INTRODUCTION

Le rapport d'activité du Service de Physique Théorique est établi tous les deux ans. Celui-ci résume l'activité scientifique du SPhT durant la période juin 1998-mai 2000, et servira de document de base pour l'évaluation du laboratoire qui aura lieu à l'automne 2000.

Pour la première fois la partie scientifique de ce rapport est écrite en anglais. Il y a plusieurs raisons à cela. D'une part un nombre important de collègues étrangers, pas tous francophones, participent à notre conseil scientifique extérieur (CSE). D'autre part ce rapport est aussi une vitrine de nos activités ; le fait qu'il soit rédigé en anglais, la langue de la majeure partie de nos échanges scientifiques, nous permet une plus grande diffusion.

L'évaluation du laboratoire a jusqu'à présent eu lieu durant un colloque de deux à trois jours au cours duquel les physiciens du SPhT présentaient leurs travaux à leurs collègues et aux membres du CSE. Ce colloque remplissait donc deux fonctions : l'une de communication interne, l'autre d'évaluation. Pour satisfaire l'objectif de communication interne, le colloque fut le plus souvent organisé loin du laboratoire de façon à libérer chacun de ses sollicitations quotidiennes. Mais l'éloignement de Paris allonge le temps de déplacement des membres du CSE, dont certains viennent de loin. Nous avons donc choisi de découpler à partir de cette année colloque interne et évaluation, et de faire l'évaluation dans le laboratoire. Les membres du CSE pourront ainsi rencontrer les physiciens sur leur lieu de travail et mieux percevoir les multiples aspects de la vie du laboratoire. Par ailleurs, dégagés des contraintes de l'évaluation, nous pourrons lors du colloque que nous organiserons l'an prochain nous concentrer sur la communication interne.

Les efforts dans ce domaine, essentiel pour un laboratoire comme le SPhT, sont sans cesse à renouveler. Rappelons que l'existence même d'un gros laboratoire de physique théorique se justifie par les possibilités exceptionnelles ouvertes par la pluridisciplinarité de ses activités. On pourrait citer à l'appui de nombreux exemples de mobilités thématiques réussies, ou de fertilisations croisées entre domaines éloignés. Mais la pluridisciplinarité contient aussi ses dangers, et l'émiettement des activités ou le manque de cohérence thématique ont été soulignés à plusieurs reprises par notre CSE. Les efforts de communication interne visent d'abord à sensibiliser chacun à l'intérêt des travaux de ses collègues. Le séminaire du mardi, censé rassembler tous les physiciens du laboratoire, y contribue, et cette année de nombreux collègues ont pu s'y exprimer ; mais cela ne suffit pas. Tout en poursuivant la plupart des actions entreprises les années précédentes, comme le journal du SPhT ou la journée des thèses (où les doctorants présentent au moins une fois par an leur travail à l'ensemble du laboratoire), de nouvelles formules ont été essayées. Par exemple les matinées thématiques internes au SPhT ont été suivies et appréciées ; il y en a eu deux cette année, une en physique des particules, une autre présentant des activités de physique théorique à l'interface avec la biophysique. Au delà de ces aspects d'échange d'information, nos efforts de communication interne visent également un autre objectif. Le contexte dans lequel nous décidons de nos recrutements a changé (nous y reviendrons). Pour que les choix que nous sommes amenés à faire conduisent à un développement harmonieux du laboratoire, il est essentiel qu'ils traduisent un certain consensus. Ceci exige débat, confrontation d'objectifs et de priorités scientifiques parfois contradictoires. Le conseil scientifique du laboratoire est le lieu naturel pour de tels débats. Ils ont sans doute cette année été facilités par l'exercice que s'est imposé le conseil scientifique en consacrant une journée à écouter chacun de ses membres exposer ses propres activités et centres d'intérêt.

Tous ces efforts seront poursuivis. Nous devrons aussi réfléchir à la structure du laboratoire et aux conséquences du découpage actuel en trois groupes. Ceux-ci correspondent aux trois grandes catégories d'activités du laboratoire, ainsi qu'elles sont présentées dans le rapport et auxquelles est associé un (voire deux) séminaire régulier : physique mathématique (le lundi matin et le vendredi matin), physique statistique le lundi après-midi, physique nucléaire, des particules, et d'astrophysique le mercredi après-midi. Certes, ce découpage en trois groupes d'effectifs comparables est commode pour la gestion, et garantit un minimum de discussions collectives sur les invitations de visiteurs ou le choix des postdocs. Il est indéniable qu'il introduit une certaine cohérence dans la présentation des activités du laboratoire, comme dans ce rapport. Mais il faut bien reconnaître que les groupes ne jouent qu'un rôle assez modeste sur le plan scientifique. En fait, la structure est un peu lourde, et ne favorise peut-être pas autant qu'elle le devrait les initiatives, en particulier celle des jeunes.

Nos efforts internes s'accompagnent d'actions d'ouverture vers l'ensemble de la communauté, ainsi que vers la DSM. Les journées Claude Itzykson sont devenues une tradition du laboratoire. Elles connaissent un grand succès et ont rassemblé une bonne centaine de participants l'an passé ainsi que cette année. Notons que cette année ces journées étaient organisées conjointement avec le SPEC. Le SPhT a accueilli pour des stages d'un an des chercheurs du CNRS (D. Boosé, C. Monthus), ainsi que deux postdocs français (C. Chandre, G. Misguich). Les cours du vendredi continuent à fonctionner avec succès. Cette année, deux de ces cours ont été acceptés comme cours de l'école doctorale de la région parisienne. Ces cours sont régulièrement suivis et contribuent entre autre à vaincre notre isolement géographique (aggravé parfois par les difficultés d'accès au laboratoire liées aux questions dites de "sécurité"...). Avec la DSM des liens profonds existent, et ce depuis longtemps. Des membres du SPhT participent aux conseils scientifiques de trois services du DAPNIA (SPP, SPhN et SAP). Les activités du SPhT sont distribuées sur cinq "segments" du CEA, et à ce titre des physiciens du SPhT participent aux réunions de segment correspondantes. Le SPhT coorganise les rencontres de la DSM, a mis en place le conseil scientifique pour le calcul centralisé de la DSM que deux de ses membres animent, participe au comité de rédaction de Phases Magazine. Des collaborations explicites existent avec le SPP et avec le SPEC. Cela dit, des liens scientifiques plus forts pourraient être tissés, et on peut avoir le sentiment que les richesses qui nous entourent ne sont pas pleinement exploitées.

Le geste d'ouverture le plus important de ces deux dernières années reste celui concernant nos recrutements sur postes CEA. La décision d'ouvrir ces postes à des jeunes formés à l'extérieur du laboratoire était souhaitée par la DSM et fortement recommandée par notre conseil scientifique extérieur. Même si elle a pu, au début, être ressentie assez durement par nos jeunes doctorants et provoquer des discussions vives à l'intérieur du laboratoire, elle était, me semble-t-il, indispensable, et beaucoup s'accordent à en reconnaître aujourd'hui le caractère positif. Tout d'abord — même si ce n'est pas le plus important, il est bon de le souligner — le fait qu'il existe des postes en physique théorique au SPhT contribue à faire connaître le laboratoire aux étudiants préparant une thèse ailleurs ; il nous permet aussi de rencontrer ces étudiants et d'apprécier leurs travaux. Mais surtout, la diversité des excellents candidats qui se présentent sur nos postes nous permet de composer l'avenir, dans une période de changements profonds liés au renouvellement des personnes qui prennent leur retraite ainsi qu'à l'évolution de certaines thématiques traditionnelles du laboratoire.

Certes, s'être donné de plus grandes possibilités de choix a rendu ces choix plus difficiles. Ceci nous a amenés à mettre en place une procédure rigoureuse et transparente, qui a été appliquée pour les recrutements décidés en 1999 et 2000 : ouverture de poste, examen des candidatures par le conseil scientifique, établissement d'une liste courte, audition approfondie des candidats de la liste courte. Le président du conseil scientifique extérieur assiste à la dernière réunion où sont arrêtées les propositions de recrutement. Bien qu'aucune règle n'ait été établie à ce sujet, les décisions de recrutements se prennent typiquement en première année de postdoc. Afin que les choix effectués jouissent d'un minimum de consensus, le laboratoire est très largement consulté. Remarquons pour finir que si les étudiants formés dans le laboratoire se trouvent en compétition avec tous les autres, ils ne sont pas pour autant systématiquement écartés, ainsi que les derniers recrutements l'ont montré.

Il est bon à ce niveau de faire quelques remarques concernant notre politique scientifique. Soulignons tout d'abord que si l'exigence sur l'excellence scientifique des jeunes physiciens que nous recrutons n'a pas changé, il est indéniable que le poids des arguments liés au choix de disciplines s'est accru. Ceci est lié au fait que les sujets dans lesquels nous recrutons ne se limitent plus aux quelques sujets des thèses préparées dans le laboratoire, ainsi qu'aux profonds changements thématiques qui ont eu lieu dans le laboratoire. En particulier, par suite de départs à la retraite et d'évolutions thématiques de membres du SPhT, certains sujets de recherche sont en train de disparaître complètement. Cela n'est pas en soi dramatique, et peut refléter l'évolution naturelle de certaines disciplines. Mais cela devient un sujet de préoccupation si l'on remarque que les disciplines touchées sont celles qui concernent les activités les plus "concrètes", en particulier en physique nucléaire et en physique des particules. Si nous avons pu accueillir en thèse un étudiant travaillant sur des problèmes de structure nucléaire, l'absence de David Kosower (en congé depuis avril pour création d'entreprise) va affecter profondément l'activité en physique des particules. Une réflexion se poursuit sur ce qu'il conviendra de faire pour ces deux disciplines traditionnellement fortes au SPhT. Je voudrais souligner ici que c'est en partie dans l'esprit de renforcer des activités en contact étroit avec les développements expérimentaux que nous avons poursuivi durant ces deux dernières années l'effort de recrutement en matière condensée. Le départ prévu à la fin de cette année de Thierry Jolicœur nous invitera peut-être à poursuivre cet effort. Sur toutes ces questions d'orientations scientifiques les recommandations de notre CSE nous sont très précieuses. Elles ont guidé nos choix pour le développement de nos activités en matière condensée. Elles nous ont conduits à des actions volontaristes pour développer la théorie des cordes. Deux recrutements ont été effectués dans ce domaine, l'un au niveau postdoc (Pierre Vanhove), l'autre à plus haut niveau (Michael Bershadsky). Ce dernier nous a quittés pour prendre un poste à l'Université de Toronto. Il nous faudra sans doute songer à le remplacer.

Je voudrais maintenant aborder un autre sujet, celui de nos relations avec le CNRS. Rappelons que des liens forts unissent le SPhT et le CNRS : les chercheurs du CNRS représentent environ un tiers des chercheurs du SPhT ; l'activité du laboratoire est examinée régulièrement par la section 02 du Comité National ; des membres du SPhT siègent régulièrement au Comité National (le président sortant est membre du SPhT) ; depuis 1989 un chercheur CNRS participe à la direction du laboratoire, en tant qu'adjoint, ou depuis fin 1998 en tant que chef du SPhT. Cependant, malgré l'existence de ces relations, le SPhT n'a pas de statut lui permettant d'être reconnu comme une unité CNRS. Actuellement, le laboratoire est considéré comme une “structure non contractualisée” (SNC2002), et les chercheurs CNRS y sont mis à disposition selon des modalités précisées par une convention particulière. Au moment où ces lignes sont écrites une association plus forte est envisagée sous la forme d'une unité de recherche associée (URA). Cette association est souhaitée par le département SPM pour rendre plus visible son implication en personnel au SPhT, et les membres du SPhT y sont très majoritairement favorables. Elle devrait permettre de faciliter l'affectation au SPhT de chercheurs du CNRS, que ce soit par recrutement ou par mobilité.

Je terminerai cette introduction en remerciant ceux qui ont pris une part importante dans l'élaboration de ce rapport. Cette année la péparation a été coordonnée par Alain Billoire. Bertrand Eynard, Vincent Pasquier, Francis Bernardeau et Kirone Mallick ont regroupé les différentes contributions individuelles en trois parties qui reflètent les grandes directions scientifiques du laboratoire. Le travail d'édition finale a été assuré par Alain Billoire et Marc Gingold. Que tous soient remerciés ici du travail fourni. Je voudrais également remercier par avance les membres de notre conseil scientifique extérieur d'avoir accepté la tâche d'examiner nos activités et de nous aider par leurs critiques et suggestions.

Jean-Paul BLAIZOT

QUANTUM FIELD THEORY AND MATHEMATICAL PHYSICS

This part gathers works done on the various mathematical structures that appear in physics. The first section is devoted to Quantum Field Theory, a traditional strong point of our activity, from rigorous results of axiomatic field theory to applications of the renormalization group to random surfaces. The second section is devoted to integrable systems, namely statistical physics models that can be exactly solved. The study of the eigenvalue distribution of large random matrices, another apex of our activities, is the subject of section three. The fourth section groups together specific works on classical gravity and string theories. Random matrices and integrable systems methods find beautiful applications here (more applications can be found in the Statistical Physics and Condensed Matter part). The fifth section contains mathematical works on quantum chaos and dynamical systems. Other mathematical works triggered by specific physics problems can be found in the last section.

Contents

1 Quantum Field Theory and phase transitions

Field theory is traditionally developed at the SPhT to analyze phase transitions by use of the renormalization group. These techniques have recently been extended to study matrix models and random surfaces. We have gathered here these contributions with some of a more mathematical character such as quantization in curved backgrounds.

1.1 Exact Renormalization Group Equations (C. Bervillier)

A critical review of the use of the exact renormalization group equation (ERGE) in the framework of the scalar theory is presented [T00/008]. We lay emphasis on the existence of different versions of the ERGE and on an approximation method to solve it: the derivative expansion. The leading order of this expansion appears as an excellent textbook example to underline the nonperturbative features of the Wilson renormalization group theory.

Using the local potential approximation of the exact renormalization group equation, we determine the various domains of the parameters of the $O(1)$-symmetric scalar Hamiltonian. In three dimensions, in addition to the usual critical surface S_c (attraction domain of the Wilson-Fisher fixed point), we explicitly show the existence of a first-order phase transition domain S_f separated from S_c by the tricritical surface S_t (attraction domain of the Gaussian fixed point). S_f and S_c are two distinct domains of repulsion for the Gaussian fixed point, but S_f is not the basin of attraction of a fixed point. S_f is characterized by an endless renormalized trajectory lying entirely in the domain of negative values of the φ^4-coupling. This renormalized trajectory exists also in four dimensions making the Gaussian fixed point ultra-violet stable (and the φ_4^4 renormalized field theory asymptotically free but with a wrong sign of the perfect action). We also show that very retarded classical-to-Ising crossover may exist in three dimensions (in fact below four dimensions). This could be an explanation of the unexpected classical critical behavior observed in some ionic systems [T00/025].

1.2 Improved Borel transform method and precise nonperturbative estimations of critical exponents (R. Guida, J. Zinn-Justin)

Perturbative series of anomalous dimensions of the $\lambda(\phi^2)^2$ Quantum Field Theory in dimension $d = 3$ and $d = 4 - \epsilon$ have been re-summed with an improved Borel transform method, and some precise nonperturbative estimations of critical exponents for the systems in the universality classes of $N = 0, 1, 2, 3, 4$ have been derived.

A study of the next to leading finite size corrections for a five dimensional Ising model on a periodic lattice is in progress.

1.3 Self avoiding random surfaces (F. David)

We continued the study of self-avoiding tethered surfaces. These systems can be studied by methods which generalize the field theoretical methods used for polymers, and one of the main achievements of the last years was the proof (by three SPhT physicists) that these models for self avoiding surfaces are renormalizable and that an ϵ-expansion for scaling exponents and other universal quantities makes sense. In the last two years, we made the first attempts to study non-perturbatively these models. The large order behavior of the perturbative expansion has been derived by semi-classical methods and we showed that this large order behavior is controlled by a classical solution (instanton) of a non-local effective theory. A factorial growth is obtained, as for local field theories (describing critical systems, polymers, ...). However the equation for the instanton configuration is non-local, and can be only solved within some approximation scheme. We proposed such a scheme, based on a variational approximation that was shown to lead to good results, and proved to become exact in the limit of large space dimensionality (this is not a simple fact, as for the mean-field approximation in local field theories, but results from subtle diagram cancellations). Attempts to go further these approximations and to go beyond the leading large order term by calculating the effects of the fluctuations around the instanton are underway [T98/064].

1.4 Renormalization group for matrix models (G. Bonnet, F. David)

Random matrix models allow to construct models of 2-dimensional quantum gravity. The central charge c of matter fields can be derived from the critical exponents of the matrix model by the KPZ (Knizhnik, Polyakov, Zamolodchikov) formula. This formula, however, is not valid for $c > 1$, and, up to now, no random matrix model has been solved, which, in the continuous limit, would allow to recover a quantum gravity plus matter model with central charge $c > 1$.

We studied the renormalization group flows of random matrix models under a shift on the size of the matrix. The main purpose is to understand better this $c = 1$ barrier. The renormalization group techniques are improved by using loop equations to reduce drastically the number of operators appearing in the renormalization process. For example, one obtains a 0.016% precision on the position of the critical point of a $tr\Phi^4$ one-matrix model instead of a previous 0.9%, found by Higuchi et al.. It is showed that critical exponents converge : this is not always true when one does not reduce enough the number of operators appearing in the renormalization process. One recovers, the qualitative renormalization flows and the 2 fixed points which were predicted in this case by F. David. Finally, using renormalization group techniques, good approximations of the critical points and flows for the 2-matrix Ising model are also found [T98/123].

1.5 Complex angular momentum and quantum field theory (J. Bros)

Some time ago [T98/014] we proved that the four point function is analytic in the complex angular momentum variable for a field theory satisfying locality, Lorentz invariance, positivity of the energy and which increases moderately in the ultraviolet regime. More recently, the mechanism of Regge particles generation (including hadrons and glueballs) from the fundamental fields (which do or do not satisfy confining properties) has been understood and analyzed in the preceding framework.

1.6 Generalization of the Fourier Transform in a curved space (J. Bros)

Results (complete in two dimensions) about the generalization of the Fourier transform to a curved space-time of de Sitter (or anti de Sitter) type have been presented at a mathematical congress [T00/016].

2 Integrable systems

This section contains contributions which use integrability to answer questions raised by field theory and more specifically conformal field theory.

2.1 Lee-Yang model (R. Tateo)

The spectrum of the Lee-Yang model was studied via a generalization of the truncated conformal space approach to the system with boundaries and via the boundary thermodynamic Bethe Ansatz [T97/163]. This allows reflection factors to be matched with specific boundary conditions, and leads us to propose a new family of reflection factors (see also [T98/106]). The equations previously proposed for the ground state are found to break down in certain regimes; we found the necessary modifications by analytic continuation. Access to the finite-size spectrum enabled us to observe boundary flows when the bulk remain massless, and the formation of boundary states when the bulk is massive. The TBA method can also be used to gain information on statistical mechanics systems. For different reasons Z_N-symmetric spin systems play an important role in condensed-matter physics. The qualitative form of the phase diagram of these systems is believed to be strongly constrained by the properties of conformal points in the phase space. In [T98/106], both exact (TBA) and numeric (Monte Carlo) methods were used to study the Z_6-symmetric spin models near to the decoupling surface and this suggested that the standard phase diagram needs to be modified.

2.2 Boundary conditions and conformal invariance (J.B. Zuber)

The determination of boundary conditions consistent with two-dimensional conformal invariance is an old problem, which has received new attention due to applications to critical systems, to systems with "quantum impurities" and to the theory of strings and branes. The problem has been reconsidered [T98/076, T98/080 , T99/085]: it has been proved that the general solution to a consistency equation due to Cardy, which determines the boundary states (in "rational" conformal theories), is equivalent to the problem of finding all representations over non negative integer valued matrices of the Verlinde fusion algebra (roughly speaking the operator algebra of the theory). This gives a direct interpretation of the ADE classification of theories with a $sl(2)$ current algebra (Cappelli-Itzykson-Zuber 1986), and more generally justifies a program of classification of conformal theories in terms of graphs initiated twelve years ago by Di Francesco and Zuber. It also gives new insight on the algebraic structure underlying the computation of the couplings of boundary fields. More generally, it recasts in a unified picture various results obtained over the last years on conformal theories and on lattice integrable models "in the bulk" or in the presence of a boundary.

3 Random matrices

Introduced by Wigner in the 1950s to elucidate the statistical properties of nuclear spectra, they found applications in statistical physics of disordered systems and quantum chaos, and with the remark of t'Hooft that QCD at large number of colors generate planar diagrams, they found applications in statistical physics on random planar lattices, random surfaces, two-dimensional quantum gravity, string theory...

SPhT was a pioneer and is still very active in this field. The period 1998-2000 has seen significant contributions to the understanding of the universal statistical properties of the eigenvalues, as well as exact results for enumerating random graphs and in particular application to mathematics with the counting of knots.

3.1 Coupled random matrices (G. Mahoux, M.L. Mehta, J.M. Normand)

Coupled random matrices models appeared in the study of planar diagrams in quantum field theory and were used later in two-dimensional quantum gravity. Real symmetric, complex Hermitian or quaternionic self-dual matrices depend upon their eigenvalues and the so called angular variables, characterizing the orthogonal, unitary or symplectic matrices which diagonalize them. To remain with quantities which only depend upon the eigenvalues, one has to integrate over these angular variables the expressions one considers. For two coupled $n \times n$ matrices A and B, this integration for the expression $\exp[\mathrm{tr}(AB)]$ has been expressed in terms of the eigenvalues and eigenfunctions of a Hamiltonian closely related to the Calogero Hamiltonian [T98/131]. This generalizes a well known Itzykson-Zuber formula for complex Hermitian matrices. For $n \times n$ matrices A_k, the integration over the angular variables of products of terms f$[tr(A_i A_j)]$, each denoted graphically by a link between vertices i and j, can be performed for $n = 2$ for all kind of diagrams. Up to now, only open chain or tree diagrams can be treated. Using tensor algebra, it is shown that, for any number of loops in the diagram, these integrals can be expressed in terms of Wigner $3j$ symbols and $3nj$ coefficients. The extension of these results (yet unpublished) for n larger than 2 is still an open question.

3.2 Multi-cut matrix model (G. Bonnet, F. David, B. Eynard)

The 1-Hermitian-matrix-model has been extensively studied in its simplest one-cut phase. Less well known is the *multi-cut* phase, where the support of eigenvalues is not connected. Surprisingly, this was considered as already solved in the literature. The long range smoothed correlation function was known and so on. The results presented in the literature were actually wrong. An important mechanism had been missed.

The multi-cut matrix model is a matrix fluctuating within a potential with several wells. The eigenvalues tend to accumulate at the bottom of the wells, and in average have a continuous density with a finite but disconnected support. The free energy is obtained by minimizing the action. For instance in the 2-cuts case, n eigenvalues lie in one well and $N - n$ in the other. One has to extremize the action with respect to the occupation ratio $x = n/N$, and finds the extremum for $x = x_c$.

What was forgotten in previous calculations is that when $n_c = N x_c$ is not an integer, the minimum is never reached. When this effect of the discreteness of the number of eigenvalues is carefully taken into account, an additional term is added to the free energy. This additional term depends on N quasi-periodically through theta-functions. Whence the quasiperiodic behavior (sometime depicted as chaotic) in numerical simulations of the early 90's. It also explains the striking paradoxes raised by several authors about the disagreement between different methods obtaining different results for the same quantities. Moreover, this effect has some important consequences, for instance it implies that the free energy admits no perturbative topological expansion as powers series of N^{-2} (contrary to the 1-cut case). From the expression of the free energy including this new term, one derives exact expressions of the correlation functions and asymptotics of the orthogonal polynomials [T00/36].

3.3 Non-Hermitian random matrix models (NHRMM) (R. Janik)

We derived a simple formula for calculating the properties of left and right-eigenvectors for a wide class of non-Hermitian random matrix models (NHRMM) [T99/018, T99/111].

3.4 Determinant of random quaternion self-dual matrices (M.L. Mehta)

The probability density function for the determinant of a $n \times n$ random Hermitian matrix taken from the Gaussian unitary ensemble has been previously calculated [T97/167]. This result has been extended to random quaternion self-dual matrices thanks to the evaluation of the special determinant $\det[(a+j-i)\Gamma(b+j+i)]$ [T99/051].

3.5 Spectrum of random incidence matrices (M. Bauer, O. Golinelli)

The quantum transport properties for free particles moving on a graph is closely related to the study of spectral properties of the incidence matrix of the graph. A possible way to take disorder into account is to consider random graphs and the associated random matrices.

We have given recursion relations to compute the moments of the eigenvalue distribution when the edges of the graph are independent and when the average connectivity α remains fixed as the number of vertices gets large. Although the support of the distribution is unbounded, we have shown that the moments determine the distribution completely. This method can be modified to handle the case of random trees. We have computed a local property of the eigenvalue distribution, namely the height of the delta peak at the origin. The case of random trees is published. In the case of random graphs, we have a conjecture, which is proved only in certain ranges of connectivity. Our formula implies an unexpected phase transition in the spectrum, at mean connectivity $\alpha = e$, well above the classical percolation transition at $\alpha = 1$ [T99/134].

3.6 Knots (J.B. Zuber)

It is well known that integrals over large matrices may be interpreted in terms of expansions over diagrams of planar topology, and may thus give a method of counting planar objects. This idea has been applied to a problem of knot theory, namely the counting of *alternating* links and tangles, *i.e.* of knotted structures in which over- and under-crossings are met alternatively along the string. The census of alternate tangles is obtained through the study of the simple integral $\int \mathrm{d}M \exp -\mathrm{tr}\,(M^2 + gM^4)$, after a suitable removal of redundancies has been carried out, and reproduces a result obtained recently in knot theory using combinatorial arguments. The census of alternating tangles in which each closed loop is weighted by a factor 2 is given by the analogous *two-matrix* integral, $\int \mathrm{d}A\mathrm{d}B \exp -[\mathrm{tr}\, A^2 + B^2 + g_1(A^4 + B^4 + 2(AB)^2) + g_2 A^2 B^2]$ whose computation is much more difficult and has been achieved only recently ([T99/130]): the result is given in terms of elliptic functions, and the counting up to 16 crossings and its asymptotic behavior have been obtained

[T99/037, T00/007].

