalar field could explain the smallness of the cosmological constant without any fine-tuning of the parameters describing the physics on the brane. The idea is that the curvature of the higher dimensional space-time can adjust itself so as to cancel the contribution of the fields living on the brane to the effective four-dimensional cosmological constant: a vacuum energy could curve the extra dimensions and not contribute to the 4D expansion of our brane universe. However, as shown in a previous SPhT publication, the consistency of this "self-tuning" mechanism requires additional contributions to the four-dimensional cosmological constant, implying some hidden fine-tuning. In [T00/105], this result has been extended to more general set-ups, also for a brane with de Sitter or anti-de Sitter geometry. Irrespective of this fine-tuning problem, which could possibly be resolved in explicit string theory compactifications, it has been shown that the solutions of Einstein equations with a vanishing four-dimensional cosmological constant are unstable against small perturbations of the bulk scalar couplings. Such perturbations are indeed expected from quantum corrections. In addition, the "self-tuning" values of the scalar couplings are inconsistent with the observed long range properties of gravity.

In [T00/152], we explore the geometry of self-tuning models where the 4D effective vacuum energy is dynamically relaxed by a 5D scalar field and we show that inevitably a naked singularity is formed at fine distance. In [T00/121], we further show that these models also suffer from classical instability due to the presence of a massless scalar field in the 4D effective action that renders the configuration highly sensitive to initial time conditions.

2.3.4 Gravitational Lorentz violations (C. Grojean)

In [T01/096] and [T01/097] we propose a new dynamical relaxation mechanism of the 4D effective cosmological constant of a brane-world. This mechanism accommodates a change in the brane vacuum energy, due to a phase transition for instance, by gravitational and electromagnetic radiation off the brane adjusting the mass and the charge of a bulk black hole. This exchange of energy adjusts the brane vacuum energy to zero and thus prevents the brane to inflate. The geometry of these configurations have the property that the speed of light along flat 4D sections varies over the extra dimensions. The main property of such spaces is that while the induced metric is flat, implying Lorentz invariant particle physics on a brane, bulk gravitational effects will cause apparent violations of Lorentz invariance and of causality from the brane observer's point of view. An important experimentally verifiable consequence of this is that gravitational waves may travel with a speed different from the speed of light on the brane, and possibly even faster, which can be searched for in gravitational wave experiments. We further investigate [T01/099] these geometries in a stringy context.

2.3.5 Non-BPS branes (P. Brax)

The spectrum of open string theories allows one to consider extended objects which break all supersymmetries. Moreover these objects are not stable due to the presence of an open string tachyon. We have studied the supergravity solutions corresponding to the non-BPS (Bogomolnyi-Prasad-Sommerfeld) branes in ten dimensions [T00/073]. We have found that Birkhoff's theorem is violated with the appearance of an extra parameter on top of the mass and the charge whose interpretation is naturally related to the tachyonic vev. These objects have a naked singularity which has been shown to absorb gravity with an infrared divergence [T01/010].

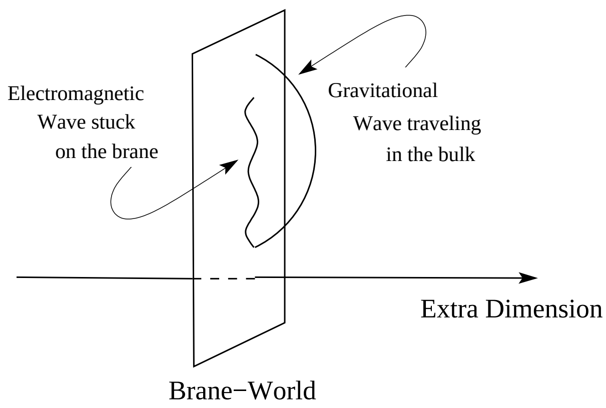
Non-BPS branes also occur in Heterotic M-Theory compactified to five dimensions on a Calabi–Yau manifold where five-branes wrap a non-holomorphic two cycle. In that case it has been shown that the five branes are attracted by the boundary walls leading to a collision reminiscent of the Ekpyrotic proposal [T01/024].

Within the supersymmetric Randall–Sundrum scenario, non-BPS configurations have been studied [T01/081]. They correspond to rotated branes or branes of equal tensions. In the latter case, the configuration possesses a Rindler horizon whose temperature signals the breaking of supersymmetry.

Understanding the behavior of cosmological perturbations is one of the arduous puzzles of brane world cosmology. In the paper [T01/168] a covariant approach has been followed for models with a bulk scalar field. An obstruction due to a non-trivial Weyl tensor induced on the brane from five dimensions limits the analysis to long wave-length perturbations. In that limit, there are extra modes compared to the four dimensional case. Lifting this obstruction and extending the investigation to all wave-lengths is an open problem.

2.3.6 Anomalies in orbifold theories (L. Pilo)

The consistency of gauge field theories on singular space like orbifold requires a non-trivial analysis of quantum anomalies. In [T02/020], we study the issue of gauge invariance in five-dimensional theories compactified on an orbifold $S^1/(Z_2 \times Z_2')$ in the presence of an external $U(1)$ gauge field. From the four-dimensional point of view the theory contains a tower of Kaluza–Klein Dirac fermions with chiral couplings and it looks anomalous at the quantum level. We show that this "anomaly" is cancelled by a topological Chern–Simons term which is generated in the effective action when the gauge theory is regularized introducing a spontaneous breakdown of the parity symmetries. In the presence of a classical background gauge field, the fermionic current acquires a parity-violating vacuum expectation value, thus generating the suitable Chern–Simons term and a gauge invariant the-



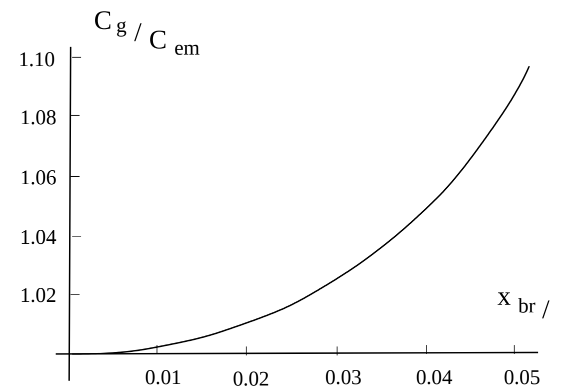


Figure 1: A graviton emitted on the brane will travel along a geodesic in the bulk before returning to the brane. A photon emitted at the same time can propagate only along the brane and may wander a shorter distance along the brane than the graviton in the same time. The 4D effective propagation speed of gravity is distance dependent (x_{br} is the distance traveled along the brane and l characterizes the curvature of the bulk).

ory. Our results reflect the profound relation between anomalies in orbifold quantum field theories with odd dimensions and parity-conservation.

3 Strong interactions

Strong interactions are studied at SPhT in various contexts, from high-energy physics to nuclear structure. The fundamental theory of strong interactions, quantum chromodynamics (QCD), is one of the major subjects of particle physics. At a phenomenological level, it is one of the main scientific investigation at present colliders, like HERA (lepton-hadron), Tevatron (hadron-hadron), RHIC (nucleus-nucleus) and sooner or later the LHC (Large Hadron Collider, at CERN). Experiments at HERA have triggered new studies of hadronic interactions in the regime of high parton densities, which is also the high-energy limit of QCD: the phenomenon of "parton saturation" is expected to occur (Sect. 3.1), which is also believed to be at the heart of RHIC physics. Sect. 3.2 describes other recent developments relative to collider experiments.

On the other hand, the relativistic heavy ion program at CERN (presently at SPS, in the future at LHC) and Brookhaven (RHIC) has stimulated various theoretical approaches to the thermodynamics of QCD (Sect. 3.3) as well as a series of works directly connected with present experiments (Sect. 3.4).

Low energy hadronic and nuclear physics is still an active field of research at SPhT, albeit only represented now by few physicists. Sect. 3.5 presents QCD-inspired studies of hadronic and nuclear interactions at lower energies, while research in the field of nuclear structure (Sect. 3.6) is represented by a fundamental, microscopic study of pairing correlations in nuclei.

3.1 Saturation in QCD

With the advent of new colliders — the electron-proton collider HERA at DESY and the relativistic heavy ion collider RHIC at Brookhaven — which produced a lot of intriguing experimental data, there has been a renaissance of interest in the dynamics of QCD at high energy, or "small x". Much of the theoretical excitement about this physics comes from the expectation that, at sufficiently high energies, one should uncover a new regime of QCD which is characterized by high parton densities and weak coupling. This regime is interesting since the color fields are strong enough for the non-linear structure of QCD to fully reveal itself, yet theoretical progress can be made, by exploiting the smallness of the coupling constant.

A remarkable novel phenomenon which is expected in these conditions is *parton saturation*, which is a limitation on the maximum phase-space densities of the "partons" (virtual quarks and gluons) in the hadron wavefunction, due to non-linear effects. The experimental data at HERA and RHIC appear to be consistent with saturation, although no firm conclusion can be drawn so far. Saturation in QCD has been studied at SPhT in two different contexts. In Sect. 3.1.1, it is investigated by exploiting the classical nature of the high-density limit. In Sect. 3.1.2, one studies how saturation occurs within an elementary system such as a color dipole.

3.1.1 The color glass condensate (E. Iancu)

For gluons, saturation is expected at a phase-space density of order $1/\alpha_s$ ($\alpha_s \ll 1$ is the QCD coupling), which is so large that the traditional perturbative techniques are not applicable. On the other hand, precisely because the occupation numbers are large, the transition amplitudes are dominated not by quantum fluctuations, but by the configurations of classical field containing large, $\sim 1/\alpha_s$, numbers of gluons. This suggests that the associated non-linear features can be investigated via semi-classical methods.

At the same time, to be realistic, any semi-classical description should include the effects of the quantum evolution towards small x, which is the physical origin of the increase in the parton densities with decreasing x (or increasing energy). That is, the appropriate "classical theory" must be an *effective theory*, whose structure is evolving with x (since obtained by integrating out quantum fluctuations, down to the value of x of interest).

Based on perturbative QCD, we have derived such an effective theory which describes the small-x gluons as a *color glass condensate*; "color" since gluons carry a non-Abelian charge; "glass" since the associated fields evolve very slowly relative to natural time scales, and are disordered; "condensate" because the gluons are packed in a state of maximum density, which is a Bose condensate [T00/166, T01/021, T01/085].

In this effective theory, observables are computed by averaging over the random configurations of the color fields with a functional "weight function", which encodes the relevant information about quantum evolution. This weight function obeys a renormalization group equation (RGE) of the Fokker–Planck type, which shows how the distribution of the classical field changes when integrating out quantum fluctuations in layers of x.

The RGE equation is non-linear in the gauge fields to all orders — the relevant degrees of freedom are "Wilson lines", i.e. path-ordered exponentials built with the gauge fields — but we have been able to obtain approximate solutions, within a mean field approximation. These solutions show gluon saturation: at momenta below some *saturation scale*, the gluon phase-space density is $\sim 1/\alpha_s$ and increases only logarithmically with the energy [T01/026].

Since the saturation scale is relatively low (one expects $Q_s \sim 1-2$ GeV for the current experiments), it is interesting to notice that this phenomenon has verifiable predictions also for the physics at much higher momenta $\gg Q_s$, where perturbation theory is better justified. Indeed, we have shown that saturation may explain the peculiar "geometric" scaling of the deep inelastic scattering cross-section which has been seen at HERA for momenta up to $Q^2 \sim 400$ GeV^2 [T02/027]. A pedagogical review of the effective theory for the color glass condensate can be found in [T02/024].

3.1.2 QCD dipoles and saturation (H. Navelet, R. Peschanski)

The QCD dipole formulation plays an essential role in the theoretical description of quantum chromodynamics (QCD) at high energy. Indeed, quarks and gluons organize themselves in extended, but simply structured, colorless states which are expected to “diagonalize” the high energy processes. SPhT is involved in the formulation of the dipole model since the beginning. We have developed this picture in a series of papers [T00/133, T01/015, T02/019]. In particular, we have shown by an exact analytic computation that taking into account the exact gluon kinematics implies the existence of non-diagonal contributions, which modify the dipole picture; we have raised the question of its generalization at next to leading order of resummation. The dipole formulation is known now to be at the heart of the saturation problem, i.e. the question of the geometrical overlap of quark and gluon fields when their density grows, leading to a new phase of QCD. In the paper [T02/019], we have derived the specific saturation mechanism due to the quantum fluctuations of virtual QCD dipoles when the energy grows. This new quantum saturation mechanism has not been previously computed due to complications that we solved using the conformal invariance of QCD amplitudes at high energy.

3.2 From perturbative to nonperturbative QCD

The first paragraphs in this section present QCD calculations applied to various observables: jet physics (Sect. 3.2.1), diffractive processes at HERA and in collider experiments (Sect. 3.2.2 and 3.2.3, in collaboration with physicists from DAPNIA); multiplicity correlations in phase space (Sect. 3.2.4). The last paragraph, Sect. 3.2.5, discusses from a more fundamental point of view the connection between strong coupling QCD and string theory.

3.2.1 Perturbative QCD calculations for jet physics (P. Uwer)

We consider the next-to-leading (NLO) corrections to parity violating observables in three-jet production of massive quarks, such as the forward-backward asymmetry. This analysis has two important applications. First, it is necessary to describe the recently measured oriented jet-rates and event-shapes at NLO accuracy. Second, this calculation is a necessary building block for the study of the forward-backward asymmetry for heavy quarks at next-to-next-to-leading (NNLO) accuracy, although the proper definition of the forward-backward asymmetry for heavy quarks remains to be clarified. In particular the forward-backward asymmetry for b-quarks which is measured at LEP can be calculated. The virtual corrections have been presented in [T00/120, T00/124]. The combination with the real corrections still needs to be done.

3.2.2 Higgs search (R. Peschanski)

The Higgs boson(s?) is the missing key for the unification of fundamental interactions (but Gravity) and the origin of the mass of particles. It is thus the priority goal of the experimental searches at accelerators. Among the production modes, the hard diffractive production in the central region of detectors has the interest to provide a good signal/background ratio. However, its cross-section, very badly determined up to now, can be very small. In [T01/078], we revisited this domain by proposing a model based on the mechanism that allows to describe the diffractive di-jets observed at Tevatron. Thus, by comparison and extrapolation, it allows realistic predictions for the Higgs boson at Tevatron and LHC. While marginal for the Tevatron, the cross-sections are much promising for the LHC, opening a new way for the Higgs boson hunt.

3.2.3 Hard diffraction (H. Navelet, R. Peschanski)

The so-called "hard diffraction" processes, discovered and studied at HERA, combine a diffractive (long distance) interaction at the level of the target with a "hard" (short distance) interaction at the level of the projectile (a virtual photon at HERA, an energetic jet at Tevatron and, in the future, at LHC). This quite unexpected combination of mechanisms has led to various, more or less contradictory, models. in a series of works [T00/142, T01/049, T01/077, T01/079], we have promoted an unifying picture of hard diffraction combining some properties of perturbative QCD in the dipole approach (see Sect. 3.1.2) with longstanding results of the S-Matrix theory of strong interactions. This work provides a new approach to various problems arising in the analysis of observed processes at accelerators, such as the gap survival probability due to re-interactions, the rate of diffractive versus non-diffractive production, etc.

3.2.4 QCD and multiplicity correlations (R. Peschanski)

Looking again to a previous program of perturbative QCD calculations for multiplicity fluctuations (intermittency effects), we proposed in [T00/182] a new scaling law for the correlations between multiplicity fluctuations in two different phase-space intervals. This prediction can be tested in the study of quark and gluon jets.

3.2.5 String theory (R. Janik, R. Peschanski)

Theoretical problems directly connected with the study of quantum chromodynamics at high energy can be divided in two groups: the resummation of the perturbative expansion at weak coupling (short distance) which we discussed in the previous sections; and the solution at strong coupling (long distance), which we now go into.

Starting with the key problem of understanding gauge field theories at strong coupling, a new stimulating direction in this difficult problem has been provided by the Maldacena conjecture, the so-called AdS/CFT correspondence, namely a duality between certain gauge theories at strong coupling with a supergravitational string theory in ten dimensions and with non-flat (Anti de Sitter) metrics.

In recent years, we have initiated a program of investigations establishing the link, using correlators of Wilson lines and loops, between the string formalism in AdS space and the high-energy scattering amplitudes in gauge theories. The computation of these observables allowed us to study the relation between confinement and the Regge properties, which was expected from general arguments based on S-matrix theory (in the 60's), but had never been derived so far. This old problem has never been addressed in this modern context.

More precisely, the properties of scattering amplitudes were mapped to certain properties of helicoid minimal surfaces. The saddle point treatment gave rise to a linear Regge trajectory and unit intercept. More recently, we studied the effect of quadratic string worldsheet fluctuations around the minimal surface considered in our previous works. After analytical continuation to Minkowski space the fluctuations gave rise to a shift of the intercept proportional to $n_\perp/96$, where $n_\perp$ is the effective number of transverse dimensions. The resulting trajectory is very close the experimentally observed soft pomeron trajectory [T00/143].

Continuing in this direction [T00/083], we have shown [T01/105] the possibility of extending to inelastic reactions at high energy (reggeon exchanges) the formalism we found for elastic ones (pomeron exchange). This extension is far from straightforward mathematically, since it requires a new minimization of a functional integral over boundary curves drawn on minimal surfaces in AdS background and the inclusion of a non-trivial topological spin factor in order to take into account the 1/2 spin of the exchanged quarks. We have found promising results on the Regge parameters obtained through this geometrical duality with string theory.

3.3 Theory of dense QCD matter

At high densities, the thermodynamics of QCD predicts that hadronic matter should turn into a quark-gluon plasma, which may be studied experimentally through ultrarelativistic heavy ion collisions (see Sect. 3.4). For many years, the only viable theoretical approach to the study of dense QCD matter was lattice numerical calculations, which only applied to systems with zero net baryon density. Recent contributions to this field are described in Sect. 3.3.1 and 3.3.2.

In the last few years, important progress was made using alternative approaches. On the one hand, universality arguments suggested a rich phase diagram in the high baryon density, low temperature limit (not accessible to lattice calculations), where the phenomenon of "color superconductivity" is expected to occur, with characteristics depending essentially on the number of quark flavors. Properties of this phase are studied in Sect. 3.3.3 using effective field theories. Application to neutron stars (Sect. 3.3.4) is very timely in view of the announcement by NASA, a few months ago, that "quark stars" may have been observed in the Galaxy.

On the other hand, analytical, perturbative approaches have reached the level where they can be compared to lattice data. Sect. 3.3.5 presents a recent perturbative calculation of susceptibilities. These thermodynamic quantities, which can also be computed on the lattice, are derivatives with respect to the baryonic chemical potential, and thus provide information about system with non-zero baryon density, which is particularly valuable in view of application to heavy-ion experiments.

3.3.1 Quenched QCD at finite temperature with chiral fermions (R. Lacaze)

It has long been understood that the screening of currents in a plasma gives us information on its excitations. Currents with certain quantum numbers excite mesons from the vacuum at low temperatures, and should exhibit deconfinement related changes above the QCD phase transition temperature (T_c). Detailed studies have shown that this does happen in the vector and axial-vector channels: the screening above T_c is clearly due to nearly non-interacting quark anti-quark pairs in the medium. On the other hand, the scalar and pseudo-scalar screening masses show more complicated behavior — strong deviations from the ideal Fermi gas and a strong temperature dependence. This puzzling behavior is generic — it has been seen in quenched and dynamical-fermion simulations with two and four flavors of staggered or Wilson quarks.

This is the puzzle that we address using the new lattice fermions representation called overlap fermions. That formulation has the advantage of preserving chiral symmetry on the lattice for any number of massless flavors of quarks. This is in contrast to classic formulations such as Wilson fermions which break all chiral symmetries or staggered fermions which break them partially.