4 Gravity and strings

String theories are the best known candidates to realize the unification of all interactions (including gravity). They have experienced major advances in the past few years, after the discovery of dualities relating weak and strong coupling regimes of (different or same) string theories. It has now become possible to get an insight on non-perturbative results. For instance the ADS/CFT correspondence conjecture gives a more precise meaning to the intuitive relationship between Gauge Field Theories and Strings. Another famous conjecture claims that string theories admit a nonperturbative definition as a random matrix model. Both those hypothesis and others have been explored at SPhT.

Prior to string theories, let us present some new exact results about classical gravity.

4.1 Exact results in Gravitation

4.1.1 Exact solutions and symmetries of gravity equations (D. Bernard, N. Regnault)

Einstein equations can sometimes present a chaotic or integrable behavior. In the presence of a sufficient number of Killing vectors, those equations possess a large symmetry group: Geroch's group. We studied this group and developed an algebraic method to obtain exact solutions of Einstein equations for metrics with two Killing vectors. Those solutions correspond either to rotating disks or to interacting gravitational waves [T99/017]. This integrability aspect of Einstein equations allows for a detailed analysis of the phase space and the Poisson algebra of physical observables; a difficult problem without the Killing vectors. This work is a possible first step towards a quantization of this sector of Gravity [T00/024].

4.1.2 Branes in a black hole background (V. Pasquier)

We have explored the possibility to locate a brane in a black hole background. It is equivalent to put perfectly reflecting boundary conditions on a sphere surrounding a black hole. Consistency of the Einstein equations requires that some kind of matter lives on the brane. If the brane is put sufficiently close to the horizon of a Shwarzschield black hole we find that the equation of state takes the form of a "Chaplin gas" which describes the hydrodynamics of a membrane quantized in the light cone gauge [T00/065].

4.2 String theory

4.2.1 String theory and supersymmetric matrix models (I. Kostov)

It is known from the early days of the string theory that the low-energy excitations of a theory containing open (super) strings are described by a (supersymmetric) Yang-Mills theory. In the last decade, as a result of several spectacular discoveries, it has been realized that the relation between strings and gauge theories is in fact much deeper than that. First, a dimensionally reduced $U(N)$ YM theory can in principle reproduce, in the limit $N \to \infty$, the whole spectrum of the string theory and not only its lowest excitations. Second, the matrix formulation allows to describe also various nonperturbative phenomena associated with the dynamics of the extended solitonic objects in string theory - the D-branes.

• *Quantitative information about the structure of the vacuum and the bound states of the superstrings and their dual objects*

The D-branes can be obtained by calculating the partition function of the dimensionally reduced (super) Yang-Mills theory, with periodic boundary conditions for the fermions. The partition function of the $\mathcal{N}=4$ SYM theory reduced on a two-dimensional torus has been calculated quasi-classically [T98/097], and it was conjectured (the proof was provided afterwards by Fumihiko Sugino) that the quasi-classical result is actually exact.

• *Dimensionally reduced YM theories*

The dimensionally reduced YM theories with lower supersymmetry ($\mathcal{N}=1,2$) are not less interesting, since they describe the dynamics of the dual objects (D-strings, D-particles and D-instantons) in various compactifications of the string theory. Some particular sectors of these theories can be mapped onto exactly solvable cohomological field theories and reveal the integrable structures of some well known hierarchies of differential equations [T98/102, T99/072].

The simplest example is the $\mathcal{N}=1$ SYM reduced to zero space-time dimensions, which describes the high-temperature behavior of D-particles in a theory of superstrings with six compactified dimensions. It has been shown that this theory contains a sector described by the Kadomtsev-Petviashvili (KP) integrable hierarchy [T98/102]. The integrability has been used to calculate explicitly the generating function of certain class of operators.

This analysis has been then generalized for the $\mathcal{N}=\infty$ SYM theory to a periodic light cone "time" [T99/072]. After mapping the theory to a cohomological field theory, the partition function with periodic boundary conditions, regularized by a massive term, appears to be equal to the partition function of the twisted matrix oscillator. The theory remains solvable after being perturbed by a holonomy around the time circle. The perturbed partition function is shown to be a tau function of Toda integrable hierarchy.

4.2.2 Matrix string theory (P. Brax, T. Wynter)

The matrix string theory is a non-perturbative candidate of string theory. We have studied the small-string coupling regime and the connection with ordinary string perturbation theory. In particular we have identified the moduli space of matrix string theory and string theory in the large N limit (N is the size of the matrices). The Weil-Peterson metric on the moduli space is retrieved for large N. This identification is also extended to the fermionic moduli leading to the inclusion of a picture changing operator at the interaction points [T99/140].

4.2.3 Lattice version of the matrix model of M-theory (R. Janik)

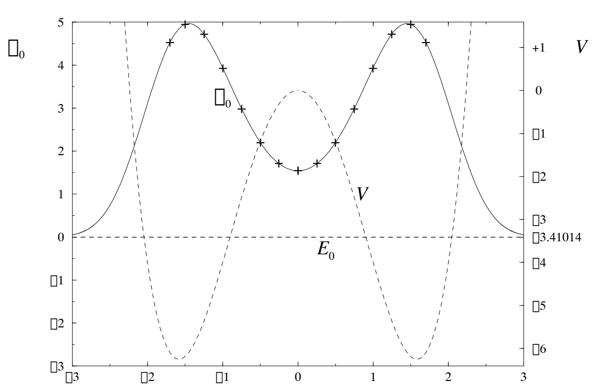
We have formulated a lattice version of the matrix model of M-theory, which enables one to use techniques and algorithms from lattice gauge theory. The numerical study of this model is especially interesting in view of various predictions from string dualities. We investigated numerically a quenched simplified version and studied its phase structure [T00/038].

5 Quantum Chaos and Dynamical Systems

This section presents progress done in the development of exact WKB methods and dynamical systems which are the continuation of works undertaken at SPhT several years ago. It also includes a study of the chaotic behavior of a quantum system.

5.1 Analytical solution for the 1D Schrödinger equation with general polynomial potential (A. Voros)

In the development process of *exact WKB methods* for quantum mechanics, an analytical solution has been reached 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 $V(q)$. Previously, only spectra of homogeneous *even* polynomials $V(q) = q^{2M}$ were exactly treatable by semiclassical analysis: an indirect exact WKB method, invoking Borel transformation with respect to $1/\hbar$ à la Balian-Bloch, plus *resurgence* relations, led to one "master" bilinear functional relation for two unknowns: the even, resp. odd, spectral determinants. This then generates exact quantization conditions of a Bohr–Sommerfeld form, which however only define equilibrium constraints involving all the even (resp. odd) energy levels. Still, when those formulae are applied iteratively, the *exact energy spectra* numerically appear as *stable fixed points*, *i.e.* they emerge upon relaxation from approximate semiclassical data.



Exact calculation of the ground state wave function $\Psi_0(q)$ for the quartic anharmonic potential $V(q) = q^4 - 5q^2$ (dashed curve), with ground-state energy level $E_0 \approx -3.41014$ (dashed horizontal line). The solid curve is the wave-function $\Psi_0(q)$ as evaluated by a numerical integration program, whereas the + show points calculated by the exact method.

1) The previous exact formalism was first enlarged to homogeneous confining potentials $V(q) = |q|^N$ of *odd degree*, giving three immediate applications.

a) The *cubic oscillator* : a Stokes multiplier gets determined, thereby solving a functional equation written for this multiplier by Sibuya in the 70's (This equation, carrying a hidden symmetry of order 5, also enters the monodromy of the — nonlinear — Painlevé I equation, and the exact integration of some 2D field-theoretical models).

b) The *Airy functions* : Ai(.) and its derivative Ai', viewed as spectral determinants for the potential $|q|$, exhibit not only their classic properties in a much wider setting, but also newer ones, arising by transposition from earlier *quartic oscillator* results (via a duality link $V = q^N \longleftrightarrow V = q^{4/N}$): i) the exact quantization conditions themselves (now yielding the *zeros* of the Airy functions); ii) countably many sum rules for these zeros (*e.g.*: for Ai', their (unsigned) *inverse cubes sum up to unity* !) iii) a nonlinear, ternary-symmetric functional equation obeyed by the product function (Ai Ai') [T98/101].

c) Thermodynamical Bethe Ansatz : Dorey and Tateo have found that the same master functional relations for homogeneous potentials solve certain integrable 2D statistical-mechanical and conformal-field models, thus creating exact connections between the *Thermodynamical Bethe Ansatz* and spectra of homogeneous Schrödinger operators.

2) The master functional relation has now been derived by a direct exact semiclassical approach, which avoids Borel transformation and also readily works for an arbitrary polynomial potential (it basically exploits the constancy of the Wronskian of 2 solutions). The exact spectrum is again found as a fixed point for an explicit self-consistency system of quantization conditions, and it can again be reached

by spontaneous relaxation — under numerical iterations fed by approximate (semiclassical) data, as tested only upon moderately inhomogeneous potentials of degrees 4 or 6. Moreover, as a major extension of the above treatment of Airy functions, the *wave-function* $\psi(q)$ *itself* at any point can be analogously specified, now through an explicitly q-dependent system. This amounts to an *analytical integration scheme* for solving 1D polynomial Schrödinger equations, with the help of a fixed-point method and of zeta-regularized products [T99/014, T99/031, T99/048, T00/078].

5.2 Asymptotics of high order noise corrections (A. Voros)

Exact asymptotic methods were put to use on a stochastic dynamical system, a discrete Langevin equation perturbed by a (Gaussian) noise. Several expansions in the noise strength (for the trace of the evolution operator) were found to diverge factorially, and their large-order behaviors were computed [T99/128].

5.3 Dynamical systems, Hamiltonian mechanics (P. Moussa)

Brujno functions are real functions with a singular behavior at every rational number. The first example was introduced in 1987 by Yoccoz in order to describe the size of the stability domains in homomorphic dynamical systems, and they provide a support for the Diophantine condition introduced previously by Brujno. In previous papers [T95/016 and T95/028] we have shown that these functions may furnish a *universal* model for singularities generated by small divisor problems in Hamiltonian dynamical systems. These topics are discussed in the paper [T099/116]. It was therefore important to understand the mathematical characterization of such functions. This is the purpose of the paper [T99/066], were we show how the singular behavior on the real axis is approached from complex values of the variable. The construction of this complex extension is a difficult problem which uses complex analysis, hyperfunction theory, number theory, a complex extension of continued fraction expansion, and also some properties specific to the so-called modular group which plays a central role in recent achievements in the theory of modular forms. In particular such functions appear to be what is called a cocycle under the modular group.

5.4 Study of the distributions of matrix elements for quantum systems with a mixed phase space (D. Boosé)

Generic quantum systems with a small number of degrees of freedom have a phase space that is partitioned into a number of separate regions in which motion is either regular or chaotic. It is therefore interesting to study how statistical properties of generic quantum systems are affected in the semiclassical limit of Quantum Mechanics by the coexistence of regular and chaotic phase space regions. We have carried out such a study for the distributions of matrix elements which are generated by an operator perturbing a classically mixed quantum system whose phase space structure is the same at all energies. The numerical computations illustrating our study have been done in the case of the Hydrogen atom in a strong magnetic field. We have found that the distribution of diagonal matrix elements is the superposition of statistically independent components, each of which corresponding to a particular region of phase space. On the one hand, any component corresponding to a region of chaotic motion is a Gaussian distribution of matrix elements which cannot be labeled by quantum numbers; the semiclassical value of its mean has been identified with the average of the Weyl transform of the perturbing operator along an ergodic trajectory of the considered region. On the other hand, any component corresponding to a region of regular motion consists of sequences of matrix elements which can be labeled by quantum numbers; all sequences converge to a common semiclassical value that has been identified with the average of the Weyl transform of the perturbing operator around the stable periodic orbit of the considered region. Our numerical calculations indicate that the probabilities of most transitions between eigenstates from different regions of phase space are much smaller than the probabilities of most transitions between eigenstates from the same region. Any distribution of transition matrix elements can therefore also be separated into statistically independent components in the semiclassical limit. We have finally shown that the semiclassical value of the variance characterizing the distribution of transition matrix elements associated to a region of chaotic (resp. regular) motion is proportional to the Fourier transformed autocorrelation function of the Weyl transform of the perturbing operator, this autocorrelation function being computed along an ergodic trajectory (resp. around the stable periodic orbit) of the considered region [T00/066].

6 Miscellaneous

In this section we have presented mathematical works related to physical applications considered elsewhere in this report.

6.0.1 Supercorrelation (B. Giraud)

A new physical effect, named "Supercorrelation", was discovered. It deals with information coherence, and is distinct from the well-known coherence effects for amplitudes. It has applications for neural networks and more generally any architecture where poor quality relays can, via parallelism, reinforce information. It can also influence inverse problems, because strong correlations are not necessarily proofs of strong, direct interactions [T98/113].

6.0.2 Ultrametric correlations (B. Giraud)

In several domains of biology and physics, experimental observables are not independent, because of underlying ultrametric correlations. Independent observables have been defined, to disentangle such spurious correlations. Furthermore, in the special case of disordered systems, and in particular for those epidemiological studies where populations can be randomly disturbed by displacements and identity problems, such observables have been proved to be, in part, robust under such a possible disorder. This allows a better detection of, *e.g.*, genetic diversification [T98/141].

6.0.3 Representation of exponentiated matrices as Laplace transform (P. Moussa)

Let A and B be Hermitian matrices (or operators). The function $Z(\lambda) = \mathrm{Tr}(\exp(A - \lambda B))$ is expressed as the Laplace transform of a distribution. This distribution is made of a discrete Dirac part with positive weights, and a continuous part. It was conjectured in 1975 that the continuous part is also positive, so that the whole distribution is in fact a positive measure. The problem arose in statistical mechanics, and the positivity property would allow to define exact bounds for the partition function from the knowledge of a finite number of terms of the perturbation expansion [T75/006]. The conjecture is not yet resolved even for three-dimensional matrices. New results on this conjecture are presented in a paper [T98/060], which present also a review on the subject. In this review the connection is also made with other questions and conjectures arising in the inverse problems for matrices and problems of commutation with derivatives in non-commuting algebras.

6.0.4 Zeroes of random polynomials (G. Mahoux, M.L. Mehta, J.M. Normand)

The zeros of the average of a polynomial with random coefficients have already been discussed in several circumstances. It has been checked up to $n = 10$, and conjecture for larger values of n, that the zeros of the polynomials $P_n(z) = \langle det(a_{i,j}) \rangle$ lie on the unit circle in the complex z plane. These polynomials are defined by $a_{i,j} = c_{i+j-2}$; $i = 1, 2, ..., n$; $j = 1, 2, ..., n+1$ and $a_{n+1,j} = z^{j-1}$; $j = 1, 2, ..., n+1$; the c_i being real independent random numbers and the average $\langle\rangle$ is taken over the c_i with an even density probability[T98/066]. This problem occurs in Padé approximants of expansions with noisy coefficients.

NUCLEAR PHYSICS, PARTICLE PHYSICS AND ASTROPHYSICS

Nuclear and particle physics are traditionally strong activities of SPhT, and more recently astrophysics and cosmology have developed. These theoretical activities parallel the corresponding experimental ones at the DAPNIA. In some particular cases, there exists direct collaborations between physicists at DAPNIA and SPhT.

Nuclear structure is investigated by effective interactions using mean field approximations.

Effective field theories are used to study hadronic matter in various states and environments, in solar interior, neutron stars or during heavy ion collisions where the signature of quark-gluon plasma is actively looked for.

Many efforts are devoted to the understanding of Quantum Chromodynamics in various regimes perturbative and non-perturbative.

Search for new physics beyond the standard model leads to model building efforts based on supersymmetric theories and their extensions.

Our department has played a significant role in the recent efforts to develop viable cosmological models on branes. This theme, which emerged recently from quite speculative aspects of superstring theories, reinforces our activities in early Universe physics and tends to bridge the gap between high energy physics and observational cosmology.

The latter is still very active and has enriched its domains of investigation from the statistical description of the large-scale structures of the Universe to the physics of the Cosmic Microwave Background, detailed mechanisms of galaxy formation or the physics of gravitational lenses.

Contents

1 Nuclear physics

Efforts done tend to bridge the gap between the physics of elementary hadrons and the physics of many-body systems, from nuclei and nuclear matter to compact stars. These studies concern our understanding of nuclear structures, development of effective hadronic theories as well as some astrophysical issues. We also present here phenomenological works concerning relativistic heavy-ion collisions.

1.1 Nuclear structure (P. Bonche, T. Duguet)

Microscopic studies of the nuclear structure at SPhT are based on the mean-field approximation. The fundamental input of these approaches is an effective two-body force which acts between nucleons within a nucleus. Once such a force is fixed, calculations can be done for all possible nuclei, including nuclei away from the stability line and for nuclei in any extreme conditions such as superdeformation.

1.1.1 Deformed nuclei

Following this strategy a complete analysis of superdeformed (SD) rotational bands has been achieved in the $A \approx 150$ mass region [T98/156]. Special attention has been given to the understanding of the so-called identical bands. The mean-field calculations are done with the Hartree-Fock Bogoliubov approximation with the Sly4 Skyrme-like effective interaction derived in earlier works [see T98/010 and T98/011]. The pairing field is described by a surface-delta density-dependent interaction. Such a pairing interaction has already been used and tested in the Hg-Pb region with success. In the present study, the validity of this choice for the pairing field has been confirmed for the $A \approx 150$ mass region without any readjustment of the parameters. SD bands in odd nuclei are calculated exactly with all the time-odd components of the force included. For pairing correlations the Lipkin-Nogami prescription has been used, which amounts to an approximate projection of mean-field intrinsic states onto good particle number. The overall agreement with experiment is quite satisfactory. These new results in this mass region further establishes the validity of the Sly4 interaction together with a surface-delta pairing field for microscopic nuclear studies. Indeed this work puts very different constraints on the force. Namely 1) nuclear properties at normal deformation: the one-proton and one-neutron separation energies are consistent with experimental data; 2) the dynamical moment of inertia of SD bands: that implies large deformations away from ground state properties and a delicate interplay between pairing which favors pairs of particles coupled to zero angular momentum and rotation which gradually breaks these pairs to build up angular momentum as the rotational frequency increases.

1.1.2 Super heavy elements

Applications of this mean-field approach has also been done in other mass regions and for other phenomena. For instance an exploratory calculation has been done for super heavy elements. Recent experimental evidences for Z=114 (Dubna) and Z=118 (Berkeley) have motivated this work. The same Sly4 interaction has been used, but with a different pairing field: a volume-delta force whose strength has been adjusted to reproduce the average proton and neutron pairing gaps in the even-even nuclei around ^{254}Fm, the heaviest nucleus with enough data for that fit. Properties of nuclei ranging from Z=112 to Z=118 have been investigated together with the possible α-decay chains of these super heavy elements [T99/161].

Works are now in progress [T00/057] to

study in details the properties of the ^{254}No and ^{252}No nuclei for which rotational bands have been recently observed up to angular momentum $20\hbar$. The same Sly4 interaction is used but now with the surface-delta pairing force which has proven to be quite successful for the $A \approx 150$ and $A \approx 190$ mass regions. Results are in good agreement with experiment. A complete analysis of the heaviest known elements with Z=112 is also in progress, again with the same Sly4 and pairing interactions, in preparation to possible future experimental programs at GANIL.

1.1.3 Correlations beyond mean-field approximation

At the other end of the mass table, namely for Mg nuclei (Z=12), study of drip-line nuclei has been done [T99/161, T00/068]. The primary aim of this work was to study correlations beyond the mean-field approximation. This has been achieved by mixing states with different deformations. The tool is the Generator Coordinate Method (GCM) with the quadrupole deformation used as the generating coordinate. Such a method has already been extensively used in this context. However in the present study an exact projection onto particle number *and* angular momentum has been implemented. A first application has been done for ^{24}Mg which lies along the β-stability line. These projections, especially on angular momentum, improves the overall agreement with experiment. For instance the calculated B(E2;$2^+ \rightarrow 0^+$) rate becomes very close to the experimental value. The study has been repeated for the exotic ^{32}Mg which corresponds to the N=20 neutrons shell closure. For this nucleus however, the calculated 2^+ state is too high in energy and the corresponding B(E2)rate too low, underestimating the collectivity of that state. However the delicate balance between the spherical minimum and the deformed configuration in this particular nucleus seems to depend upon fine details of the interaction. Further investigation of these correlations beyond mean-field are required before one can draw definite conclusions concerning the interaction. Nevertheless the calculation confirms the weakening, if not disappearance, of magicity for N=20 away from stability line.

The GCM method with projection onto particle number only, has also been applied to superdeformed Hg and Pb isotopes to study octupole degrees of freedom. On a qualitative level, the agreement with experiment is rather good. A better description of octupole correlations at SD minima requires a coupling between the two q_{30} and q_{32} modes which were introduced separately in the present study [T98/158]. Work along this line is in progress. Finally the decay out of SD states through $E0$ electric monopole transitions has been studied for these nuclei. In most cases it is shown that $E0$ transitions cannot compete with $E2$ transitions to low lying states, even for the lightest ^{190}Hg and ^{192}Pb where the excitation energy of the SD bands is lower and where $E0$ transitions are substantially enhanced. Transitions to excited states in the first well are more favored so that one should search for γ-rays lower than say 1 Mev to have any chance to detect such $E0$ transitions, if any [T98/155].

1.2 Screening of the Coulomb barrier in the solar plasma (B. Giraud)

The famous solar neutrino problem is sensitive to nuclear fusion rates which in turn are sensitive to the screening of the Coulomb barrier in the solar plasma. This screening has been calculated by means of the finite temperature Hartree-Fock method. Slight, but significant differences with previous estimates were found.

But they still do not not solve the solar neutrino problem [T99/029].

1.3 Effective field theories

1.3.1 First-principle nuclear physics (M. Rho)

Effective field theory of strongly interacting hadronic systems, that is, a low-energy nonperturbative approach to QCD, has been formulated à la Wilson and Weinberg and applied with a remarkable success to two-nucleon systems [T98/054, T98/077, T98/135, T99/042, T99/063]. This may be viewed as the *first* first-principle calculation in nuclear physics. Generalizing the notion of effective field theory to a system endowed with a Fermi surface, we obtain nuclear matter emerging naturally as a fixed point in Landau Fermi liquid theory [T98/103, T98/135]. This theory implements the BR scaling introduced by Brown and Rho in 1991 in the formulation of many-body problems and provides a simple description of how hadrons behave in medium when density increases toward the chiral phase transition point as expected to occur in heavy-ion collisions or in neutron stars [T98/055, T99/015, T99/150].

1.3.2 "Astro-hadron" physics (M. Rho)

QCD predicts that when a hadronic matter is compressed to a super-high density, the color as well as flavor symmetries could be spontaneously broken with the colorful quark pairs condensing into the "vacuum." This is predicted to lead to color superconductivity. In addition, the color and flavor can get locked and give rise to a spectrum which closely resembles that of matter-free systems. This implies an intriguing continuity from hadrons at low density to quarks/gluons at high density. The symmetry breaking pattern allows one to give an effective field theory treatment as in zero-density regime with a fascinating consequence (such as Overhauser effect, Higgs phenomena etc.) on the structure of the core of compact stars (*e.g.*, neutron-star cooling) as well as in heavy-ion collisions at RHIC or LHC [T98/116, T99/093, T99/136, T99/137, T00/006].

A spin-off of this class of research is the birth of a new (sub)field of physics, called "astro-hadron physics," which purports to correlate what is understood in the proton structure to that of nuclei and hadronic matter and ultimately provide the equation of state of matter relevant to the interior of neutron stars and to the collapse to Bethe-Brown light-mass black holes [T99/092, T99/135]. This development is admittedly at its embryonic stage encompassing, on the one hand, such a topical subjects as the "proton spin" [T98/114] and, on the other hand, the more recent activity on AdS/CFT duality in high-energy elastic scattering [T99/094].

1.3.3 A chiral quark model for nucleons (G. Ripka)

The structure of nucleons has been calculated using a chiral quark model. A new and more realistic regularization was used. The calculation is a bit harder but the soliton, describing the nucleon, is found to be stable without the need to introduce artificial constraints to maintain the fields on the chiral circle. Such constraints are found not to be satisfied dynamically [T99/122].

The quantum fluctuations of the quark condensate have been evaluated and found to be surprisingly large. The vacuum stability is studied under a constraint proportional to the squared quark condensate. New instabilities have been discovered which are due to the Lorentz invariant regularization [T00/040].

1.4 Phenomenology of heavy ion collisions (J.Y. Ollitrault, M. Dinh)

Collisions between lead nuclei at 160 GeV/nucleon are realized at the CERN SPS in order to study nuclear matter at extreme densities, where a quark–gluon plasma might be formed. Up to 2500 particles are produced in such collisions. Their directions are characterized by a polar angle θ (the collision axis being the polar axis $\theta = 0$) and an azimuthal angle ϕ. It was predicted a few years ago by one of us that for collisions with non-zero impact parameter, the azimuthal angle ϕ of outgoing particles should be correlated with the direction of impact Φ_R, due to final state interactions. In particular, one expects that the average value of $\cos 2(\phi - \Phi_R)$ is positive. This phenomenon was subsequently observed, in 1997, in several experiments performed at the Brookhaven AGS and the CERN SPS, and referred to as "in–plane elliptic flow". Its magnitude is sensitive to the pressure achieved during the collision, which is one of the quantities one aims to measure.

Unfortunately, the impact direction is not known event by event, so it is not obvious to measure the above mentioned correlations. Our recent works show that the methods currently in use are not reliable: they assume that the only azimuthal correlation between particles results from their correlation with the impact direction. We have shown that there are several other sources of direct correlations, which are of the same order of magnitude. First, quantum correlations between identical pions (also known as the Hanbury-Brown and Twiss effect) produce a short range azimuthal correlation. We have shown that this effect alone explains several puzzling experimental results: the so-called "higher harmonics" (*i.e.* non–zero values of $\cos n(\phi - \Phi_R)$ with $n = 3, 4, 5, 6$) observed by the NA45 and NA49 collaborations at CERN, and the large flow of pions with low transverse momentum seen by NA49 [T99/139]. More recently, we have shown that global momentum conservation produces a back-to-back correlation between particles, which is even larger than the correlation due to flow for protons with high transverse momenta. Taking this correlation into account, one finds that the direction of impact determined by NA49 is wrong by 180°. However, other correlations also exist, in particular those due to resonance decays, which cannot be estimated quantitatively. This suggests that the current methods are unable to produce quantitative results [T00/049].