The overlap Dirac operator (D) can be defined in terms of $(D_w^\dagger D_w)^{-1/2}$ where D_w is the usual Wilson–Dirac operator. We developed a new method based on the conjugate-gradient algorithm to compute this inverse square root and used an efficient way to remove the zero modes of the resulting overlap Dirac operator. With this formulation we have analyzed quenched QCD configurations at temperatures of T/T_c =1.25, 1.5 and 2 on 4×8^3 and 4×12^3 lattices and found several new results with a consistent picture of the high temperature phase of quenched QCD. Axial $U(1)$ symmetry is not restored even at $2T_c$. As a result the thermal ensemble contains gauge fields which give rise to fermion zero modes of definite chirality. When the effect of these modes is subtracted, the chiral condensate vanishes (for $T \geq 1.5T_c$) in the zero quark mass limit, showing that chiral symmetry is indeed restored. Simultaneously, parity doubling is seen in the spectrum of screening masses, which are close to those expected in an ideal Fermi gas, even for the S/PS sector. Since some of these results are not obtained with staggered quarks, it raises the interesting question whether the two-flavor QCD phase transition is properly described by such a representation of quarks [T01/076].

3.3.2 High temperature QCD in 2+1 dimensions (A. Morel)

The nature of the Debye screening expected for (2+1)-D QCD at high temperature has been investigated by numerical simulations of the 2D model obtained by dimensional reduction: a model for a Higgs boson in the adjoint representation coupled to the $SU(3)$ gauge fields. The scalar sector consists of two colorless states, respectively coupled to the real and imaginary parts of the (2+1) Polyakov loops. The analysis shows that they result from the confinement of respectively an even and an odd number of Higgs bosons into a colorless bound state (like quarks in hadrons), and *cannot* be interpreted as due to Debye screening in the electric (2+1) gluon channel [T00/167, T01/115]. While usual dimensional reduction breaks the $Z(3)$ symmetry of the original model, a $Z(3)$ symmetric model for the Polyakov loops has been built in such a way that it reproduces the same high temperature physics [T02/041], but at the same time has a transition to a spontaneously broken phase reminiscent of low temperature confinement in $(2+1)$ dimensions.

3.3.3 Cold dense superconducting QCD matter (M. Rho)

The effective field theory formulated few years ago [T99/093] for the color-flavor-locked (CFL) superconducting system at super-high density was applied to the ABJ (Adler–Bardeen–Jackiw) anomaly in the CFL phase with $\pi^0 \to \gamma\gamma$ [T00/127]. This is an additional evidence for continuity in excitations between the hadronic sector at low density and the QCD sector at high density, an analog to the Cheshire-Cat phenomenon. This idea of continuity/duality is also exploited to verify, and put on a firm basis, "BR scaling" in medium [T01/030, T01/031, T02/025]. Understanding nuclear matter and dense matter from the point of view of large N_c QCD is initiated in [T02/004] where the Atiyah–Manton instanton configuration is used to simulate a skyrmion crystal of infinite baryon number.

3.3.4 Cooling of neutron stars (M. Rho)

The structure of dense and super-dense matter described above in Sect. 3.3.3 has been applied to compact stars, particularly in connection with the cooling of neutron stars after supernova explosions [T00/146, T00/125].

3.3.5 Quark number susceptibilities in high temperature QCD (J.-P. Blaizot, E. Iancu)

At high temperature, $T \gg \Lambda_{QCD}$, the coupling constant of QCD is relatively small (by asymptotic freedom), but direct perturbative calculations turn out to be only poorly convergent, and therefore useless for all practical purposes. This lack of convergence is to be attributed to the large collective effects which develop in the quark-gluon plasma.

In previous publications, we have developed a resummation scheme to include these collective effects in the calculation of thermodynamical quantities like the entropy or the quark number density. Recently, we have extended this scheme to the calculation of the (flavor-diagonal) quark number susceptibilities, for which lattice results are now available (in the limit where the baryon chemical potential vanishes). For relatively small temperatures, between 1.5 to 5 T_c (with T_c the critical temperature for the deconfinement phase transition), our results follow the same trend as the lattice data, but exceed them in magnitude by about 5-10%.

We have also noticed a disagreement between the lattice results and perturbation theory for the off-diagonal susceptibility: perturbation theory predicts a small, but non-vanishing, value, in contradiction with the lattice data which are consistent with zero [T01/108].

A review paper on "The quark-gluon plasma: collective dynamics and hard thermal loops" has been published in Physics Reports [T01/005].

3.4 Phenomenology of ultrarelativistic heavy ion collisions

In summer 2000, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven (USA) managed for the first time to collide beams of fully ionized gold nuclei at energies in the center-of-mass system of 100 GeV per nucleon, ten times larger than in any previous experiments. This was a major event for the nuclear physics community. Physicists at SPhT have been deeply involved in phenomenological studies of ultrarelativistic heavy ion collisions since the first experiments started in 1986 at the CERN SPS.

3.4.1 J/ψ suppression (J.-P. Blaizot, P.M. Dinh, J.-Y. Ollitrault)

One of the goals of these experiments was to produce and study the quark-gluon plasma, the ultimate stage of hadronic matter at high densities, predicted by QCD. It had been predicted in 1986 that in a quark-gluon plasma, the production of rare heavy-quark bound states such as the J/ψ (a $c\bar{c}$ pair) would decrease dramatically due to the screening of the chromoelectric force between the quarks. The first evidence of such a decrease came in 1996 with the first analyzes of Pb-Pb collisions at CERN by the NA50 Collaboration. It was soon shown by two of us that the observed effect (a 50% suppression for the most central collisions) was compatible with the above scenario, given the existing experimental constraints from lighter nuclei.

In February 2000, NA50 published new data with improved statistics, which showed a two-step pattern of J/ψ suppression as a function of the total "transverse" energy released in the collision (which is used as a measure of the impact parameter, the most central collisions being the most energetic ones). As in earlier data, the suppression appeared at impact parameters below 8 fm, but in addition a second threshold was observed for the most central collisions where the suppression was even more pronounced. This was interpreted as a spectacular signature of successive meltings of the χ (a less bound $c\bar{c}$ state) and the J/ψ, which both contribute to the observed J/ψ yield.

We have shown [T00/098, T01/036] that the "second threshold" does not contain any new physics: it was in fact already predicted in our earlier work, as a natural consequence of the fact that the "transverse energy" used to estimate the centrality has small fluctuations for a given impact parameter. This effect explains quantitatively the "second threshold" without any additional parameter, and our model provides a perfect fit to NA50 data.

3.4.2 Cumulant analysis of multi-particle azimuthal correlations (P.M. Dinh, J.-Y. Ollitrault)

The specificity of heavy ion collisions, compared to standard high-energy physics experiments, is the crucial role played by the geometry. The magnitude of the impact parameter is an important observable, as we have seen above. In addition, the direction of the impact parameter in the transverse plane also matters. One of us predicted in 1992 that particle momenta were correlated to this impact parameter: more particles should be emitted parallel (or antiparallel) to the impact parameter than orthogonal to it. This phenomenon, later called elliptic flow, was first observed at AGS (Brookhaven) and SPS (CERN) in 1997. Since then, it has been actively studied both theoretically and experimentally, since it is a very sensitive probe of final-state interactions between the produced particles. The first paper published by the STAR collaboration at RHIC (September 2000), generated considerable excitement among the heavy ion community by showing that the magnitude of elliptic flow was twice larger than at SPS. These results showed evidence that interactions in the colliding system were strong enough to achieve thermal equilibrium.

Our recent work focuses on the methods used to analyze elliptic flow in heavy ion experiments. Since the direction of impact parameter is not known, the correlation of momenta with the direction of impact parameter can only be inferred from azimuthal correlations between the outgoing particles. Standard methods, taken from lower energy experiments, are based on two-particle correlations. We had shown in two earlier publications (in 2000) that these methods no longer apply at ultrarelativistic energies, where many other sources of correlations appear which had so far been neglected. This had led us to a revision of the data published in 1997 by the NA49 Collaboration at CERN.

We proposed new methods based on a systematic study of multiparticle azimuthal correlations [T00/110, T00/154, T01/051, T01/112, T01/114]. By means of a cumulant expansion of these correlations, we are able to get rid of the effects which plagued earlier analyzes. Our method was used already in 2001 by the STAR collaboration at RHIC. The results differ significantly from the ones previously published, and may invalidate the conclusion which had been drawn that the colliding system reaches "thermal equilibrium".

3.4.3 Analysis of directed flow (P.M. Dinh, J.-Y. Ollitrault)

Directed flow is a closely related phenomenon, which is well known at lower energies: nucleons from the projectile are deflected away from the target, so that one observes slightly more projectile nucleons parallel to the impact parameter than antiparallel to it. This effect, however, becomes very small at ultrarelativistic energies. Standards methods are unable to give reliable results, as in the case of elliptic flow, while our cumulant analysis (see above) is limited by statistical errors: it would require a hundred times more events than are actually available.

A first attempt to solve this problem, in collaboration with A. Poskanzer and S. Voloshin from the NA49 Collaboration, was to correct the standard flow analysis by taking into account azimuthal correlations from momentum conservation, which turn out to be the major bias in the analysis of directed flow. This correction was successfully applied to NA49 data [T02/014].

Recently, we proposed a new method of analysis [T02/036], based on three-particle correlations (instead of two in the standard method) which generalizes the cumulant method discussed above, and uses the property that elliptic flow is large at high energies. The corresponding estimates of directed flow are free from the biases associated with the standard method, and the associated statistical errors are not much larger (typically by a factor of two) than with the standard analysis. This new method is being applied to NA49 data and will soon be used by the STAR collaboration at RHIC.

3.5 Low-energy QCD (M. Rho)

The physics of hadrons and their interactions at low energies is governed by the phenomenon of chiral symmetry breaking. The application of chiral symmetry to nuclear and hadronic physics is also an area where SPhT traditionally has a strong expertise, as reflected by a recent publication in Physics Reports [T01/030]. A particularly important result obtained at SPhT is the prediction that hadronic masses in a medium follow a scaling behavior. Recent developments along these lines are described in Sect. 3.5.1. Effective field theories for nucleon-nucleon interactions, obtained by "integrating out" the mesons, have recently become popular. This approach is applied to fusion in 3.5.2.

3.5.1 Gluon-meson/quark-baryon continuity or "duality" in QCD

The idea of "Cheshire-Cat" mechanism proposed more than a decade ago for a "continuity" between the quark-gluon picture and hadronic picture for the nucleon, the ground state of the baryons, is verified in the celebrated proton spin problem [T00/085] confirming the previous work [T98/114]. The general argument that there is a web of continuities (or "dualities") between the QCD degrees of freedom and effective hadronic degrees of freedom in hadronic matter is developed in terms of the color-flavor locking (CFL) in QCD in [T01/031, T02/025]. The scaling behavior of hadronic masses in medium proposed in 1991 with G.E. Brown (known as "BR scaling") is put on a firm basis [T01/030, T01/031, T01/122, T02/025] by means of two developments: Wetterich–Berges' CFL in the Goldstone phase and Harada–Yamawaki's vector manifestation fixed point theory. The relation between BR scaling and Landau Fermi-liquid parameters is further clarified [T00/126, T02/025].

3.5.2 The solar fusion process

Effective field theory (EFT) for nuclei developed since several years is applied with unprecedented accuracy to the solar proton fusion process [T01/058, T01/083] and exploited to make — for the first time in nuclear physics — a model-independent prediction [T01/069, T01/083] for the solar *hep* process recently "seen" in the super-Kamiokande experiments. Both are relevant for the solar neutrino and neutrino mass problems. These two cases represent the *first* use of EFT for making *predictions*, instead of post-dictions. Only the latter can be accessed by the standard nuclear physics approach with no reference to EFT of QCD.

3.6 Pairing correlations in nuclei (T. Duguet, P. Bonche)

3.6.1 Odd-even mass differences in self-consistent mean-field calculations

The odd-even mass staggering (OES) of nuclei is analyzed in the context of self-consistent mean-field calculations. The procedure developed allows to understand the OES for spherical as well as for deformed nuclei. Comparison with results at the Hartree–Fock level shows the non-perturbative effect on this observable of the inclusion of pairing correlations. [T00/149]

3.6.2 Rotational properties of ^{252,253,254}No: influence of pairing correlations

Rotational bands of ^{252,253,254}No and the fission barriers of ^{254}No at spin $0\hbar$ and $20\hbar$ are calculated with the Hartree–Fock–Bogolyubov theory and the Lipkin–Nogami approximate particle number projection. The SLy4 Skyrme force is used in the particle-hole channel. A zero-range force with and without density-dependence is used in the particle-particle channel. The experimental ground state deformation ($\mathcal{Q}_{20}$ = 32.8 b) is reproduced as well as the increase of the dynamical moment of inertia with frequency both for ^{252}No and ^{254}No. The rotational band of ^{253}No is also calculated. Fission barriers of ^{254}No at spin $0\hbar$ and $20\hbar$ show the robustness of shell-corrections against rotation in these heavy nuclei [T00/150].

3.6.3 Description of odd nuclei in mean-field theories

In order to extract informations on pairing correlations in nuclei from experimental mass differences, the different contributions to odd-even mass differences are investigated within the Skyrme HFB method. In this first paper, the description of odd nuclei within HFB is discussed since it is the key point for the understanding of the above mentioned contributions. To go from an even nucleus to an odd one, the advantage of a two steps process is demonstrated and its physical content is discussed. New results concerning time-reversal symmetry breaking in odd-nuclei are also reported [T01/053].

3.6.4 Microscopic analysis of odd-even mass staggering in nuclei

The odd-even mass staggering in nuclei is analyzed in the context of self-consistent mean-field calculations, for spherical as well as for deformed nuclei. For these nuclei, the respective merits of the energy differences $\Delta^{(3)}$ and $\Delta^{(5)}$ to extract both the pairing gap and the time-reversal symmetry breaking effect at the same time are extensively discussed. The usual mass formula $\Delta^{(3)}$, is shown to contain additional mean-field contributions when realistic pairing is used in the calculation. A simple tool is proposed in order to remove time-reversal symmetry breaking effects from $\Delta^{(5)}$. Extended comparisons with the odd-even mass staggering obtained in the zero pairing limit (schematic model and self-consistent calculations) show the non-perturbative contribution of pairing correlations on this observable [T01/054].

STATISTICAL PHYSICS AND CONDENSED MATTER

A great variety of subjects is gathered in this chapter devoted to statistical physics. A lot of the topics presented here have benefited from the cross-fertilization between different methods sometimes developed in other branches of physics (integrable systems, quantum field theory, mathematical physics, ...). Thanks to collaborations and discussions between researchers of very different backgrounds, many different sophisticated techniques have been used to tackle actual problems in physics.

This chapter is divided in four parts: i) General aspects of statistical physics, ii) Disordered, glassy and granular systems: statics and dynamics, iii) Quantum systems, and iv) Soft condensed matter and biological systems.

- The first section is devoted to general aspects of statistical physics. The first themes includes formal studies of possible geometrical structures of thermodynamics, as well as the thermodynamical foundation of quantum measurement, viewed as a phase transition. The next themes are devoted to transport phenomena (kinetic theory, hydrodynamics and turbulence) while the last themes are devoted to out of equilibrium systems (stochastic dynamics, persistence and growth). The techniques involved here are typical of applied analysis: stability criteria, mode decomposition, shocks and stochastic equations.

- The second section deals with disordered, glassy or granular systems. The first themes deals with their equilibrium aspects. The complexity of these systems can be studied through the structure of their phase space. Disordered assemblies of spheres or grains share with glasses and spin-glasses the property of having a huge number of metastable states. The geometry of this phase space is studied in several works: the overlap distribution can now be computed with a very high precision; the boundary energy between low lying states does not behave like in ordinary systems, and the Edward's hypothesis of equiprobability of low lying metastable states is invalidated. The ruggedness of the energy landscape leads to very unusual dynamics, which brings us to the next set of themes of section 2, namely non-equilibrium properties. The phenomenon of aging, characteristic of glassy dynamics, is studied in several models, and is shown to be also present in the shaking of a box of sand. Dynamics of biological systems or of fracture is shown to bear some resemblance with that of disordered systems. Model solving plays here a crucial role since no general theory is yet available. The dynamics of several one-dimensional disordered models has been solved exactly. The techniques used are borrowed from traditional mathematical analysis; one also needs algebraic tricks, the renormalisation group and numerical simulations to reveal and encode the combinatorics of the models under investigation.

- The third part of this chapter is devoted to quantum systems. Field-theoretic methods are perfectly suited not only for modeling correlated electrons and quantum spin chains, but also for quantum fluids such as Bose–Einstein condensates, 2D electron systems, superconductors or the Hall effect. Path integral methods are well suited to calculations concerning disordered systems. When coupled to supersymmetry techniques, they provide an efficient tool to describe strongly correlated electrons.

Non-equilibrium properties of quantum systems such as the dynamics of formation of a Bose–Einstein condensate or out of equilibrium quantum dots begin to be studied.

- In the last part of this chapter, we describe soft condensed matter and biological systems. Here again path integral representations are invaluable to describe polymers, proteins and self- avoiding membranes. Using these methods, problems as diverse as the titration of a weak polyacid by a strong base, the denaturation transition of DNA, or bridge-hopping in conducting polymers have been addressed. The problem of RNA folding has been formulated in terms of a matrix field-theory. As an outcome, it is possible to write an algorithm to predict pseudo-knots. This emphasizes again the cross-fertilisation between various fields present in the lab. Similarly, studies of ultrametricity in biological systems, and the dynamics of neural networks provide a link with disordered systems.

Contents

1 General aspects of statistical physics

1.1 Mathematical structure of thermodynamics (R. Balian)

The work in [T00/099] is a study of the formal mathematical structure of thermodynamics. In Callen's approach, all equilibrium properties of a given system are characterized by its entropy regarded as a function of its n extensive variables. The n intensive variables are introduced as the partial derivatives of this function. Close to equilibrium the dynamics is governed by the conservation and transport equations. For practical purposes it is convenient to deal with all the variables simultaneously, and this leads to various geometric structures. It is known that the $2n + 1$ dimensional space of extensive and intensive variables plus the entropy is endowed with a contact structure, where the states of a physical system are represented by a n-dimensional Legendre manifold. By introducing an extra gauge variable which multiplies the intensive variables, we find a simpler — symplectic — structure in the extended $2n + 2$ dimensional space. As an application, the mappings from a physical system onto another, which are currently used to build phenomenological equations of state, are shown to be canonical transformations, a property which simplifies their construction. The dynamics of a single system, even though it is dissipative, is also seen to be generated by a Hamiltonian, owing to the extra variables, so that the intensive and extensive variables appear as conjugate in the sense of analytical mechanics. A natural metric structure also arises, where these variables appear as co- and contravariant.

1.2 Quantum dissipation and quantum measurement (R. Balian)

We study the dynamics of a quantum particle interacting with a quantum thermal bath and subjected to a potential. It is shown that the motion can be mapped onto that of two classical Brownian particles, provided one introduces in the formalism non-observable quantities which behave as probabilities, but are not necessarily positive. The classical limit is recovered at high temperatures. An effective Fokker–Planck equation is derived at low temperature, where specific quantum correlation effects are found [T01/007].

The purpose of the work in [T01/008, T02/031] is to improve our understanding of quantum measurements through the study of exactly soluble models, governed by a Hamiltonian, which simulate the dynamical process of interaction between an apparatus and a tested system. We require the model to display the main features of an actual measurement: collapse of the common state of the system and the apparatus; triggering of the system by the apparatus; jump of the apparatus from an initial metastable state to one or another final stable state correlated with the final state of the system; non-ergodicity; Born's probabilities of transition. This is achieved by taking for the apparatus a macroscopic object having a phase transition; the order parameter plays the role of a pointer. In the first model, the apparatus is a non-interacting Bose gas; in the second model, which is more satisfactory, it is an Ising ferromagnetic dot, represented by a Curie–Weiss model. In both cases a thermalization of the apparatus is ensured by a phonon thermal bath. The process is shown to proceed in two steps. The collapse of the system first take place over a very brief time. The apparatus is then driven towards one or the other of its equilibrium states over a much longer time. Features that can make the measurement non-ideal are discussed. The measurement process owes its specific features to the macroscopic size of the apparatus, which implies the use of quantum statistical mechanics.

1.3 Discrete kinetic theory (H. Cornille)

We studied different properties and classes of the planar discrete velocity models, DVM's: DVM's for gas mixtures and single-gas, DVM's tilling all integer coordinates of the plane (except the interface for half-space DVM's) with only binary collisions (or not), connections with the continuous theory (quadratic collisions). The great difficulty is to build-up "physical" models (with only physical conservation laws invariants).

In [T00/148] we study binary planar mixtures (two species with masses $m = 1$ and $M = 2, 3, 4, 5, 3/2$), we construct, with only binary collisions, models tilling all integers of the plane. There was no boundary conditions for the gas.

In [T00/089] we study different planar half-space (without velocities along the interface) DVM's. We present a criterion which predicts the nonmonotonic behavior of the pressure and another for the internal energy. We verify numerically the predictions with our explicit models.

For two classes of planar DVM's (arbitrary number of velocities), we check whether they can satisfy two continuous relations (deduced from Maxwellian at equilibrium states). The second continuous relation, giving the energy to the mass ratio at an equilibrium state, was previously discussed by Cercignani, as a drawback for DVM's. We check whether this ratio can be satisfied. Also, for a single-gas, models with only binary collisions tilling all integers of the plane, are presented [T01/084].

For half-space single-gas, we still consider the models tilling all the integers (no velocities along the interface), with only binary collisions [T02/016].

1.4 Hydrodynamics (C. Normand)

Marangoni flows are induced at a liquid-gas interface by surface tension variations. In binary mixtures, the surface tension is a function of the temperature and the solute concentration. In some systems like aqueous fatty alcohol solutions, the surface tension as a function of the temperature goes through a minimum in some range of concentrations. In such a system it is possible to reverse the direction of the thermocapillary flow. This was indeed observed for a water-heptanol solution. However, it happened that the surface motions went from the cold towards the hot areas for temperature much lower than that of the surface tension minimum. We investigated the assumption that evaporation-condensation of alcohol is the main cause of the anomalous direction of the flow. The surface tension is a decreasing function of the solute concentration which expresses in terms of the equilibrium constant for distribution of solute between the liquid and the gas phase. It was shown that for temperature lower than that of the minimum the thermocapillary and soluto-capillary contributions to the surface flow are opposite and they cancel each other near 24°C where reversal of the flow is predicted to occur [T00/160, T01/106].

In pure liquids, Marangoni flows are known to be unstable towards hydrothermal waves. In cylindrical containers, when the flow is driven by a radial thermal gradient, we have shown that the properties of these waves evolve with the curvature parameter, thus leading to a nonuniform pattern over the cell [T01/023].

1.5 Gravitational oscillations of a liquid column (J.-Y. Ollitrault)

We study gravity oscillations of a liquid column in a pipe partially immersed in a bath of liquid, a problem already addressed by Daniel Bernoulli in his *Hydraulics*, some three hundred years ago. Damping of these oscillations is found to be dominated at low viscosity by entrance and exit effects: due to the abrupt contraction between the tank and the pipe, eddies appear which dissipate some energy. Taking this effect into account, we obtain a simple, parameter-free model in perfect agreement with experimental data over more than ten periods of oscillation. In particular, the amplitude of oscillations decreases at large time like $1/t$, rather than exponentially [T01/067].

1.6 Turbulence (D. Bernard)

Series of lecture notes on turbulence have been written [T00/093]. They cover standard aspects of two and three dimensional fluid turbulence, as well as more recent results, which have been partially obtained at the SPhT, on the influence of friction in 2D turbulence and on properties of Lagrangian trajectories in turbulent systems.

1.7 Systems out of equilibrium and stochastic dynamics (K. Mallick)

The one-dimensional asymmetric simple exclusion process (ASEP) is a model of driven diffusive particles on a lattice with hard core exclusion. The ASEP appears as a minimal building block in different models that describe a large variety of physical phenomena such as growth processes (the ASEP is a discrete version of the KPZ equation), hopping conductivity, diffusion of particles through narrow pores, polymer reptation and traffic flow, ... From a theoretical point of view the ASEP is a key model for the study of non equilibrium statistical mechanics. In particular, it is one of the very few systems far from equilibrium, for which exact solutions have been obtained. We have studied the properties of the non-equilibrium steady state of the ASEP on a ring with an impurity that can generate a shock dynamically. Using a generalized matrix Ansatz, we have calculated exactly time-dependent correlation functions in the steady-state. We have also obtained an explicit expression of the diffusion constant of the impurity which was calculated earlier by Bethe Ansatz. Our solution shows that the two methods (Bethe Ansatz and matrix Ansatz) are complementary and can be related in the case of a closed system with a non-trivial stationary state. Besides, the scaling of the diffusion constant with the size of the system allows to determine anomalous diffusion exponents in the thermodynamic limit [T02/052].

Motivated by experiments on the effect of internal noise on the onset of hydrodynamic instabilities, we studied anomalous diffusion in nonlinear oscillators with multiplicative noise. The time-asymptotic behavior of undamped, nonlinear oscillators with a random frequency has been investigated analytically and numerically. We found that averaged quantities of physical interest, such as the oscillator's mechanical energy, root-mean-square position and velocity, grow algebraically with time. The scaling exponents and associated generalized diffusion constants have been calculated when the oscillator's potential energy grows like a power of its position. Correlated noise yields anomalous diffusion exponents equal to half the value found for white noise [T02/043].

1.8 Persistence, occupation times, and related topics (J.-M. Luck, G. De Smedt)

The concept of persistence has been introduced in order to shed some new light on the dynamics of systems far from equilibrium, such as a ferromagnet quenched below its critical temperature, undergoing domain growth. Considering Ising spins for clarity, the persistence probability is defined as the probability that a given spin has never flipped up to time t. More generally, the occupation time S of the plus phase is the time spent by the spin in that phase up to time t. Equivalently, the temporal magnetization reads $M = 2S/t - 1$. In general M depends both on the initial state and on the thermal history of the spin, so that its whole probability distribution is of interest. The distribution of the temporal magnetization, and related quantities, have been investigated by analytical means in a variety of model systems. Renewal processes are abstract processes (zero-dimensional systems) defined by the property that time intervals between zeros (i.e. spin flips) are independent random variables, with a given narrow or wide distribution. Several quantities related to persistence phenomena in renewal processes have been investigated [T00/086]. Another natural class of processes is defined by the stochastic motion of a point particle on the line. The occupation time is then defined as the time spent by the particle to the right of its starting point, say. For usual Brownian motion, the occupation time follows the celebrated arcsine law, as shown by Paul Lévy in 1939. We have generalized this result in several ways. The distribution of the occupation time has been determined for a biased random walker having a constant mean velocity, both in discrete and in continuous time [T01/071]. A deformation of Brownian motion, first introduced by Dhar and Majumdar, which possesses a continuously varying persistence exponent α, has also been studied by several approaches [T00/139]. We have also considered a particle submitted to a random force, so that its acceleration is modeled as a white-noise signal (just as the velocity of a Brownian particle). In this situation, the problem of evaluating the distribution of the occupation time has been reduced to an interesting, yet unsolved, problem in complex analysis. Novel explicit results have been obtained for related questions, concerning e.g. the survival probability in the presence of partially absorbing collisions with a fixed obstacle, or the inelastic collapse when the same collision events are assumed to be inelastic [T00/122].

2 Disordered, glassy and granular systems: statics and dynamics

2.1 Geometrical characterization of the phase space of disordered system models: from mean-field spin glasses to real glasses (I. Giardina)

Disordered systems are characterized by a very complicated landscape, which in turn results in their peculiar static and dynamical behaviors. An interesting problem is whether a geometrical description of the landscape is possible and to which extents it can be used to explain and interpret the macroscopic properties of the system. For mean-field spin glass models for example, one can compute analytically the distribution of the stationary points of the Hamiltonian according to their energy and stability properties. This quantity enables a description of the topology of constant energy manifolds, and it is possible to relate the occurrence of the phase transitions to qualitative changes in the topology of the equilibrium manifold.

This geometrical perspective can be successfully applied to structural glasses also. Indeed recent studies on supercooled liquids have shown that the geometrical properties of the potential energy landscape are strongly related to the dynamical behavior of the system close to the glass transition. Until recently people had focused on the minima of the potential energy. Inspired by our previous analytical work on mean-field model we decided to look also at the properties of generic saddles and, for different models of glass forming liquids, we performed a numerical analysis of the stability properties of the stationary points of the potential energy. This has enabled us to i) determine with a purely geometric criterion the characteristic temperature provided by the dynamical mode coupling theory (in the same light of what was previously obtained for mean-field spin glass models); ii) give an estimate of the barriers between metastable minima; iii) analyze possible scenarios for the degree of fragility of the system [T00/195, T02/051].

Given the analogy between structural glasses and discontinuous models of mean-field spin glasses we have also performed some analytical computations on a mean-field p-spin glass model to support the conceptual validity of the numerical procedure [T01/162].

2.2 Reparametrization invariance (C. De Dominicis)

We show how reparametrization invariance allows a rederivation of Ward–Takahashi identities (e.g. the occurrence of Goldstone modes) previously derived via the introduction of infinitesimal permutations (in the limit where the number R of replica symmetry breaking steps goes to infinity) [T00/071].

2.3 Random field Ising model (C. De Dominicis)

We exhibit the instability of the Parisi–Sourlas solution on the Curie line and show that by lowering the temperature in a random magnetic field of given variance one undergoes a transition towards a vitreous phase generated by the occurrence of bound states between pairs of replicas [T00/111].

2.4 Free-energy of a twist (C. De Dominicis)

We first considered a simple system (the $O(N)$ model) where the field theory is (in the absence of a twist) under full control. This allowed us to check that the (one-loop level) renormalization constant obtained from the paramagnetic phase is enough to properly renormalize the theory when a twist in the boundary conditions is imposed, thereby providing the expected corrections to the stiffness constant [T01/088].

We have applied the same approach to the (Ising) spin-glass, where the twist on the spin direction at the boundaries is replaced by a twist in the reparametrization. We show, after a rather involved calculation, that here again, the theory renormalizes with the renormalization constants obtained in the paramagnetic phase. Corrections to the stiffness constant are likewise determined but also corrections to the size L exponent. Indeed, contrary to what happens in the $O(N)$ case, the Goldstone modes are not isolated here (they are the bottom of the transverse mode bands). Hence their effective coupling does not vanish in the infra-red limit generating thus size corrections. The L exponent furnishes besides the lower critical dimension $D_c = 2 - \eta(D_c)$ [T02/005].

2.5 Spin-glass in a magnetic field (C. De Dominicis)

We have done a one-loop renormalization group study of the spin-glass in a magnetic field. A lengthy calculation shows that at this order there is no fully stable fixed-point (in the limit of the number of replicas going to zero). This does not exclude the existence of a strong coupling fixed point [T02/044, T02/045].

2.6 Numerical simulation of the Edwards–Anderson model with the multi-overlap algorithm (A. Billoire)

Using our "multi-overlap" Monte Carlo algorithm, we have the unique capability to measure (alas for T not too small as compared to the critical temperature) the overlap probability density $P^J(q) = \langle \delta(q - 1/N \sum_i \sigma_i \tau_i) \rangle_J$ (where J denotes a realization of the quenched disorder) of any disordered system with discrete variables, in the whole $[-1, +1]$ interval, that is even in the large deviation region $q > q_{EA}$. For the 3D Edwards–Anderson Ising model, we measured probabilities as small as 10^{-160}. In this region we find that the disordered averaged $P(q)$ is quite well represented by a variant of the so called Gumbel probability distribution of extreme order statistics. This generalizes to the distribution $P(q)$ of a disordered system a remarkable observation made in the literature (Bramwell at al) for the magnetization probability density of simpler systems [T00/090, T00/106, T00/156, T01/070, T01/132].

2.7 Temperature chaos in spin glasses (A. Billoire)

We went back to the question of the sensitivity of the spin glass phase with respect to temperature change. We measured by quite large scale numerical simulations the probability density $P^J_{T,T'}(q)$ of the overlap between two replica at different temperatures T and T' for the Sherrington–Kirkpatrick model, with binary couplings, and up to 4096 sites. After disorder average (between 1024 and 4096 disorder samples have been generated), the results are in qualitative agreement with an analytical computation by Tommaso Rizzo (that motivated this new numerical work) which indicates the absence of chaos with respect to temperature. What Rizzo did is to apply the mean-field replica method to a system of two replica with constrained value of the overlap, assuming the validity to all orders in $T_c - T$ of some rermarkable relations observed at low order. In our data $P_{T,T'}(q)$ is double peaked, and is similar to $P_{\tilde{T},\tilde{T}}(q)$, with $\tilde{T} = max\{T, T'\}$ (as predicted by Rizzo), whereas the support of a chaotic $P_{T,T'}(q)$ goes to zero exponentially as $N \to \infty$, for all $\neq T'$.

The unexpected very slow increase of the peak height with system size, and the appearance for the lowest temperatures (we simulated down to $T = 0.4T_c$) of a bump for small q's, leaves unfortunately open the possibility (the observed bump is at the edge of statistical significance) that temperature-chaos sets in for very large systems, in a region definitively out of reach of simulations (and experiments) [T02/021].

2.8 Disordered assemblies of interacting spheres (A. Gervois)

A great number of systems may be modeled by disordered assemblies of interacting spheres: suspensions, fluidized beds or more compact particle assemblies such as liquids, glasses or non consolidated granular media. Many building algorithms are now available especially in the case of hard spheres, where very large assemblies may be realized, providing good statistics.

Part of the physical properties of these assemblies actually depends on their geometrical arrangement only. Though spheres are simple objects, the interparticle space is topologically very complicated and a good tool is the construction of the Voronoi cells (in the mono-size case) and of the radical cells and/or the "navigator map" (in the poly-disperse case). The topological and metrical properties of the partition, or "foam", are good indicators of the type of disorder [T01/135].

In the case of mono-size systems, the main parameter is the packing fraction C, i.e. the percentage of occupied volume. However, main characteristics, (such as the average number of faces $\langle f \rangle$ of a cell) depend not only on C but on the building procedure. Differences appear because of a possible anisotropy (building under gravity, modified RSA ....) and the relevant parameter is no longer the packing fraction but the dimensionless sphericity parameter K_{sph}. It turns out that $\langle f \rangle$, the dispersion μ_2, ..., are universal functions of this parameter [T00/164].

It is known that in a small range of packing fraction ($0.55 < C < 0.61$), molecular dynamics favors the apparition of order, which is well measured by the global parameter Q_6 introduced by Nelson et al. Another way consists in following the evolution of the local parameter Q_6 of each sphere, calculated from its twelve closest neighbors. As time goes and order sets in, this parameter increases and exhibits two (sharper and sharper) peaks around the two values relative to a fcc and an hcp ordered array respectively, with a domination of the fcc environment however, as it should be from configurational entropy considerations. Depending on the sample, the proportions are different, and in some cases drastic planar reorganizations may occur leading to a quasi pure fcc crystal [T00/162].

For binary assemblies of spheres [T01/134], we considered both the radical tessellation and the "navigator map" which are the two natural extensions of the Voronoi construction. We have proposed a theoretical model which describes the repartition of the different types of neighbors and looks for segregation. It is a generalization of our previous 2D model for disk assemblies and of the Dodds compact model.

In a real sample, it is not possible to know the position of the spheres and the only method consists in trying to get information from random planar cuts large enough to provide good statistics. Cuts are polydisperse assemblies of disks which can be studied using the 2D (radical) tessellation and all the stuff for polydisperse systems. In the case of monosize spheres, the tessellation performed in the random cuts behave like ordinary disordered foams with the same size distribution. They strongly differ from the cut of the 3D tessellation, which is more widely spread [T00/064, T00/163].

In connection with this question, we have calculated the frequency of n-polygons in the section of a Wigner–Seitz cell in the fcc and the bcc case. The most striking features are the distribution $p(n)$ which is not Gaussian-like and the non linearity in n and m of the correlations functions $A(n,m)$, showing the non validity of the MAXENT principle [T02/028] in the ordered case.

2.9 Equilibrium dynamics of the Sherrington–Kirkpatrick model (A. Billoire)

We revisited in [T01/012] the problem of the equilibrium dynamics of the Sherrington–Kirkpatrick model (with binary couplings) in the low T phase. Let τ_x be the sample-dependent waiting time before $q(t) = 1/N \sum_i \sigma_i(0)\sigma_i(t) = x$. We measured the probability distribution of τ_x for a couple of definitions of x. We also monitored the value of $\overline{< q(t) >}$ and $\overline{< q(t)^2 >}$. All time scales we considered behave according to the same scaling law $\ln \tau_X \sim A_X N^\epsilon$, with ϵ compatible with the value 1/3. This is true whether the autocorrelation function used to define τ_X is symmetric with respect of a global flip of the spins or not, in contradiction with claims made in the literature.

2.10 Aging and glassy dynamics (J.-M. Luck)

Consider a ferromagnet quenched from an infinite-temperature disordered initial state, either to its critical point or to the low-temperature phase. The system has a slow non-equilibrium dynamics in both cases, because of either critical slowing down or domain growth (coarsening). The two-time spin correlation and response functions, and the associated fluctuation-dissipation ratio or effective temperature, have been shown to obey non-trivial scaling laws in the two-time plane [T01/090]. We have argued that the dynamical scale invariance observed in these situations generalizes towards a subgroup of conformal invariance. As a first consequence, we have obtained the explicit scaling form of the response function, which only depends on the values of two critical exponents. This prediction is confirmed by analytical or numerical results in a variety of models [T01/113]. Features of non-equilibrium dynamics have also been investigated in the zeta urn model. This mean-field dynamical model, initially inspired from two-dimensional quantum gravity, exhibits a line of continuous phase transitions in the temperature-density plane, where critical exponents vary continuously. We have determined analytically the scaling behavior of the correlation and response functions of the local density fluctuations, and the associated fluctuation-dissipation ratio. The limit value of the latter quantity for well-separated times in the scaling region assumes rather unusual values, both along the critical line (nonequilibrium critical dynamics) and in the high-density phase (condensation dynamics) [T01/065, T01/091]. It has also been demonstrated that the presence of a drift velocity, even at the microscopic level, gives rise to anomalous aging, characterized by a specific form for the two-time correlation functions. The first example considered is the oscillatory phase previously observed in a model of competitive learning. Further examples, where the proposed scaling law is exact, include the anisotropic voter model, the Ohta–Jasnow–Kawasaki theory for domain growth in any dimension, and a theory for the smoothing of sandpile surfaces [T00/119].

2.11 Shaking a box of sand (J.-M. Luck)

We have introduced a simple model of a vibrated box of sand, and investigated its dynamics by means of numerical simulations. Three regimes have been identified: fluidized, intermediate, and frozen or glassy. In the latter regime, the model is solvable in terms of non-interacting Ising spins, and allows for the qualitative description of aging phenomena in terms of two characteristic lengths [T01/109, T01/110].

2.12 Metastability at zero temperature (J.-M. Luck and G. De Smedt)

Glassy dynamics is often described as slow motion in a complex energy landscape, with valleys separated by barriers. The relevant valleys have been given several inequivalent definitions in different contexts. One of the main difficulties resides in the fact that truly metastable states are only observed at the mean-field level or at zero temperature. The second instance had so far attracted much less attention than the first one. We have performed a parallel investigation of several one-dimensional spin models with kinetic constraints. The zero-temperature dynamics of all these models is fully irreversible, leading to an exponentially large number of blocked states. Exploiting an exact mapping onto sequential adsorption models, we have derived a variety of results on the statistics of blocked states, allowing us to test the validity of the so-called Edwards flatness hypothesis. In a celebrated work of 1994 on the slow compaction dynamics of granular systems, Edwards has proposed to evaluate stationary or slowly varying quantities as flat averages over all the blocked configurations with given density. In the present context, a comparison of the available dynamical results with an approach based on a priori statistics reveals qualitative discrepancies with the Edwards hypothesis, concerning in particular the fall-off of spin or energy correlations. Connected correlations are found to decay super-exponentially, namely as the inverse factorial of the distance, whereas they decay exponentially in the Edwards approach, just as in any equilibrium ensemble [T02/023].

2.13 The random fuse network as a dipolar magnet (H. Orland)

We present a mapping, valid at least at the initial stages of failure, between the random fuse network and a driven random field Ising model with dipolar coupling. This mapping associates the configuration of the burnt fuses at a given value of the applied electric field with a zero temperature metastable state of the random field dipolar Ising model. The mapping between fracture and a classical model of statistical mechanics, is supported by mean-field and heuristic arguments and by a preliminary numerical study, from which a generic phase diagram with a disorder induced transition emerges. At low disorder, the growth of a single unstable "crack" leads to an abrupt global failure (first order breakdown). Beyond a critical disorder, the conducting network sustains significant damage before the coalescence of cracks results in the global failure (second order breakdown) [T01/060].