1.5 Langevin equation in the vicinity of saddle points (B. Giraud)

Analytically soluble models were found for the Langevin equation in the vicinity of saddle points. Such multidimensional models are useful for the study of fission and heavy ion fusion [T99/088].

2 Quantum Chromodynamics

The study of strong interactions remains one of the major subjects of particle physics, it is one of the main scientific investigation at the very high energy colliders, like LEP (lepton-lepton), HERA (lepton-hadron) and Tevatron (hadron-hadron). Prospects for LHC and other future accelerators are also involved in these studies. Among other pending physical phenomena to be understood, one of the main goals is the need to go beyond the small coupling approximation, either by a resummation of the perturbative expansion or, more ambitiously, to the strong coupling regime where the still mysterious confinement of quarks and gluons takes place. It should be noted that the ongoing research towards higher precision is not only interesting on its own but is also a necessary ingredient for the new physics searches at the future colliders.

2.1 Perturbative QCD (D.A. Kosower, P. Uwer)

Calculations in perturbative QCD reflect three main strands of activity: (a) the development and application of new techniques for the calculation of virtual corrections to QCD processes (b) the application of these new techniques to general questions in gauge theories (c) the development of a new framework for assigning uncertainty estimates to parton distribution functions, and to observables dependent on them.

2.1.1 Radiative corrections in perturbative QCD

Activities at SPhT include development of formal methods for loop calculations in gauge theories. The focus shifted from one-loop calculations to two-loop ones, in particular the simplest helicity amplitude in QCD has been worked out at this order, with all helicities identical. It is one of the two which vanish at tree level, and which therefore are finite at one loop, and simpler at two loops than the most complicated helicity amplitude. This calculation required extending the unitarity-based method that has been used extensively in one-loop calculations to two loops.

Not surprisingly, the resulting integrals are more difficult than one-loop ones. In particular one of the integrals requires special care because of its analytic structure (the lack of a Euclidean region), and in general the computation and checking of the integrals turns out to be the most time-consuming part of the calculation, whose result is described in ref. [T99/147]. Works on the calculation of the double box integral are still in progress.

2.1.2 Collinear limits of amplitudes, splitting amplitudes, and the Altarelli-Parisi kernels

Gauge theory scattering amplitudes show a simple behavior in the collinear limit of two or more partons: in this limit amplitudes can be factorized into a lower point scattering amplitude and universal functions, the so-called splitting amplitudes. It has been demonstrated in the past that the splitting amplitudes are very useful to construct general algorithms to perform higher order calculations in perturbative QCD. In particular the leading order results have been used in next-to-leading order (NLO) jet calculations. The NLO splitting amplitudes are necessary for next-to-next-to-leading order (NNLO) jet calculations.

The factorization at the amplitude level is similar and related to the factorization of cross sections which was proven more than 20 years ago to all orders in perturbation theory. Although in some sense more fundamental, the factorization of amplitudes was proven to all orders only one year ago in [T98/144] where a new method to calculate the splitting amplitudes in higher order of perturbation theory was also given. In ref. [T99/032] this new method has been used to calculate all the splitting amplitudes relevant in QCD at NLO accuracy. By this calculation we extend the existing results to all orders in the dimensional regularization parameter ϵ. This extension is necessary for NNLO jet calculations. The results are valid in two different variants of dimensional regularization: the conventional dimensional regularization scheme and the four dimensional helicity scheme.

The splitting amplitudes can be used not only in jet physics but also to calculate the Altarelli-Parisi kernels describing the evolution of parton distribution functions. While the relation between the two is well known at leading-order, the exact relation at NLO was unknown until recently. In [T99/117] first results elucidating this relation at NLO have been presented; the final results should appear soon.

By this derivation one gets deeper insight into phenomena related to collinear limits. In addition the extension of our analyses to NNLO provides a new method to calculate the Altarelli-Parisi kernels at NNLO. The NNLO Altarelli-Parisi kernels are demanded by the increasing precision of todays experiments.

2.1.3 Mass effects in $e^+e^- \to 3$ jets at next-to-leading order

Taking advantage of previous works the 3-jet cross section in e^+e^- annihilation has been calculated for six different jet algorithms at NLO accuracy for massive b-quarks [T99/047, T99/118]. The mass dependence of the 3-jet rate allows to fit the b-quark mass by comparison with the available experimental results from SLD.

Taking correlations between the different algorithms into account we obtained from a combined fit of the six different jet algorithms the following result for the running b-quark mass

$$m_b(M_Z) = 2.52 \pm 0.27 \text{ (stat.) } {}^{+0.28}_{-0.38} \text{ (syst.)}$$

$$ {}^{+0.49}_{-1.48} \text{ (theor.) GeV}/c^2.$$

This result is in good agreement with low energy determinations and measurements from the LEP experiments. The high energy determinations of the running b-quark mass (or more precisely: the mass renormalized in the the modified minimal subtraction scheme) provide for the first time direct experimental evidence for the "running" of the mass parameter.

2.1.4 Polarization and spin correlations of top quarks at a future e^+e^- collider

It is known that top quark production at a future e^+e^- linear collider provides an excellent possibility to study polarization phenomena of quarks without hadronization ambiguities in a "clean" environment. Such analyzes can be used to study the fundamental interactions in more details. To this aim polarization effects and spin-spin correlations of top quark pairs produced in e^+e^- annihilation have been reviewed [T99/132]. The study includes the NLO QCD corrections. The low and high energy limits of the predictions are discussed. The results presented in are a necessary ingredient for the search of anomalous top couplings as they present the Standard Model prediction including the NLO QCD corrections.

2.1.5 Error estimates in parton distribution functions

The parton distribution functions (PDFs) of the nucleon are the non-perturbative input needed, in addition to the strong coupling α_s, in order to describe short-distance hadron–hadron and lepton–hadron scattering processes using perturbative QCD. The PDFs used in present-day calculations are those determined in global fits to experimental data (deeply-inelastic scattering and Drell-Yan data, primarily) by Martin, Roberts and Stirling (MRS) and by the CTEQ collaboration. However, these fits do not provide for uncertainty estimates, that are of increasing importance on precision measurements (for example, of the W mass).

A formalism that would allow such errors to be estimated has been set up, reflecting the original experimental errors in the data used to extract the PDFs. Our solution relies on performing a numerical Monte Carlo integration over different candidate PDFs, weighting each by the differential probability of its providing a suitable fit to experimental data. In particular it avoids theoretical prejudices and takes into account the non-Gaussian nature of the distributions around the "best-fit" value. This requires a code to evaluate observables for tens of thousands of PDFs, a task made possible with computer programs that had been developed previously at SPhT [T97/043].

The initial numerical work [T99/149] was based on the H1 and BCDMS deeply-inelastic scattering data, shows as examples estimates of uncertainties in F_2 measurements and in the W and Z cross sections as measured in the Tevatron.

2.2 Pertubative / non perturbative interface

2.2.1 Gauge theories at strong coupling (R. Janik, R. Peschanski)

A new stimulating direction in the difficult problem of understanding gauge field theories at strong coupling has been provided by the Maldacena conjecture, the so-called AdS/CFT correspondence, a duality between certain gauge theories at strong coupling with a super-gravitational string theory in one more dimension and with non-flat (Anti de Sitter) metrics. We established 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 [T99/079, T00/033]. First computation of these observables allowed us to study the relation between confinement and the Regge properties, which are expected (but never derived) from general S-Matrix arguments. This old problem has never been addressed to in this modern context.

A second area of our research was the investigation of amplitudes odd under charge conjugation, corresponding to the odderon exchange. Its description within leading logarithmic perturbative QCD involves a strongly coupled interacting system described by an effective integrable spin chain with a noncompact group. Earlier, in collaboration with J. Wosiek we solved the relevant Baxter equation and derived quantization conditions which put together gave a prediction for the odderon intercept for vanishing conformal spin [T99/061].

2.2.2 Conformal invariance for hard processes (S. Munier, H. Navelet, R. Peschanski)

The resummation of the QCD perturbative expansion at high energy is a full domain of investigation since it is invoked for the description of many "hard processes" under experimental study. In fact, at leading logarithm order (the effective coupling constant is $g^2 \log E$, which may be of order one even when g^2 is small), a beautiful new symmetry appears: conformal invariance in transverse space. We found a series of properties and applications of this intriguing symmetry, *e.g.* the study of the conformal spin components [T98/122], the derivation of their conformal couplings (generalizing Clebsh-Gordon coefficients) [T99/044], the calculation of one-loop contributions to elastic amplitudes [T98/079, T98/107]. Particular attention has been devoted to the multi-particle amplitudes, for which a formalism inspired by two-dimensional conformal field theory [T99/009] proved to be very useful.

The conformal invariance was used in particular to investigate the Pomeron-$\gamma - \gamma$ vertex for any conformal spin. Exact results, relying heavily on a series of analytical results for integral calculations [T00/034], have been obtained for the conformal spin 0 [T99/096].

It turns out that due to the conformal invariance, only the conformal spin n=0 and n=2 are present.

At next-to-leading level, now under investigation, conformal invariance is broken in a specific way, which requires a thorough investigation, which we started from a phenomenological point of view.

2.2.3 Comparison with experimental data (R. Peschanski)

While the evolution of the proton structure functions with q^2 is well reproduced by the QCD perturbative renormalization group, the truly "hard collisions" are not yet understood, in particular the energy dependence (which is parameterized by the so-called Pomeron intercept). This problem is directly related to the next-to-leading level already mentioned above.

In a series of papers in collaboration with experimentalists [T00/017, T00/018, T00/019], we proposed a new method for extracting the necessary information from the data, and analyze it in terms of leading and next-to-leading logarithm order predictions. It appears that an unconsistency remains between theory and experimental data. Interesting comparisons with LEPII (photon-photon) and Tevatron (di-jet) data lead to further study. Prospects for the LHC have been provided at working groups.

The future program (2001-2006) "RUNII" at Tevatron suggests a more basic comparative study between a virtual photon probe (as at HERA) and a virtual gluon probe (provided at hadronic colliders by forward jets). Interestingly enough, the investigation in configuration space [T99/098, T99/114] leads to striking differences both in range (much longer for the gluon) and in interpretation in terms of wave functions on the light-cone. Phenomenological consequences of these facts deserve further study.

Finally the funny empirical phenomenon of "hard diffraction" (a "hard" interaction which leaves the proton intact) has been analyzed in terms of a specific QCD picture [T98/065, T99/098, T98/117].

2.3 High temperature QCD, and quark-gluon plasma

2.3.1 High temperature QCD (J.P. Blaizot)

At high temperature, $T \gg \Lambda_{QCD} \approx 200$ Mev, and/or large density (chemical potential $\mu \gg \Lambda_{QCD}$), hadronic matter behaves as a weakly interacting ($g(T) \ll 1$) quark-gluon plasma. Such a system exhibits collective phenomena over large space-time scales, typically of order $\geq 1/gT$. Such collective effects can be taken into account by appropriate resummations of the perturbative expansion. Alternatively, as shown in our previous studies, the physics at the "soft" scale gT can be described by kinetic equations of the Vlasov type. Solving these equations is equivalent to "integrating out" the hard degrees of freedom (with typical momenta $k \sim T$) to leave an effective theory for the soft modes with momenta $k \sim gT$.

Recently this analysis has been extended in two directions:

i) We have shown that the effective theory for "ultrasoft" modes (with $k \sim g^2T$) which results from integrating the hard and soft modes involves a Boltzmann equation for color degrees of freedom [T99/026, T99/059]. The main difficulty in establishing this equation was to build a collision term from QCD using a succession of approximations which exploit the scale separation and preserve gauge symmetry. The resulting effective theory can be used in numerical simulation of the ultrasoft dynamics that is needed for instance in problems of baryogenesis.

ii) We have devised an approximation scheme which allows us to include non-perturbatively the effects of the soft modes in the thermodynamics of QCD. The results obtained are in excellent agreements with lattice calculations when comparison can be made [T99/055, T99/113]. Our strategy rests on a "skeleton" representation of the free energy such as been developed long ago by Luttinger and Ward, or De Dominicis and Martin for instance. The central quantity to be calculated is the entropy for which we can construct self-consistent approximations with a rather simple ultraviolet behavior. The method can be extended to systems with a finite chemical potential for which lattice calculations are not yet possible [T99/113].

2.3.2 Numerical simulations of High Temperature QCD (A. Morel)

Non-perturbative properties of the quark-gluon plasma, are currently investigated via numerical simulations of a so-called "dimensionally reduced" theory. In $D+1$ dimensions at finite temperature T, the integration of the Lagrangian over the imaginary time coordinate τ is restricted to the interval $[0,T^{-1}]$. At high T, this defines a classically reduced action S_0 obtained by setting $\tau = 0$ in the Lagrangian, to be supplemented by quantum corrections S_1 coming from the (perturbative) path integral over the τ-dependent (non-static) field degrees of freedom [T00/012].

Some of the numerical results obtained in the physical dimension $D = 3$ by different groups are somewhat inconclusive or controversial. A study of the case $D = 2$, where very similar questions can be answered for a smaller computing effort, even though the IR situation is more severe, has led to the following results: Dimensional reduction, with S_1 computed analytically at one loop order, works extremely well for temperatures as low as $\sim 1.5T_c$. This is obtained by comparing the Polyakov loop correlations (PLC) and spatial string tension resulting from QCD_3 at finite T and from the reduced action. Scaling properties associated with the continuum limit are verified. The analysis of the large distance behavior of the PLC's gives evidence for the existence of a Debye screening length. It corresponds to a true color singlet excitation, whose mass is measured, rather than to a pair of massive electric gluons, as usually stated for D=3. A different reduced action, with a global Z_3 symmetry similar to that of the Polyakov loop effective action, has now been designed and the way how this symmetry is realized is under investigation.

3 Physics beyond the standard model

Supersymmetric models and their natural extensions, supergravity and superstrings models, are the most popular candidates for describing the physics beyond the standard model. Signatures of these models are actively searched for. This is the case for the production of s-particles with future accelerators, or indirect effects at low-energies. SPhT has also made contributions to more fundamental issues related to model building.

3.1 Broken R-parity in SUSY models (M. Chemtob, G. Moreau)

R-parity acts as a custodial symmetry to protect the supersymmetric models against a violation of baryon and lepton numbers, while ensuring an absolute stability to the lightest supersymmetric particle. An approximate breaking of R-parity should have important implications, especially with respect to a discovery of supersymmetry.

We examined the effects of the lepton number violating R-parity odd interactions on single production of fermion (charginos and neutralinos) and scalar (sleptons and sneutrinos) superpartners at leptonic colliders for center of mass energies up to $500 GeV - 1 TeV$ [T98/061]. An analysis is carried out for the rates and branching fractions associated with the five basic $2 \to 2$ body processes: $e^+e^- \to \tilde{\chi}^{\pm} l^{\mp}$, $e^+e^- \to \tilde{\chi}^0 \nu$ $(\tilde{\chi}^0 \bar{\nu})$, $e^+e^- \to \tilde{l}^{\mp} W^{\pm}$, $e^+e^- \to \tilde{\nu} Z^0 (\tilde{\bar{\nu}} Z^0)$, $e^+e^- \to \tilde{\nu}\gamma(\tilde{\bar{\nu}}\gamma)$. In an extension to the previous work, we developed a similar study for the single production of a chargino at the Fermilab Tevatron collider [T99/115].

The R-parity odd coupling constants could incorporate complex phases which might constitute new sources of CP violation. The main purpose of the work presented in [T98/056, T99/099] was to develop a quantitative study of the asymmetries due to CP violation which might become observable at the high energy leptonic colliders. We examined the effects of the R parity odd renormalizable interactions on flavor changing rates and CP asymmetries in the production of fermion-antifermion pairs at leptonic colliders. In the reactions $l^- + l^+ \to f + \bar{f}'$, $[l = e,\ \mu]$ the produced fermions may be leptons, down-quarks or up-quarks, and the center of mass energies may range from the Z-boson pole up to 1000 GeV.

Some work has also been focused on the associated production of a top quark (antiquark) with a charm antiquark (quark) at the leptonic colliders which appears as a favorable case from an experimental point of view [T99/124]. We study a CP-odd observable, associated with the top spin, which leads to an asymmetry in the energy distribution of the emitted charged leptons for the pair of CP-conjugate final states, $b\bar{l}\nu\bar{c}$ and $\bar{b}l\bar{\nu}c$. A similar study has been developed for the production of slepton-antislepton pairs of different flavors at the leptonic colliders through the R-parity odd interactions [T98/062].

3.2 The SUSY flavor problem (C. Savoy)

Experimentally, fermions appear in twelve species, called flavors, $(e, \mu, \tau, \nu_e, \nu_\mu, \nu_\tau, u, d, c, s, t, b)$. However, the pattern of these fermions, appearing in three families, is not understood. This flavor mystery – whose elucidation presumably needs a new theoretical framework well beyond the present standard theory – has several low-energy avatars: the hierarchies in the fermion masses, the values of their weak interactions mixing angles, the violations of the CP parity, violations of the baryon and lepton numbers, neutrino oscillations,... This problem is more easily formulated in supersymmetric extensions of the standard theory. However, we have also to face new problems, all directly related to the introduction of bosonic matter, namely, the scalar quarks and leptons, and of fermionic forces, induced by gauge fermions. This supersymmetric flavor problems are certainly amongst the "seven deadly sins" of the tantalizing supersymmetry hypothesis. But they could also provide clues for the physics across the present energy frontiers [T99/155].

One supersymmetric flavor problem is related to the preservation of the exact local symmetries of Nature: the electric charge and the quark colors. We have to impose more or less arbitrary conditions on the parameters that represent the breaking of supersymmetry in our models. An analysis of these constraints must be done both at zero and finite temperature, to take into account the evolution of the Universe. They could only be replaced by strong cosmological assumptions, or, interestingly enough, by the explicit violation of the lepton and baryon numbers at a level that is still consistent with the experimental bounds [T98/149, T98/023]. This brings out another supersymmetric flavor problem. Indeed, automatic or accidental global symmetries of the standard theory, like baryon and lepton numbers, are not so anymore in its supersymmetric extensions. They must be assumed or ensured to a high degree in order to respect many experimental results. In particular there would be supersymmetric contributions to neutrino masses that seem in contradiction with the observed pattern of neutrino oscillations [T99/155].

A supersymmetric CP problem arises also. A small but non-zero CP asymmetry is observed in the weak interactions but not in the strong interactions. A striking example is provided by the electron and the neutron electric dipole moments, which are predicted to be quite small in the standard theory, in good agreement with the present experimental bounds, if one assumes that the "strong" CP problem has been solved. Instead, in the supersymmetric models, there are new phases which are generically present in the supersymmetric interactions whose contributions could exceed the experimental limit. The resulting bounds on these phases turn out to be significant [T99/154]. A real insight into this question is made difficult by our lack of understanding of the origin of CP asymmetry. One possibility, now under investigation, is suggested by the analysis of the realization of the CP parity as a local symmetry in the framework of string theory.

3.3 Model building issues

3.3.1 Confinement and duality (P. Brax, C. Grojean, C. Savoy)

Supersymmetry also shreds new light on two beautiful physical phenomena: confinement and dualities. The 't Hooft condition is instrumental in the approaches to these problems as it requires the matching between the anomalies in the theory formulated in terms of the "elementary" fields and the corresponding ones in the theory formulated in terms of gauge invariant polynomials of these fields. Actually, the realization of this condition becomes more nebulous when these polynomials are algebraically constrained by the relations that are called "syzygies". Recently, it has been shown that the 't Hooft condition is satisfied if and only if these syzygies are derived from an analytic function of these polynomials, which correspond to the superpotential of the confined theory. This also corroborates a previous definition of confinement in supersymmetric gauge theories which was rather formal, but quite useful in practice [T98/090].

3.3.2 Orbifolds and orientifolds (S. Lavignac)

Most of the early attempts to describe the known particles and interactions in the framework of string theory have relied on compactifications to four space-time dimensions of the $E_8 \times E_8$ heterotic string. Semi-realistic models containing the Standard Model gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y$ and three families of quarks and leptons have been obtained in this way. In the last few years, a new class of four-dimensional string models has been discovered. These models known as "type IIB orientifolds" are open string compactifications obtained from orbifolds of type IIB string theory by moding out the world-sheet parity that reverses the orientation of the string. This class of models offers new perspectives for string phenomenology, such as new scenarios of gauge coupling unification or new mechanisms of supersymmetry breaking, and although no realistic model for particle physics has been constructed so far, it deserves further study.

An interesting feature of orientifold models is the presence of anomalous Abelian gauge symmetries showing many differences with the heterotic anomalous $U(1)$. Such a symmetry appears indeed in a large class of heterotic string compactifications, where it has been shown to play an outstanding role in several phenomenological problems, such as the origin of the quark and lepton mass hierarchies, supersymmetry breaking or inflation. The generalized Green-Schwarz mechanism ensuring the compensation of Abelian anomalies in orientifolds has been described in detail [T99/127, T99/159], and it has been shown that the anomalous $U(1)$'s are broken close to the string scale, while their Fayet-Iliopoulos terms, contrary to the heterotic case, have arbitrary values associated with the moduli of the model. This last property strongly restricts the phenomenological interest of orientifold anomalous $U(1)$'s.

The description of the cancelation mechanism of Abelian anomalies has made it possible to test the conjectured duality between type IIB orientifolds and orbifolds of the $SO(32)$ heterotic string, which was expected to be a four-dimensional manifestation of the heterotic - type I duality in ten dimensions. In those papers, some discrepancies at the level of the gauge group and massless spectrum between models that were previously thought to be dual have been found [T99/127, T99/159]. Although these discrepancies could be resolved by nonperturbative effects, they cast doubts on the validity of this four-dimensional duality, which have been reinforced by the computation of one-loop corrections to gauge couplings in orientifolds by Antoniadis, Bachas and Dudas.

Symmetries of the moduli space (the space of vacua corresponding to a given compactification scheme, which are described by the values of scalar fields called moduli) play an important role in heterotic string models, where they constrain not only the tree-level effective Lagrangian, but also its one-loop structure. Thus investigating whether the corresponding orientifold symmetries hold at the quantum level can provide us with a better knowledge of the low-energy effective Lagrangian of orientifolds, which is required for phenomenological studies. It has been found [T00/061] that even in the simplest orientifold models, it is not possible to compensate simultaneously for the mixed-gauge and mixed-gravitational anomalies associated with these symmetries through a Green-Schwarz mechanism; other effects, presumably of nonperturbative origin, would be necessary. Also the structure of one-loop corrections to the gauge couplings is not compatible with such a mechanism. This gives a new argument against the postulated orbifold-orientifold duality.

4 The early Universe

While observational cosmology has been developed at SPhT for quite a while now, investigations on the physics of the early Universe have emerged only recently. These studies concerned very fundamental issues related to the understanding of quantification rules in curved space-time, as well as model building issues in theories inspired by super-string theories.

4.1 Branes world scenarios (C. Grojean, S. Lavignac, G. Servant)

In the Kaluza-Klein picture, it is well known that if there exist some extra-dimensions to our Universe, an infinite number of massive states will be associated to each usual 4D field. Because these KK modes have not yet been observed, their masses have to be beyond the experimental range of energies accessible in colliders ($\sim 1\,\mathrm{TeV}$). This is why, in this scenario, the size of extra-dimensions cannot exceed scales of the order of $\sim 10^{-19}\,\mathrm{m}$.

However the discovery of p-branes (extended objects spanning (p+1) space-time dimensions) in string theory has suggested an alternative scenario in which the Standard Model gauge interactions are confined to a four dimensional hypersurface while gravity can still propagate in the whole *bulk* space-time. In such a scenario the constraints on the extra-dimensions evade the standard ones and are solely determined by the behavior of gravity alone at short distances. The bounds on the extra dimensions are now much lower ($\sim 1\,\mathrm{mm}$). However this analysis was not yet complete because it assumes a particular factorizable geometry associated to the higher-dimensional space-time being a direct product of a 4D space-time with a compact space.

Recently this last assumption has been overcome in a work by Randall and Sundrum unveiling a very rich source of physical effects. The most exciting one reveals the non-incompatibility between non-compact extra-dimensions and experimental gravity. The crucial point is the existence, in some curved background, of a normalizable bound state for the metric fluctuations which can be interpreted as the usual 4D graviton. Of course, there still exists an infinite tower of KK modes, even a continuum spectrum without gap, but the shape of their wave functions is such that they almost do not overlap with the 4D graviton and thus maintain the deviations to the Newton's law in limits which are still very far from experimental bounds.

In [T99/065] and [T99/108], we have studied the cosmological expansion of such a brane Universe and computed the Hubble parameter (that measures the time variation of the expansion factor on the brane) in terms of the energy density. It has been found that, up to corrections suppressed at the Planck scale, the standard FRW cosmology is recovered at the cost of a fine tuning required to localize gravity on the brane in the Randall–Sundrum scenario.

In [T99/112], interpretation of these cosmological constants are given as an effective description of the dynamics of the low-energy degrees of freedom of string theory and we have shown that the previous picture was consistent with the equations of motion.

The necessity of a fine-tuning has been challenged in some particular set-up which was proposed to explain the smallness of the cosmological constant without any fine-tuning. The idea is that the curvature of the higher dimensional space-time can adjust itself so as to cancel any contribution of the fields living on the brane to the effective four-dimensional cosmological constant. It has been however shown [T00/062] that this mechanism requires additional contributions to the four-dimensional cosmological constant, implying some hidden fine-tuning.