2.14 Nonequilibrium dynamics of classical random Ising spin chains: exact results via real space RG (C. Monthus)

We use an asymptotically exact real space renormalization group method to study the non-equilibrium dynamics of the random field

Ising model with and without an applied field (and of the Ising spin glass in a field), in the universal regime of a large Imry–Ma length so that coarsening of domains after a quench occurs over large scales. The two types of domain walls diffuse in opposite Sinai random potentials and mutually annihilate upon meeting. We obtain the time dependent energy, magnetization and domain size distribution (statistically independent), the two-point equal time correlation, the two-time autocorrelation, the two-point two-time correlation and the persistence exponents of a single spin, of local magnetization, and of domains, the response to a small field applied after waiting time t_w, and the fluctuation-dissipation ratio $X(t, t_w)$ [T00/180].

2.15 Localization of thermal packets and metastable states in the Sinai model (C. Monthus)

We revisit the question of the localization of the thermal packet in the Sinai model. We first generalize the result of Golosov by computing explicitly the joint asymptotic distribution of relative position $y = x(t) - m(t)$ and relative energy $u = U(x(t)) - U(m(t))$ for the thermal packet, with respect to the (disorder and time dependent) most probable position $m(t)$. Next, we compute in the infinite-time limit the localization parameters Y_k and the correlation function $C(l)$. We moreover prove that our results for Y_k and $C(l)$ exactly coincide with the thermodynamic limit of the analog quantities computed for independent particles at equilibrium in a finite sample of length L. Finally, we discuss the properties of the finite-time metastable states that are responsible for the localization phenomenon and compare with the general theory of metastable states in glassy systems, in particular as a test of the Edwards conjecture [T02/018].

2.16 Exact solutions for the statistics of extrema of some random 1D landscapes. Application to the equilibrium and the dynamics of the toy model (C. Monthus)

The real-space renormalization group (RSRG) method introduced previously for the Brownian landscape is generalized to other one-dimensional landscapes. For a large class of models we give exact solutions obtained either by the use of constrained path-integrals, or by solving the RSRG equations. We apply in particular our results to the toy model energy landscape which consists in a quadratic potential plus a Brownian potential. The measure of the renormalized landscape is obtained explicitly in terms of Airy functions, and allows to study in details the Boltzmann equilibrium of a particle at low temperature as well as its non-equilibrium dynamics. For the equilibrium, we give results for the statistics of the absolute minimum which dominates at zero temperature, and for the configurations with nearly degenerate minima which govern the thermal fluctuations at very low-temperature. For the dynamics, we compute the distribution over samples of the equilibration time, or equivalently the distribution of the largest barrier in the system, and the disorder averaged diffusion front, which interpolates between the Kesten distribution of the Sinai model at short rescaled time and the reaching of equilibrium at long rescaled time. Finally, the method allows to describe the full coarsening (i.e. many domain walls) of the 1D RFIM in a field gradient as well as its equilibrium [T02/039].

2.17 Adaptive agents models (I. Giardina)

There is currently much interest in the challenges which other fields of research can provide to statistical physics. The case of biology is probably the best known, but recently an increasingly strong interest is focusing on problems of economic origin. Indeed, for example, stochastic calculus is at the basis of option pricing theory, and, despite the different perspectives, this very fact makes this field enough close to traditional branches of statistical physics. Besides, a natural evolution of classical game theory consists in considering models of interacting agents which are intrinsically dynamical and do not approach equilibrium. Many models of this sort have been recently introduced, where agents compete for some common resources and evolve adaptively in order to maximize their profit. Quenched or even annealed disorder is usually present to model the influence of the environment, and frustration is encoded in the constraints to which agents are subjected. Thus, these models represent in a way or another examples of disordered frustrated systems. Even if their formulation may appear simple in terms of computer algorithms, their behavior is not trivial for what concerns the analytical resolution. The case of the minority game is a good example. This is a very simple model of adaptive agents where the individuals interact through a minority rule. Despite its simplicity, this model enables the study of some microscopic mechanisms which may be relevant for realistic situations. For example, in the minority game the agents choose between different individual strategies of action as a function of their past performance. This simple process of decision making, which encodes the adaptivity of the model, is able by itself to explain some general features observed in real financial markets [T01/167].

2.18 Generalized diffusion equations (I. Giardina)

Generalized diffusion equations have been much studied in the last years, under different forms and with a great variety of modifications. The Burgers equation, the Kardar–Parisi–Zhang equation, the Sivanshinski equations are the most known examples of models describing the evolution of many degrees of freedom. The physical situations described are various: interface growth processes, driven diffusion, directed polymers in random media, flame fronts and many others. A very interesting project in this context is the pursue of a simple model to describe in schematic terms a population dynamics. An appropriate equation should account for diffusion processes, inhomogeneous convection and growth rate. A model of this kind has been studied in [T01/163]. It interpolates between the behavior predicted by two well known equations: the KPZ equation and the equation of diffusion in a random environment, and provides for a new asymptotic diffusion behavior. There appears a novel mechanism of proliferation assisted diffusion where the presence of a growth term drastically increases an otherwise slow diffusive motion. This mechanism appears to be extremely powerful, but remains still not completely understood. Research in this direction seems promising, and rich of interesting developments.

3 Quantum systems

3.1 Mesoscopic superconductors (K. Mallick)

A significant amount of experimental work has been recently devoted to the study of classical superconductivity in mesoscopic samples the size of which is comparable with both the coherence length and the London penetration length. Mesoscopic superconductors are able to sustain superconductivity only in a finite number of well-defined quantum states, classified by an integer corresponding to the total vorticity. Due to strong boundary effects which produce energy barriers between the allowed states, the system can exhibit a metastable behavior leading to unusual phenomena such as paramagnetic Meissner effect, negative vortices, magnetization hysteresis .... We performed an analytical study of the behavior of metastable vortices based upon the London limit of the Ginzburg–Landau equations. This enabled us to derive closed expressions for the magnetic field, the Gibbs free energy and the energy barriers between the states, and to explain the origin of the paramagnetic magnetization. Because the vortex number is not a sharp enough invariant to describe all the states and structural transitions between different vortex patterns, we proposed a description based on the critical points of the magnetic field and their topological nature; we also calculated the critical fields that correspond to transitions between different topological states [T00/113, T00/191].

In a subsequent work, we analyzed multiply charged ($n > 1$) vortex solutions of the Ginzburg–Landau equations for arbitrary values of the Landau–Ginzburg parameter κ. For $n \gg 1$, they have a simple structure and a free energy $\mathcal{F} \propto n$. In order to relate this behavior to the classic Abrikosov result $\mathcal{F} \propto n^2$ when $\kappa \to +\infty$, we considered the limit where both $n \gg 1$ and $\kappa \gg 1$, and obtained a scaling function of the variable κ/n that describes the crossover between these two behaviors of $\mathcal{F}$. Using large and small n expansions, we calculated perturbatively phenomenological exponents characterizing the scaling with κ of a giant vortex free energy [T01/052].

3.2 Supersymmetric approach to strongly correlated electrons (C. Pépin)

In many strongly correlated electrons systems, the phase diagram has a metallic phase where elementary excitations are fermionic in nature, as well as a magnetically ordered phase, where elementary excitations are bosonic in nature. Motivated by this remark, we have introduced a supersymmetric representation of $SU(N)$ spin operators which unifies the Schwinger bosons and Abrikosov pseudo-fermions representations of the spin. This technique allows a second quantized treatment of L-shaped representations of the $SU(N)$ group. We have applied this representation to the problem of a single underscreened Kondo impurity embedded into a metal. For certain classes of L-shaped representations the system undergoes a two-stage Kondo screening. We have then generalized these representations to Hubbard operators in order to incorporate the physics of charge fluctuations. We then obtain a supersymmetric formulation of the Hubbard and t-J models, where the $SU(1|1)$ gauge transformations rotate between the slave-fermions and slave-bosons representations of the Hubbard operators [T00/184]. We apply this method to the phase diagram of the infinite U Hubbard model. We find a first-order phase transition from a ferromagnetic ground state to a paramagnetic ground state at critical dopings in good agreement with numerical simulations [T01/156].

3.3 Quantum criticality and heavy fermions compounds (C. Pépin)

Quantum criticality has been invoked recently in order to explain the anomalous metallic properties of the normal phase in the high-T_c superconductors. Nevertheless in the cuprates, the exact nature of the order parameter remains controversial. Heavy fermions compounds are three dimensional rare earth composite elements which undergo an antiferromagnetic or uncommensurable transition at zero temperature when the chemical or hydrostatic pressure is varied. A large amount of experimental evidence has recently shown that the Fermi liquid properties are broken at the quantum critical point. The quadratic dependence of the resistivity is no longer obeyed; the specific heat coefficient diverges at the quantum critical point suggesting that the Fermi temperature renormalizes to zero and the quasi particle mass diverges. Moreover, recent experiments suggest the existence of a local critical mode at the transition. In order to fully determine the universal features of this new state of matter we have undergone a phenomenological discussion, jointly with experimentalists in Dresden. Motivated by our recent work on supersymmetry we have introduced a toy model which involves spin and charge deconfinement at the transition as an attempt to capture the essential features of the quantum critical point. This model particularly predicts a jump in the Hall coefficient at the transition, jumps recently observed in $CeCu_{6-x}Au_x$ [T01/048, T01/157].

3.4 Optical sum rule violation in the cuprates (C. Pépin)

It is still an open question to understand where does the condensation energy in the high temperature superconductors comes from. Nonetheless recent evidences show that kinetic energy effects are to play a role in condensation energy. This question can be addressed by looking at the optical conductivity sum rule. Indeed a sum rule violation between the normal and superconducting states implies a change in the kinetic energy of the system. Recently two experimental groups (N. Bontemps at ESPCI and D. van der Marel at Gröningen respectively) claimed to observe such a change. Using a simple model for the frequency-dependent scattering rate, we evaluate the in-plane optical integral for cuprate superconductors in the normal and superconducting states. In the overdoped region, this integral is conserved. In the optimal and underdoped region, though, the optical integrals differ, implying a lowering of the in-plane kinetic energy in the superconducting state. This sum rule violation, due to the difference of the non Fermi liquid normal state and the superconducting Fermi liquid state, has a magnitude comparable to recent experimental results [T02/033].

3.5 Heat capacity of lattice spin models from high-temperature series expansion (G. Misguich)

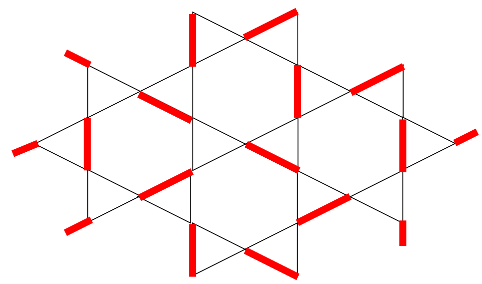
We devised a simple method to extrapolate the high-temperature series expansion of the *specific heat* $c_v(T)$ to zero temperature for lattice models. It applies to spin models without finite-temperature phase transition such as low-dimensional quantum magnets. For many such models the following data are available: 1) Ground-state and infinite temperature energies; 2) Leading terms of the high-temperature expansion of the free energy; 3) Total entropy per spin, which is just $\log(2S+1)$; 4) Qualitative low-temperature behavior of $c_v(T)$. We combined these informations into a procedure to estimate $c_v(T)$. This is done by a two-point Padé interpolation for the entropy as a function of the energy. Going back to $c_v(T)$, we get a result which, in addition to matching the high-temperature expansion, exactly satisfies two sum rules imposed by the knowledge of the ground-state energy and the total entropy, namely $\int c_v(T)dT = E(T=\infty) - E(T=0)$ and $\int c_v(T)/T dT = \log(2S+1)$. We illustrated this method on several systems (spin chains and many two-dimensional spin-1/2 Heisenberg models). These sum rules turn out to constrain $c_v(T)$ so that, unlike other standard approaches, accurate results can be obtained (relative error of the order of a few percent) *down to zero temperature* [T00/173].

3.6 Lieb–Schultz–Mattis theorem in dimension larger than one (G. Misguich)

The Lieb–Schultz–Mattis (LSM) theorem (1961) states that the ground-state of a quantum spin chain (or ladder) with a half-integer spin in the unit cell is either degenerate or supports gapless excitations. Since the argument is readily extended to spin ladders of arbitrary finite width, it is a natural to consider the validity of this theorem in higher dimension. We analyzed its validity in dimension two in various cases. Systems which spontaneously breaks a continuous (spin rotation) or discrete (lattice) symmetry will have degenerate ground-states but we found examples where the corresponding momenta are not those imposed by the LSM theorem. On the other hand, spin models which do not break any symmetry (spin liquids) are also observed to have degenerate ground-states. This phenomenon is related to the use of boundary conditions and has a topological origin. This is best understood in the language of short-range resonating valence-bond (RVB) states (Rokhsar and Kivelson 1988) where the degeneracy is a consequence of the disconnected topological sectors in the space of dimer coverings of the lattice. We have illustrated this aspect by several numerical calculations of exact spectra and have determined the quantum numbers associated to the ground-state multiplet as a function of the lattice geometry. Here again we provided examples where the momenta differ from the one-dimensional situation [T01/153].

3.7 Quantum dimer models on the kagome lattice (G. Misguich, D. Serban and V. Pasquier)

Quantum dimer models were introduced in the context of resonating valence-bond (RVB) theories for the high-temperature superconductors. Such models are expected to describe the dynamics of singlet bonds (dimer) in quantum disordered spin-$\frac{1}{2}$ antiferromagnets. They can describe two generic phases: spin-liquids where the system breaks no symmetry at all and dimer (or valence-bond) crystals where long-range dimer-dimer correlations develop. Such liquid states have attracted a lot of interest because they display both fractional excitations and topological order. While fractionalization could play an important role in some theories of high-temperature superconductors (Senthil and Fisher, 2000), the topological properties of these liquid states have been recently proposed as possible devices to implement q-bits for quantum computations (Ioffe, 2002).



Nearest-neighbor dimer covering on the kagome lattice.

We have introduced a quantum dimer model on the kagome lattice (see Figure), as well as on other lattices made of corner-sharing triangles, which realizes such a dimer-liquid phase. It is made of local kinetic terms which allow the motion of dimers around hexagons. Due to its geometrical properties, this model is exactly solved by very simple means. Our model has several important differences with previous analogs : 1) Dimer-dimer correlations are strictly zero above one lattice spacing. This makes our wave function the most possible disordered dimer liquid state; 2) Not only the ground state but all excited states wave functions are known. Elementary excitations appear to be (pairs of) non interacting and gapped vortices (the *visons* introduced by Senthil and Fisher (2001); 3) The model can be defined (and solved) on almost any geometry: torus but also discs or spheres. This allows to investigate the interplay between topology, ground-state degeneracy and elementary excitations in an very simple way; 4) It is known that quantum dimer models can be obtained as special limits of Z_2 gauge theories, the gauge variable being the dimer number on a bond. Here, we show a complete equivalence between our dimer models and a Z_2 gauge theory. This allows to investigate the confinement transition which goes with a dimer solidification accompanied by a vison condensation [T02/058].

3.8 Excitations in fractional quantum Hall effect (D. Serban)

Studying properties of the quantum Hall systems requires to know the properties of the elementary excitations. These can be studied starting from the Laughlin wave function. On the other hand, low-energy excitations located at the edges can be described by means of conformal field theory. The excitations in the bulk can be obtained in field theories with Chern–Simons term, as for example the so-called Zhang–Hansson–Kivelson (ZHK) model. It consists of a complex scalar field coupled to a statistical gauge field, which performs the statistical transmutation from bosons to fermions. Similarly to the Landau–Ginsburg model for the superconductivity, the ZHK model shows vortex solutions, vortices being identified to the Laughlin quasiparticles. The vortices carry (fractional) electric charge, as well as statistical flux. In [T00/144] we studied the vortex solutions in the situation where the bosonic field has p components. The relevant filling fractions are of the type $\nu = p/(p\beta + 1)$, where $\beta = 2n$ is an even integer (the number of fluxes attached to the electrons). When $p > 1$, we find that the vortex equations have several types of solutions, depending on the monodromy conditions around the vortex center imposed to the electron fields, so we conclude that the filling fraction does not uniquely characterize a quantum Hall liquid for the Jain series.

3.9 Bose–Einstein condensation (J.-P. Blaizot)

We have continued our study of the effect of weak interactions on the transition temperature of a dilute Bose gas [T01/149]. New developments concern the identification of a non analytic dependence of the transition temperature on the scattering length a. This comes from contributions $\propto a^2 \ln a$ which limit the region where the expected linear behavior can actually be observed [T01/171].

3.10 Dynamical formation of a Bose–Einstein condensate (R. Lacaze)

The observation of Bose–Einstein condensation in atomic vapors opens the way to test in a rather detailed fashion some predictions of equilibrium and nonequilibrium quantum statistical mechanics. We address the question of the formation, after a finite time, of a singular equilibrium distribution as a solution of the Boltzmann–Nordheim equation. We explain how some solutions of the kinetic equation may blow–up at time t_*, if the initial density exceeds a critical threshold. This time t_* is the incipient time for the condensate. Once the condensate is formed, its mass can still evolve by exchange with the thermal background, until the global equilibrium distribution is reached (for the given conditions of mass and energy).

The dynamical Boltzmann–Nordheim equation for the energy probability distribution $w(\epsilon, t)$ is shown to have a self-similar solution which describes the finite time singularity. Our numerical investigation is in complete agreement with the self-similar solution. The behavior $w(\epsilon, t) \propto \epsilon^{-1.234}$ is observed (close to t_*) for ϵ between 10^{-19} and 10^{-1}. For smaller values of t we can see how this solution is build. The value 1.234 of the exponent differs significantly from the values 7/6 and 3/2 that would follow from the scaling properties of the solutions at constant mass or energy flux [T01/148].

3.11 Out of equilibrium quantum dots (O. Parcollet)

Quantum dots are mesoscopic devices in which a "dot" containing a small number of electrons is isolated from two macroscopic leads by potential barriers, through which tunneling processes take place. Experimentally, these systems are small devices fabricated using a two-dimensional electron gas, or carbon nanotubes. One of the most interesting aspects of these systems in the manifestation of the Kondo effect in some regimes. The Kondo model describes the interaction of a localized spin and conduction electrons in a metal. It is one of the most studied strongly correlated electrons problem, whose solution in equilibrium lead to the development of numerous theoretical methods. The experimental study of quantum dots renewed the subject by allowing more controlled experiments and in particular out-of-equilibrium experiments (when the potential difference between the leads is not small), outside the scope of linear response.

Although the Kondo model is well understood in equilibrium, a complete solution is still not available for out-of-equilibrium regimes. Indeed, one basic question recently debated is whether the Kondo problem has a strong coupling regime at low temperature and high voltage. Recently, we have shown that out-of-equilibrium perturbative expansions (for example of the dot magnetization) is more subtle than widely believed, due to degeneracy of the impurity problem. This clarification is a necessary step to an out-of-equilibrium perturbative renormalization group approach, which was also undertaken by other groups [T02/042].

3.12 Multiple-spin exchange model on the triangular lattice (G. Misguich)

We studied an $SU(2)$ symmetric spin-1/2 Hamiltonian which includes Heisenberg (J_2) as well as 4-spin interactions in the form of cyclic permutation operators around rhombus of a triangular lattice (J_4). This kind of interaction has been recognized as the origin of the unusual magnetic properties of ^{3}He atomic monolayers adsorbed on graphite, which form a triangular solid of nuclear spin-1/2 at very low temperatures. In this work we address the question of how the 3-sublattice Néel long-ranged order of the Heisenberg antiferromagnet is destroyed, at zero temperature, by the effect of 4-spin cyclic exchange J_4. We used the method of numerical diagonalizations on finite-size systems. A small but finite amount of 4-spin exchange turns out to be necessary to destroy magnetic long-ranged order. We measured how the spin-wave velocity of the Néel phase vanishes at the transition, which we estimated to be around $J_4/J_2 \approx 0.07 - 0.1$. Above this value, a gap to magnetic excitations opens in the spectrum. The system, then, presents a very unusually large number of $S = 0$ excitations below the first $S = 1$ state. This situation is interestingly reminiscent of the kagome antiferromagnet. It might be due to the proximity of a critical point or to a more intrinsic property of this spin-liquid phase. The effect of an applied magnetic field is also studied and reveals magnetization plateaus at 1/3 and 1/2 of the saturated moment [T00/174].

3.13 Quantum Hall effect (V. Pasquier)

The two letters [T00/107, T00/177] are devoted to establish an exact relation between the classical solutions of a two dimensional non linear σ model and the ground state of an electronic Hamiltonian in the quantum Hall regime. It turns out that the classical solutions can be put in one to one correspondence with the ground states of a quantum Hamiltonian. The classical field configuration is the local expectation value of the electronic spin which can be perfectly localized in the limit where the magnetic length is equal to zero. The topological winding number of the classical configuration turns out to be the excess of charge with respect to a filling factor equal to one.

4 Soft condensed matter and biological systems

4.1 Bridge hopping on conducting polymers in solution (H. Orland)

Conducting (conjugated) polymers have been of great interest because of their unusual electrical and optical properties, combined with mechanical features very different from those of metallic conductors. Here we concentrate on the effects of "bridge conduction", the hopping of electrons between monomers distant from one another as measured along the polymer backbone, but close to each other in configuration space as a consequence of the bending of the dissolved polymer. This bridge conduction is also believed to be one of the important mechanisms for electron transfer reactions which play a key role in several biological processes, such as photosynthesis and cell metabolism [T01/059].

4.2 Polyelectrolyte titration: theory and experiment (H. Orland)

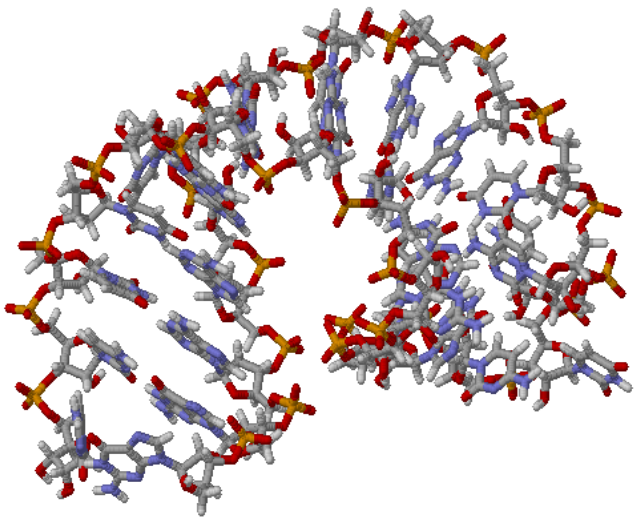
Titration of methacrylic acid / ethyl-acrylate copolymers is studied experimentally and theoretically. At low salt concentrations, this polyacid exhibits a plateau in the titration curve below the neutralization point. The plateau has been often attributed to a first-order phase transition associated with polymer conformational changes. We argue that the specific shape of titration curves of hydrophobic polyelectrolytes is due to electrostatics and does not necessarily require a conformation change of the polyelectrolyte chains. We calculate the free energy at the mean-field level and its first-order (one loop) correction using a loop expansion. We show that the one-loop corrections to the free energy lead to titration curves that agree with experiments [T00/069].

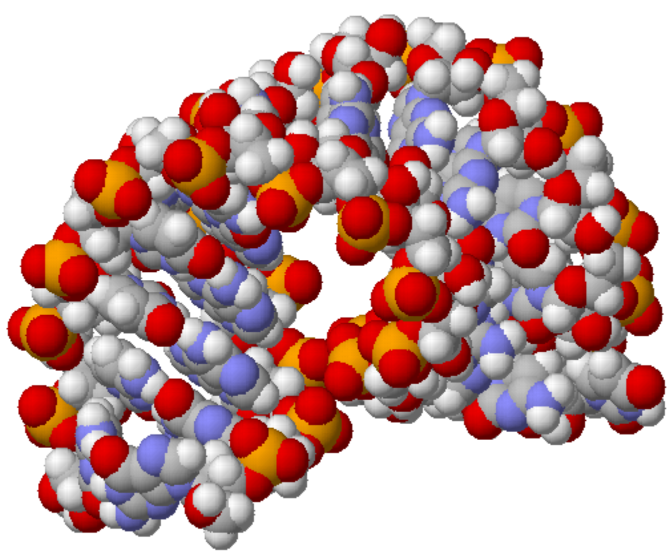
4.3 Localization transition of an amphiphilic chain (T. Garel, C. Monthus and H. Orland)

We have studied the localization transition of an ideal periodic hydrophilic (A) -hydrophobic (B) chain at a water-oil interface [T00/037]. Each monomer of the chain has a "charge" q_i (with $q_{(2n+1)} = q_A > 0$ and $q_{(2n)} = -q_B < 0$), and the Hamiltonian of the chain is simply given by $H = -\sum q_i \operatorname{sign} z_i$. The phase transition is best characterized by a grand canonical approach, where the probability distribution of localized and de-localized loops is made explicit. A parallel approach can be used in the wetting transition, with similar results. The influence of disorder on these localization transitions is marginal since $\alpha_{(pure)} = 0$ (Harris criterion), and previous studies have shown that disorder is marginally relevant.

4.4 A simplified model for DNA denaturation (T. Garel, C. Monthus and H. Orland)

We have studied a simplified version of the DNA denaturation transition, where the two strands are modeled as interacting polymer chains [T01/003, T02/032]. The attractive interactions, which mimic the pairing of the four bases are reduced to a single short range binding term. Furthermore, base-pair misalignments are forbidden, which implies that this binding term exists only for corresponding (same curvilinear abscissae) monomers of the two chains. Taking into account the excluded volume between the chains, leads to a long range effective repulsion, which decays as $1/r^{d-2}$. The balance between this repulsion and the binding term yields a pairing transition which has both a latent heat and an infinite correlation length, in broad agreement with studies by Coluzzi et al. and Kafri et al.





Two graphic representations of the same RNA molecule.

4.5 RNA folding and large N matrix theory (H. Orland)

We formulate the RNA folding problem as an $N \times N$ matrix field theory. This matrix formalism allows us to give a systematic classification of the terms in the partition function according to their topological character. The theory is set up in such a way that the limit $N \to \infty$ yields the so-called secondary structure (Hartree theory). Tertiary structure and pseudo-knots are obtained by calculating the $1/N^2$ corrections to the partition function. We propose a generalization of the Hartree recursion relation to generate the tertiary structure [T01/062].

4.6 General formalism for phase combination and phase refinement: a statistical thermodynamics approach in reciprocal space (H. Orland)

The mean-field optimization methodology has been used to recast in a single formalism the problem of phase optimization using an arbitrary function, in the presence of an experimentally determined phase probability distribution function. A formal analogy between the phase reconstruction problem and the Ising model allows to use a mean-field method to break the phase ambiguity which plagues the crystallographic determination of protein structures [T00/054].

4.7 Symmetries of independent statistical observables for ultrametric populations (B.-G. Giraud)

In several domains of biology and physics, experimental observables are not independent, because of underlying ultrametric correlations. Independent observables are defined, to disentangle such spurious correlations. Furthermore for those epidemiological studies where populations can be randomly disturbed by displacements and identity problems, such observables are shown to be, in part, robust under such a possible disorder. Their symmetry group is studied, in connection with their robustness [T00/050].

4.8 Elementary derivative tasks and neural net multiscale analysis of tasks (B.-G. Giraud)

Two distinct results are found, namely i) if elementary neural responses belong to a basis of wavelets, the gain parameter of the wavelets suffices for a universality theorem; ii) it may happen that training the net induces elementary systems to become practically identical and subtract this response from one another, thus implementing a “derivative” task; namely the net becomes sensitive to tasks which are derivatives of elementary tasks with respect to neuronal parameters. Such derivative tasks may have biological illustrations and/or industrial applications [T01/064].

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T02/027 **IANCU E., ITAKURA K., MCLERRAN L.,** *Geometric scaling above the saturation scale,* 24 pp. [hep-ph/0203137]

T02/028 **GERVOIS A., TROADEC J.-P., OGER L.,** *Frequency of n-Polygons in Sections of a fcc and a bcc Lattices,* submitted to Adv. Appl. Probab.

T02/030 **ALEXANDROV S.Y.,** *Hilbert space structure of covariant loop quantum gravity,* submitted to Phys. Rev. D [gr-qc/0201087]

T02/031 **ALLAHVERDYAN A.E., BALIAN R., NIEUWENHUIZEN T.M.,** *Curie-Weiss model of the quantum measurement process,* submitted to Europhys. Lett. [cond-mat/0203460]

T02/032 **GAREL T., MONTHUS C., ORLAND H.,** *Reply to the Comment by S. M. Bhattacharjee on "A simple model for DNA denaturation",* Europhys. Lett. 57, p. 774 (2002) [Reply]

T02/033 **NORMAN M.R., PÉPIN C.,** *Quasiparticle Formation and Optical Sum Rule Violation in Cuprate Superconductors,* submitted to Phys. Rev. Lett. [cond-mat/0201415]

T02/034 **BUCCELLA F., SAVOY C.A.,** *Intermediate Symmetries in the Spontaneous Breaking of Supersymmetric* $SO(10)$, submitted to Mod. Phys. Lett. A [hep-ph/0202278]

T02/035 **ANTONIADIS I., MINASIAN R., VANHOVE P.,** *Non-compact Calabi-Yau Manifolds and Localized Gravity,* submitted to Nucl. Phys. B [hep-th/0209030]

T02/036 **BORGHINI N., DINH P.M., OLLITRAULT J.-Y.,** *Analysis of directed flow from elliptic flow,* Phys. Rev. C 66, 014905 (2002) [nucl-th/0204017]

T02/037 **AKEMANN G.,** *Microscopic correlation functions for the QCD Dirac operator with chemical potential,* Phys. Rev. Lett. 89, 072002 (2002) [hep-th/0204068]

T02/038 **CHACKO Z., GROJEAN C., PERELSTEIN M.,** *Fine Structure Constant Variation from a Late Phase Transition,* submitted to Phys. Rev. Lett. [hep-ph/0204142]

T02/039 **LE DOUSSAL P., MONTHUS C.,** *Exact solutions for the statistics of extrema of some random 1D landscapes, Application to the equilibrium and the dynamics of the toy model,* submitted to Physica A [cond-mat/0204168]

T02/040 **RIAZUELO A., VERNIZZI F., STEER D., DURRER R.,** *Gauge invariant cosmological perturbation theory for braneworlds,* submitted to Phys. Rev. D [hep-th/0205220]

T02/041 **BIALAS P., MOREL A., PETERSSON B., PETROV K.,** *Z(3) Symmetric Dimensional Reduction of (2+1)D QCD,* Statistical QCD, Bielefeld, Germany, August 2001, to appear in Nucl. Phys. B (Proc. Suppl.) [hep-lat/0112008]

T02/042 **PARCOLLET O., HOOLEY C.,** *On the perturbative expansion of the magnetization in the out-of-equilibrium Kondo model,* [cond-mat/0202425]

T02/043 **MALLICK K., MARCQ P.,** *Anomalous diffusion in nonlinear oscillators with multiplicative noise,* submitted to Phys. Rev. E

T02/044 **TEMESVÁRI T., DE DOMINICIS C., PIMENTEL I.R.,** *Generic replica symmetric field-theory for short range Ising spin glasses,* Eur. Phys. J. B 25, 361-372 (2002) [cond-mat/0202162]

T02/045 **PIMENTEL I.R., DE DOMINICIS C., TEMESVÁRI T.,** *Spin glass transition in a magnetic field: a renormalisation group study,* submitted to Phys. Rev. B

T02/046 **BALIAN R.,** *La physique quantique à notre échelle,* Colloque Les quanta : un siècle après Planck, Académie des Sciences, Paris, France, 15 décembre 2000, to appear in Physique et Interrogations Fondamentales - Un siècle de quanta, COHEN-TANNOUDJI G., ed. (EDP Sciences, 2002)

T02/047 **HOLZ D.E., ORLAND H., ZEE A.,** *On the Remarkable Spectrum of a Non-Hermitean Random Matrix Model,* [math-ph/0204015]

T02/051 **GRIGERA T.S., CAVAGNA A., GIARDINA I., PARISI G.,** *Geometric Approach to the Dynamic Glass Transition,* Phys. Rev. Lett. 88, 055502 (2002)

T02/052 **BOUTILLIER C., FRANÇOIS P., MALLICK K., MALLICK S.,** *A matrix Ansatz for the diffusion of an impurity in the asymmetric exclusion process,*

T02/054 **ALLAHVERDYAN A.E., NIEUWENHUIZEN T.M.,** *Bath generated work extraction and inversion-free gain in two-level systems,* submitted to J. Phys. A [cond-mat/0201408]

T02/058 **MISGUICH G., SERBAN D., PASQUIER V.,** *Quantum dimer model on the kagome lattice: solvable dimer liquid and Ising gauge theory,* Phys. Rev. Lett. 89, 137202 (2002) [cond-mat/0204428]

T02/088 **DUPLANTIER B.,** *Higher conformal multifractality,* in: Proceedings of the 86th Statistical Mechanics Conference, a celebration of Michael E. Fishers' 70th birthday, Rutgers University, USA, December 16-18 2001, to appear in J. Stat. Phys.

LIST OF REFERENCES

List of the SPhT preprints that are referenced in this text,
and appeared already in the list of publications of a previous report, mostly by mistake.

T98/114 **LEE H.-J., MIN D.-P., PARK B.-Y., RHO M., VENTO V.,** *The proton spin in the chiral bag model: Casimir contributions and Cheshire Cat Principle,* Nucl. Phys. A 657, 75-94 (1999) [hep-ph/9810539]

T99/093 **HONG D.K., RHO M., ZAHED I.,** *Qualitons at high density,* Phys. Lett. B 468, 261-269 (1999) [hep-ph/9906551]

T00/037 **MONTHUS C., GAREL T., ORLAND H.,** *Copolymer at a selective interface and two-dimensional wetting: a grand canonical approach,* Eur. Phys. J. B 17, 121-130 (2000) [cond-mat/0004141]

T00/050 **GIRAUD B.G.,** *Symmetries of independent statistical observables for ultrametric populations,* Phys. Rev. E 62, 4450-4453 (2000)

T00/054 **DELARUE M., ORLAND H.,** *General formalism for phase combination and phase refinement: Mean-field optimization in reciprocal space,* Acta Crystallogr. A 56, 562-574 (2000); Acta Crystallogr. A 57, p. 118 (2000)

T00/064 **RICHARD P., OGER L., TROADEC J.-P., GERVOIS A.,** *Comparison between a 2D froth and a cut of 3D froth,* to be published in: Third Conference on Foams, Emulsions and Applications (Eurofoam 2000) Delft, The Nederlands, June 5-8 2000, Zitha P., ed. (Verlag MIT Publishing, Bremen 2000) pp. 313-320

T00/069 **BORUKHOV I., ANDELMAN D., BORREGA R., CLOITRE M., LEIBLER L., ORLAND H.,** *Polyelectrolyte Tritration: Theory and Experiment,* J. Phys. Chem. B 104, 11027-11034 (2000)

T00/072 **ZUBER J.-B.,** *CFT, BCFT, ADE, and all that,* Lectures at Quantum Symmetries in Theoretical Physics and Mathematics, Bariloche, Argentina, January 10-21 2000, [hep-th/0006151]

T00/073 **BRAX P., MANDAL G., OZ Y.,** *Supergravity description of non-Bogolmol'nyi-Prasad-Sommerfield branes,* Phys. Rev. D 63, 064008 (2001) [hep-th/0005242]

T00/074 **KOSTOV I.,** *Exact Solution of the Three-colour Problem on a Random Lattice,* submitted to Phys. Lett. A [hep-th/0005190]

T00/075 **PITARD E., GAREL T., ORLAND H.,** *Sur le repliement des protéines,* Phases Magazine, La Lettre du DRECAM et du SPhT No 23, pp. 1-2 (2000)

T00/080 **KOSTOV I.K., KRICHEVER I., MINEEV-WEINSTEIN M., WIEGMANN P.B., ZABRODIN A.,** *τ-function for analytic curves,* MSRI Workshop Matrix Models and Painlevé Equations, Berkeley, California, USA, 1999, MSRI Lectures Notes 40, 1-15 (2001): Random Matrices and Their Applications [hep-th/0005259], Its A., Bleher P., eds. (MSI Publications)

CONSEIL SCIENTIFIQUE EXTÉRIEUR

A l'initiative de notre service, un conseil scientifique extérieur a été mis en place en 1990. Son rôle est de procéder à une évaluation critique de notre activité. Ce conseil, renouvelé par partie tous les deux ans, a la composition suivante :

Costas BACHAS, ENS Paris
Riccardo BARBIERI, ENS Pise
George F. BERTSCH, University of Washington
Krzysztof GAWEDZKI, ENS Lyon
Michelangelo MANGANO, CERN
Bernard NIENHUIS, université d'Amsterdam
Michel TAGGER, DAPNIA/SAP, CEA-Saclay
Jean VANNIMENUS, ENS Paris (président)
Peter YOUNG, University of California at Santa-Cruz

ANNEXES

Ces annexes sont basées sur les informations fournies pas les membres du laboratoire. Il se peut que certaines rubriques soient incomplètes.

LES THÈSES SOUTENUES AU SPhT

- Gabrielle BONNET

  Modèles de matrices aléatoires à N grand, groupe de renormalisation, solutions exactes et universalité, thèse de l'université Paris XI, soutenue le 16/6/2000 [T00/095].
- Gregory MOREAU

  Étude phénoménologique des interactions violant la symétrie de R-parité dans les théories super-symétriques, thèse de l'université Paris VII Denis Diderot, soutenue le 27/11/2000 [T00/176].
- Stéphane MUNIER

  Contributions à l'étude de la chromodynamique quantique perturbative appliquée à la diffusion profondément inélastique à petit x_{Bj}, thèse de l'École polytechnique, soutenue le 15/9/2000 [T00/138].
- Karim BENABED

  Effets de lentilles gravitationnelles sur le rayonnement de fond cosmologique, thèse de l'université Paris XI, soutenue le 12/11/2001 [T01/124].
- Géraldine SERVANT

  Études phénoménologiques au-delà du modèle standard, thèse de l'université Paris XI, soutenue le 1/6/2001 [T01/050].
- Nicolas REGNAULT

  Solutions exactes de la gravité réduite. Effet Hall quantique de spin, thèse de l'université Paris XI, soutenue le 13/02/2002 [T02/017].

PRIX, MÉDAILLES, DISTINCTIONS

• Christophe GROJEAN

- Médaille de bronze du CNRS (2002),
- *First award in the 2001 Annual Essay Competition of the Gravity Research Foundation* (2001).

• Vincent PASQUIER

- Prix Langevin 2001 de la Société française de physique.

• Mannque RHO

- Ho-Am "Science" Prize (Ho-Am Foundation, Corée), 2002.

• Jean ZINN-JUSTIN

- Nommé Schrödinger professor 2001 de l'université de Vienne.

Thèses en préparation au SPhT

Liste des étudiants préparant une thèse au SPhT au 1^er^juin 2002.

- Phuong Mai Dinh, *Étude des effets collectifs dans les collisions d'ions lourds ultra-relativistes*, sous la direction de Jean-Yves Ollitrault, soutenue le 26 juin 2002.
- Guillaume De Smedt, *Systèmes hors d'équilibre : persistance et métastabilité*, sous la direction de Jean-Marc Luck et Claude Godrèche (SPEC), soutenance le 11 septembre 2002.
- Thomas Duguet, *Forces effectives dans les calculs microscopiques de la structure des noyaux*, sous la direction de Paul Bonche, soutenance le 30 septembre 2002.
- Serguei Alexandrov, *Modèles de matrices, gravité quantique et théorie de cordes*, sous la direction d'Ivan Kostov et V. Kazakov (ENS), soutenance prévue en 2003.
- Urko Reinosa, *Théorie des champs à température finie*, sous la direction de Jean-Paul Blaizot et Edmond Iancu, soutenance prévue en 2003.
- Paolo Ribeca, *Évaluation précise des quantités universelles dans les transitions de phase*, sous la direction de Riccardo Guida, Alberto Blasi (Dipartimento di Fisica Universitá di Genova) et Jean Zinn-Justin, soutenance prévue en 2003.
- Jérémie Bouttier, *Physique statistique combinatoire en géométrie fixe et aléatoire*, sous la direction de Philippe Di Francesco et Emmanuel Guitter, soutenance prévue en 2004.

Stages universitaires, et thèses hors du SPhT

• Claude BERVILLIER

- Nicolas Grach, stage de licence de physique de l'université de Rennes I, *Une étude de l'équation exacte du groupe de renormalisation dans l'approximation du potentiel local*, stage en mai-juin 2001, soutenance orale le 5 octobre 2001 à l'université de Rennes I.