4.2 Metric fluctuations in curved space (J. Bros, R. Schaeffer)

The primordial fluctuations of the energy density field are the result of quantum processes in the expanding Universe at the remote epoch where the scale of these fluctuations was of the order of the microphysics scale. However, except in the case where the kinetic and potential energies exactly cancel, the space-time is curved due to gravity. Canonical quantization by mode expansion does not provide an unambiguous answer in this case. One does not know which modes to include in the expansion. Those that are L^2-summable as expected from elementary quantum mechanics, or those that correspond to all fields which behave at most as a constant at infinity as seems required if one is willing to treat all theories with positive m^2? It turns out that the latter is true. We have cleared out this problem, shown why this is consistent with quantum mechanics and have given methods to handle these (only apparently) non-normalizable modes. The answer to the above problem, that amounts to find the correct expansion of a 4-D two-point function into 3-D correlation functions with time dependent weights, can be used in a much more general context. Indeed, it provides a relation -that works both ways- between the two-point (n-point) function in a curved space of dimension d and the two-point (n-point) functions of particles with a given mass spectrum in one dimension less. For instance the Bunch-Davis two-point function in de Sitter space can be obtained as a superposition of Minkowski two-point functions in one dimension more [T99/062]. The AdS/CFT correspondence can also be viewed the same way, and we find not only the correspondence between the physics in anti-de Sitter space and Conformal Field Theory, but much more generally a correspondence of the former with QFT [T99/091]. Similarly, there is a correspondence of the physics in branes with the one in a bulk with extra-dimensions [T00/035].

4.3 Quintessence from a SuperGravity point of view (P. Brax)

Recent observations seem to indicate that the Universe contains a new type of matter with negative pressure. A possible candidate is a scalar field called quintessence. We have studied quintessence models and shown that they have to be described in a SuperGravity theory context due to the large value, close to the Planck mass, of the quintessence field at present time. We have given a general class of such supergravity models and investigated their stability with respect to quantum corrections. The phenomenology of these models is promising due to the low value of the pressure energy density ratio. This has lead us to study the CMB anisotropies in this class of models [T99/046, T99/075, T99/133].

5 From Cosmic Microwave Background anisotropies to galaxies

This section is devoted to the presentation of research topics more directly related to phenomenological aspects of cosmology. Some issues are related to the content of the Universe – the existence of a non-zero cosmological constant is a formidable challenge from a high-energy physics point of view – others to structure formation mechanisms in the Universe.

5.1 Large-scale structure formation

The observed structures in the Universe: dark clouds, galaxies, groups of galaxies or rich galaxy clusters are the result of gravitational collapses of tiny irregularities pre-existing (due to quantum fluctuations) in the primordial Universe. This is in general a complex issue because of the intricate nonlinearities that the gravitational dynamics contains. The regime which corresponds to only slight deviations from the linear behavior has been studied in detail during the previous years at SPhT and is still an active topic. Most of the effort in this domain have however been devoted to the strongly nonlinear regime where observational consequences can be drawn more directly.

5.1.1 Perturbation Theory results (F. Bernardeau)

Numerous results have been obtained using perturbation theory applied to the initial density fluctuations of the Universe. A review paper presenting the state of the art in this domain is actually in preparation for Physics Report. These results actually lead to better understandings of phenomenological aspects related to the large-scale velocity flows [T99/006, T99/038], as well as to possible estimate of finite volume effects in data analysis [T99/121].

5.1.2 Analytical and observational aspects of structure formation (R. Schaeffer, P. Valageas)

The previous investigations have however intrinsic limitations because the observed astrophysical objects are nowadays extremely dense objects, that are more suitably described by a nonlinear theory. The theoretical investigations are somewhat simplified because, at the scales involved, object formation is the result of the sole gravitational interaction, through a process that is called hierarchical clustering: the smaller mass condensations form first, contain nearly all the matter in the Universe but occupy a negligible fraction of space, these condensations then cluster together, forming larger associations with almost all the mass, surrounded by nearly empty regions. This process repeats itself, resulting in a mass distribution that is self-similar at all the relevant scales. Objects then exist only after some additional physical properties are imposed (for instance galaxies form at locations where cooling rates are rapid enough compared to the accretion rate).

We have been able to find an analytical description of the density field, as well as to attach and derive the relevant physical and clustering properties to the astrophysical "objects" [T99/053]. These results constitute the most elaborate model of matter clustering properties in hierarchical models. Our approach has been comforted by checks against observations [T98/108] as well as against numerical simulations [T98/098, T99/027]. Moreover, this is the only available model that can cope with such a large variety of objects (overdensed as well as underdensed structures) and which can describe substructures. Besides, it has been noted that a reinterpretation of this description within the more general framework of multifractals [T99/104] shows that this bifractal model is the simplest realistic description of the non-linear density field.

Using these results and the model of galaxy formation developed in a previous work, one can draw a complete picture of the non-linear structures which fill our Universe. For instance, one can simultaneously account for the X-ray emission from clusters of galaxies, individual galaxies and quasars [T99/146]. In a similar fashion, it is possible to describe the properties of the diffuse intergalactic medium which fills most of the volume of the Universe and surrounds these high-density objects [T99/040]. Then, looking back in time one can reconstruct the reionization history of the Universe by the first stars and quasars [T99/064]. This analytic study agrees with the available results from numerical simulations (*e.g.*, the gas was reionized at $z \sim 8$ within the framework of current cosmological models) and it allows one to cover the whole range of interest (while simulations cannot extend below $z \sim 4$ down to the present epoch because of limited resolution). Moreover, it provides a convenient tool to investigate hypothetical scenarios which may be needed to explain some observations (*e.g.*, large reheating of the intergalactic medium to recover the observed "entropy floor" of the gas within clusters) [T99/138]. This domain of high redshifts (when the age of the Universe was smaller by a factor ~ 20) have only recently been accessible to observation and should be explored in detail in future observational projects.

5.2 Gravitational lenses

A number of works described in the previous paragraphs deal with the statistical properties of the cosmic matter field at large scale. One very efficient way of revealing these properties is to take advantage of the so-called gravitational lens effects. Any mass concentration indeed deflects the photons that are passing by. These slight deflections induce specific patterns on the background objects that can be analyzed to reveal the shape of the projected potential of the lenses.

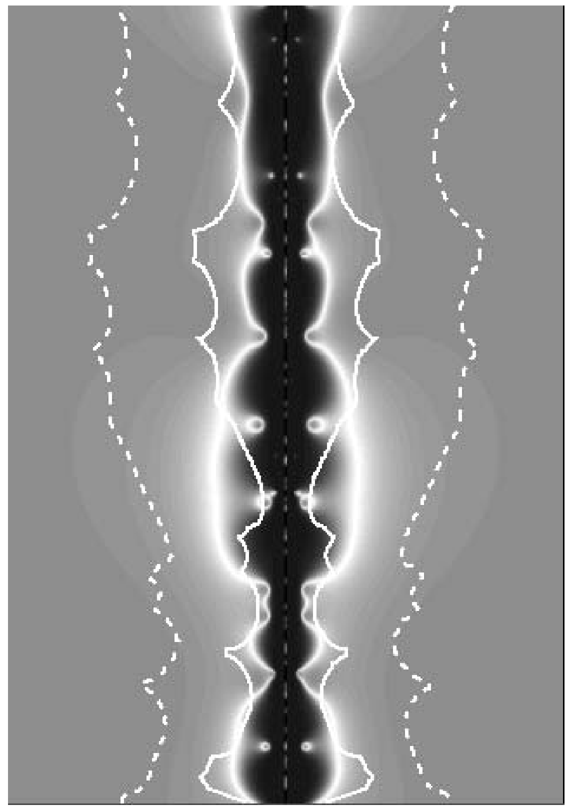
5.2.1 Weak lensing by the large-scale structures (F. Bernardeau, P. Valageas)

The theoretical interests of such observations for mapping the large-scale structures had been explored in a previous paper [T96/108]. This work has been complemented by numerical investigations that have confirmed our predictions [T98/081, T99/007]. Moreover very recently the first report of weak lensing detection at large angular scale has been made [T00/031] which reinforce the interest of such methods for exploring the large-scale structure properties of the Universe.

Further analytical works have been developed that allow to compute the full probability distribution of the convergence (which measures whether the light beam gets broader or thinner) in this regime was proposed [T99/050, T00/023]. It agrees with the results of numerical simulations and it explicitly shows how one can recover the properties of the density field from the measure of such effects.

5.2.2 Gravitational lensing phenomenology of cosmic strings (F. Bernardeau)

Although current observations rather favor models with initial adiabatic scalar fluctuations for seeding the large-scale structures of the Universe, the formation of cosmological relics, such as cosmic strings, cannot be a priori excluded. This is a natural outcome of explicit inflationary scenario in SUSY context for instance. We have investigated general phenomenological aspects of string detection with gravitational lensing effects. We have shown is particular that the local convergence is always zero (except on the projected angular position of the string) and exhibited the source term for the deformation effects [T00/051].



Numerical experiment showing the amplification map of a straight "Poisson string". The brightest pixels correspond to infinite magnification: they form the critical lines. The solid lines correspond to the caustics, positions of the critical lines in the source plane. The external dashed lines are the counter images of the critical lines.

To obtain a more phenomenological picture of such string induced lens effects we have also developed a model of strings where the energy, position and shape fluctuations of the string are described by a random lineic energy fluctuation with a vanishing coherence length. In such a model it appears that most of the lens phenomenology, structures of the critical lines, caustics, can be explicitly calculated [T00/052].

5.2.3 Lens effects on Cosmic Microwave Background properties (F. Bernardeau)

If the lens effects that are most commonly encountered are those induced on background galaxies, they can also be significant on the properties of the Cosmic Microwave Background anisotropies. Completing previous studies we have shown that the orientation of the CMB temperature patterns could be revealed by cross-correlation examinations of CMB maps with weak lensing surveys [T99/120]. However the most dramatic effects turn out to be the one on the polarization properties. Taking explicitly into account that in usual inflationary models the CMB polarization is dominated by scalar modes (primary pseudo-scalar modes induced by tensor fluctuations are negligible) we have shown that this property does not survive lens effects. As a result the so-called B-type CMB polarization can be used to unveil lens effects on the CMB plane, whether it is because of topological defect relics [T99/052] or because of the large-scale structures of the Universe [T00/030].

STATISTICAL PHYSICS AND CONDENSED MATTER

A great variety of subjects is gathered in this chapter devoted to Statistical Physics. The majority of the topics presented here benefited from the cross-fertilization between different methods, originally developed in other branches of Physics (integrable systems, quantum field theory, mathematical physics...), thanks to collaborations and discussions between members of our laboratory having very different backgrounds. Thus, although the subjects in which we have been interested may seem extremely diverse, and sometimes rather mathematical, their unity stems from our desire to understand actual problems in Physics with the use of a handful of techniques, however sophisticated.

This chapter is divided in four parts. The first section is devoted to general aspects of Statistical Physics; we describe various models related to combinatorial problems (graphs, folding of polymers, meanders), to Brownian walks and to classical models formulated on random lattices. Exact solutions of such models are often obtained with the help of related matrix-models, a long-standing speciality of our laboratory. More generally, clever mappings to related 2D Quantum gravity models and the identification of a central charge have allowed to determine non-trivial exponents. Time dependent systems are treated in the first section from a traditional view-point (kinetic theory, hydrodynamic instabilities, turbulence). The techniques involved here are typical of applied analysis: stability criteria, mode decomposition, shocks and stochastic equations.

This leads us naturally to the first theme of section 2: non-equilibrium statistical physics. Model solving plays again a crucial role since no general theory is yet available. 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. Systems out of equilibrium are related to disordered systems. Path integral methods are well suited to calculations concerning disordered systems (*e.g.* they were used to obtain an effective description of a random medium); when coupled to supersymmetry techniques, they provide an efficient tool to describe superconductors with impurities. Among disordered systems, the study of spin glasses remains an active field in the SPhT. An essential and outstanding question in spin glass theory is to discriminate between two models: the droplet description and the Parisi replica symmetry breaking scheme. Numerical simulations and analysis of the fluctuations around Parisi's mean field solution, conducted by members of our group, seem to favour replica theory.

The third part of this chapter is devoted to Quantum systems. Field-theoretic methods are perfectly suited not only for modeling correlated electrons and spin chains, but also for quantum fluids such as Bose-Einstein condensates, 2D electron systems or superconductors. The reader will find here a collection of techniques applied to concrete problems in condensed matter: large-N expansion for the temperature transition of a weakly interacting Bose gas, integrable models and conformal field theory for the Hall effect, Chern-Simons action or duality for calculating magnetization curves...

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. Moreover, space geometry and combinatorial topology start now playing a preeminent role: polyhedral tilings to understand sphere packings, tensorial order parameters to describe conformational phase transitions, secondary structures and folding mechanism of proteins. Coulombic systems such as polyelectrolytes are relevant both for industrial purposes and to understand biological fluids. For instance, from variational descriptions of polyelectrolytes one calculates phase diagrams for the stability of a vesicle in water that may serve as a simple model for 'drug delivery' in a target cell.

Contents

1 Statistical Physics and Models

1.1 Pedagogical aspects of Statistical Physics (R. Balian, J. P. Blaizot)

Two articles containing some suggestions on the pedagogy of Statistical Mechanics appeared in a special issue of The American Journal of Physics. In the first paper, we present a synthetic approach to Statistical Mechanics based upon different types of relevant entropies which depend not only on the state but also on the coarseness of the description of a system. The use of these relevant entropies sheds light on the second law, both in equilibrium and in irreversible thermodynamics, and unifies many approximation methods of non-equilibrium statistical mechanics. In the second paper, we review different aspects of the physics of stars, their workings and their evolution, which is a gold-mine of problems in statistical mechanics and thermodynamics. Statistical Physics indeed plays a major role in the understanding of the fundamentals of stellar machines. Hence, statistical physics can be taught via a suitably crafted course on astrophysics [T99/043, T99/101].

1.2 The free energy at a first order transition. Condensation and metastability (A. Morel)

Perhaps because they are not directly related to field theory, first order phase transitions are often considered less appealing than continuous transitions. Nevertheless they exist, in Nature as well as in theoretical models, and their thermodynamical properties, if not universal, are sufficiently generic to be described better than is done in the Van der Waals theory of condensation.

In the 2D q-states Potts model above $q_c = 4$, cooling the system from a high temperature β favors the alignment of spins inside domains (droplets) which grow and eventually condense at $\beta_t(q)$. This droplet picture has been adapted à la Fisher to incorporate the knowledge accumulated on the model, in particular in previous numerical and analytical works also performed here. An explicit analytic function of β represents the free energy in the thermodynamical limit. It has an essential singularity at $\beta_t(q)$, characterized in terms of the correlation length and of the critical indices α and ν at the end point q_c, which explains quantitatively the behavior of energy cumulants measured in numerical experiments. Standard Van der Waals phenomenology (metastability) is recovered by replacing this singularity by an effective one located slightly away from $\beta_t(q)$ ("end of metastability", "spinode"). Peculiar scaling properties and finite-size effects in energy distributions follow specifically from the singular structure of the free energy, and they also compare successfully with numerical results on lattices of various sizes [T99/030].

The droplets invoked are not genuine geometrical objects: their surface/perimeter ratio scales as $R^{2(1-\nu)} = R^{2/3}$, not R as it is in the classical condensation model of round shaped droplets. At β_t, the relative weight of one large disk like droplet (unproperly called "critical droplet" because it gives the system a chance to tunnel to another equally probable phase) is estimated in a capillary wave calculation. Although it is found extremely small, its contribution is detected in one existing simulation. These findings reconcile the geometric and Fisher's views of what a droplet is: both types exist. This situation should be generic, at least when a first order line ends at a critical point. If there ν is not too close to 1/2, the two contributions can in principle be disentangled, possibly by using both equilibrium and dynamical properties of the system [in preparation].

1.3 Graphs and discrete folding problems

1.3.1 Incidence matrices of random trees (M. Bauer, O. Golinelli)

The study of random graphs is closely related to the problem of percolation. The spectrum of the incidence matrix of such a random graph provides information on a different problem that one may call "quantum percolation". There is good numerical and analytical evidence that global properties of the spectrum (moments for instance) do not give all the relevant physical information. So we studied local properties such as the height of the delta peak at the eigenvalue 0 in the spectrum. Since random graphs with small connectivity are assemblies of trees, we were led to study the kernel of incidence matrices of trees. By a classical result in graph theory, the number of labeled trees on $n \geq 1$ vertices is n^{n-2}. We endow the set of such labeled trees with uniform probability, giving weight n^{2-n} to each tree. Each tree comes with an $n \times n$ symmetric incidence matrix, with entry ij equal to 1 if there is an edge between vertices i and j and to 0 otherwise. Each such matrix has n real eigenvalues. This leads in turn to $n \times n^{n-2}$ eigenvalues for the whole set of labeled trees on $n \geq 1$ vertices. We call z_n the total multiplicity of the eigenvalue 0 in this set of n^{n-1} eigenvalues. The first terms of the sequence $(z_n)_{n \geq 1}$ are given by: 1,0,3,8,135,1164,21035 ... We found in closed form a generating function and an asymptotic estimate for the sequence $(z_n)_{n \geq 1}$. In particular, we show that the average fraction of the spectrum occupied by the eigenvalue 0 in a large random tree is asymptotic to $2x - 1 = 0.1342865808195677459999\ldots$ where x is the unique real root of $x = \exp(-x)$ [T99/134].

1.3.2 Membrane folding (P. Di Francesco, O. Golinelli, E. Guitter)

We have been working for a few years on various folding problems inspired by physics and biology, mainly of the two following classes:

(1) tethered membrane folding: the study of folded configurations of a two-dimensional lattice allowed to interpenetrate itself (phantom folding);

(2) fluid membrane folding: same problem for fluid versions of the lattice, namely tessellations of Riemann surfaces of arbitrary genus.

In the particular case of the two-dimensional square-diagonal lattice, a detailed study of the folding configurations has led to a reformulation in terms of two underlying Temperley-Lieb algebras, themselves corresponding to a two-color fully-packed loop gas on the square lattice, leading to various bounds on the folding entropy [T98/071]. A numerical study using transfer matrices has led to an interesting phase diagram, displaying both first and second order phase transition curves [T98/072].

A number of general results on these questions have been collected in a research-expository article [T00/028]. This work shows in particular some generic connections between lattice folding problems and the physical systems formed by fully-packed colored loop gases defined on the same lattices or tessellations to be folded.

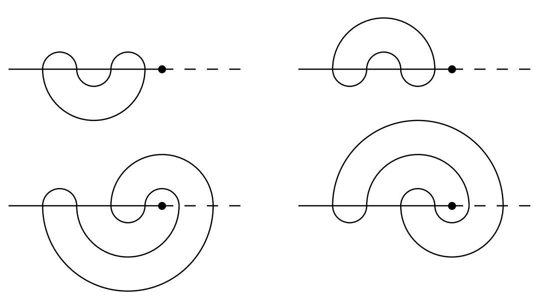
1.3.3 Polymer folding: meanders and fully-packed loops (P. Di Francesco, O. Golinelli, E. Guitter)

The statistics of meanders, it i.e. counting the number M_n of configurations of a road crossing a river through n bridges, is a long standing problem which interests us since many years, in particular in relation with the compact folding of polymers, the one-dimensional self-avoiding version of the membrane-folding problem. We have followed several approaches:

(1) by making use of the representation theory of the Temperley-Lieb algebra [T99/025], also present in most integrable lattice models in two dimensions, but also in the theory of links and knots;

(2) using random matrix models [T99/131], a class of integrals providing generating functions for random graphs that can be reinterpreted as folded configurations of polymers;

(3) using various algorithms of direct enumeration, in particular a new Monte Carlo method has been introduced to study this problem, which randomly constructs large meanders by recursion. This algorithm is particularly efficient on a parallel computer, allowing large simulations [T99/109]. In particular, precise critical exponents, related to the counting and the shape of meanders, have been estimated [T99/045].



The 4 semi-meanders of size 4: The *road* is the non-self-intersecting loop. The semi-infinite *river* is the half-line, starting at the source (black dot). The *size* is the number of bridges.

On the theoretical front, we have made a crucial step [T99/126, T00/021] by identifying the meander problem as being the "gravitational version", *i.e.* the random lattice version, of a particular fully-packed loop model, the FPL^2 model, with two co-existing systems of loops. This identification with a $c = -4$ conformal field theory coupled to gravity allowed us to obtain exact predictions for many exponents, including the configuration exponent of the original meander problem, and those corresponding to various other geometries (several rivers, river with a source, which branching points,....). We then performed a systematic check of these asymptotic predictions by a direct enumeration, using a transfer matrix approach, of the (generalized) meandric objects corresponding to these various situations. All our numerical estimates [T00/027] agree with our theoretical predictions.

1.4 Random walks and random lattices

The models presented in this section have been studied via mappings to 2D Quantum problems, and the use of specific techniques such as the KPZ formula or random matrix models. These elegant methods allowed to find subtle properties of Brownian paths and of some fractals ensembles, and also to solve random lattice versions of classical models of Statistical Physics.

1.4.1 Brownian motion and Quantum Gravity; Exact electrostatics of conformally invariant fractals (B. Duplantier)

Classical statistical problems in the standard two-dimensional plane $\mathbf{R}^2$ have been solved by $2D$ quantum gravity methods and extensions thereof. In [T98/063], the non-intersection exponents describing the probability that a given number of Brownian paths diffuse without intersecting, conjectured in 1988, have been derived from that technique. The structure so revealed also allows mixing Brownian paths and polymers, and deriving the exact statistical mechanics of arbitrary 2D copolymers [T99/021]. The related critical exponents are no longer rational but algebraic real numbers. One can also mix Brownian paths with the percolation problem [T98/125] to get the harmonic measure behavior near a critical percolation cluster. Alternately, a direct study of the probabilistic geometry of a percolation cluster allows deriving a family of path-crossing exponents [T99/024]. Both yield the Hausdorff dimension $D = 4/3$ for the external perimeter of a percolation cluster, conjectured in 1986.

The multifractal (MF) distribution of the electrostatic potential near any conformally invariant fractal boundary, like a critical $O(N)$ loop or a critical Q-state Potts cluster, has been solved in two dimensions [T99/158]. The results can be stated as follows. Consider a single (conformally invariant in a statistical sense) critical random cluster, generically called $\mathcal{C}$. Let $H(z)$ be the potential at exterior point $z \in \mathbf{C}$, with Dirichlet boundary conditions $H(w \in \partial\mathcal{C}) = 0$ on the outer (simply connected) boundary $\partial\mathcal{C}$ of $\mathcal{C}$, and $H(w) = 1$ on a circle "at ∞", *i.e.*, of a large radius scaling like the average size R of $\mathcal{C}$. $H(z)$ is identical to the *harmonic measure*, *i.e*, the probability that a Brownian motion started at z, escapes to ∞ without having hit $\mathcal{C}$. The multifractal formalism characterizes subsets $\partial\mathcal{C}_\alpha$ of boundary sites w by a Hölder exponent α, and a Hausdorff dimension $f(\alpha) = \dim(\partial\mathcal{C}_\alpha)$, such that the potential, or harmonic measure content of a ball $B(w,r)$ of radius r, centered at w, locally scales as

$$H\left(B(w,r)|w \in \partial\mathcal{C}_\alpha\right) \approx (r/R)^\alpha, r \to 0. \quad (1)$$

By Eq. (1) a Hölder exponent α thus defines a local equivalent *harmonic angle* $\theta = \pi/\alpha$, and the MF dimension $\hat{f}(\theta)$ of the boundary subset with such angle θ is found to be

$$\hat{f}(\theta) = f(\alpha = \pi/\theta) = \frac{\pi}{\theta} - \frac{25-c}{12}\frac{(\pi-\theta)^2}{\theta(2\pi-\theta)}, \quad (2)$$

with c the central charge of the conformal field theory describing the critical model. Values of c are, for instance, $c = 1/2$ for an Ising cluster ; $c = 0$ for the frontier of a Brownian motion [T98/063], for a self-avoiding walk [T99/021], as well as for a critical percolation cluster [T98/125]. One thus finds for $c = 0$ that these three boundaries all have the statistics of a self-avoiding walk, with a unique external perimeter dimension $D_{\mathrm{EP}} = sup_\theta \hat{f}(\theta) = 4/3$, which establishes and extends Mandelbrot's conjecture for the frontier of a Brownian motion. For any value of c, the Hausdorff dimension of the frontier $D_{\mathrm{EP}} = sup_\theta \hat{f}(\theta) = \hat{f}(\hat{\theta})$, and the *typical harmonic angle* $\hat{\theta}$ satisfy $\hat{\theta} = \pi(3 - 2D_{\mathrm{EP}})$. For a critical Potts cluster, the dimensions D_{EP} of the external perimeter (which is a simple curve) and D_{H} of the cluster's hull (which possesses double points) obey the *duality* equation [T99/158]

$$(D_{\mathrm{EP}} - 1)(D_{\mathrm{H}} - 1) = \frac{1}{4}, \quad (3)$$

independently of the model. A corollary is that the maximal Hausdorff dimension of a simple (*i.e.* non self-intersecting), and conformally invariant curve in 2D is the symmetric point $D = 3/2$ of Eq. (3). A related covariant MF spectrum similar to result (2) is obtained for *any* other critical system wetting the fractal cluster boundary.

1.4.2 Lorentzian gravity (P. Di Francesco, E. Guitter)

A discrete version of two-dimensional quantum gravity models uses in general random triangulations. A particular case of such models is that of the so-called "Lorentzian" gravity, obtained by demanding that the triangulation is organized into constant time layers of triangles. This layer structure allows for the use of transfer matrices to study the problem. Introducing, in addition to the weight t per triangle, a weight a associated with the intrinsic curvature of the triangulation, we showed that the problem becomes integrable (*i.e.* the transfer matrix $T(t,a)$ commutes with the transfer matrices $T(t',a')$ on a line $t' = F(a',t,a)$), which allows for an explicit solution of the problem. We also showed the existence of a direct equivalence between Lorentzian gravity with intrinsic curvature and Brownian walks with extrinsic curvature, which allows to connect many of their respective statistical properties. For instance, the loop-loop correlator of the gravitational problem translates into the large excursion probability of the Brownian walk [T99/073].