• Philippe BRAX

- Nicolas Chatillon, stage du DEA CPM, *Supersymétrie et dimensions supplémentaires*, 1^er^mai - 16 juin 2002.

• Thomas GAREL

- Arnaud Letourmy, stage de maîtrise de l'université Pierre et Marie Curie, *Équilibre d'un fil dipolaire, effet de chiralité*, stage du 4 septembre au 6 octobre 2000.

• Irene GIARDINA

- François Ghoulmie, stage du DEA de physique théorique, *Problèmes d'écono-physique (minority game)*, stage du 15 janvier au 15 avril 2001.

• Bertrand GIRAUD

- Arnaud Touzeau, stage de 2^e^année de l'École centrale de Lyon, stage au SPhT en juin et juillet 2001, résultats publiés [T01/064].

• Jean-Marc LUCK

- Encadrement scientifique partiel de la thèse de Sebastiao Correia, au Laboratoire de physique théorique de Strasbourg, soutenue en 2000.

• Kirone MALLICK

- Stage X: Cédric Boutillier et Paul François, *Exact diffusion constant of an impurity in the exclusion process.*

• Catherine PÉPIN

- Jérome Rech, stage de DEA (de physique théorique rhône-alpin) d'avril à août 2002, *Étude théorique de points critiques quantiques.*

• Robi PESCHANSKI

- Julien Salomez, stage de DEA (de physique théorique rhône-alpin), *Modèle des dipôles*, en cours,

- Julien Lamouroux, stage de magistère Paris VI, *Génération dynamique des distributions de partons dans le pomeron*, en cours.

• Richard SCHAEFFER

- Encadrement partiel de la thèse de Céline Boehm (soutenue le 4 juillet 2001), *Matière noire, formation des structures de l'univers et supersymétrie.*

ACTIVITÉS PÉDAGOGIQUES

Sont indiqués ici uniquement les cours donnés dans des universités ou des grandes écoles pendant les années scolaires 2000-2001 et 2001-2002, les cours du vendredi du SPhT, ainsi que les autres cours ayant donné lieu à une publication (par exemple cours d'écoles d'été).

Cours et travaux dirigés universitaires

• Karim BENABED
- 2000-2001 : TD de Fortran. Licence de science physique, Paris XI - Orsay, 76 heures.

• Guillaume De SMEDT
- Remise à niveau ex-PCEM, département SNV, université Paris VII.

• Mai DINH
- TD de physique en premier cycle d'études en médecine (PCEM), université Paris XI - Orsay, années 2000-2001 et 2001-2002, 72 heures par an.

• Nicolas REGNAULT
- Projet professionnel, DEUG 1reannée, université Paris XI - Orsay 20 heures, 2000-2001.

• Urko REINOSA
- 2000-2001 : TP de physique E2A, université Paris XI - Orsay (92 heures),
- 2001-2002 : TD de physique PCEM, université Paris XI - Orsay (64 heures).

• Géraldine SERVANT
- 2000-2001 : TD et TP de mécanique des fluides et phénomènes de transport pour DEUG Sciences de la Vie.

• Jean ZINN-JUSTIN
- *Intégrale de chemin en mécanique quantique*, cours annuel du MIP (magistère interuniversitaire de physique, École normale supérieure) 2^{e}année [T01/020],
- *Introduction à l'analyse complexe*, cours de licence à l'université de Cergy-Pontoise 2000-2001 et 2001-2002.

Cours grandes écoles

• Bertrand DUPLANTIER
- École polytechnique : Physique statistique, cours *Polymères et colloïdes du vivant* (2000-2001); cours de mécanique quantique (2001-2002).

• Thomas DUGUET
- TD en 1reannée de l'École centrale de Paris : cours de mécanique quantique et de physique statistique.

• Jean-Yves OLLITRAULT
- Préceptorats de méthodes mathématiques, ESPCI 1re et 2^{e} années, 2000-2001 (45 heures) et 2001-2002 (18 heures).

• Georges RIPKA
- Cours de programmation à l'ESITC (École supérieure d'ingénieurs des travaux de la construction) Cachan, depuis 1998.

Cours, TD en DEA et en écoles doctorales

• Cirano De DOMINICIS

- Fragments du cours donné à Saclay ("cours du vendredi") au printemps 2000 présentés en 2001-2002 à Budapest, Lisbonne, São Paulo, Recife et Natal.

• François DAVID

- *Théorie statistique des champs*, cours du tronc commun du DEA de physique théorique, école doctorale de physique de la région parisienne, 2001-2002.

• França̧is BERNARDEAU

- Cours de cosmologie à l'école doctorale d'astronomie et d'astrophysique d'Île-de-France, 16 heures en 2000-2001 et en 2001-2002.
- Cours de cosmologie au DEA de physique théorique de l'école doctorale de physique de la région parisienne, 15 heures en 2001-2002.

• Christophe GROJEAN

- Cours de relativité générale à l'université de Californie Berkeley (4 heures, janvier-mars 2000).

• Jean-Marc LUCK

- Printemps 2000 : Cours intitulé *Systèmes désordonnés unidimensionnels*, à l'école doctorale *Physique, chimie-physique et mathématiques* de l'université de Strasbourg I.

• Jean-Yves OLLITRAULT

- Cours de théorie des champs (tronc commun) au DEA *Champs, particules, matière* (30h); ce cours est également suivi en option par les élèves de 2^e^année du magistère interuniversitaire de physique, École normale supérieure.

• Philippe DI FRANCESCO

- 2000-2001: cours *Modèles matriciels intégrables*, DEA de mathématiques de Paris VII, 60 heures.

• André VOROS

- DEA de mathématiques, université Paris VII : *Analyse semi-classique et applications*, février-mai 2001.

• Jean ZINN-JUSTIN

- *Symétries et transitions de phase : la théorie de Landau*, DEA de physique statistique de l'université de Cergy-Pontoise 2000-2001 et 2001-2002 [T00/081, T01/019],
-*Le groupe de renormalisation*, DEA de mathématiques Paris VII, 2001-2002.

Cours publiés

• Roger BALIAN

- *Physique fondamentale et énergétique : les multiples visages de l'énergie.* Cours donné à l'école d'été de Caen (2001) à destination des enseignants (du Lycée à l'Université). Publié par le rectorat de Caen, le Bulletin de l'Union des professeurs de spéciales et sur le site http://e2phy.in2p3.fr [T01/125].

• Jean-Paul BLAIZOT

- *Theory of the quark-gluon plasma*, cours donné à l'école d'hiver de Schladming, Autriche, mars 2001 [T01/074].

• Denis BERNARD

- *Turbulence for (and by) amateurs*, école à Montpellier/Sètes, TMR, 2000 [T00/093].

• Françis BERNARDEAU

- *Gravitational lenses to probe the universe.* Notes de cours pour l'école de Cargèse 2000, *Understanding the Universe at the close of the 20th century*, organisée par M. Signore et A. Blanchard [T01/043].

• Jean-Paul BLAIZOT

- *Quantum fields at finite temperature: a brief introduction*, cours présenté à l'école d'été *QCD perspectives on hot and dense matter* (a NATO Advanced Study Institute), organisée à Cargèse par J.-P. Blaizot, E. Iancu et al., Cargèse, Corse, 6–18 août 2001. En cours de publication [T01/174].

• Edmond IANCU

- *The color glass condensate: an introduction*, cours présenté à l'école d'été *QCD perspectives on hot and dense matter* (a NATO Advanced Study Institute), organisée à Cargèse par J.-P. Blaizot, E. Iancu et al., Cargèse, Corse, 6–18 août 2001. En cours de publication [T02/024].

• Jean-Yves OLLITRAULT

- *Collective effects in nucleus-nucleus collisions*, cours présenté à l'école d'été *QCD perspectives on hot and dense matter* (a NATO Advanced Study Institute), organisée à Cargèse par J.-P. Blaizot, E. Iancu et al., Cargèse, Corse, 6–18 août 2001. En cours de publication [T01/175].

• Jean ZINN-JUSTIN

- *The regularization problem and anomalies in quantum field theory*, publié dans les proceedings de l'école d'automne de Lisbonne 2000 [T01/018],

- *Chiral Anomalies and Topology*, à paraître dans les proceedings de l'école d'été de Rot an der Rot [T02/012].

• Jean-Bernard ZUBER

- *Conformal Boundary Conditions*, école d'hiver de Cheju Island (Corée) 28 février-4 mars 2000 *Integrable QFT and their applications* [T00/189],

- *Conformal Boundary Conditions and what they teach us*, école d'été et workshop *Non-perturbative Quantum Field Theoretic Methods and their Applications*, Budapest, août 2000 [T01/022].

Cours du vendredi

Les cours du vendredi après-midi sont une tradition bien établie au SPhT. Ils ont lieu à l'Orme des Merisiers et sont ouverts à tous les chercheurs de la région. Un certain nombre font partie de l'enseignement de l'école doctorale de physique de la région parisienne. Certains de ces cours ont été donnés par des visiteurs du SPhT.

- Bertrand EYNARD, *Introduction aux matrices aléatoires*, 22 septembre au 24 novembre 2000 [T01/014].
- Yuri DOKSHITZER (LPTHE, Orsay and LPTHE, Jussieu), *Basics of QCD*, 1$^{\text{er}}$décembre 2000 à mars, 2001.
- A.H. MUELLER (Columbia University), *Basics of QCD*, 27 avril au 18 mai 2001.
- Bertrand DUPLANTIER, *Multi-fractalité conforme*, 8 et 15 juin 2001.
- Michael R. NORMAN (Argonne National Laboratory), *High Temperature Cuprate Superconductors*, octobre 2001.
- David LANGLOIS (IAP, Paris), *Univers primordial et naissance des fluctuations cosmologiques*, 9 novembre au 21 décembre 2001.
- Grégoire MISGUICH, *Introduction à la physique de la matière condensée I : introduction au magnétisme localisé*, 3 cours d'une heure et demie, janvier 2002.
- Catherine PÉPIN, *Introduction à la physique de la matière condensée II : théorie du liquide de Fermi*, janvier 2002.
- Olivier PARCOLLET, *Introduction à la physique de la matière condensée III : impuretés quantiques*, mai 2002.
- Frédéric FAURE (université Joseph Fourier, Grenoble), *Théorie adiabatique et indices topologiques en physique du solide et moléculaire*, 8 mars au 12 avril 2002.

EDITION DE REVUES SCIENTIFIQUES

- Roger BALIAN

- Membre de l'Advisory Panel du *Journal of Physics A.*

- Michel BAUER

- Membre du Comité de rédaction de *CEA Saclay, le Journal.*

- Bertrand DUPLANTIER

- Éditeur de *Nuclear Physics B [FS]*,
- Éditeur de *Geometric and Functional Analysis [GAFA].*

- Alain BILLOIRE

- Éditeur de *International Journal of High Speed Computing.*

- Jean-Paul BLAIZOT

- Éditeur de *Physics Letters B.*

- Annie GERVOIS

- Advisory Editor de *Physica A* (jusqu'en 2001).

- Henri ORLAND

- Éditeur associé à EPJB.

- Mannque RHO

- Éditeur de *International Journal of Modern Physics E.*

- André VOROS

- Membre du Comité éditorial de *Journal of Physics A.*

- Jean ZINN-JUSTIN

- Éditeur de *Nuclear Physics B*,
- Éditeur de *Fortschritte der Physik*,
- Éditeur de *The New Journal of Physics.*

- Jean-Bernard ZUBER

- Éditeur des *Annales Henri Poincaré* (2002).

LIVRES ET CHAPITRES DE LIVRES

• Roger BALIAN

- Contribution à un livre sur *Les enjeux du XX^{e} siècle* publié par l'université de Lille I (2001) : réflexions intitulées *Pour une revalorisation de la Science* [T00/096],

- Préface du livre *L'énergie dans le monde : bilan et perspectives* de Bobin, Nifenecker et Stefan, EDP Sciences, 2001 (Collection dossiers scientifiques) [T00/103].

• François DAVID

- *L'Univers Primordial*, Les Houches Session 71, P. Binétruy, R. Schaeffer, J. Silk et F. David éds., EDP Sciences; Springer-Verlag 2000 [T99/164],

- *Ondes de Matière Cohérentes*, R. Kaiser, C. Westbrook et F. David éds., Les Houches Session 72, EDP Sciences; Springer-Verlag 2000 [T01/116],

- *Agrégats Atomiques et Nanoparticules*, C. Guet, P. Hobza et F. David éds., Les Houches Session 73, EDP Sciences; Springer-Verlag 2001 [T01/172],

- *Turbulence : Nouveaux Aspects*, M. Lesieur, A. Yaglom et F. David éds., Les Houches Session 74, EDP Sciences; Springer-Verlag 2001 [T01/173].

• Paul BONCHE

- Livre du CESEN, *Le nucléaire expliqué par des physiciens*, EDP Sciences 2002.

• Jean ZINN-JUSTIN

- *Quantum Field Theory and Critical Phenomena*, 4^{e} édition, Oxford University Press [T02/002].

• Roger BALIAN

- 239^{e} Conférence de *l'Université de tous les savoirs* (28/8/2000) sur *Entropie, information : un concept protéiforme*. Publié en 2001 (Odile Jacob, volume 4) [T00/158],
- Participation à plusieurs *Bars des Sciences* ; présidence de l'Association du Bar des Sciences de Meudon,
- Assistance à des journalistes scientifiques (*Science et Avenir*, *National Geographic Magazine*),
- Membre du Conseil d'administration de *Science-Contact* (jusqu'en 2001),
- Membre du jury du Prix Roberval, décerné à des ouvrages technologiques de vulgarisation et d'enseignement,
- Participation à un colloque de réflexion sur l'avenir de l'école des Houches,
- Membre du Comité de rédaction de *la lettre de l'Académie des Sciences.*

• Francis BERNARDEAU

- *La quintessence en physique des particules*, *Pour la science* No 281 (2001) [T01/028].

• Paul BONCHE

- *Clefs CEA*, N^{o} 45, automne 2001 : *Physique nucléaire et sûreté*,
- CESEN (*Cercle d'études sur l'énergie nucléaire*).

• Jacques BROS

- Conférencier invité au colloque *Interrogations fondamentales : causalité et finalité* (SFP et Bibliothèque nationale de France), le 22/05/2002.

• François DAVID

- Organisation de conférences grand public aux Houches, dans le cadre de la direction de l'école de physique des Houches,
- Organisation du colloque et des célébration du cinquantenaire de l'école de physique des Houches en juin 2000,
- Participation à un reportage "Anniversaire" dans l'émission Archimède du 30 octobre 2001 sur la chaîne Arte.

• Marc GINGOLD et Olivier GOLINELLI

- Membres du Comité de rédaction de *Phases magazine, La lettre du DRECAM et du SPhT.*

• Estell PITARD, Thomas GAREL, Henri ORLAND

- Article dans Phases magazine, La lettre du DRECAM et du SPhT, N^{o} 23 (2000), *Sur le repliement des prot'eines* [T00/075].

• Richard SCHAEFFER

- Article dans *La Recherche*, janvier 2001, *La matière noire manque toujours à l'appel* [T01/011].

• Géraldine SERVANT

- Brève dans *La Recherche*, avril 2001, *Gravité et dimensions cachées.*

• Patrick VALAGEAS

- Exposé devant deux classes de terminale de physique, avril 2002.

• André VOROS

- Rédaction (avec M. CHOUCHAN) de l'article : *Des mathématiques à long terme*, pour le dossier *L'an 2000, année mondiale des mathématiques*, Journal du CEA-Saclay N^o 12 (déc. 2000) p. 6–7.

ORGANISATION DE CONFÉRENCES OU D'ECOLES

• Bertrand DUPLANTIER

- Actuellement, organisation d'un trimestre de recherche à l'IHP (janvier 2003-mars 2003) sur *Geometry and Statistics of Random Growth.*

• Bertrand DUPLANTIER et Vincent PASQUIER

Séminaire Poincaré. Le but de ce nouveau séminaire est de permettre à chacun de s'informer de sujets de grande actualité en physique. Son fonctionnement est directement inspiré de celui du séminaire Bourbaki en mathématiques. Le premier séminaire a eu lieu le samedi 9 mars 2002 à l'IHP, avec comme sujet l'énergie du vide.

• Jean-Paul BLAIZOT

- Co-organisateur, avec Edmond Iancu, de l'école d'été *QCD perspectives on hot and dense matter*, (a NATO Advanced Study Institute), Cargèse, France, 6–18 août 2001,

- Membre du Comité d'organisation de Quark-Matter 2002, Nantes, juillet 2002.

• Philippe BRAX

- Organisation de *The ekpyrotic universe*, 10–11 décembre 2001, atelier de l'euro-GDR *supersymétrie*,

- Organisation de *The nature of dark energy*, 1–5 juillet 2002, colloque IAP.

• François DAVID

- Direction de l'école de physique des Houches, université Joseph Fourier, Grenoble (jusqu'au 31 décembre 2001) :

- Session 73: *Agrégats Atomiques et Nanoparticules*, juillet 2000,

- Session 74: *Turbulence : Nouveaux Aspects*, août 2000,

- Session 75: *Physique des Bio-molécules et des Cellules*, juillet 2001,

- Session 76: *Gravité, Théories de Jauge et Cordes*, août 2001.

• Denis BERNARD

- co-organisation : *TMR final conference*, Paris, septembre. 2000,

- co-organisation : *Bologna workshop on integrable and conformal field theory*, Bologne, Italie, septembre 2001.

• Edmond IANCU

- Co-organisateur, avec Jean-Paul Blaizot, de l'école d'été *QCD perspectives on hot and dense matter* (a NATO Advanced Study Institute), Cargèse, France, 6–18 août 2001.

• Ivan KOSTOV et Philippe DI FRANCESCO

- 6^{e} rencontres Claude Itzykson, *Matrix Models 2001*, SPhT, Saclay, 18–21 juin 2001.

• Stéphane LAVIGNAC

- Membre du Comité d'organisation de la conférence *From the Planck scale to the electroweak scale*, La Londe-les-Maures (France), 11-16 mai 2001,

- Coordinateur de la session *Supersymétrie et physique théorique* des *Journées jeunes chercheurs 2001* (division *particules et champs* de la SFP), Arcachon, 10-14 décembre 2000,

- Membre du Comité d'organisation de l'école de Gif depuis 2001.

• Jean-Marc LUCK

- 5^{e} rencontres Claude Itzykson, *Dynamics of Nonequilibrium Systems*, SPhT, Saclay, 20–23 juin 2000.

• Jean-Yves OLLITRAULT

- Membre du Comité national d'organisation de la conférence Quark Matter 2002, Nantes, 18-24 juillet 2002.

• Henri ORLAND

- Organisateur de la sous-session sur le repliement des protéines à l'ITP de Santa Barbara, dans le programme : *Statistical Physics of Biological Information* (février 2001).

• Paul BONCHE

- École Joliot-Curie de physique nucléaire 2002.

• Catherine PÉPIN

- Organisatrice du 13e *Workshop on Strongly Correlated Electrons*, Trieste, August 2002.
- Aide à l'organisation de la conférence TH-2002, Paris, 22-27 juillet 2002.

• Robi PESCHANSKI

- *Low-x Workshops* : Oxford (2000), Cracow (2001), Anvers (2002),
- *Xth International Workshop on Deep Inelastic Scattering (DIS)* Cracow, 30 Avril - 4 Mai 2002.

• Mannque RHO

- Co-Chair, *International Workshop on Explosive Phenomena in Astrophysical Compact Objects*, Korea Institute for Advanced Study, Seoul, Korea, 2000,
- Membre, International Advisory Committee, International Nuclear Physics Conference 2001, Berkeley, CA, USA, 2001.

• Georges RIPKA

- Organisateur du *International Workshop on The Physics of Color Confinement*, ECT* (Trento, Italie), septembre 2001.

• Carlos SAVOY

- Euro-conférence : *From the Planck Scale to the Electroweak Scale*, La Londe les Maures, mai 2001.

• Daniel IAGOLNITZER, Jean ZINN-JUSTIN

- Organisation de la conférence internationale TH2002, Paris, 22–27 juillet 2002.

LES RENCONTRES CLAUDE ITZYKSON : PROGRAMMES

The Fifth Claude Itzykson Meeting: Dynamics of Nonequilibrium Systems
Saclay, June 20 to 23, 2000

Organizers: J.M. Luck (SPhT, Saclay) and C. Godrèche (SPEC, Saclay)

Tuesday, June 20

E. Vincent, SPEC, Saclay
Aging and wall dynamics in random magnets: experiments
H. Horner, Univ. Heidelberg
Models of aging of glasses and spin glasses
S. Franz, ICTP, Trieste
Some insights on glassy dynamics
J. Kurchan, ESPCI, Paris
Metastable states in glasses

A.J. Bray, Univ. Manchester
Unusual dynamical scaling in the spatial distribution of persistent sites
H. Chaté, SPEC, Saclay
Assessing the universality of persistence decay: some new facts
C.M. Newman, Courant Institute, New York
Local non-equilibration and chaotic time dependence
S. Redner, Boston Univ.
Fate of finite ferromagnets

Wednesday, June 21

S. Ciliberto, ENS, Lyon
On the violation of the fluctuation-dissipation theorem in aging systems: an experimentalist point of view
L. Cugliandolo, LPTENS, Paris
Quantum spin glasses: a comparison between theory and experiments
F. Ricci-Tersenghi, ICTP, Trieste
Chaotic, memory and cooling rate effects in spin glasses: is the Edwards-Anderson model a good spin glass?
J.P. Bouchaud, SPEC, Saclay
Simple dynamical models for power-law tails: from directed polymers to economy

M. Schreckenberg, Univ. Duisburg
Dynamics of traffic flow and congestion
P.L. Krapivsky, Boston Univ.
Traffic flows on one-lane roadways
D. Mukamel, Weizmann Institute, Rehovot
Coarsening processes in driven systems
M. Evans, Univ. Edinburgh
Alternating steady state in a simple model of flocking

Thursday, June 22

T.W. Burkhardt, Temple Univ. and ILL, Grenoble
Confined polymers, inelastic collapse of granular matter, and the Fokker-Planck equation
C. Godrèche, SPEC, Saclay
Sums of temporally correlated random variables
S. Majumdar, LPQ, Toulouse
Slow logarithmic decay of magnetization in the zero-temperature dynamics of an Ising chain: analogy to granular compaction
H.J. Hilhorst, LPT, Orsay
The set of sites visited by a lattice random walk

B. Derrida, LPS, Paris
Statistical properties of genealogical trees

Friday, June 23

J. Krug, Univ. Essen
Diffusion and electromigration on disordered surfaces
Z. Racz, Univ. Budapest
Width distributions for growth and deposition processes
M. Droz, Univ. Geneva
A new theoretical approach for the formation of Liesegang patterns
C. Sire, LPQ, Toulouse
Numerical renormalization group of vortex aggregation in 2D decaying turbulence: the role of three-body interactions

G. Parisi, Univ. Rome
Generalized fluctuation-dissipation relations in off-equilibrium systems
M. Mézard, LPTMS, Orsay
Population dynamics in random media
Th. M. Nieuwenhuizen, Univ. Amsterdam
New surprises in thermodynamics far from equilibrium
E. Domany, Weizmann Institute, Rehovot
Cluster analysis of the ground states of the short-range $\pm J$ *Ising spin glass*

The Sixth Claude ITZYKSON Meeting: Matrix Models 2001

Saclay, June 18 to 21, 2001

Organizers: I. Kostov and P. Di Francesco (SPhT, Saclay)

Monday, 18 June, 2001

M. L. Mehta, CEA/Saclay
Some questions and conjectures rel ated to random matrix theory
E. Brézin, CEA/Saclay
Characteristic polynomials of random matrices
P. Bleher, Indiana University
Double scaling limit in the matrix model: the Riemann-Hilbert approach
K. Efetov, Bochum
Directed Disorder and Non-Hermitian Random Matrices
P. Wiegmann, EFI, Chicago
Matrix models and the Dirichlet boundary problem
A. Marshakov
Tau-functions of curves, Dirichlet problem and integrable hierarchies J. Verbaarschot, University of Stony Brook, New York
Chiral Random Matrix Theory and Unitary Matrix Integrals

Tuesday, 19 June, 2001

H. Kawai, University of Kyoto
Constructing new types of matrix models for critical string
V. Kazakov , ENS, Paris
Vortices on planar graphs and a matrix model for the 2D black hole N. Nekrassov , IHES, Bures-sur-Yvette
Instantons and fluid mechanics
M. Douglas , Rutgers University, Piscataway
D-branes and world volume gauge theory
H. Spohn, Technische Universität, Munich
Random matrices and scale invariance of growth processes
K. Johansson, Royal Institute of Technology, Stockholm
Random growth and random matrices
H. Widom, Northeastern University, Boston
A growth model in a random environment

Wednesday, 20 June, 2001

J. Ambjørn, NBI, Copenhagen
3D quantum gravity, matrix models and wormholes
Ch. Kristjansen, Niels Bohr Institut, Copenhagen
Generalized Lorentzian Triangulations and the Calogero Hamiltonian
E. Guitter , CEA/Saclay
Critical and Multicritical Semi-Random Lattices and Hard Objects
J.-B. Zuber
Matrix models and knot theory - I
P. Zinn-Justin , LPTMS, Orsay
Matrix models and knot theory - II

A. Migdal , Metastream, Princeton
Loop approach to QCD

Poster Session

G. AKEMANN, M. BENNAI, Z. BURDA, A. COSTE, Y. FYODOROV, S. GALA, S. ISO, J. NISHIMURA, F. SUGINO

Thursday, 21 June, 2001

D. Kutasov, University of Chicago
From null states to matrices
M. Fukuma, Yukawa Institute, Kyoto
Holographic RG Structure in Higher-Derivative Gravity
T. Wynter , ENS, Paris
Testing Matrix String Theory
M. Staudacher , AEI, Golm
Dimensionally Reduced D=10 Super Yang-Mills matrix models
M. Kontsevich, IHES, Bures-sur-Yvette
Gromov compactness and Unitary Conformal Field Theories
O. Bohigas, LPTMS, Orsay
Chaotic dynamics: random-matrix theory and beyond
J. Hoppe, Technische Universität, Berlin
Aspects of M-algebras

COLLABORATIONS INSTITUTIONNALISÉES

Participation à des GDR et programmes nationaux

• Programme national de cosmologie : Francis BERNARDEAU, Richard SCHAEFFER.

• GDR européen *Supersymétrie* (responsable : Pierre Binétruy) : Christophe GROJEAN, Stéphane LAVIGNAC, Carlos SAVOY (membre du Conseil de groupement du GDR), Richard SCHAEFFER.

• GDR MIDI (*milieux divisés*) : Annie GERVOIS.

• GDR européen *Mathématiques et physique quantique* : Stéphane NONNENMACHER, André VOROS.

• GDR *Noyaux exotiques* : Paul BONCHE.

• GDR *Oxydes à propriétés remarquables* : Catherine PÉPIN.

• GDR *Structures non perturbatives en théories des champs et des cordes* : Jean-Bernard ZUBER.

Programmes de Collaboration européens

• Roger BALIAN

- Visite de 16 jours à Amsterdam dans le cadre d'un programme néerlandais.

• Réseau ESF SPHINX, *Statistical physics of glassy and non-equilibrium systems* (1999-2003, coordinateur David Sherrington) : Alain BILLOIRE, Jean-Marc LUCK.

• Réseau RTN (5^{e} Framework programme) *Physics Across the Present Energy Frontier: Probing the Origin of Mass* (1/10/2000 - 30/9/2004, responsable Ignatios Antoniadis) : Philippe BRAX, Christophe GROJEAN, Stéphane LAVIGNAC, Carlos SAVOY et Géraldine SERVANT.

• Réseau RTN (5^{e} Framework programme) EUROGRID, *Discrete Random Geometries: from Solid State Physics to Quantum Gravity* (1/4/2000-31/3/2004, coordinateur Desmond Johnston) : François DAVID (local coordinator), Emmanuel GUITTER, Ivan KOSTOV et Philippe DI FRANCESCO.

• Réseau (5^{e} Framework programme) RTN LENSNET : *Gravitational Lensing: New constraints on Cosmology and the Distribution of Dark Matter* (1/3/1998-28/2/2002, coordinateur Yannick Mellier) : Francis BERNARDEAU.

• Réseau (5^{e} Framework programme) RTN : *Mathematical Aspects of Quantum Chaos* (1/9/2000-31/8/2004, coordinateur Jonathan Robbins) : Stéphane NONNENMACHER et André VOROS.

• Réseau ESF FERLIN *Fermi-liquid instabilities in correlated metals* (1998-2002, Coordinateur Hilbert von Löhneysen) : Catherine PÉPIN

• Réseau RTN (5^{e} Framework programme) *QCD and Particle Structure* (25/3/1998-24/3/2002, coordinateur James Stirling) : Stéphane MUNIER, Henri NAVELET, Robi PESCHANSKI.

• Réseau RTN (5^{e} Framework programme) *Integrability, non-perturbative effects and symmetry in quantum field theory* (1/10/1996-30/9/2000, coordinateur Ed Corrigan) : Michel BAUER, Jean-Bernard ZUBER.

Programmes de Collaboration internationaux

• Sergei ALEXANDROV

- Programme ECOS de collaboration avec l'université catholique de Santiago, Chili.

• Alain BILLOIRE, Jean-Paul BLAIZOT (PI), Robert LACAZE, et Jean-Yves OLLITRAULT

- Centre franco-indien pour la promotion de la recherche avancée (CEFIPRA). Projet "Quark-Gluon Plasma" en collaboration avec l'institut Tata de Bombay (2000-2002).

• Philippe BRAX

- Bourse CNRS- Royal Society entre France et Grande-Bretagne.

• Cirano De DOMINICIS

- Programme de collaboration France-Brésil COFECUB,
- Convention de subvention "COCOP" CEA/MAE d'échanges avec la Hongrie (I. Kondor).

• Christophe GROJEAN, Carlos SAVOY

- Programme d'action integrée Polonium (France-Pologne), 2000 - 2002.

• Riccardo GUIDA

- Cotutelle de la thèse de Paolo Ribeca avec le professeur Alberto Blasi de l'université de Gênes.

• Jean-Paul BLAIZOT, Edmond IANCU

- Programme d'action integrée Amadeus (France-Autriche), collaboration avec le Technische Universität Wien, jusqu'à la fin 2000.

• Ivan KOSTOV

- Programme bilatéral CNRS-CONECIT (Chili), 2002.

• Pierre MOUSSA

- Accord entre le CNRS et le CNR Italien, collaboration de 1997 à 2001, pour un travail en collaboration avec Stefano Marmi (Udine & Pise) et J.-C. Yoccoz, Collège de France, Paris.

• Stéphane NONNENMACHER et André VOROS

- Programme ECOS-Sud avec l'Argentine (M. Saraceno),
- Convention de subvention "COCOP" CEA/MAE d'échanges avec la Hongrie (G. Vattay).

• Robi PESCHANSKI

- Convention de subvention "COCOP" CEA/MAE d'échange avec la Pologne (Romuald Janik).

• Georges RIPKA

- Conseiller scientifique au ECT* (Trento, Italie) : novembre-décembre 2000, janvier-mai et décembre 2001 janvier-février 2002.

• Jean-Bernard ZUBER

- Réseau OTAN (Italie-Grèce-Bulgarie-France) Algebraic and Geometric Aspects of Conformal Field Theories and Superstrings, depuis 2002.

• Jean-Paul BLAIZOT

- Membre du Conseil scientifique de l'UFR de physique de l'université Paris VI, depuis 2001.

• François DAVID

- Membre (nommé) de la Commission de spécialistes, 29^{e} section, université Paris VI.

• Francis BERNARDEAU

- Membre du Comité national de la recherche scientifique en section 02 depuis décembre 2000.

• Stéphane LAVIGNAC

- Membre de la Commission de spécialistes, 29^{e} section, à Paris XI Orsay (membre suppléant) depuis 2001.

• Jean-Yves OLLITRAULT

- Membre suppléant des Commissions de spécialistes, 29^{e} section, à Paris VII et Nantes.

• Henri ORLAND

- Membre élu du Comité national de la recherche scientifique en section 02 depuis décembre 2000.

• Jean-Bernard ZUBER

- Membre de la Commission de spécialistes, $29-30^{\rm mes}$ sections, Laboratoire LMTP de Tours.

• Roger BALIAN

- Délégué de la section de physique de l'Académie des Sciences,
- Membre de deux groupes de travail devant élaborer deux rapports de prospective de l'Académie des Sciences, l'un sur les interactions des mathématiques, l'autre sur la physique de demain,
- Membre du groupe de réflexion sur la réforme de l'Académie (2000-2001),
- Membre du Conseil scientifique de l'ENS Lyon (jusqu'en 2000),
- Membre du Conseil scientifique du CEA,
- Membre du Conseil d'administration du Laboratoire Léon Brillouin,
- Membre du Conseil scientifique de la DAM (depuis le premier juin 2001),
- Membre du Conseil scientifique et éthique d'AREVA,
- Membre de la Commission de réflexion sur l'enseignement des mathématiques.

• Alain BILLOIRE

- Secrétaire du Conseil scientifique du calcul centralisé de la DSM (CSCC),
- Membre du Comité d'orientation de l'informatique scientifique et des réseaux de la DSM,
- Membre du Comité d'orientation de l'information scientifique et technique de la DSM (COIST)
- Représentant de la DSM au projet POLIST (politique IST du CEA).

• Bertrand DUPLANTIER

- Directeur adjoint de l'IHP jusqu'en février 2001.

• Jean-Paul BLAIZOT

- Invité permanent des CSTS du SPP, SPhN et SAP (DAPNIA),
- Président du Comité d'évaluation du CPT Marseille (2001),
- Membre du Comité d'évaluation de l'Institut "Riken-BNL-Research-Center" à Brookhaven, USA (2000-2002).

• François DAVID

- Président du Comité d'évaluation du Laboratoire de physique théorique de Strasbourg, juin 2000,
- Membre du Comité d'évaluation du Laboratoire de physique de l'École normale supérieure de Lyon, avril 2002.

• Denis BERNARD

- Membre du Comité d'évaluation du LAPTH-Annecy, mars 2002.

• Marc GINGOLD

- Correspondant IST pour le SPhT,
- Membre du Comité d'orientation de l'information scientifique et technique de la DSM (COIST),
- Membre du COMEX IST : Comité (CEA) d'exploitation de l'information scientifique et technique.

• Robert LACAZE

- Membre du Comité de programme 6 de l'IDRIS, *Systèmes modèles*,
- Membre du Comité *Nouveaux ordinateurs du CEA Recherche* (renouvellement des moyens de calcul centraux du CEA civil).

• André MOREL

- Membre de la Commission enseignement de la Société française de physique (responsable),

- Organisation d'une session aux Houches (24-28 juin 2002) : *Teaching Physics: A European Confrontation.*

• Henri ORLAND

- Membre des Comités d'évaluation du Laboratoire de physique des liquides (Jussieu), du Laboratoire de neurophysique et physiologie du système moteur (Paris V), du Laboratoire de physique statistique de l'ENS Paris, et de l'ENS Lyon.

• Paul BONCHE

- Membre du Conseil scientifique du GANIL,

- Invité permanent au CSTS du SPhN (DAPNIA),

- Membre du Conseil scientifique de l'école Joliot-Curie,

- Membre du Conseil scientifique de la DAM (audit consacré à la physique nucléaire), 1erseptembre 1997 - 31 mai 2001.

• Philippe DI FRANCESCO

- Membre du Comité d'attribution du prix CAP-CRM de l'université de Montréal en physique théorique et mathématique.

• Jean ZINN-JUSTIN

- Président du Conseil scientifique du calcul centralisé de la DSM,

- Membre du Comité scientifique et technique (CSTS) du SPP (DAPNIA),

- Membre de la Commission calcul du *John von Neumann Institute für Computing* (NIC) de Jülich, Allemagne,

- Membre du Conseil d'administration de l'école de physique des Houches,

- Membre des Conseils scientifique et d'orientation de l'école de Cargèse.

• Jean-Bernard ZUBER

- Membre du Conseil scientifique de l'IHÉS (1995-2001),

- Membre du Comité d'évaluation du LPMT Montpellier.

LE GROUPE DE DOCUMENTATION SPhT-SPEC

Notre bibliothèque “de proximité” est riche d’un fonds de plus de 9500 ouvrages et souscrit à 150 abonnements à des revues scientifiques.

Une attention toute particulière est apportée au maintien de la qualité et au développement de cet outil de travail indispensable pour la physique théorique. La sélection des acquisitions est effectuée par les chercheurs qui choisissent les nouveaux ouvrages qui viennent enrichir notre fonds (processus coordonné par Didina Serban).

La tenue des locaux, du matériel et des ouvrages est assurée par Bruno Savelli et par Philippe Fontaine. Claudine Verneyre assure la maintenance informatique locale et gère la base des annonces de séminaires.

Nous avons à déplorer le départ quasi-simultané en juillet 2001 de Liliane Dumets et Nathalie Pelletier qui composaient le secrétariat scientifique. Elles assuraient la frappe scientifique de quelques articles, et la gestion des publications. Cette dernière tâche a été reprise pour l’essentiel par le reste du groupe, grâce notamment à une automatisation des procédures d’enregistrement, mais au prix d’une surcharge de travail pour Marc Gingold responsable du groupe. La quasi-totalité des chercheurs assurant maintenant eux même la frappe de leurs articles, et par ailleurs une simplification de la gestion des articles étant nécessaire, un seul poste de secrétariat scientifique a été ouvert. Répondre au profil de poste souhaité a pris du temps et c’est seulement au 1er septembre 2002 que Loic Bervas prendra ses fonctions dans le service.

Le site Web externe du SPhT (`www-spht.cea.fr`) a été développé. Il présente l’activité du service et offre un accès à l’essentiel des informations créées en interne : textes des publications, annonces de séminaires, cours et conférences, ... Son serveur, ainsi que celui du site interne devront subir une profonde réorganisation, suite à un changement de l’ensemble des machines dédiées aux sites du SPhT et du SPEC.

Dans le cadre de la réorganisation de l’informatique et des technologies de l’information au CEA, Alain Billoire participe au projet POLIST qui doit définir une politique de l’information scientifique et technique (IST) au CEA, Marc GINGOLD participe au COMEX-IST, et tous deux participent au COS-IST de la DSM.

Liliane DUMETS (secrétariat scientifique), jusqu’en juin 2001
Philippe FONTAINE (bibliothèque)
Marc GINGOLD (responsable du groupe)
Nathalie PELLETIER (secrétariat scientifique), jusqu’en juin 2001
Bruno SAVELLI (bibliothèque)
Claudine VERNEYRE (informatique)

LE SECRÉTARIAT ADMINISTRATIF

Le secrétariat administratif est assuré par deux personnes pour un effectif moyen des présents dans le laboratoire de 80. La charge qui pèse sur le personnel administratif va croissante en raison de l'effet conjugué de l'alourdissement des tâches (entre autre résultant de la multiplication des types de financement et de la mise en place du logiciel de gestion SIGMA au CEA) et de la mise en œuvre de la loi sur la RTT.

Outre le secrétariat courant d'un laboratoire dont le responsable a rang de chef de département, Sylvie Zaffanella assure principalement la gestion du personnel (CEA, CNRS et doctorants), de toutes les missions et des commandes (fournitures de bureau, matériel informatique, mobilier, travaux, ...). La gestion financière est assurée par le groupe administratif du DRECAM.

Anne-Marie Arnold a pour tâches principales la gestion des dossiers et l'accueil de l'ensemble des visiteurs, de courtes et longues durées, français et étrangers et relevant de statuts très divers (post-doc, CTE, EGIDE, IFS, stagiaires, ...). A cela s'ajoute, entre autre, une tâche de support logistique pour l'organisation annuelle des "Journées Claude ITZYKSON".

Pour faire face à la charge de travail croissante, un poste de secrétariat administratif a été ouvert.

Anne-Marie ARNOLD
Sylvie ZAFFANELLA

L'INFORMATIQUE AU SPhT

La gestion du système informatique est commune au SPhT et au Département de recherches sur l'état condensé, les atomes et les molécules (DRECAM). La réorganisation de la Direction Informatique du CEA, devenue Direction des Technologies de l'Information (DTI) et le redémarrage du projet SOLEIL ont entraîné d'importants mouvements de personnel et la mise en place de nouvelles structures, les Unités Locales des Technologies de l'Information (ULTI). Tout cela a profondément affecté le Groupe informatique DRECAM-SPhT.