1.4.3 The Potts model and the six-vertex model on a random surface (G. Bonnet, B. Eynard, I. Kostov)

We have studied the general Potts-q models on planar random surfaces, using the loop equations method. In these models, q matrices are coupled to each other, thus making the resolution of the model difficult. We showed for the 3-states Potts model that there exists a closed set of loop equations (although this does not generally appear to be the case for $q = 2$ or $q > 3$). Using the invariance by circular permutation of traces, we related all the expectation values of the operators of the Potts-3 model on planar random surfaces to only 4 unknown operators. These were in turn determined by a one-cut assumption, and we finally obtained an algebraic equation of degree 5 for the resolvent, as well as the critical points and exponents of the model [T99/020].

More generally, a new approach, based on the equations of motion of a corresponding random-matrix model, allowed us to find new results for the q-states Potts Model on a random lattice. We derived a closed set of equations of motion, leading to a functional equation for the resolvent function of the model. With some analyticity assumptions, this equation could be rewritten as the equation of the $O(n)$ model: this mapping enabled us to derive exact analytical solutions. In particular, for "rational" values of q of the form $\sqrt{q} = 2\cos(s/r)pi$, the resolvent satisfies an algebraic equation of degree $r-1$ (this property was previously known only for $q = 1,2,3$). The equations of motion method in principle allows one to study the model beyond the spherical limit, *e.g.* the Potts model on a torus [T99/060].

Although most of the classical solvable models have been generalized and solved on a random graph about ten years ago, the six-vertex model of Baxter resisted until recently all attempts to be solved, in spite of the fact that its formulation as a large N matrix model was known. The solution of the model was finally obtained, using rather traditional methods. It was shown, as expected, that the partition function of the model coincides with that of a $c = 1$ string theory, compactified at some length depending on the vertex coupling. This is however not true for the correlation functions, because of the different operator content of the two theories. Precisely, the 6-vertex model on a random surface is related to the compactified $c = 1$ string theory by duality; its geometrical interpretation is that of a gas of dense nonintersecting oriented loops coupled to local curvature defects on the lattice [T99/130].

1.4.4 Fully-packed loop models on random triangulations (P. Di Francesco, E. Guitter)

The fully-packed $O(n)$ model describes the statistics of loops drawn on a two-dimensional lattice and constrained to visit *all* the vertices of the lattice. This model allows in particular to study the folding onto itself of the underlying lattice (for $n = 2$). On the regular (honeycomb) lattice, the full-packing constraint makes the model different from the usual $O(n)$ model in which vacancies are allowed. This difference appears as a shift $c \to c + 1$ in the central charge of the associated conformal theory, which in particular implies a change in the critical exponents. When defined on a random lattice, we have shown that a similar phenomenon of shift in the central charge occurs provided the random lattice is *bipartite* (*i.e.* the dual random triangulation is *Eulerian*, with an even number of triangles around each vertex). The dependence of the critical behavior on such a refined detailed structure is unusual in critical phenomena. This result was first corroborated by a numerical study of the $n \to 0$ limit of the problem, describing Hamiltonian cycles on random Eulerian triangulations, which has a very simple formulation in terms of arch statistics [T98/119]. In spite of its apparent simplicity, such a system is found to exhibit an irrational value of the configurational exponent. The shift in the central charge for Eulerian triangulations was then confirmed in the case $n = 1$ for which an exact mapping onto a recently solved random matrix model (describing the critical point of the six vertex model) was found [T99/010].

1.5 Kinetic theory and hydrodynamics

1.5.1 Discrete Kinetic Theory (H. Cornille)

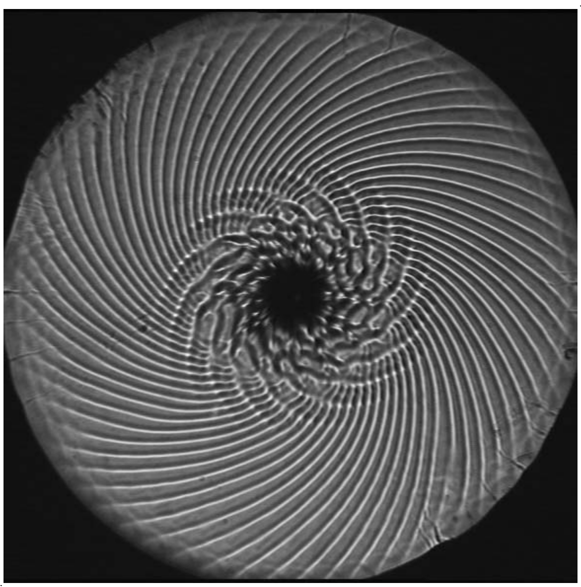
We study two different classes of discrete velocity models (DVM) of kinetic theory: models without conservation relations and DVM's for gas mixtures. Non conservative discrete velocity models (also called Extended discrete kinetic theory) have been introduced by Boffi and Spiga fifteen years ago. These models add to elastic collisions a background medium, external sources and sinks, effects of absorption and generation due to inelastic scattering etc... In these models the usual conservation laws are modified by including nonconservative terms (for instance, polynomials of the density, either linear or quadratic). Recently, exact traveling wave solutions and (1+1) dimensional solutions were found. In order to test the traveling waves as shock waves (Whitham-Lax criteria and shock inequalities), we consider models in which mass conservation is satisfied, *i.e.* we restrict the parameters in the nonconservative models in such a way that the sum of sources plus sinks is zero. We find rarefactive (with pressure and mass decreasing) shocks. We have been able to construct traveling waves for a large class of DVM's and we found conditions for the Lax criterion and shock inequalities to be satisfied. We also find that a criterion for overshoots of the internal energy, established previously for conservative models, still works for nonconservative ones [T98/084].

A general approach to the problem of constructing DVM's for binary planar mixtures, with masses equal to 1 and M for the two species, was introduced recently by Bobylev and Cercignani. These planar models have 5 invariants: only 1 for the mass of the heavy species, 1 for the light species, 2 for the momenta and 1 for the energy. However, the first constructed DVM's for mixtures (having respectively 13 and 25 possible values for the discrete velocities and $M = 2, 5$) appeared to have some other invariants, called "spurious" invariants. It is therefore a challenging difficulty to find "normal" or "physical" binary models having no such spurious invariants. We have studied two physical DVM's (the first with 11 velocities and masses equal to 1 and $M > 1$; the second with 13 velocities and masses equal to 1 and $M = 5$). For these models, we have studied exact shock waves, determined a criterion predicting that the internal energy will have overshoots and verified this criterion for different values of M [T99/013]. Secondly, we have found an analytical method to prove whether a model is physical or not. We have been able to construct a class of $11v, 13v, 15v$ physical models. Furthermore, using our analytical method we have also shown that the $25v, M = 2$ Bobylev-Cercignani model, which was suspected to have spurious invariants by different people with powerful computers, was in fact physical [T99/067]. Finally we developed a method to construct physically acceptable large size DVM's for binary gas mixtures. The models so obtained have an arbitrary number of momenta and all integer coordinates of the plane are filled. We start by constructing a small size, preliminary, "physical" model. Then with geometrical tools (the simplest being squares or rectangles with 3 previously known momenta), we enlarge the class of "physical" models and at the end all the coordinates of the plane are filled. We apply our technique to models with $M = 2, 3, 4, 5$ [T00/044].

1.5.2 Hydrodynamical instabilities (C. Normand)

Time-periodic states are encountered in hydrodynamical systems when one of the parameters of the equilibrium state is modulated in time. Depending on the proper tuning of the amplitude and frequency of the modulation, the stability properties of the time-dependent system can be very different from that of the unmodulated one, leading either to a positive or a negative shift for the instability threshold. Prototypal problems having periodic time variation include parallel shear flows like Poiseuille flow driven by a sinusoidal pressure gradient, convective systems when the equilibrium temperature or acceleration of gravity is modulated in time. Another example is provided by centrifugal instabilities of the flows generated by the time-periodic forcing of one or both cylinders of the Taylor-Couette system [T99/144]. We investigated the stability of pulsed flows characterized by a pure torsional oscillation of both cylinders with the same amplitude and frequency either in-phase or out-of-phase. Our analysis takes into account the gap size effect and investigates the influence of a superimposed mean angular rotation of the whole system. In case of no mean rotation, the finite gap geometry is found to affect the shape of the stability diagrams obtained in the narrow gap approximation. In particular, in the out-of-phase configuration a new low frequency branch was found, enabling better agreement with experimental results. When cylinders are oscillating in-phase and subject to a whole rotation, our results provide the evolution of the critical Taylor number versus the rotation number for two values of the frequency. A maximum of instability is found for an intermediate value of the rotation number in agreement with experimental results. A general tendency towards a restabilization of the flow is reported when the rotation number and the gap size are of the same order, as well as when the rotation increases. These two features are attributed respectively to the near cancellation of centrifugal and Coriolis effects on one side, and to the stabilizing influence of Coriolis force on the other side [T99/019].

The end structures of thermocapillary-driven flows in an extended horizontal liquid layer are considered as perturbations of the plane parallel core flow. The spatial stability analysis of the plane flow leads to an eigenvalue problem for the wave number of the perturbed state. The end flow structures are related to the nature of the eigenvalue with the lowest real part. A non-vanishing imaginary part reveals the existence of recirculation eddies. It was found that depending on the Prandtl number, recirculation eddies can exist either near the hot sidewall or the cold one. Our results provide a direct interpretation of the spatial behaviours observed in experiments and numerical simulations [T99/023]. Thermocapillary flows induced by a radial thermal gradient in a cylindrical geometry exhibit instability in the form of hydrothermal waves. Different patterns have been observed depending on the height of fluid and on whether the cell is heated from the center or the outside. Including curvature effects in the temporal stability analysis reveals that the instability pattern is not uniform through the whole extent of the fluid layer, in agreement with experimental observations.



Shadowgraphic picture of hydrothermal waves in a cylindrical cell heated from the outside (radial extent: 63.5mm, height of fluid: 1.2mm). Curvature effects give rise to inhomogeneous instability patterns like these two interpenetrating spiral waves rotating in opposite directions with different frequencies. Cliché Nicolas Garnier et Arnaud Chiffaudel, Groupe Instabilités et Turbulence, SPEC (CEA/Saclay).

1.5.3 Lagrangian trajectories in turbulent flows (M. Bauer, D. Bernard)

Important properties of turbulence are encoded in the behavior of Lagrangian trajectories, the trajectories of marked "particles" that are transported by the flow without disturbing it. For instance, do trajectories of initially nearby particles separate exponentially fast ? Do trajectories have a tendency to join in a finite time? Does the energy flow to large or to small distances in the cascade? The answers to these questions can be used to organize turbulent flows in families. We have studied this problem for the toy model of Burgers decaying turbulence in $1 + 1$ dimensions in the Kida statistics. This case is interesting because the statistical properties of the velocity field are strongly correlated in time. We have computed gluing probabilities, shock statistics, and certain persistence properties. The same methods can be applied to the case with forcing, but the situation is much more complicated [T98/136].

1.5.4 Two dimension turbulence (D. Bernard)

According to Kraichnan, 2D turbulent systems do not behave like 3D ones. Namely as the system starts to flow at a given scale, the turbulent energy cascade propagates towards large scales whereas enstrophy cascades towards small scales. We have shown how to modify Kolmogorov classical arguments in order to take this phenomenon into account. An exact formula for the third order velocity structure function follows [T99/012].

Experiments show that the energy injected into a 2D turbulent system is extracted by the friction with the container wall. We discuss different scenarios of the influence of friction on the enstrophy cascade [T99/039].

2 Time Dependent and Disordered Systems. Spin Glasses

2.1 Systems out of equilibrium

2.1.1 Persistence (M. Bauer, J.M. Drouffe, J.M. Luck)

The concept of persistence has been recently 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. For instance, if one considers a spin system at zero temperature, the question is to determine the fraction of space $R(t)$ which remains in the same phase up to time t, while the system evolves from a completely disordered state. For the Ising model, two phases coexist, corresponding to all spins equal to $+1$ or to -1. $R(t)$ is therefore equivalently defined as the probability that a spin never flipped up to time t, *i.e.* was never swept by an interface.

At finite temperature, this notion of persistence is more subtle, since thermal fluctuations induce flips in each phase. Several extensions have been proposed, but they appear to become numerically unstable as the temperature raises. A new proposal is to consider the mean value of a given spin between times 0 and t and to compute the probability $R(t,x)$ that this quantity remains always greater than some value x up to time t. This is a generalization of the previous definition (retrieved for $x = 1$). Extensive numerical simulations for the 2- and 3-dimensional Ising model show that this quantity behaves as a power law $t^{-\theta(x)}$ in the whole low temperature phase when $|x| \leq < \sigma >$. Hence, this method allowed us to define a persistence exponent, valid in the coarsening region $T < T_c$, and to study its dependence with respect to temperature [T98/091].

A problem closely related to persistence is the following: what is the probability that an asymmetric random walker remains up to time n on the left of an obstacle moving ballistically with velocity v? There are three different regimes (depending on the value of the drift of the random walk compared to v) that we study thoroughly. In the most intricate one, the problem can be reformulated mathematically as the law of the maximum of the average speed of the walker. We have shown that this law is made of jumps and given algorithms to compute these jumps. There is a nice connection with combinatorics, elementary number theory, algebraic functions, and algebraic curves defined over the rationals [T98/124].

2.1.2 Sinai Model (E. Guitter)

The Sinai model describes the diffusion of a particle in a one-dimensional random energy landscape. The asymptotic, large time, properties of this model are well understood and rely on a property of localization of the particle in the deepest accessible minimum of the potential. Dynamical properties of the Sinai model are then related to the statistics of minima of the landscape. We tested how this asymptotic equivalence is modified at smaller time scales. This is particularly important for the interpretation of numerical simulations. We computed exactly the statistics of minima reached at finite times and compared it with that observed numerically for the dynamical system. We find that the equivalence is still valid at short times, at least for low enough temperature [T98/078].

2.1.3 Exact solutions for the Exclusion Process (K. Mallick)

The one-dimensional asymmetric exclusion process (ASEP) has been extensively studied as one of the simplest models for non-equilibrium behaviour in statistical mechanics. The ASEP is a model of particles diffusing on a lattice driven by an external field and with hard-core interactions. This model can be adapted to describe a variety of phenomena such as super-ionic conductors, traffic flows, reptation of polymers or interface growth. Exact results have been obtained recently using a matrix-product Ansatz. This Ansatz has led to new results about the stationary state of diverse models, and about fluctuations in the stationary state. Finding a suitable matrix Ansatz involves solving an algebraic representation problem: one has to construct explicitly a set of operators with finite trace, that solve a set of quadratic equations uniquely defined by the evolution (or transfer) matrix of the system under study. We have been able to find an exact solution for an exclusion process with three classes of particles and vacancies. Our solution involves tensor products of quadratic algebras and shows that the matrix-product Ansatz is a versatile method that can be adapted to solve various multi-particle processes and related combinatorial problems [T99/152].

2.1.4 Population dynamics in a random environment (I. Giardina)

We studied the competition between barrier slowing down and proliferation induced superdiffusion in a model of population dynamics in a random force field. More precisely we focused on two mechanisms which lead, when considered independently, to opposite modifications of the normal diffusion behaviour: random walks in a random potential are trapped in deep potential wells leading to sub-diffusion, *i.e.* the typical distance traveled by the walkers grow more slowly than the square-root of time. On the other hand, in the case of random proliferation, where each random walker can either die or give birth to new random walkers at a rate which is random, "outlier" random walkers that have by chance traveled a distance much greater than the square-root of time, may be particularly prolific and lead to superdiffusive motion. The resulting behaviour of these two combined mechanisms is the problem we have investigated. A one-loop RG analysis close to the critical dimension $d_c = 2$ predicts a second order phase transition between a subdiffusive regime and a superdiffusive regime. This is however at variance with our numerical results in $d = 1$ which suggest that a new *stable* mixed fixed point appears. In order to understand qualitatively the observed diffusive behaviour at this mixed fixed point we introduce the idea of proliferation assisted barrier crossing, and give some heuristic Flory like arguments [in preparation].

2.1.5 Models of competitive learning (J.M. Luck)

We have introduced two models of competitive learning. Such models aim at describing *e.g.* the dissemination of a new technology through a population. Individuals sitting at lattice sites can be of two types, say type + if they have adopted the new technology, and type − otherwise. They learn (and eventually switch type) from comparing their own performance to those of their neighbors, according to some local stochastic rules. The first model is interfacial: an individual surrounded by neighbors of its own type will not switch type. The second model is cooperative: collective conversions of a cluster of individuals from one type to the other are allowed. We investigated the behavior of the models at coexistence, where no type is globally favored over the other. Their phase diagrams possess a rich variety of phase transitions, and especially a phase involving a novel kind of nonequilibrium behavior, called oscillatory coarsening [T99/086].

2.1.6 Glassy dynamics: violation of the fluctuation-dissipation theorem (J.M. Luck)

The study of the nonequilibrium dynamics of glassy systems has been pursued on several models. The emphasis has been put on the aging properties of correlation and response functions in the two-time plane (waiting time and observation time), and on the so-called fluctuation-dissipation ratio, measuring the violation of the fluctuation-dissipation theorem.

The first work in this area deals with the backgammon model, a mean-field dynamical urn model which exhibits a vitreous phase transition at zero temperature. We have determined analytically the scaling behavior of the correlation and response functions of the density fluctuations, and of the associated fluctuation-dissipation ratio, throughout the scaling regime of low temperature and long times [T99/036].

The same quantities have been investigated in the situation of a ferromagnet quenched from infinite temperature to its critical point. It has been shown that such a system is also aging in the long-time regime, because of critical slowing down. The two-time correlation and response functions of the spins and the associated fluctuation-dissipation ratio are non-trivial scaling functions in the two-time plane. We have shown in particular that the fluctuation-dissipation ratio possesses a limit value, in the regime where the observation time is much larger than the waiting time. The latter limit appears as a dimensionless amplitude ratio, and is therefore a new universal characteristic of nonequilibrium critical dynamics, intrinsically related to the memory of the initial state. A complete set of analytical predictions has been derived, both for the ferromagnetic Ising chain with Glauber dynamics, and for the spherical model in any dimension, while numerical results are available for the Ising model in two and three dimensions [T99/107, T00/004].

2.2 Disordered Systems

2.2.1 Electromagnetic properties of disordered media (H. Orland)

We have proposed a new method to compute the effective properties of non-linear disordered media. We use the fact that the effective constants can be defined through the minimum of an energy functional. We express this minimum in terms of a path integral representation allowing to use many-body techniques and the replica method. We have obtained the perturbation expansion of the effective constants to second order in disorder, for any kind of non-linearity. We apply our method to the case of strong and weak non-linearities. Our results are in agreement with previous ones and could easily be extended to other types of non-linear problems in disordered systems [T98/132].

2.2.2 Disordered two dimensional systems (D. Bernard)

Recent works have brought to light the existence of new universality class for the localization-delocalization transitions in two dimensions. These transitions may appear in certain superconductors with impurities. We have analyzed a field-theoretical model for such a transition. For some particular values of the external control parameters, there exists a remarkable decoupling between spin and charge degrees of freedom [T00/029].

2.2.3 Superconductors and disorder (M. Bocquet, D. Serban-Teodorescu)

The effect of disorder on superconductors depends on the symmetries of the Hamiltonian which are preserved by the impurities. There exist four symmetry classes, depending on the fact that time reversal symmetry and spin rotation invariance are preserved or not. We have studied the case when spin rotation invariance is present and time reversal invariance is broken (class C), realized in a vortex in a type II superconductor, or in high T_c superconductors [T98/089, T98/099] (see also the previous report). The next case we have studied corresponds to broken spin rotation invariance *and* time reversal invariance (class D). This symmetry class is also that of Dirac fermions with random mass in two dimensions or, by squaring the partition function, that of the random bond Ising model. We have shown that for more than two Dirac fermion species, or for two fermions with anisotropy, there exist three phases: insulator, thermal quantum Hall phase, and metallic phase. The metallic phase can be described via a sigma model. For a single species of Dirac fermions, the metallic phase is absent. We have also solved a controversy concerning the density of states at zero energy, by showing that the density of states goes to a constant in the metallic phase, but goes to zero for a single fermion species [T99/143].

2.2.4 Spectral properties of the one-dimensional disordered Dirac equation (M. Bocquet)

Many one-dimensional disordered systems appearing in condensed matter physics are related to the behaviour of a Dirac fermion in a random one-dimensional medium. Among them: the random hopping model for spinless fermions, the random XX spin chain model in a transverse magnetic field, or the stochastic diffusion of a classical particle in a random force field. These models (for which the disorder is called off-diagonal) exhibit a singularity at zero energy (Fermi energy) both in the density of states and in the localization length. It is reminiscent of the existence of (at least) one extended state at this energy. Using replicas and original algebraic tools, we calculated those thermodynamic quantities exactly, not only for off-diagonal disorder but also for a diagonal one (scalar potential) and even in a mixed case. We showed that the Dyson singularity appearing in the off-diagonal case is smoothed out by any other random Gaussian (forward scattering) perturbation. Our formalism can be developed in the framework of supersymmetry. We have also shown how the off-diagonal model can be mapped onto the diagonal one through a non trivial non-unitary transformation. This reasoning can be seen as a toy-model for the 2D case, where such a mapping would be hepful to reach the integer quantum Hall fixed point, supposedly nested in the 2D random Dirac fermion phase diagram [T98/126].

2.3 Spin Glasses

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

We have performed a large-scale simulation of the 3-d and 4-d Edwards-Anderson model using an original Monte Carlo algorithm designed for systems whose phase space is made of distinct regions, separated by large free-energy barriers. Two real replicas (two copies of the system, with the same quenched exchange interactions) are simulated using an artificial Hamiltonian designed to level barriers as much as possible. The bias introduced can be exactly compensated when computing thermodynamical averages. For each realization, the Parisi overlap parameter q is defined by $q = \frac{1}{N}\sum_{i=1}^{N}\sigma_i^1\sigma_i^2$, where the sum goes over the total number N of spins of the system and the spin superscripts label two replicas of the same realization. Our simulation allows for the first time to measure the probability distribution $P_J(q)$ in the whole range of q as well as the averaged canonical probability $P(q)$ which also contains important information on the system [T98/138, T98/139, T99/095, T99/129].

2.3.2 Replica method and dimensional reduction (C. De Dominicis)

There is a long standing controversy about the real nature of the spin glass phase, *i.e.* whether it is described by the droplet picture as proposed by Bray and Moore, and Fisher and Huse, or whether it preserves features of the mean field theory with ultra-metric organization of 'states' as favoured by Parisi and the Rome school. In our recent work we have pursued the analysis of the field theory of fluctuations around the Parisi mean field solution. These fluctuations have a complicated structure with massive ones (in the longitudinal sector) and bands of massless but also of small mass fluctuations (in the transverse sectors). We have shown that, with the small mass behaving like the square of the marginal coupling constant w^2, a perturbation expansion in w^2 leads to a pile up of infrared divergences and as a consequence one has to work with the complicated structure of the transverse propagators.

Another long standing problem in the field of phase transitions in disordered systems is the Random Field Ising Model (RFIM) and why the dimensional reduction fails, that states that near the Curie line the universal features (exponents etc...) of the RFIM in dimension D are the same as those of the pure system in $D-2$. In preliminary work we have shown that one should take into account more couplings that were so far considered in the standard replica approach. And in so doing one discovers that the standard stable fixed point given by the renormalization group becomes unstable. Besides, in order to get a more physical grasp, we have reproduced our result using a dynamical approach instead of the technique of replicas, and given a connection between replica number and waiting time [T98/047, T98/074].

2.3.3 Temperature chaos in spin glasses (A. Billoire)

A disordered system is said to be chaotic in temperature if a typical configuration at temperature $T + \delta T$ is very different from a typical configuration at temperature T. The precise definition involves the probability distribution of the overlap $q_{T,T+\delta T}$ between two real replicas σ (at temperature T) and τ (at temperature $T + \delta T$) $q_{T,T+\delta T} = \frac{1}{N}\sum_i \sigma_i\tau_i$. Temperature chaos is predicted by the phenomenological droplet picture of spin glasses, and was up to recently believed to hold also in the mean field approach. It has also been used to interpret the cooling rate independence of spin glass aging experiments. We have performed large-scale simulations of the Sherrington-Kirkpatrick model (an unphysical model that can be solved using mean field techniques), the so-called dilute mean field model with fixed connectivity 6, and the 3-d Edwards-Anderson model. In all three cases, we find no evidence of temperature chaos for systems with up to 4096 spins and temperatures $0.4T_c < T < T_c$. Assuming that our results are not spoiled by small system artifacts, an assumption always implicit in numerical simulations, our results rise serious doubts on the relevance of the droplet picture for 3-d spin glass [T99/119].

3 Quantum systems

3.1 Strongly correlated electrons

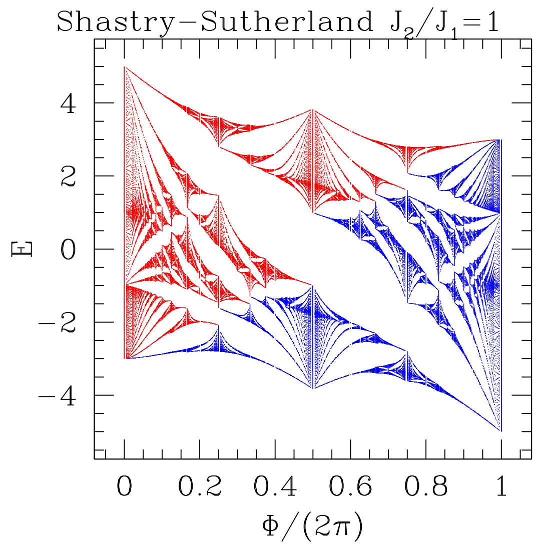
3.1.1 Suppression of ferromagnetism in flat band double exchange models (R. Lacaze, K. Penc)

The recent experimental activity on manganites, $La_{1-x}A_x$ MnO_3 (where A=Ca,Sr or Ba), motivated by their colossal magnetoresistance, has stimulated the interest of theorists for these compounds. It is believed that some aspects of the electronic properties of the strongly correlated transition metal oxides can be revealed by considering the Kondo-lattice Hamiltonian with ferromagnetic exchange between the localized and itinerant electrons. In this Kondo-lattice Hamiltonian, the kinetic part, characterized by a coupling t, describes the hopping of electrons on a lattice, while the interacting part includes two terms: (1) the interaction of strength J_H between the conduction electrons and localized core electrons; (2) the on-site Coulomb repulsion between the electrons, of strength $U > 0$, which is of the order of J_H.

We have considered the model where the hopping is infinitely long ranged. Numerical diagonalization on small clusters show that the spectrum separates into well-defined bands when J_H is large enough. It appears that, with long ranged hopping, the lowest band becomes simple in the limit $J_H/t \to \infty$: it is independent of U and has huge degeneracies. In order to understand this behavior, we introduced Schwinger bosons to describe the spin degrees of freedom, and noticed that the form of the effective strong coupling Hamiltonian becomes remarkably simple for $U = J_H/2$. Then, we have shown that the strong coupling limit of the Kondo lattice with infinite long range hoppings can be solved exactly using the underlying spl(2,1) dynamical supersymmetry. On this particular lattice, we found that the ferromagnetic ground state is not favored. Finally, we argued that these results can be extended to finite dimensional lattice like Kagomé (D=2) or pyrochlore (D=3). From our analysis, we deduced the following phase diagram: for low densities (below $1/D$), the usual double exchange mechanism will stabilize the ferromagnetic phase in a large parameter range, whereas for high densities (larger than 2/D), the physics is governed by the antiferromagnetic term. For intermediate densities, between 1/D and 2/D, there are indications of a kind of ferrimagnetic state. In order to verify this scenario, we have carried out a numerical simulation where classical core spins are integrated by Monte Carlo whereas conduction electrons are integrated out exactly. Preliminary numerical results support our expected phase diagram, with an intermediate density region characterized by a phase separation [T99/157].

3.1.2 Dynamic dielectric response of 1D cuprates (K. Penc)

Quasi-1D materials based on cuprate compounds have become new candidates for ideal model systems which allow to study basic physical concepts in one-dimension. Information on the electronic structure and the dynamics of the charge carriers is highly desirable, especially against the background of spin–charge separation expected in 1D. Besides the one-particle spectral function obtained by photoemission, the dielectric function is the most basic and important quantity reflecting the electronic structure of a solid. The dielectric response is accessible using electron energy-loss spectroscopy (EELS), offering the possibility to study the momentum dependence of the electronic excitations, *i.e.* the dynamical dielectric response $\mathrm{Im}(-1/\epsilon(\vec{q},\omega))$. We have reported the first experimental and theoretical investigations of the $\mathrm{Im}(-1/\epsilon(\vec{q},\omega))$ of single crystal Sr_2CuO_3. While for small momentum transfer we see a broad continuum of inter-band plasmons above the gap, on the way to the zone boundary a sharp peak develops. We show that the data can be understood within an extended effective one-band Hubbard model, and that both the spin-charge separation which occurs in 1D as well as excitonic effects are essential [T98/035].



Band structure of non-interacting fermions in a uniform magnetic field on the Shastry-Sutherland lattice with tight-binding Hamiltonian. The flux (horizontal axis of this spectrum) is measured in units of flux quanta per square plaquette (here $\phi_0 = hc/e = 2\pi$). J_1 (resp. J_2) is the hopping amplitude along the bonds of the square lattice (resp. diagonal bonds). Here $J_2 = J_1 = 1$. The mean-field consequence of the flux-attachment is that the fermion density should be proportional to the statistical flux. This constrain implies that the blue bands are occupied by the fermions in the mean-field groundstate and that the red ones are empty.

3.2 Quantum Magnetism

3.2.1 Chern-Simons-Hofstadter theory for the magnetization curve of two-dimensional magnets (T. Jolicœur, G. Misguich)

The discovery of the quantization of the Hall conductance σ_{xy} of a two-dimensional gas of electrons in a strong perpendicular magnetic field has opened a new chapter in condensed matter physics. This phenomenon, the Quantum Hall Effect (QHE), leads to plateaus in the curve of the transverse conductance σ_{xy} as a function of the magnetic field. More recently, a rather different class of Fermi systems has lead to plateaus phenomena: low-dimensional spin systems and plateaus in their magnetization curve. Among the recently studied compounds exhibiting magnetization plateaus, the copper oxide $SrCu_2(BO_3)_2$ studied by H. Kageyama *et al.* and K. Onizuka *et al.* gives clear evidence of plateaus at $M/M_{\text{sat}} = 0$, $M/M_{\text{sat}} = \frac{1}{4}$ and $M/M_{\text{sat}} = \frac{1}{3}$. This system can be described by a quasi two-dimensional spin-$\frac{1}{2}$ Heisenberg model on the Shastry-Sutherland lattice (a square lattice with one additional bond along the diagonal of every other plaquette).

In this work, we apply some methods developed in the context of the QHE to the magnetization plateau problem. We use an exact mapping between the spin Hamiltonian and spinless fermions interacting with a statistical gauge field with Chern-Simons (CS) action (derived by E. Fradkin in 1989). This two-dimensional version of the Jordan-Wigner transformation attaches a flux tube to each fermion in order to modify its statistics from fermionic to bosonic (as it should be since raising and lowering spin operators S_i^+ commute from one site i to another j). The principle of the statistical transmutation is to modify the statistical phase obtained in the adiabatic transport of one particle around another by an Aharonov-Bohm phase. This additional phase is generated by the interaction between one fermion and the flux tube attached to the other. When the flux is precisely equal to *one* flux quantum, the "fermion+flux" composite particle is bosonic.

The way to perform such a flux attachment is to couple the fermions to a CS (Abelian) gauge field. We discuss the construction of the microscopic CS action on a lattice with frustration. Then, following previous work of S. M. Girvin *et al.*, we use a mean-field and Gaussian treatment of the gauge field. At the mean-field level, the fermions are non-interacting and feel a uniform (statistical) magnetic field (*i.e*, the well known Hofstadter problem). This one-body Hamiltonian gives complex spectra with fractal structures. We compute these spectra numerically (see figure) and deduce the mean-field magnetization curve of the spin model. We find magnetization plateaus at $M/M_{\mathrm{sat}} = 0$, $\frac{1}{3}$ and $\frac{1}{4}$, as in experiments on $SrCu_2(BO_3)_2$. One additional plateau at $\frac{1}{2}$ is also predicted for values of the magnetic field which have not yet been investigated experimentally.

Fermions can be formally integrated out to obtain an effective action for the gauge field. At the Gaussian level and in the low-momentum and low-energy limit, this effective action contains Maxwell and CS terms. Plateaus can only appear when the CS coefficient does not vanish. This coefficient is simply related to the *Hall conductance* σ_{xy} of the fermions. We compute this σ_{xy} and find that the CS term vanishes except at the magnetization where plateaus are observed at the mean-field level (0, $\frac{1}{3}$, $\frac{1}{4}$ and $\frac{1}{2}$). Furthermore, the stability of the plateaus against higher order fluctuations is insured by the topological quantization of this conductance. Eventually, we discuss the nature of the excitations of the spin model from the point of view of the effective action for the gauge field. The next task to perform is now to look for spatially inhomogeneous solutions of the mean-field equations when the magnetization has a quantized value and to relate them to possible striped structures of the spins [in preparation].

3.2.2 Quantum spin chains (O. Golinelli, T. Jolicœur)

We have studied the magnetic excitation spectrum of a quantum spin-1 chain with a bilinear and biquadratic Hamiltonian $H = \sum_i \cos\theta \mathbf{S}_i \cdot \mathbf{S}_{i+1} + \sin\theta(\mathbf{S}_i \cdot \mathbf{S}_{i+1})^2$. This family of Hamiltonians includes the familiar Heisenberg model for $\theta = 0$. For $\tan\theta = 1/3$, one recovers the Affleck, Kennedy, Lieb and Tasaki (AKLT) Hamiltonian, the ground state of which is explicitly known and is given by the Valence Bound Solid (VBS) state. Our study focused in the range $0 \leq \theta \leq \pi/4$ where the spin chain is in the gapped Haldane phase. We found that for the biquadratic intensity a critical value $\theta_c \simeq 0.38$ appears. When $\theta < \theta_c$ (for example, the Heisenberg Hamiltonian), the lowest excitation has momentum $k = \pi$ which means that the corresponding state is spatially periodic with period two lattice units. When $\theta > \theta_c$, the momentum of the lowest excitation is now different from π and varies continuously as a function of $(\theta - \theta_c)$: the momentum becomes incommensurate. However, in both cases, the lowest excitations remain isolated in the spectrum. This value θ_c is different from other special value previously known in this quantum system (such as the VBS point or the Lifshitz point) [T98/120].

3.3 Bose-Einstein condensation (J.P. Blaizot, J. Zinn-Justin)

The effect of weak repulsive two-body interactions on the temperature of the Bose-Einstein condensation of a dilute gas at fixed density is an old but controversial problem and conflicting results can be found in the most recent literature. Modeling the atom-atom potential in terms of the s-wave scattering length a, we have shown that the change in the transition temperature is proportional to a (when $a \to 0$) with a positive coefficient. The value of the coefficient can not be obtained from perturbation theory. However, recognizing that the Hamiltonian of the system under study, which also describes the helium superfluid transition, is a particular example of the general N vector model, with $N = 2$, we have been able to calculate the value of this coefficient using a large N approximation. Our result is in remarkable agreement with recent numerical simulations [T99/077, T99/090].

3.4 Quantum Hall effect and mesoscopic systems

3.4.1 Fractional statistics (M. Bergère)

We modified Haldane's formula, which determines the number of possible configurations for N particles distributed over d different states in fractional statistics, so that it makes sense for any finite N and d without changing its thermodynamic limit. As a result, we obtained a quasi-geometric rearrangement of the particles into 'composite particles" [T99/035]. We calculated the partition function for the composite particles and for any finite number d of states. In the cases where the states have the same energy or where the energy is linearly distributed over the states, the partition function is obtained as a finite sum of terms which exhibit trivially their d dependence. The large d expansion is determined and in the second case, we recovered the universal chiral partition function for exclusion statistics of Berkovich and Mc Coy [T99/097]. Finally, we established a relation between the composite particles and the models of Calogero-Sutherland and Ruijsenaars-Schneider. Then, we used the vertex operator formalism to give a representation of the composite particles in position space. In the special case where the composite particles are bosons, adding one extra quasiparticle or quasihole we could construct the ground state wave functions corresponding to the Jain series $\nu = p/(2np \pm 1)$ of the fractional quantum Hall effect [T99/080].

3.4.2 Dipoles and fractional quantum Hall effect (V. Pasquier)

Some time ago we have proposed a simple theory to explain the occurrence of the $\nu = 1/2$ state in the quantum Hall effect. The fundamental particles are neutral fermions built upon a $\nu = 1/2$ bosonic incompressible charged vacuum. Semiclassically an excitation is made by the electron and its correlated hole and moves as a bound state perpendicularly to its dipole momentum. We have generalized this picture to describe the filling fractions of the Jain's series around $\nu = 1/2$ and $\nu = 1/4$. In this case the charge of the electron differs from that of the hole so that the excitation carries a fractional charge. The surprising outcome is that the wave functions of the bound states are universal (independent of the interaction potential). They are the seeds to construct Jain's wave functions. We have used this model to compute the masses of the composite fermions in good agreement with experimental results. In particular we have predicted the equality of the masses at the $\nu = 1/2$ and $\nu = 1/4$ filling fractions [T99/074, T99/081, T99/082].

3.4.3 Edge excitations in the fractional quantum Hall effect (V. Pasquier, D. Serban-Teodorescu)

Motivated by recent experimental results, we have reconsidered the theory of the edge excitations for the fractional Hall effect at filling factors $\nu = p/(2np+1)$. We proposed to modify the standard conformal field theory for the edge with $u(1) \otimes su(p)$ symmetry by introducing twist fields. This has the effect of removing the conserved charges associated to the $p-1$ neutral modes while keeping the right statistics of the particles. The Green's function of the electron in the presence of twists decays at long distance with an exponent varying continuously with ν, consistent with the experimental results [T99/143].

3.4.4 Mesoscopic superconductivity (K. Mallick)

The ability to detect and manipulate vortices with great sensitivity in systems of small size such as mesoscopic superconductors or atomic condensates has generated an outgrow of interest in the mechanism of creation and annihilation of vortices and in the study of stable and metastable vortex configurations. Recent experiments conducted on aluminum well below its superconducting transition temperature have allowed to measure the magnetization of small superconducting discs containing only a few vortices. Such systems are called mesoscopic since their dimensions are comparable to the two superconducting characteristic lengths, *i.e.* the London penetration depth and the coherence length. As surface effects are of the same order of magnitude as bulk effects, the magnetic response of such a mesoscopic disc to an applied magnetic field is very different from that of a macroscopic superconductor and depends strongly on its size. In particular, a series of jumps in the magnetization curve, corresponding to the successive entry of flux lines into the sample, was observed experimentally. We have performed a theoretical analysis of these systems. Our approach is based on special properties of the two dimensional Ginzburg-Landau equations, satisfied for a particular value of the ratio of the two characteristic lengths, called the self-dual (or Bogomol'nyi) point. In an infinite system, the Ginzburg-Landau equations have a purely geometrical interpretation at the self-dual point. We have extended these properties to a finite system with boundaries. We applied our results to the calculation of the thermodynamic properties of a mesoscopic superconductor and to the interpretation of the recent experimental results. Our analytical expressions are in excellent agreement with the experimental data [T99/153, T00/020, T00/022, T00/047].

4 Soft condensed matter and biological physics

4.1 Granular materials (A. Gervois)

The analysis of real 3D granular media is a very difficult task, even in the case of spherical grains, because the centers of the particles are randomly positioned and may move under stress or shaking. Therefore, numerical packings of spheres are extensively studied and many efforts have been devoted to the elaboration of efficient algorithms. A granular medium is modeled as an assembly of spherical beads, either monosize (all the spheres have the same radius) or polydisperse. Assemblies of spheres can be generated by several numerical methods: static algorithm, collective reorganization, or molecular dynamics. In particular, in the case of **hard spheres**, we have developed a simple version of molecular dynamics calculations (event driven algorithm) which allows to create assemblies of up to 16 000 spheres, very large compared to assemblies generated from molecular dynamics with soft Lennard-Jones interactions, and therefore more suitable to statistical analysis.

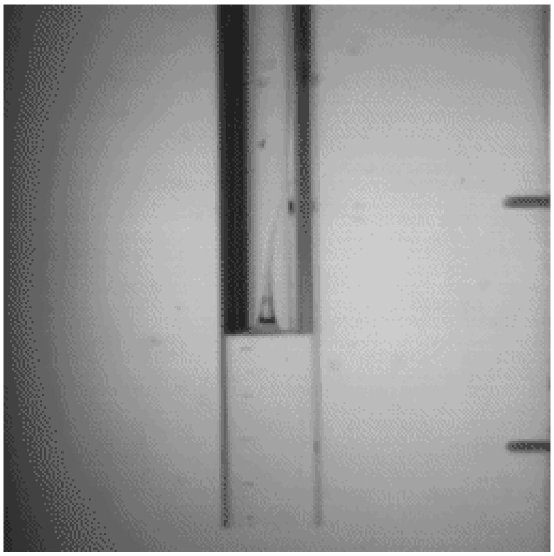
Geometrical aspects of packings of spheres can be studied using a Voronoi tessellation (for monodisperse spheres) or a radical tessellation (which generalize Voronoi's construction to polydisperse systems). We began with the study of a binary assembly of discs in 2D (the binary disperse system can be considered as the situation opposite to the monodisperse one: a polydisperse assembly behaves in between these two extreme cases). We found that the two species behave separately like froths if one considers topological properties, but not regarding metric properties (differences are however less pronounced when packing fractions are lower).

Molecular dynamics calculations in 3D compact systems (*i.e.* in the solid phase, with packing fraction greater than 0.54-0.55) lead after a long equilibration time to an ordered crystalline phase, which in the hard sphere case is rather of the fcc (face centered cubic) type. We studied this transition, of the glass-crystalline type, in the Voronoi frame. Topological parameters such as the number of edges of each face change drastically as crystallization begins, but they do not vary anymore as the crystallization goes on. Therefore, in order to characterize how the packing restructures itself, we measured more sensitive parameters (such as the rotationally invariant local and global parameters introduced by Nelson *et al.*), which are well defined only in the Voronoi frame (in which neighbours are defined unambiguously). We found that the crystallized structure is a mixture of fcc and hcp (hexagonal compact) clusters, and as expected, the fcc symmetry is more stable than the hcp one in hard sphere crystallized systems [T99/022, T99/033, T99/076].

Another way for analyzing 3D spherical monosize or polydisperse systems consists in performing random planar sections (or cuts) in samples. Provided that these sections are large enough, the quantities measured in the 2D cuts may give valuable information on the 3D assembly. A stereological analysis in 3D monosize sphere packing was carried out in two different (non commuting) manners. First, we analyzed a 2D *cut* of the classical Voronoi polyhedra tessellation of the 3D monosize sphere assembly. In the second method, we start by cutting the 3D mono-size assembly of spheres to obtain a 2D polydisperse system of discs and then we perform a radical tessellation on this 2D assembly to generate a 2D *froth*. We showed that the 2D froth behaves like an ordinary random assemblies of discs, whereas the 2D cut behaves differently [T99/057]. We are presently trying to investigate how crystallization may appear in these sections.

4.2 Capillarity (J.Y. Ollitrault)

When a narrow tube is put in contact with a wetting liquid, the liquid rises in the tube up to a height where the capillary force balances the weight of the liquid column. In the case of a liquid with small viscosity, oscillations around the equilibrium height have been observed recently. We have proposed a simple theory which is able to reproduce quantitatively the shape of these oscillations. We have shown in particular that even in the limit of zero viscosity, they are damped due to eddies at the entrance of the tube. Taking this dissipation into account, one obtains two universal differential equations which describe the rise and the fall of the liquid in the tube, respectively. Remarkably, both equations admit a simple integral of motion, despite the existence of a source of dissipation, thanks to the fact that turbulent damping is quadratic, rather than linear in the amplitude of the oscillation [T99/001].



Oscillations of a liquid column, under the influence of gravity, in an open tube whose lower extremity is immersed at a depth of 30cm below the surface of the liquid.

4.3 Polymers and self-avoiding membranes

4.3.1 Proteins and polymers (T. Garel, H. Orland)

We have studied amphiphilic chains, with a periodic hydrophobicity along the sequence. This model may be of interest in various situations (protein folding, polysoaps...). The competition between intrachain phobic attractions and philic repulsions may lead to compact or branched phases, which we have studied in two dimensions through Monte Carlo lattice simulations [T98/095].

Some recent numerical studies seem to indicate that fast folding proteins are those with a large gap (*i.e.* a large difference of energy between the native state and the first excited state with a different conformation). Other models suggest that the correspondence between gap and rapidity does not hold. We have studied the effect of the gap on protein folding in the framework of the dynamics of a Random Energy Model. We have shown that the folding can be either accelerated or slowed down, depending upon the choice of the transition probabilities between different states [T98/115].

Schematically, proteins can be represented as compact self-avoiding walks. On a lattice, these correspond to the so-called Hamiltonian paths. For a walk of N steps, the number of Hamiltonian paths grows as μ^N, where μ is a characteristic of the lattice. This exponential number of paths is reminiscent of the number of metastable states in a spin glass. We have therefore computed the distribution law of the fraction of common bonds (or overlaps) between two Hamiltonian paths. We have shown that two paths have a minimum and a maximum possible overlap. This means in particular that two compact Hamiltonian paths with overlap greater than the upper limit must be identical. Such a property can be crucial for counting the number of constraints needed to specify the structure of a protein [T98/128].

We had studied earlier the effect of the peptic bond electric dipoles on the folding of a protein. We had shown that the dipolar order that may appear could be identified with the secondary structures of proteins. We have now considered a simplified model consisting of a magnetic polymer on a lattice such that each monomer carries a spin (Ising, XY or Heisenberg like) with short-ranged ferromagnetic interaction. We have shown that, as a function of temperature, such a polymer undergoes a phase transition between a swollen high temperature phase without magnetization and a collapsed, magnetic, low temperature phase. Besides, a magnetic field can be used to control this phase transition. Synthesis of such materials could be of great practical interest [T99/008].

Some proteins such as chlorophyll have a function of electron transport through cellular membranes. To assure this transport the proteins undergo conformational transformations. We are currently studying a model of a random chain on a lattice, the chain being a classical self-avoiding walk that represents the protein. Along the chain, electrons (considered as quantum objects) can hop from site to site with a hopping constant t_0 (tight-biding model). Besides, we suppose that if two monomers are spatially close an electron can jump from one monomer to the other with a hopping constant t_1. We have shown that for this model there is a collapse phase transition: at high temperature the chain is swollen, because of entropy; at lower temperature, as the chain collapses its entropy decreases but lateral jumps of electrons are energetically favoured: this competition provokes the phase transition [in preparation].

4.3.2 Knotted polymers in two dimensions (E. Guitter, E. Orlandini)

Once closed onto itself, a polymer forms in general knots which limit its accessible configurational space. The statistics of a polymer in the presence of knots is still poorly understood. We developed a lattice model for knotted polymers allowing to explore this statistics numerically in two dimensions (projected knots). Our main results are the *localization* of primary knots along the polymer chain, and the existence of a transition between a self-avoiding regime and a branched polymer regime by increasing the fugacity associated with the number of crossings in this two-dimensional projection of the knots [T98/087].

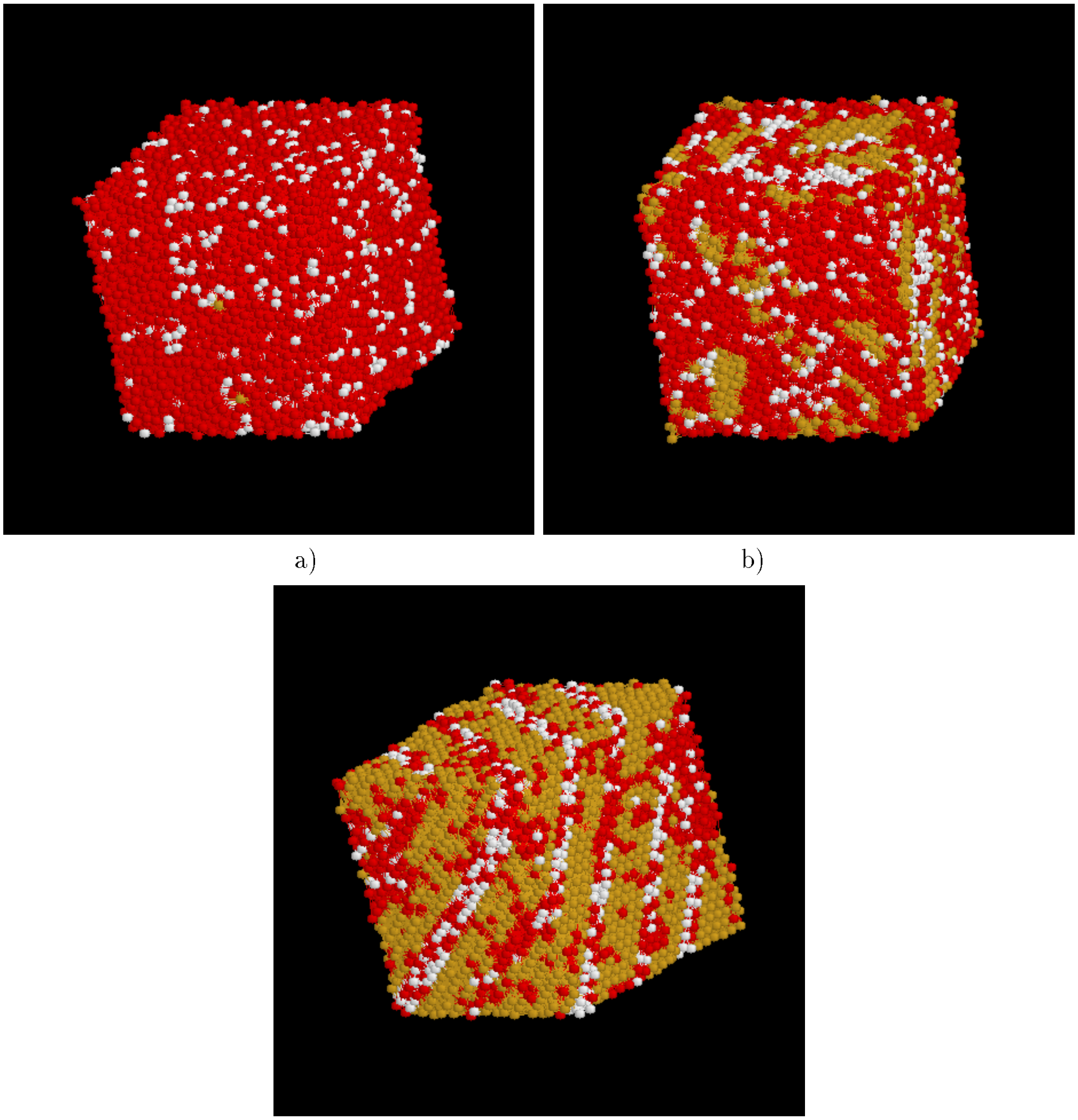
4.4 Coulombic systems: electrolytes and polyelectrolytes (H. Orland)

We have investigated the behaviour of polyelectrolytes made of weak acids in acid/base neutralization reactions in collaboration with the experimental group of L. Leibler (ELF-CNRS). The following problem, though a basic question in polymer chemistry, has scarcely been studied: what is the titration curve of a weak polyacid by a strong base? In the system under study, the polyelectrolyte is weakly charged in pure water and is in a collapsed phase (because it is built of hydrophobic monomers). By adding NaOH, the weak acid dissociates and the polymer swells due to the presence of charges on it. We calculated the titration curve of this polyelectrolyte and also the liquid structure function, which is being measured currently.