Jean-Louis Gréco a remplacé Brigitte Gagey à la direction du groupe. Suite au départ de Christian Juret du DRECAM, où il assurait, en particulier, le support technique des PC, Laurent de Seze a pris la responsabilité de l'ensemble des PC Windows, des réseaux et de la sécurité informatique. Alain Buteau du Laboratoire Léon Brilloin (DRECAM/LLB), responsable du support technique des PC administrés sous Windows NT, a été remplacé par Christophe Person. Localement pour le SPhT, le support informatique est assuré par une équipe interdépartementale : Anne Capdepon (DRECAM) est responsable de l'équipe, de l'ensemble des services Unix (serveurs-terminaux X et PC sous Linux) et des services Web ; Catherine Bourgois (SPhT) gère les sauvegardes et l'ensemble des comptes (login) ; après le départ de Nathalie Ravenel du SPhT, Patrick Berthelot, arrivé le 1er juillet 2002, assurera le support des PC Windows NT et le passage à Windows 2000 en fin d'année 2002 ; le poste DRECAM de support Unix, laissé vacant par les nouvelles fonctions de Anne Capdepon, devrait prochainement être pourvu par mutation interne. Deux autres personnes assurent une aide importante :

Christian Perez, en formation par alternance au DRECAM, participe à la restructuration des serveurs Web et Claudine Verneyre (SPhT), à temps partiel, assure un support technique spécifique au SPhT et participe à la gestion du parc informatique.

Des ULTI Saclay et DSM ont été mises en place. A ce jour, il n'en a pas résulté une amélioration du service local aux utilisateurs, par contre la charge en réunions et discussions des personnels de support informatique a augmenté.

Compte tenu des besoins informatiques au SPhT et des forces disponibles, trois axes de développement sont poursuivis simultanément : - serveurs Unix et terminaux X - PC administrés sous Windows NT et devant passer sous Windows 2000 fin 2002 - PC administrés sous Linux. Une exigence d'interopérabilité entre ces différentes approches reliées en réseau est poursuivie : accès aux logiciels Windows à partir des terminaux X et émulation de terminaux X pour les PC sous Windows et les quelques Mac.

Les serveurs

Le support des postes de travail, les services interactifs et les calculs de taille moyenne en batch sont assurés par des serveurs Sun UltraSparc. Le SPhT dispose en propre : d'un serveur Sun UltraSparc bi-processeur "wasa" (renouvelé en milieu d'année 2000), assurant entre autre la gestion de l'ensemble des comptes (login) du service, de deux stations Sun "elfe" et "manureva", destinées en priorité au calcul formel avec les logiciels MacSyma et Mathematica et aux applications graphiques, et d'une station SGI O2 "daisybelle". Correspondant à une tendance actuelle, un serveur de calcul bi-processeur PC sous Linux "annamaria" est venu compléter cet ensemble de serveurs SUN. Ce serveur est principalement destiné aux calculs formels. Par ailleurs, le serveur Sun "kontiki", utilisé par la documentation et le Web, est en cours de remplacement par un ensemble de PC sous Linux.

Les postes de travail

Le poste de travail standard est encore le terminal X équipé d'un écran couleur 19" (environ 80 postes). Un ensemble de 25 PC, dont 10 sous Linux et le reste sous Windows NT ou 2000, ainsi que 6 Mac constitue les autres postes de travail scientifique et administratif.

Le calcul centralisé

Les physiciens disposent pour leurs calculs lourds des moyens de calcul centralisés du CEA civil à Grenoble : un ordinateur vectoriel VPP5000 Fujitsu à 16 processeurs "nymphea" et un ordinateur parallèle Compaq à 256 processeurs "ixia". Les projets importants font l'objet d'un examen au niveau DSM par un Comité scientifique le CSCC, présidé par Jean Zinn-Justin, qui juge de la validité du projet et de l'adéquation avec les machines, et alloue un contingent d'heures par semestre. Le SPhT assure le fonctionnement de ce Comité. Citons parmi les projets importants du SPhT des simulations de verres de spins et de QCD sur réseau avec "overlap-fermions" et des calculs d'exposants critiques du modèle $O(N)$.

Communication et information

Les caractéristiques du câblage des locaux et la mise en place au début 2000 de nouveau commutateurs rendent possible un fonctionnement du réseau informatique avec un débit de 100 Mbit/s. Les physiciens utilisent l'ensemble de la panoplie des outils d'accès au réseau : messagerie, connexion, transfert de fichiers, News, Web. Un serveur Web interne (`http://www-sphti/`) permet aux utilisateurs d'accéder aux bases de la documentation SPEC-SPhT (recherche d'ouvrages, listes de prétirages, rapports, ...). Comme pour le Web externe, une nouvelle version du Web interne est en cours de développement. Des bases bibliographiques générales (INSPEC, Science Citation Index, Zentralblatt-MATH, . . .) sont accessibles par le serveur de la DTI.

Depuis le début 2000, une commission informatique se réunit régulièrement. Son objectif est d'avoir une réflexion sur les évolutions des moyens informatiques, d'organiser et de décider, en accord avec la direction, les réponses à donner aux besoins exprimés et de jouer le rôle de comité des utilisateurs du SPhT pour le groupe informatique DRECAM-SPhT.

Catherine BOURGOIS
Anne CAPDEPON (DRECAM, responsable local du groupe informatique)
Nathalie RAVENEL, jusqu'au 28 février 2002
Laurent de SEZE (DRECAM)
Claudine VERNEYRE

PHYSICIENS DU SERVICE DE PHYSIQUE THÉORIQUE
Situation au 1er mai 2002

Roger BALIAN (conseiller scientifique CEA)
Michel BAUER (CEA)
Michel BERGÈRE (CNRS)
Denis BERNARD (CNRS)
Francis BERNARDEAU (CEA)
Claude BERVILLIER (CNRS)
Alain BILLOIRE (CEA)
Jean-Paul BLAIZOT (CNRS)
Paul BONCHE (CEA, directeur de recherches DSM)
Philippe BRAX (CEA)
Jacques BROS (conseiller scientifique CEA)
Marc CHEMTOB (CNRS)
Henri CORNILLE (chercheur émérite CNRS)
François DAVID (CNRS)
Cirano DE DOMINICIS (conseiller scientifique CEA)
Philippe DI FRANCESCO (CEA)
Jean-Michel DROUFFE (CEA, expert senior DSM)
Bertrand DUPLANTIER (CEA)
Bertrand EYNARD (CEA)
Thomas GAREL (CNRS)
Annie GERVOIS (CNRS)
Bertrand GIRAUD (conseiller scientifique CEA, depuis le 1/7/2000)
Olivier GOLINELLI (CEA)
Christophe GROJEAN (CEA, depuis le 5/10/2001)
Riccardo GUIDA (CEA)
Emmanuel GUITTER (CEA)
Daniel IAGOLNITZER (conseiller scientifique CEA, depuis le 1/11/2000)
Edmond IANCU (CNRS, depuis le 1/10/2000)
David KOSOWER (CEA)
Ivan KOSTOV (CNRS)
Robert LACAZE (CNRS)
Stéphane LAVIGNAC (CNRS)
Jean-Marc LUCK (CEA, expert senior DSM)
Kirone MALLICK (CEA)
Grégoire MISGUICH (CEA, depuis le 3/1/2001)
Madan Lal MEHTA (chercheur émérite CNRS)
Cécile MONTHUS (CNRS, depuis le 1/12/2000)
André MOREL (conseiller scientifique CEA)
Pierre MOUSSA (CEA)
Stéphane NONNENMACHER (CEA, depuis le 2/10/2000)

Christiane NORMAND (CNRS)
Jean-Marie NORMAND (CEA)
Jean-Yves OLLITRAULT (CNRS)
Henri ORLAND (CEA)
Olivier PARCOLLET (CEA, depuis le 5/12/2001)
Vincent PASQUIER (CEA)
Catherine PÉPIN (CEA, depuis le 13/7/2000)
Robert PESCHANSKI (CEA, expert senior DSM)
Mannque RHO (conseiller scientifique CEA, depuis le 1/1/2002)
Georges RIPKA (conseiller scientifique CEA)
Carlos SAVOY (CNRS)
Richard SCHAEFFER (conseiller scientifique CEA, depuis le 1/5/2002)
Didina TEODORESCU (CEA)
Patrick VALAGEAS (CEA)
Pierre VANHOVE (CEA, depuis le 2/10/2000)
André VOROS (CEA, expert senior DSM)
Jean ZINN-JUSTIN (CEA, directeur de recherches DSM)
Jean-Bernard ZUBER (CEA, directeur de recherches DSM)

POST DOCS

Gernot AKEMANN (à partir du 1/9/2001)
Barbara COLUZZI (à partir du 15/1/2002)
Boris GUTKIN (à partir du 14/12/2001)
Isabella MASINA (à partir du 8/1/2001)
Luigi PILO (à partir du 1/10/2001)
Alain RIAZUELO (à partir du 5/11/2001)
Roman SCHUBERT (à partir du 31/10/2001)
Fumihiko SUGINO (à partir du 1/9/2000)
Cristel CHANDRE (du 1/1/2000 au 1/1/2001)
Irene GIARDINA (du 11/10/1999 au 11/10/2001)
Romuald JANIK (du 1/10/1998 au 4/10/2000)
Grégoire MISGUICH (du 1/9/1999 au 31/12/2000)

STAGIAIRES GRANDES ECOLES ET UNIVERSITES

Stagiaires ayant séjourné au SPhT durant la période de juin 2000 à mai 2002

Cédric Boutillier, École polytechnique
Nicolas Chatillon, Université Pierre et Marie Curie
Paul François, École polytechnique
François Ghoulmié, ENS Cachan
Nicolas Grach, Université de Rennes I
Julien Lamouroux, Université Pierre et Marie Curie
Arnaud Letourmy, Université Pierre et Marie Curie

Jérome Rech, ENS Lyon
Julien Salomez, ENS Lyon
Arnaud Touzeau, École centrale de Lyon

VISITEURS DE LONGUE ET MOYENNE DUREE

Visiteurs du SPhT ayant séjourné un mois ou plus durant la période de juin 2000 à mai 2002 (hors post-docs)

Steven Abel, Durham University (UK)
Armen Allahverdyan, Yerevan State University (Arménie)
Carl Bender, Washington University (USA)
Bernd Berg, Florida State University (USA)
Rajeev Bhalerao, TIFR (Tata Institute), Mumbai (Inde)
Andrzej Bialas, Université de Cracovie (Pologne)
Pavel Bleher, IUPUI (Indiana University Purdue), Indianapolis (USA)
Alexey Boyarsky, Niels Bohr Institute, Copenhagen (Danemark)
Carlo Cercignani, École polytechnique de Milan (Italie)
Patrick Dorey, Durham University (UK)
Frédéric Faure, CNRS Grenoble
Paul Fendley, University of Virginia (USA)
Silvio Franz, ICTP Trieste (Italie)
Masafumi Fukuma, Yukawa Institute for Theoretical Physics, Kyoto (Japon)
Rajiv Gavai, TIFR (Tata Institute), Mumbai (Inde)
Elena Gonzales-Ferreiro, Université de Santiago de Compostela (Espagne)
Sourendu Gupta, TIFR (Tata Institute), Mumbai (Inde)
Kazunori Itakura, Brookhaven National Laboratory (USA)
Romuald Janik, Jagellonian University, Cracow (Pologne)
Nicolai Kitanine, Inst. Steklov St Petersburg (Russie)
Yuri Kovchegov, University of Washington (USA)
Alan Lapedes, Los Alamos National Laboratory (USA)
André Leclair, Cornell University (USA)
Hyun-kyu Lee, Séoul University (Corée)
Frédéric Lesage, Université de Montréal (Canada)
Enzo Marinari, Università di Roma I La Sapienza (Italie)
Larry McLerran, Brookhaven National Laboratory (USA)
Dong-Pil Min, Séoul National University (Corée)
Cécile Monthus, LPTMS - Orsay
Mosche Mosche, Technion Inst. Haifa (Israël)
Ugo Moschella, Università Como (Italie)
Mike Norman, Argonne National Laboratory (USA)
Paul Pearce, University of Melbourne (Australie)
Maxim Perelstein, Lawrence Berkeley National Laboratory (USA)
Stefan Pokorski, Université de Varsovie (Pologne)
Thomas Reisz, Universität Heidelberg (Allemagne)
Hubert Saleur, University of South California (USA)

Mykola Shpot, Inst. of Condensed Matter Physics, Lviv (Ukraine)
Semjon Stepanow, Universität Halle (Allemagne)
Kin'ya Takahashi, Kyushu Inst. (Japon)
Tamas Temesvári, Eötvos University, Budapest (Hongrie)
Herbert Weigert, Universität Regensburg (Allemagne)
Stefan Weinzierl, NIKHEF Amsterdam (Pays-Bas)

VISITEURS DE COURTE DURÉE

Visiteurs du SPhT ayant séjourmé moins d'un mois consécutif durant la période de juin 2000 à mai 2002 (arrivés entre le 1erjuin 2000 et le 31 mai 2002)

Steven Abel, University of Durham (UK)
Luis Alvarez-Gaumé, CERN (Suisse)
David Andelman, Tel Aviv University (Israël)
Takashi Aoki, Kyoto University (Japon)
Ian Balitsky, Jefferson Laboratory (USA)
Peter Bantay, Eötvös University, Budapest (Hongrie)
Rodney Baxter, The National Australian University, Canberra (Australie)
Jean Bellissard, IHÉS
Karim Benabed, New York University (USA)
Giulo Biroli, Rutgers University (USA)
Pavel Bleher, IUPUI (Indiana University Purdue), Indianapolis (USA)
Céline Boehm, Université Montpellier II
Loriano Bonora, Sissa, Trieste (Italie)
Detlev Buchholz, Universität Göttingen (Allemagne)
Alessandra Buonanno, California Institute of Technology, Pasadena (USA)
Yoram Burak, Tel Aviv University (Israël)
Vladimir Buslaev, University Saint Petersburg (Russie)
Andrea Cappelli, INFN Florence (Italie)
Francesco Caravaglios, Università di Milano (Italie)
Domenico Carlucci, Theoretical Physics, Katholieke Universiteit, Leuwen (Belgique)
Aharon Casher, Tel Aviv University (Israël)
Pierre Chiappetta, CPT Marseille
Piers Coleman, Rutgers University USA
Ed Corrigan, University of York (UK)
Bernard de Wit, Utretch University (Pays-Bas)
Cédric Deffayet, New York University (USA)
Éric Delabaere, Université d'Angers
Stanley Deser, Brandeis University (USA)
Patrick Dorey, University of Durham (UK)
Marc Dreiner, Universität Bonn (Allemagne)
David Dunbar, University of Wales (UK)
Yves Ellinger, Université de Nice Sophia-Antipolis
Ayse Erzan, Gürsey Institute, Istansbul (Turquie)
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Dan Freedman, MIT (USA)
Dimitry Gangardt, Technion Hafa (Israël)
Rajiv Gavai, TIFR (Tata Institute), Mumbai (Inde)
Krzysztof Gawedzki, ENS Lyon
François Gelis, Université Paris XI - Orsay

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Samuel Gurvitz, Weizmann Institute (Israël)
Boris Gutkin, Weizmann Institute (Israël)
Michael Gutperle, Harvard University (USA)
Masayasu Harada, Nagoya University (Japon)
Paul-Henri Heenen, Université Libre de Bruxelles (Belgique)
Malte Henkel, Université Henri Poincaré, Nancy
Carl Herrmann, Università di Turino (Italie)
Jiri Hosek, Nuclear Physics Institute, Rez (République Tchéque)
Jérome Houdayer, Universität Gutenberg, Mainz (Allemagne)
Satoshi Iso, KEK Tsukuba (Japon)
Roman Jackiw, MIT (USA)
Romuald Janik, Jagellonian University, Cracow (Pologne)
Bert Janssen, Universidad Autonoma Madrid (Espagne)
Hannes Jung, University of Lund (Suede)
Stavros Katsanevas, Université Claude Bernard, Lyon
Dimitri Kharzeev, Brookhaven National Laboratory (USA)
Elias Kiritsis, University of Crète (Grece)
Nicolai Kitanine, University of York (UK)
Igor Klebanov, Princeton University (USA)
Tatsuya Koike, Kyoto University (Japon)
Gabriel Kotliar, Rutgers University (USA)
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Lev Lipatov, Université Montpellier II
Lon Chang Liu, Los Alamos National Laboratory (USA)
Nicodemo Magnoli, INFN Gênes (Italie)
Giuseppe Maiella, Università di Napoli (Italie)
Uri Maor, Tel Aviv University (Israël)
Philippe Marcq, Université de Provence, Aix-Marseille
Enzo Marinari, Università di Roma I (Italie)
Marcos Marino, Harvard University (USA)
Andrei Marshakov, Lebedev Physics Institute, Moscow (Russie)
Isabella Masina, Université de Padoue (Italie)
Tetsuo Matsui, University of Tokyo (Japon)
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Anita Mehta, S. N. Bose National Center for Basic Sciences, Calcutta (Inde)
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Theo Nieuwenhuizen, Université d'Amsterdam (Pays-Bas)
Mike Norman, Argonne National Laboratory (USA)
Sachiko Ogushi, Yukawa Institute for Theoretical Physics (Japon)
Enzo Orlandini, Università di Padova (Italie)
Jean Orloff, Université Clermont-Ferrand II
Stephane Padovani, CEA Grenoble
Gergely Palla, Eötvös University, Budapest (Hongrie)
Olivier Parcollet, Rutgers University (USA)
Paul Pearce, University of Melbourne (Australie)
Bengt Petersson, Universität Bielefeld (Allemagne)
Emmanuel Petitgerard, Ohio State University (USA)
Toni Pich, Universidad de València (Espagne)
Iveta Pimentel, Université de Lisbonne (Portugal)
Dan Pirjol, UCSD, San Diego (USA)
Hans-Juergen Pirner, Universität Heidelberg (Allemagne)
Fabio Pistolesi, ILL Grenoble
Pavel Pobylitsa, Universität Bochum (Allemagne)
Stefan Pokorski, Université de Varsovie (Pologne)
Peter Pollner, Eötvös University, Budapest (Hongrie)
Bénédicte Ponsot, MPI Golm (Allemagne)
Mariano Quiros, Instituto de Estructura de la Materia (CSIC), Madrid (Espagne)
Anton Rebhan, Technische Universität Wien (Autriche)
Hugo Reinhardt, Universität Tübingen (Allemagne)
Soo-Jong Rey, Seoul National University (Corée)
Alain Riazuelo, Université de Genève (Suisse)
Patrick Richard, INSA de Lyon
Paul Romaschke, Technische Universität Wien (Autriche)
Mariusz Sadzikowski, Université de Cracovie (Pologne)
Marcos Saraceno, CNEA Buenos Aires (Argentine)
Volker Schomerus, MPI Golm (Allemagne)
Ara Sedrakyan, LAPTH Annecy
Julien Serreau, Universität Heidelberg (Allemagne)
Géraldine Servant, University of Chicago (USA)
Samson Shatashvili, Yale University (USA)
Yakov Shnir, Universität Köln (Allemagne)
Qimiao Si, Rice University, Texas (USA)
Günter Sigl, IAP, Paris
Joe Silk, Astrophysics Laboratory, Oxford (UK)

Matthias Staudacher, A. Einstein Institut, Golm (Allemagne)
Yoshitsugu Takei, Kyoto University (Japon)
Patrick Talou, Los Alamos National Laboratory (USA)
Véronique Terras, Rutgers University (USA)
Ivan Todorov, IRNE de Sofia (Bulgarie)
Alexei Tsvelik, Brookhaven National Laboratory (USA)
Alexander Turbiner, Université Nationale du Mexique
Sara Vaiana, INFM Palerme (Italie)
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Jean Vannimenus, ENS Paris
Gabor Vattay, Eötvös University, Budapest (Hongrie)
Graziano Vernizzi, Oxford University (UK)
Hendrik Von Hees, GSI Darmstadt (Allemagne)
Gerard Watts, King's College London (UK)
Herbert Weigert, Universität Regensburg (Allemagne)
Kay Wiese, USSB, Santa Barbara (USA)
Nichola Wilkin, University of Birmingham (UK)
Peter Young, UCSC, Santa Cruz (USA)
Anthony Zee, UCSB, Santa Barbara (USA)