We have studied a simple model for "drug delivery": a drug is inserted in a vesicle (lipidic bilayer) and is to be delivered into the cell. The following experimental technique is under study: the drug is introduced inside the vesicle together with a weak polyacid; as the pH inside the cell is higher than outside, the polyacid dissociates; if the lipid forming the vesicle is suitably chosen such that the vesicle is destabilized at high pH, the drug is liberated into the cell. Therefore, we studied a system with three phases: water, lipid and a weak polyacid. The interactions between water and the lipids are repulsive (thus stabilizing the vesicle), and they are weakly repulsive between the lipids and the neutral polyacid. The polyacid is hydrophobic at weak pH (when it is neutral) but becomes hydrophilic at higher pH (due to the presence of ions on its skeleton). The phase diagram thus obtained is rather complex and reveals that the vesicle is destabilized at basic (high) pH. We are actually looking for interaction strengths for which the destabilization of the vesicle is of the first order, so that it occurs in a given region inside the cell and not progressively [in preparation].

The Poisson-Boltzmann equation is a mean-field equation that relates the charge density of an electrolyte to the electric potential. It was solved in the beginning of the century by Gouy and Chapman for the case of a charged plane in a solution of oppositely charged ions. Recent Monte Carlo simulations have shown that the mean-field result does not correctly describe the density profile of the counter-ions, especially in the vicinity of the charged surface. We calculated analytically the 1-loop corrections to the mean-field result and showed that the corrections to the Poisson-Boltzmann equation can be significant. Besides, we calculated the self-energy of an ion and the effective interaction between two ions in the solution. All these quantities can be related to experimental observables [T99/011]. Lastly, we have calculated the low-density expansion of the Coulomb gas (with one or two components) taking into account the hard-core. We have thus shown that this expansion is singular (the first term is of the type $c^{3/2}$ and the next one is $c^{5/2}$). In the case of the two-component plasma, opposite charges form pairs at low temperature [T99/016].

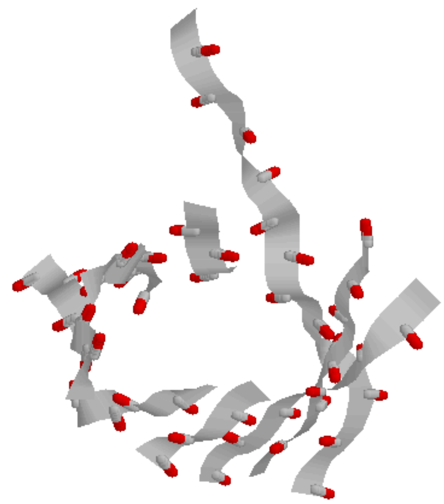
In order to take into account the effect of the hard-core repulsion on coulombic systems, we have derived a modified Poisson-Boltzmann equation. A significant new result is the saturation of the adsorption layer of the electrolytes on a charged surface. These results have been experimentally confirmed (F. Rondelez, Curie Institute) by the study of adsorption of large ions on charged Langmuir films [T00/041].



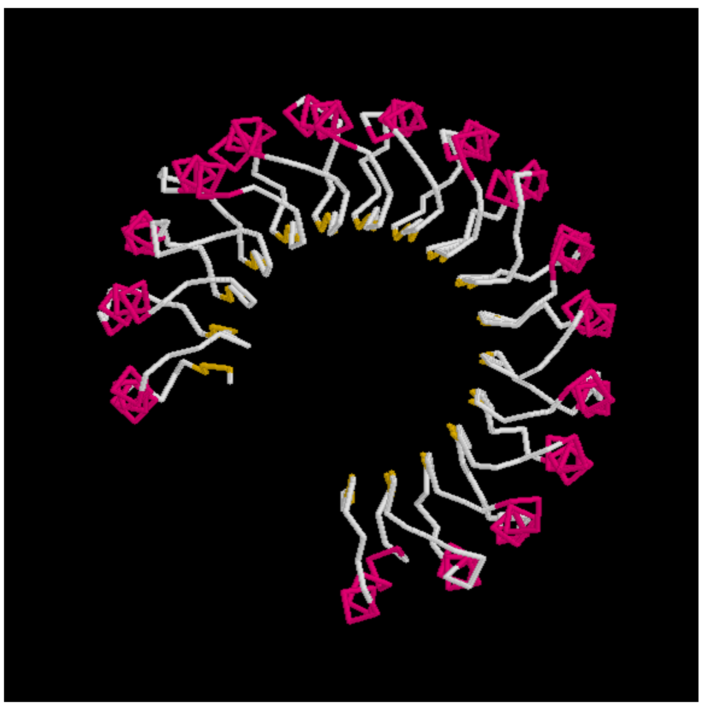
a) b)

c)

Packing with 16 300 hard spheres (packing fraction C=0.558) at 3 stages of the crystallization. Atoms are colored following their local environment: fcc (yellow), hcp (white) and others (red). a) Amorphous state; b) beginning of crystallization: small hcp and fcc clusters begin to appear; c) end of the process: fcc atoms are dominant and are clearly organized along parallel planes with hexagonal symmetry.



This picture of the ENOLASE protein shows ribbon-like strands of the main chain. The CO links are drawn (Carbon atoms, belonging to the main chain of the protein, are represented in gray and Oxygen atoms in red). This CO link materializes a dipolar moment (from O to C) that strongly influences the secondary structure of the protein. This structure is called a beta barrel because the strands enclose a region having the shape of a barrel.



Ribonuclease inhibitor (1a4y) main chain. Alpha helices are pink, beta sheets yellow and loops gray. There are 460 amino acids.

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T00/062 FÖRSTE S., LALAK Z., LAVIGNAC S., NILLES H.P., *A comment on self-tunning and vanishing cosmological constant in the brane world,* à paraître dans Phys. Lett. B [hep-th/0002164]

T00/063 CHANDRE C., MOUSSA P., *Scaling law for the critical function of an approximate renormalization,* soumis à Nonlinearity [nlin.CD/0005020]

T00/064 RICHARD P., OGER L., TROADEC J.-P., GERVOIS A., *Comparison between a 2D froth and a cut of 3D froth,* Conference on Foams, Emulsions and Applications (Eurofoam 2000), Delft, Pays-Bas, June 5-8 2000, Zitha P., ed.

T00/065 KAMENSHCHIK A.Y., MOSCHELLA U., PASQUIER V., *Chaplygin-like gas and branes in black hole bulks,* à paraître dans Phys. Lett. [gr-qc/0005011]

T00/066 BOOSÉ D., MAIN J., *Distributions of transition matrix elements in classically mixed quantum systems,* Phys. Rev. E 60, 2831-2843 (1999)

T00/067 BONCHE P., *Microscopic Description of Low-Energy Nuclear Collisions Review and Perspective,* The 14th Nishinomiya-Yukawa Memorial Symposium: Frontiers of Nuclear Collision Dynamics [invited paper], Nishinomiya, Japan, November 18-19 1999, J. Phys. Jap.

T00/068 VALOR A., HEENEN P.-H., BONCHE P., *Configuration mixing of mean-field wave-functions projected on angular momentum and particle number; application to ^{24}Mg,* Nucl. Phys. A 671, 145-164 (2000)

T00/069 BORUKHOV I., ANDELMAN D., BORREGA R., CLOITRE M., LEIBLER L., ORLAND H., *Polyelectrolyte Tritration: Theory and Experiment,* soumis à J. Phys. Chem. B

T00/070 DOREY P., PILLIN M., TATEO R., WATTS G.M.T., *One-point functions in perturbed boundary conformal field theories,* soumis à Nucl. Phys. B [hep-th/0007077]

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

T00/073 BRAX P., MANDAL G., OZ Y., *Supergravity Description of Non-BPS Branes,* soumis à Nucl. Phys. B [hep-th/0005242]

T00/074 KOSTOV I.K., *Exact Solution of the Three-colour Problem on a Random Lattice,* soumis à 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)

T00/076 BERNARDEAU F., *The large-scale structures of the Universe,* Proceedings of the Sixth International Workshop: Topics in Astroparticle and Underground Physics (TAUP 99), Collège de France, Paris, France, September 6-10 1999, Nucl. Phys. B 87, 13-20 (2000), DUMARCHEZ J., FROISSART M., VIGNAUD D., eds. (North-Holland, 2000)

T00/077 MEYER-ORTMANNS H., REISZ T., *Dynamical Linked Cluster Expansion for Spin Glasses,* à paraître dans: Recent Research Developments in Statistical Physics [cond-mat/0005412] (Transworld Research Network, India)

T00/078 VOROS A., *Exercises in exact quantization,* soumis à J. Phys. A [math-ph/0005029]

T00/079 BERNARD D., REGNAULT N., *New Lax Pair for 2d Dimensionally Reduced Gravity,* à paraître dans J. Phys. A [invited paper]

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, [hep-th/0005259]

LIST OF REFERENCES

SPhT papers before June 1998, that are referenced in the text

T95/016 **MARMI S., MOUSSA P., YOCCOZ J.-C.**, *Continued fraction transformations, Brjuno functions and BMO spaces,* Note CEA N-2788, 1995

T95/028 **MARMI S., MOUSSA P., YOCCOZ J.-C.**, *The Brjuno functions and their regularity properties,* Commun. Math. Phys. 186, 265-293 (1997)

T96/108 **BERNARDEAU F., VAN WAERBEKE L., MELLIER Y.**, *Weak lensing statistics as a probe of Ω and power spectrum,* Astron. Astrophys. 322, 1-18 (1997)

T97/043 **KOSOWER D.A.**, *Evolution of parton distributions,* Nucl. Phys. B 506, 439-467 (1997)

T97/163 **DOREY P., POCKLINGTON A., TATEO R., WATTS G.**, *TBA and TCSA with boundaries and excited states,* Phys. Lett. B 525, 641-663 (1998)

T97/167 **MEHTA M.L., NORMAND J.-M.**, *Probability density of the determinant of a random hermitian matrix,* J. Phys. A 31, 5377-5391 (1998)

T98/010 **CHABANAT E., BONCHE P., HAENSEL P., MEYER J., SCHAEFFER R.**, *A Skyrme parametrization from subnuclear to neutron star densities. Part II: Nuclei far from stabilities,* Nucl. Phys. A 635, 231-256 (1998)

T98/011 **CHABANAT E., BONCHE P., HAENSEL P., MEYER J., SCHAEFFER R.**, *A Skyrme parametrization from subnuclear to neutron star densities,* Nucl. Phys. A 627, 710-746 (1997)

T98/034 **PARK T.-S., KUBODERA K., MIN D.-P., RHO M.**, *The solar proton burning process revisited in chiral perturbation theory,* Astrophys. J. 507, 443-453 (1998) [astro-ph/9804144]

ANNEXES

LES THÈSES SOUTENUES AU SPhT

• Stefan WEINZIERL
"QCD corrections to $e^+e^- \to 4$ jets", thèse de l'Université de Paris 11 soutenue le 8/9/98.

• Christophe GROJEAN
"Symétries et brisures de symétries au-delà de la théorie électrofaible", thèse de l'Université de Paris 11 soutenue le 4/5/99.

• Vivien BRUNEL
"Systèmes de spins quantiques unidimensionnels : désordre et impuretés", thèse de l'Université de Paris 11 soutenue le 29/6/99.

• Marc BOCQUET
"Chaînes de spins, fermions de Dirac et systèmes désordonnés", thèse de l'École polytechnique soutenue le 14/1/2000.

PRIX, MÉDAILLES, DISTINCTIONS

• BALIAN Roger
- Officier de l'Ordre du mérite (1998),
- Fellow of the Institute of Physics (1999).

• BERNARDEAU Francis
- Prix Compaq de la Société française d'astronomie et d'astrophysique (septembre 1999).

• OLLITRAULT Jean-Yves
- Prix Thibaud 2000 (décerné par l'Académie de Lyon).

• RHO Mannque
- Prix de la "National Academy of Sciences of Republic of Korea " (1999),
- Elu à la "Korean Academy of Science and Technology" (1999).

• ZINN-JUSTIN Jean
- Harris visiting scholar du MIT (1999).

ENCADREMENT DE JEUNES CHERCHEURS

• Thèses en cours au SPhT

Liste des étudiants préparant une thèse au SPhT au 1er juin 2000. Entre parenthèses figurent le nom du directeur de thèse et l'année prévue pour la soutenance.

Gabrielle BONNET (F. David, 2000)
Karim BENABED (F. Bernardeau, 2001)
Guillaume DE SMEDT (J. M. Luck, 2002)
Mai DINH (J.Y. Ollitrault, 2002)
Thomas DUGUET (P. Bonche, 2002)
Gregory MOREAU (M. Chemtob, 2000)
Stéphane MUNIER (R. Peschanski, 2000)
Nicolas REGNAULT (D. Bernard, 2001)
Géraldine SERVANT (C. Savoy, 2001)

• Thèses extérieures

Les physiciens du SPhT encadrent, complètement ou partiellement, des étudiants appartenant à d'autres organismes français ou étrangers.

GERVOIS Annie
- Co-direction de la thèse de Patrick Richard (Rennes 1, soutenance le 23 juin 2000).

NORMAND Christiane
- Directeur de thèse de Nathalie Mukolobwiez (soutenue en juin 1998 à Orsay).

• Stages DEA

BONCHE Paul
- Stage de DEA de Thomas Duguet (DEA de physique quantique, 1999).

PESCHANSKI Robi
- Stage de DEA de Nils Marchal (DEA de physique théorique, 1999).

• Stages X

BONCHE Paul
- Frédéric Legoll (1998).

PASQUIER Vincent
- Nicolas Vanhaecke et Stéphane Fidanza (1999).

• Divers

GOLINELLI Olivier

- Julien Lamarcq, stage Supelec (printemps 1998).

PESCHANSKI Robi

- Stage de jeunes chercheurs étrangers : Leszek Motyka et Beata Ziaja.

ACTIVITÉS PÉDAGOGIQUES

Sont indiqués ici uniquement les cours donnés dans des Universités ou des Grandes Ecoles pendant les années scolaires 1998-1999 et 1999-2000, et ceux ayant donné lieu à une publication.

• Premier et deuxième cycle d'Université

• BENABED Karim
- TD de FORTRAN, Licence de physique fondamentale - Orsay (1998-1999),
- Cours et TD de C, Licence de sciences physiques - Orsay (1998-1999),
- TD de FORTRAN, Licence de physique fondamentale - Orsay (1999-2000),
- TD de C++, Maitrise EEA - Orsay (1999-2000).

• BONNET Gabrielle
- DEUG biologie Orsay (1998-1999 et 1999-2000).

• BRUNEL Vivien
- Premier cycle PCEM Orsay (1998-1999 et 1999-2000).

• DAVID François
- Mécanique quantique avancée, Magistère inter-universitaire de physique, ENS-Ulm (1998-1999).

• DE SMEDT Guillaume
- Cours et TD DEUG SNV (Sciences nature vie) à Jussieu (1999-2000).

• DINH Mai
- TD de physique en PCEM Orsay (1999-2000).

• MISGUICH Grégoire
- TD d'informatique en classe préparatoire (logiciel Maple), Lycée Lavoisier (1999-2000).

• MOREAU Grégory
- Enseignement en classe de préparation aux concours des ENSI, à l'Université Paris VII Denis-Diderot (1998-1999),
- TD de thermodynamique physique du DEUG "Sciences de la nature et de la vie" (SNV) à l'Université Paris VII Denis-Diderot (1999-2000).

• OLLITRAULT Jean-Yves
- Cours de mécanique quantique relativiste, Magistère inter-universitaire de physique 2^{e} année, commun avec le DEA CPM (1998-1999 et 1999-2000).

• REGNAULT Nicolas
- Projet professionnel, 1re année de DEUG à Orsay (1999-2000).

• SERVANT Géraldine
- TD d'electromagnétisme DEUG MIAS (Maths-informatique) (1998-1999),
- TD et TP de physique pour DEUG "Sciences de la vie" (1999-2000),

- Probabilités et statistiques pour la Licence du Magistère EEA (Electronique, électrotechnique et applications) (1998-1999 et 1999-2000).

• ZINN-JUSTIN Jean

- Université de Cergy-Pontoise : "Fonctions analytiques", cours de Licence,

- Magistère inter-universitaire de physique, 2^{e} année : "Intégrale de chemin".

• Grandes Ecoles

• BALIAN Roger

- Ecole polytechnique (jusqu'à l'été 1998) : Cours de physique statistique. Organisation de l'option de physique théorique.

• BLAIZOT Jean-Paul

- Ecole polytechnique : "Application de la théorie des groupes à la physique", "Approfondissement de physique nucléaire".

• DUGUET Thomas

- TD de mécanique quantique, 1re année de l'Ecole centrale de Paris.

• GIRAUD Bertrand

- "Réseaux de neurones", Ecole des mines de Paris.

• JOLICŒUR Thierry

- Ecole polytechnique TD "Mécanique statistique" 1re année. "Théorie statistique des champs" 2^{e} année.

• OLLITRAULT Jean-Yves

- ESPCI, préceptorats de physique quantique, 1re année (1998-1999), préceptorats de méthodes mathématiques, 1re et 2^{e} année (1999-2000).

• RIPKA Georges

- TP en mécanique quantique et en mécanique statistique à l'ENSTA.

• Troisième cycle d'Université

• BERNARDEAU Francis

- Cours d'option de cosmologie au DEA "Astrophysique et techniques spatiales", Meudon (1998-1999 et 1999-2000).

• BRAX Philippe

- TD de "Théorie de jauge" et "Modèle standard" au DEA de physique théorique (1998 et 1999).

• De DOMINICIS Cirano

- Université fédérale Rio Grande do Norte Natale : "Mécanique statistique des systèmes critiques" (août-septembre 1998).

• DI FRANCESCO Philippe

- "Mécanique statistique et gravitation bidimensionnelle", DEA de mathématiques, Paris 7 (1998-1999),

- "Modèles de matrices intégrables", DEA de mathématiques, Paris 7 (1999-2000).

• GINGOLD Marc

- DESS "Biologie et pharmacologie du vieillissement", Institut Jacques Monod, Université Denis Diderot (1998-1999 et 1999-2000).

• LUCK Jean-Marc

- Cours au DEA "Mécanique et énergétique" à l'IUSTI (Institut universitaire des systèmes thermiques industriels, Château-Gombert, Marseille) : "Introduction aux systèmes désordonnés et aux transitions de phases" (1998-1999 et 1999-2000),

- Cours à l'école doctorale de Strasbourg : "Systèmes désordonnés unidimensionnels" (1999-2000).

• MUNIER Stéphane

- TD de mécanique quantique relativiste, tronc commun du DEA de physique quantique, ENS (1999-2000).

• NORMAND Christiane

- DEA Dynamique des fluides et des transferts (1998-1999 et 1999-2000).

• OLLITRAULT Jean-Yves

- Cours de mécanique quantique relativiste, DEA CPM (champs, particules, matière), 1998-1999 et 1999-2000,

- Cours de théorie quantique des champs, DEA physique quantique (1999-2000).

• VOROS André

- "Méthodes semi-classiques en mécanique quantique" (1998-1999), "Analyse semi-classique et applications" (1999-2000) (DEA de mathématiques à l'Université Paris 7),

- "Méthodes de quantification semi-classique exacte", Ecole doctorale de l'Université de Reims (1999-2000).

• ZINN-JUSTIN Jean

- Université de Cergy-Pontoise : "Introduction au groupe de renormalisation", DEA de Physique Statistique.

• Cours ayant donné lieu à publication

• BALIAN Roger

- Les Houches (mars 1998) : "Distribution of galaxies : scaling vs fractality", dans "Order, chance and risk" (Springer-EDP Sciences, 1999),

- Les Houches (juin 1998) : "Correlation functions through variational methods", dans "Quantum Field Theory : Perspective and Prospective" (Kluwer, 1999).

• OLLITRAULT Jean-Yves

- Ecole Joliot-Curie de physique nucléaire, Maubuisson (septembre 1998).

• SAVOY Carlos

- Cours à l'Ecole de Cargèse "Gauge Hierarchies and Fermion Hierarchies" (juillet 1998).

• ZUBER Jean-Bernard

- Cours à Bariloche, Argentine : "CFT, BCFT, ADE and all that", [T00/072], janvier 2000, en cours de publication.

• Cours du vendredi au SPhT, Saclay

• BALIAN Roger

- "Bases de la mécanique statistique hors d'équilibre" (1999).

• BERNARD Denis

- "Turbulence pour (et par) des amateurs" (juin 2000).

• BERSHADSKY Michael

- "String theory" (octobre 1999).

• BLAIZOT Jean-Paul

- "Théorie des champs à température finie" (janvier-mars 2000).

• BRAX Philippe

- "La violation CP", dans le cadre de la série de cours "quelques sujets "chauds" en physique des particules".

• BROS Jacques

- "Aspects structurels de la théorie quantique des champs" (mai 2000).

• De DOMINICIS Cirano

- "Théorie des champs des systèmes désordonnés" (2000).

• KOSTOV Ivan

- "Théorie des cordes et modèles de matrices" (1999).

• LAVIGNAC Stéphane

- "Les neutrinos" (19 février 1999), dans le cadre de la série de cours "quelques sujets "chauds" en physique des particules".

• SAVOY Carlos

- "Physique des saveurs" (janvier 1999).

• VOROS André

- "Méthodes de quantification semi-classique exacte" (1998).

• ZINN-JUSTIN Jean

- "Quantum Field Theory at Finite Temperature : an Introduction" (2000).

ÉDITION SCIENTIFIQUE

Des physiciens du SPhT contribuent en tant que rédacteurs en chef, éditeurs, ou membres des bureaux éditoriaux, à diverses revues scientifiques.

• BALIAN Roger
- Editeur pour la série "Texts and monographs in physics" (Springer),
- Editeur pour les comptes-rendus de l'Académie des sciences (jusqu'à fin 1998).

• BILLOIRE Alain
- Editeur de International Journal of High Speed Computing.

• BLAIZOT Jean-Paul
- Editeur de Physics Letters B.

• BROS Jacques
- Membre du Comité de rédaction des annales de l'Institut Henri Poncaré, section physique théorique, jusqu'au 31/12/1999.

• GERVOIS Annie
- Advisory Editor à Physica A.

• MOREL André
- Membre de l'International Editorial Council de Acta Physica Polonica.

• ORLAND Henri
- Editeur à The European Physical Journal B.

• PASQUIER Vincent
- Annales de l'IHP jusqu'en 2000.

• RHO Mannque
- Editeur, Int. J. Mod. Phys. E.

• VOROS André
- Membre du Comité éditorial du Journal of Physics A (depuis janvier 2000).

• ZINN-JUSTIN Jean
- Nuclear Physics B,
- Forschritte der Physik,
- Journal of Physics A (jusqu'en juin 1999).

• ZUBER Jean-Bernard
- Annales de l'Institut Henri Poincaré.

LIVRES ET CHAPITRES DE LIVRES

• BALIAN Roger

- Les états de la matière et leurs symétries, dans "Symétrie et brisure de symétrie" (EDP Sciences, 1999),

- Présentation des travaux de Jules Horowitz en physique théorique, dans le tome I de ses œuvres (CEA, 1999),

- Postface sur les problèmes énergétiques, dans un livre de Ayerdhal "L'homme aux semelles de foudre" (Flammarion, 2000).

• BLAIZOT Jean-Paul

- Traduction russe de "Quantum Theory of Finite Systems", Blaizot and Ripka [T98/150].

• DI FRANCESCO Philippe

- CFT, P. Di Francesco, P. Mathieu et D. Senechal, GTCP, Springer (1997) seconde édition 1999.

• MALLICK Kirone

- Rédaction d'un cours, avec E. Akkermans, pour l'Ecole "Topological Aspects of Low Dimensional systems' (juillet 1999).

• ZINN-JUSTIN Jean

- Troisième révision de la troisième édition de Quantum Field Theory and Critical Phenomena, (Clarendon Press, Oxford 1989, 2^{e} éd. 1993, 3^{e} éd. 1996) 1000 pages.

ACTIONS DE VULGARISATION

• BALIAN Roger

- Trois Articles dans “la Jaune et la Rouge” (Mathématiques et sciences de la nature, 1998 ; Centenaire de la radioactivité, 1999 ; Problèmes énergétiques, 2000),

- Conférence donnée dans le cadre de “Physique et interrogations fondamentales” de la SFP (société française de physique), sur les symétries (1998),

- Conférences sur “la Radioactivité, un siècle après”, données l'une sous la coupole de l'Institut, l'autre à l'Ambassade de Pologne à Londres (fin 1998). Publié par l'Académie des sciences,

- Participation à deux émissions de radio (France Culture, 1998 et 2000),

- Participation à plusieurs “Bars des sciences” de la SFP (Paris et banlieue, Normandie, 1998 et 1999),

- Membre du Conseil d'administration de Science-Contact, organisme d'information scientifique,

- Assistance à plusieurs journalistes scientifiques,

- Membre du jury du Prix Roberval, décerné à des ouvrages technologiques, depuis 1998.

• BONCHE Paul

- Responsable du CESEN, Cercle d'études sur l'énergie nucléaire,

- Coordination scientifique et membre du comité de rédaction du livre :“Électronucléaire, Une présentation par des physiciens”, publication du CESEN, Cercle d'études sur l'énergie nucléaire (Publication DSM, ISBN : 2-11-091405-X),

- 9^{e} Festival des sciences de Chamonix Mont-Blanc, 12-15 mars 1999. Internant invité à une rencontre intitulée : “Peut-on se passer du nucléaire ?”.

• BROS Jacques

- Conférence dans le cadre de la “Semaine de la science” (21/10/1999) destinée aux élèves du lycée franco-allemand de Buc : “De la géométrie du cercle à l'espace-temps de la relativité” [T00/053].

• DAVID François

- Organisation de conférences grand public dans le cadre de l'Ecole des Houches.

• GIRAUD Bertrand

- Semaine de la science 1999 : intervention au Collège Bergson de Montigny-le-Bretonneux.

• GOLINELLI Olivier

- Comité éditorial de “Phases Magazine, la lettre du DRECAM et du SPhT”.

• MOREL André

- Semaine de la science 1999 : deux interventions au Collège Pierre de Nohlac de Versailles.

- SCHAEFFER Richard

- Article d'ouverture d'un dossier sur la matière noire à paraître dans “La Recherche”.

- ZINN-JUSTIN Jean

- “Renormalisation et groupe de renormalisation : les infinis en physique microscopique contemporaine”, Colloque de la Société française de physique : “Physique et interrogations fondamentales”, Paris, France [T00/002], 27 octobre 1999 ; conférence à l'Université de Lille sur un sujet voisin (2000).

ORGANISATION DE CONFÉRENCES OU D'ÉCOLES

• BAUER Michel et DI FRANCESCO Philippe

- Journées C. Itzykson, satellite de la conférence Stat Phys 1998, Institut H. Poincaré.

• BLAIZOT Jean-Paul

- Nuclear Matter in Different Phases and Transitions, workshop, Les Houches 31 mars-10 avril 1998, avec X. Campi et M. Ploszajzak,

Co-organisateur de la conférence Nucleus-Nucleus, Strasbourg, Juillet 2000.

• BONCHE Paul

- Coorganisateur de la conférence INPC98, 24-28 août 1998, Paris,

- Membre du Conseil scientifique de l'École Joliot-Curie.

• DAVID François

- Ecole d'été de physique théorique des Houches, Session 69 : "Aspects topologiques de la physique de basse dimension", juillet 1998,

- Ecole d'été de physique théorique des Houches, Session 70 : "Astronomie spatiale infrarouge, aujourd'hui et demain", août 1998,

- Ecole d'été de physique théorique des Houches, Session 71 : "L'Univers primordial", juillet 1999,

- Ecole d'été de physique théorique des Houches, Session 72 : "Ondes de matière cohérentes", août 1999.

• DUPLANTIER Bertrand

Directeur adjoint de l'IHP.

• GERVOIS Annie

- STATPHYS 20, juillet 98.

• GUIDA Riccardo

- Cours du vendredi du SPhT 1999-2000 et 2000-2001.

• IAGOLNITZER Daniel

- STATPHYS 20, 20^{e} conférence internationale IUPAP de physique statistique, 20-24 juillet 1998 (co-président),

- TH-2002, Conférence internationale en physique théorique, Paris, juillet 2002, en préparation (co-président).

• JOLICŒUR Thierry

- Session de 3 mois à l'Institut Henri Poincaré "Fermions fortement corrélés".

• LUCK Jean-Marc

- Co-organisation avec Claude Godrèche (SPEC) de la 5^{e} Rencontre Claude Itzykson (Saclay, 20-23 juin 2000) : "Dynamique des systèmes hors d'équilibre".

• NAVELET Henri

- Membre du Comité d'organisation de l'Ecole de Gif-sur-Yvette depuis 1995.

• ORLAND Henri

- Co-organisateur d'une école d'été à l'ISI (Turin) sur le repliement des protéines (fin juin 1998),

- Co-organisateur avec R. Netz (MPI Teltow) de la 4^{e} rencontre Claude Itzykson : "Theoretical approaches to soft and biological matter" (Saclay, fin juin 1999).

• PESCHANSKI Robi

- Workshop on small-x Physics 1998 (Zeuthen), 1999 (Jérusalem), 2000 (Oxford),

- Deep Inelastic Scattering, session théorique 1998 (Bruxelles).

• RHO Mannque

- Co-chair, International Workshop on "Explosive Phenomena in Astrophysical Compact Objects," Korea Institute for Advanced Study, Seoul, Korea, 2000.

• SAVOY Carlos

- Membre du Comité d'organisation des Rencontres de Moriond, jusqu'en 1999.

• SCHAEFFER Richard

- Les Houches, juillet 1999 "L'Univers primordial".

• ZUBER Jean-Bernard

- Co-organisateur avec C. De Witt du workshop des Houches : Quantum Field Theory, Perspective and Prospective, juin 1998.

COLLABORATIONS INSTITUTIONNALISÉES

A l'intérieur du CEA

Le SPhT participe à 6 "segments" CEA :

- Physique des particules (31),
- Physique nucléaire (32),
- Astrophysique (33),
- Chimie et ingénierie moléculaire (34),
- Science des matériaux et nanostructures (46),
- Supraconductivité, magnétisme et cryotechnologie (47).

GDR

- GDR "Structures non perturbatives en théorie des champs et des cordes" (responsable A. NEVEU) : BERNARD, DAVID, PASQUIER, ZUBER,
- Programme national de cosmologie : BERNARDEAU, SCHAEFFER, VALAGEAS,
- GDR GEDEON, "Gestion des déchets par des options nouvelles" : BONCHE,
- GDR "Aspects théoriques et expérimentaux de la recherche de la super-symétrie" (responsable P. BINETRUY) : BRAX (responsable du groupe saveur), CHEMTOB, GROJEAN, LAVIGNAC, MOREAU, SAVOY (membre du Conseil du GDR), SCHAEFFER, SERVANT,
- GDR "Structure des systèmes nucléaires dans des conditions extrêmes" (responsable P. SCHUCK) : BLAIZOT, BONCHE, DUGUET,
- GDR PMHC "Physique des milieux hétérogènes complexes", remplacé au 01/01/00 par le GDR MIDI (milieux divisés) : GERVOIS,
- GDR "Fermions : systèmes fortement corrélés, systèmes quantiques mésoscopiques, systèmes de spins" (responsable M. GABAY) : PASQUIER, PENC,
- GDR "Structure interne des étoiles" : SCHAEFFER.

Programmes Internationaux

- Réseau TMR "Integrability, Non Perturbative Effects and Symmetry in Quantum Field Theory" (responsable E. CORRIGAN) : BERNARD, BRAX, DI FRANCESCO, KOSTOV, PASQUIER, ZUBER,
- Réseau TMR "Gravitational Lensing : New constraints on Cosmology and The Distribution of Dark Matter" (responsable R. ELLIS) : BERNARDEAU,
- Réseau TMR "Physics beyond the Standard Model"(responsable I. ANTONIADIS) : LAVIGNAC,

- Réseau TMR "Quantum Chromodynamics and the Deep Structure of Elementary Particles (responsable J. STIRLING) : MUNIER, PESCHANSKI,

- Réseau IHP "Discrete Random Geometries : from solid state physics to quantum gravity" (à partir de mars 2000, responsable Des JOHNSTON) : BONNET, DAVID, DI FRANCESCO, EYNARD, GUITTER, KOSTOV,

- European Research Training Network "Mathematical Aspects of Quantum Chaos" (à partir de 07/00) (responsable J. ROBBINS) : VOROS,

- Réseau ESF SPHINX "Statistical physics of glassy and non-equilibrium systems" (responsable D. SHERRINGTON) : BILLOIRE, GAREL, ORLAND,

- Centre franco-indien pour la Promotion de la Recherche Avancée (CEFIPRA) : BILLOIRE, BLAIZOT, LACAZE, OLLITRAULT,

- Programme d'actions intégrées "Amadeus" (MAE) avec Vienne. Terminé en 1999 : BLAIZOT,

- Programme COFECUB (MAE) avec les Universités de Sao Paulo et Natal : De DOMINICIS,

- Conventions de subvention CEA/MAE, collaboration avec l'Université Eötvös (Budapest) : De DOMINICIS et VOROS,

- Programme de collaboration sur la construction d'un accélérateur linéaire européen dans le cadre du "European Commity for Futur Accelerators" (ECFA) à DESY : MOREAU,

- Accord CNRS-CNR Italie (1998-1999), renouvelé pour 2000-2001 : collaboration avec J.-C. Yoccoz (Collège de France) et S. Marmi (Universités de Florence et Udine, Italie) : MOUSSA,

- Programme de collaboration COFECUB (MAE) avec le Brésil : ORLAND,

- Programme d'actions intégrées franco-polonais "Polonium" du MAE 1997-1999 et 2000-2001 : SAVOY,

- Programme ECOS-Sud (MAE), avec le Laboratoire TANDAR, CNEA, Buenos Aires (Argentine) : VOROS.

ADMINISTRATION DE LA RECHERCHE

• BALIAN Roger

- Président (1998-1999) puis vice-président (1999-2000) de la Société française de physique et activités associées (rapports avec les pouvoirs publics, relation avec d'autres sociétés savantes en France et à l'étranger, animation scientifique, problèmes d'enseignement et d'emploi, édition, congrès, expositions, jurys de prix, etc),
- Délégué de la section de physique de l'Académie des sciences (activités d'organisation) ; membre du Comité de réflexion sur la réforme de l'académie,
- Président du groupe de prospective sur les neutrons : élaboration d'un rapport (1998),
- Membre du Conseil scientifique de l'Ecole normale supérieure de Lyon,
- Membre du Conseil d'administration du Laboratoire Léon Brillouin,
- Membre du Comité d'évaluation externe du CNRS (1998),
- Participation aux travaux de l'Office parlementaire d'évaluation des choix scientifiques et technologiques sur "Les conditions d'implantation d'un nouveau synchrotron" et "Le rôle des très grands équipements"; contributions au rapport (tome I, 2000),
- Membre de la Commission de réflexion sur l'enseignement des mathématiques auprès du Comité national des programmes,
- Contributions au séminaire de Malvern organisé en 1999 par la Société européenne de physique, sur l'avenir de la physique, son appréciation par le grand public et la désaffection des étudiants pour la science.

• BERNARD Denis

- Membre du Comité scientifique extérieur du laboratoire de physique mathématique et théorique (LPM) de Montpellier, 1999.

• BILLOIRE Alain

- Membre du Conseil scientifique pour le calcul centralisé (DSM),
- Membre du Comité d'orientation de l'informatique scientifique et des réseaux (DSM).
- Membre du groupe de travail NuPECC "Computational Nuclear Physics", rapport à paraître.

• BLAIZOT Jean-Paul

- Membre du Conseil de département SPM du CNRS jusqu'en 2000,
- Membre de la Commission de spécialistes 29^{e} section à Orsay (membre suppléant), 29^{e} section à Nantes (membre nommé).

• BONCHE Paul

- Responsable du segment 32 "Physique nucléaire" (CEA) ,
- Membre du Conseil scientifique du GANIL,
- Membre du CSTS du DAPNIA/SPhN,

- Chairman du PAC Vivitron/EUROBALL,
- ECT* (European Center for Theoretical Physics and related areas) : Link member pour la France, Représentant du CEA/DSM à l'EJFRC, European Joint Finance Review Committee.

• DAVID François
- Directeur de l'Ecole de physique des Houches,
- Membre du Comité scientifique extérieur du CPT Marseille 1998,
- Membre du Comité scientifique du LPTHE de Jussieu (UMR 7589) du 6 octobre 1998,
- Membre de la Commission de spécialistes, Université Paris 6, 29^{e} section.

• LACAZE Robert
- Membre du Comité d'exploitation des moyens de calcul centralisés du CEA (COMEX-Calcul),
- Membre du Comité CP6 "systèmes modèles" de l'IDRIS (CNRS).

• ORLAND Henri
- Membre du Comité d'audit du CNRS du laboratoire de Physique théorique de l'Université Paul Sabatier de Toulouse (novembre 1998),
- Membre du Comité national de la recherche scientifique depuis février 2000.

• SAVOY Carlos
- Membre du Comité de sélection des bourses CERN (IN2P3).

• ZINN-JUSTIN Jean
- Membre du CA des Editions de physique, de la Commission des publications de l'EPS,
- Commission calcul du HLRZ (Jülich) organisme chargé de fournir des moyens de calcul centralisé aux universités allemandes,
- Conseil scientifique externe du laboratoire de physique théorique de l'Institut Dubna,
- Expert auprès de la Deutsche Forschungsgemeinschaft (DFG) pour les théorie des champs sur réseau,
- COS et Conseil scientifique de l'Institut d'etudes scientifiques de Cargése,
- Membre du CA de l'Ecole des Houches,
- Présidence du Conseil scientifique pour le calcul centralisé de la DSM,
- Membre des CSTS du Service de physique des particules (DAPNIA).

• ZUBER Jean-Bernard
- Président de la Commission 02 du Comité national de la recherche scientifique.

LE GROUPE DE DOCUMENTATION SPhT-SPEC

Notre bibliothèque “de proximité” est riche d'un fonds de plus de 9000 ouvrages et souscrit à plus de 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. Un comité de sélection des acquisitions, animé par Bruno Savelli, rassemble régulièrement des physiciens du service pour choisir les nouveaux ouvrages qui viennent enrichir notre fonds.
Jusqu'à son départ à la retraite en mars 2000, Jeanine Delouvrier a assuré, parmi toutes ses activités, l'essentiel de la bonne tenue des locaux, du matériel et des ouvrages. L'ensemble de ces tâches sont poursuivies par Bruno Savelli et Philippe Fontaine, qui est arrivé dans le service au début de l'année 2000. Claudine Verneyre assure la maintenance informatique locale et gère la base des annonces de séminaires.
Le secrétariat scientifique assure la gestion des publications et Liliane Dumets participe également au secrétariat d'édition d'une revue scientifique. A la suite du départ de Josiane Beucher, le secrétariat scientifique a été reconstitué par l'arrivée de Nathalie Pelletier en mars 2000.
Le serveur Web externe du SPhT (`www-spht.cea.fr`) présente l'activité du service et offre un accès à l'essentiel des informations créées en interne : textes des publications, annonces de séminaires, etc. Une nouvelle version de ce serveur Web est en cours de développement.
Le groupe de documentation, sous la responsabilité de Marc Gingold, joue un rôle de support important dans l'activité du SPhT. Les dernières années ont vu, à la suite de retraites et de mutations, un changement important du personnel. Ces faits, associés aux progrès de l'informatisation, sont source de perturbations et impliquent un effort d'organisation et de formation.

Josiane BEUCHER (Secrétariat scientifique), jusqu'au 31 décembre 1999
Jeanine DELOUVRIER (Bibliothèque), partie à la retraite le 31 mars 2000
Liliane DUMETS (Secrétariat scientifique)
Philippe FONTAINE (Bibliothèque), arrivé le 1er janvier 2000
Marc GINGOLD (Responsable du groupe)
Nathalie PELLETIER (Secrétariat scientifique), arrivée le 1er mars 2000
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 et de la mise en œuvre des 35 heures. 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".

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'etat condensé, les atomes et les molécules (DRECAM). En 1999 les différents sous-groupes informatiques du DRECAM ont été regroupés sous la direction de Brigitte Gagey. Pour le SPhT, la gestion informatique reste pour l'essentiel assurée localement par une équipe interdépartementale de quatre personnes : Laurent de Seze, responsable du groupe, et Anne Capdepon du DRECAM ; Catherine Bourgois et Nathalie Ravenel du SPhT. Une $5^{ème}$ personne, présente à temps partiel, Claudine Verneyre, assure un support spécifique au SPhT. Par ailleurs, le service bénéficie du support technique pour les PC scientifiques et administratifs, apporté respectivement par les équipes d'Alain Buteau et de Christian Juret du DRECAM. L'architecture retenue, à base de serveurs Unix, de terminaux X, de PC et de MacIntosh, permet à l'équipe système d'assurer l'administration de plusieurs dizaines de serveurs et stations et de plusieurs centaines de terminaux X répartis sur l'ensemble du site de Saclay. Le système est en constante évolution pour s'adapter aux besoins des utilisateurs et suivre les progrès technologiques.

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 biprocesseur “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”. Un serveur Sun “kontiki” est utilisé en particulier pour la documentation et le Web.

Les postes de travail

Le poste de travail standard est le terminal X équipé d'un écran couleur 19” (environ 80 postes). Deux serveurs Windows multi-utilisateurs (Metaframe) offrent l'accès aux logiciels bureautiques standards à partir des terminaux X. Une vingtaine de PC et une dizaine de MacIntosh permettent de répondre à des besoins spécifiques, entre autre au niveau des secrétariats scientifique et administratif. L'utilisation sur ces ordinateurs personnels d'un logiciel serveur X-Window permet d'accéder au système Unix dans les mêmes conditions que les terminaux X.

Le calcul centralisé

Les physiciens disposent pour leurs gros calculs des moyens de calcul centralisés du CEA civil : un ordinateur vectoriel VPP5000 Fujitsu à 15 processeurs et un ordinateur parallèle Compaq à 232 processeurs. 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. Citons parmi les projets importants du SPhT des simulations en mécanique statistique et des calculs de structure nucléaire.

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 DIST.

Depuis le début 2000, une commission informatique se réunit régulièrement. Son objectif est d'avoir une reflexion 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)
Nathalie RAVENEL, arrivée en septembre 1998
Laurent de SEZE (DRECAM, Responsable local du groupe informatique)
Claudine VERNEYRE

LES PHYSICIENS AU SPhT

PHYSICIENS DU SERVICE DE PHYSIQUE THÉORIQUE

Situation au 1er mai 2000

Roger BALIAN (conseiller scientifique CEA)
Michel BAUER (CEA)
Michel BERGERE (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 (CEA)
Olivier GOLINELLI (CEA)
Riccardo GUIDA (CEA)
Emmanuel GUITTER (CEA)
Daniel IAGOLNITZER (CEA)
Thierry JOLICŒUR (CNRS)
David KOSOWER (CEA)
Ivan KOSTOV (CNRS)
Robert LACAZE (CNRS)
Stéphane LAVIGNAC (CNRS, depuis le 1/10/98)

Jean-Marc LUCK (CEA, expert senior DSM)
Kirone MALLICK (CEA)
Madan Lal MEHTA (chercheur émérite CNRS)
André MOREL (conseiller scientifique CEA)
Pierre MOUSSA (CEA)
Henri NAVELET (CEA)
Christiane NORMAND (CNRS)
Jean-Marie NORMAND (CEA)
Jean-Yves OLLITRAULT (CNRS)
Henri ORLAND (CEA)
Vincent PASQUIER (CEA)
Robert PESCHANSKI (CEA, expert senior DSM)
Mannque RHO (CEA, expert senior DSM)
Georges RIPKA (conseiller scientifique CEA)
Carlos SAVOY (CNRS)
Richard SCHAEFFER (CEA, expert senior DSM)
Didina TEODORESCU (CEA)
Patrick VALAGEAS (CEA, depuis le 15/10/98)
André VOROS (CEA, expert senior DSM)
Jean ZINN-JUSTIN (CEA, directeur de recherches DSM)
Jean-Bernard ZUBER (CEA, directeur de recherches DSM)

POST DOCS

Cristel CHANDRE (à partir du 1/01/00)
Steven CREAGH (du 4/09/97 au 4/09/98)
Irene GIARDINA (à partir du 11/10/99)
Romuald JANIK (à partir du 26/05/98)
Grégoire MISGUICH (à partir du 1/10/99)
Enzo ORLANDINI (du 2/10/96 au 2/10/98)
Karlo PENC (du 15/09/97 au 3/03/99)
Roberto TATEO (du 1/10/97 au 1/10/99)
Peter UWER (à partir du 28/09/98)
Thomas WYNTER (du 14/10/96 au 14/10/98)

SCIENTIFIQUES DU CONTINGENT

Laurent CHARLES (du 1/12/97 au 30/11/98)
Laurent LAFFORGUE (du 30/09/97 au 15/09/98)

VISITEURS DE LONGUE ET MOYENNE DUREE

Visiteurs du SPhT ayant séjourné un mois ou plus durant la période de juin 1998 à mai 2000

Steven ABEL, CERN (Suisse)
Armen ALLAHVERDYAN, Yerevan (Arménie)
Gordon BAYM, Illinois Univ. - Urbana (USA)
Zvi BERN, UCLA (USA)
Andrzej BIALAS, Univ. de Cracovie (Pologne)
Dominique BOOSE, CNRS - Strasbourg
Andrea CAPPELLI, Univ. de Florence (Italie)
Carlo CERCIGNANI, Polytechnique - Milan (Italie)
James CLINE, McGill Univ. - Montréal (Canada)
Patrick DOREY, Durham Univ. (UK)
Joshua FEINBERG, Technion - Haïfa (Israël)
Silvio FRANZ, ICTP - Trieste (Italie)
Alejandro GONZALES-RUIZ, Harvard Univ. (USA)
Lev KOFMAN, Inst. d'Astrophysique - Honolulu (USA)
Imre KONDOR, Univ. Eötvös - Budapest (Hongrie)
Alan LAPEDES, Los Alamos National Lab. (USA)
André LECLAIR, Cornell Univ. (USA)
Andrei LEONIDOV, Lebedev Inst. - Moscou (Russie)
Valeri LOUTCHNIKOV, Univ. de Novosibirsk (Russie)
Stefano MARMI, Univ. de Florence (Italie)
Alexander MATVENKO, JINR - Dubna (Russie)
Gheorghe MEZINCESCU, Inst. de Physique - Bucarest (Roumanie)
Dong-Pil MIN, Univ. de Séoul (Corée du Sud)
Cécile MONTHUS, LPTMS - Orsay
Moshe MOSHE, Tokyo Inst. (Japon)
Ugo MOSCHELLA, Univ. de Côme (Italie)
Lesjek MOTYKA, Univ. de Cracovie (Pologne)
Paul PEARCE, Univ. de Melbourne (Australie)

Stefan POKORSKI, Inst. de Physique Théorique de Varsovie (Pologne)
Pal RUJAN, Univ. d'Oldenburg (Allemagne)
Hubert SALEUR, Univ. of South California (USA)
Michael SCHICK, Univ. de Washington (USA)
Mykola SHPOT, Inst. de la Matière Condensée - Lviv (Russie)
Semjon STEPANOW, Univ. de Halle (Allemagne)
Igor SUSLOV, Inst. P.L. Kapitza - Moscou
Tamas TEMESVARI, Eötvös Inst. Budapest (Hongrie)
Alba THEUMANN, Inst. de Physique - Porto Alegre (Brésil)
Gabor VATTAY, Eötvös Inst. Budapest (Hongrie)
Nicolas WSCHEBOR, ENS - Paris
Thomas WYNTER, Princeton Univ. (USA)

VISITEURS DE COURTE DURÉE

Visiteurs du SPhT ayant séjourmé moins d'un mois durant la période de juin 1998 à mai 2000

Yasuhusba ABE, Kyoto Univ. (Japon)
Viktor ABRAMOVSKII, Novgorod Univ. (Russie)
David ANDELMAN, Tel Aviv Univ. (Israël)
Patrick AURENCHE, LAPP Annecy-le-Vieux
Alexander BELAVIN, Inst. Landau (Russie)
Bernd BERG, Florida State Univ. (USA)
Nihat BERKER, MIT Cambridge (USA)
Gautam BHATTACHARYA, Saha Inst. Calcutta (Inde)
Céline BOEHM, Univ. de Montpellier
David BOILLEY, Kyoto Univ. (Japon)
Itamar BORUKHOV, Tel-Aviv Univ. (Israël)
Arnd BRANDENBURG, DESY - Hambourg (Allemagne)
Franco BUCCELLA, Univ. de Naples (Italie)
Arnaud BUHOT, Oxford Univ. (UK)
Alessandra BUONANNO, Caltech (USA)
Andrea CAPPELLI, INFN (Italie)
John CARDY, Oxford Univ. (UK)
Domenico CARLUCCI, ENS de Pise (Italie)
Christophe CHATELAIN, Univ. de Nancy I
Subhash CHATURVEDI, Hyderabad Univ. (Inde)
Pierre CHIAPPETTA, CNRS Marseille Luminy
Barbara COLUZZI, Univ. de Rome (Italie)

Amah Séna d'AlMEIDA, Univ. du Bénin (Togo)
Rava Da SILVEIRA, MIT - Cambridge (USA)
François DELDUC, ENS - Lyon
Lance DIXON, SLAC Standford Univ. (USA)
Gerald DUNNE, Oxford Univ. (UK)
Ruth DURRER, Univ. de Genève (Suisse)
Gabor FATH, C. Cavendish Lab. Cambridge (UK)
Giovanni FELDER, ETH. Zurich (Suisse)
Sergio FERRERA, Division Théorique CERN (Suisse)
Silvio FRANZ, ICTP Trieste (Italie)
Katy FREESE, Michigan Univ. (USA)
Masafumi FUKUMA, Kyoto Univ. (Japon)
Yan FYODOROV, Essen Univ. (Allemagne)
Laurent GALLOT, Univ. de Turin (Italie)
Enrique GAZTANAGA, IEEC - Barcelone (Espagne)
François GELIS, LAPP - Annecy-le-Vieux
Irène GIARDINA, Oxford Univ. (UK)
Harold GRIESSHAMMER, Washington Univ. - Seattle (USA)
Ilya GRUZBERG, Santa Barbara (USA)
Arthur HALPRIN, Univ. of Delaware (USA)
Thomas HALSEY, Exxon Research - Annandale (USA)
Johannes HAUSSMANN, Univ. Carl von Ossietzky - Oldenburg (Allemagne)
Peter HASENFRATZ, Univ. de Berne (Suisse)
Paul-Henri HEENEN, ULB de Bruxelles (Belgique)
Malte HENKEL, Univ. de Nancy 1
Dan HONE, ITP Santa Barbara (USA)
Jens HOPPE, Postdam (Allemagne)
Romuald JANIK, Univ. de Cracovie (Pologne)
Rachel JEANNEROT, SISSA - Trieste (Italie)
Jean-François JOANNY, Inst. Charles Sadron - Strasbourg
Hannes JUNG, DESY - Hamburg (Allemagne)
Gordon KANE, Univ. of Michigan (USA)
Stéphane KELLER, CERN (Suisse)
Nicolai KITANINE, ENS - Lyon
Imre KONDOR, Univ. Eötvös - Budapest (Hongrie)
Charlotte KRISTJANSEN, Niels Bohr Inst. - Copenhague (Danemark)
Hervé KUNZ, Inst. Phys. Lausanne (Suisse)
Alexander KUSENKO, UCLA (USA)
Denis LACROIX, Ganil - Caen

Kurt LANGFELD, Univ. de Tübingen (Allemagne)
Stéphane LAVIGNAC, Univ. de Bonn (Allemagne)
Michel Le BELLAC, Inst. Non Linéaire Nice
André LECLAIR, Cornell Univ. (USA)
Hyun-kyu LEE, Stony Brook (USA)
Laurent LELLOUCH, LAPTH - Annecy
Andrei LEONIDOV, Lebedev Inst. - Moscou (Russie)
Julien LESGOURGUES, Sissa - Trieste (Italie)
Lev LIPATOV, Saint-Petersburg (Russie)
Valeri LOUTCHNIKOV, Univ. de Rennes I
Nicodemo MAGNOLI, Univ. de Gènes (Italie)
Giuseppe MAIELLA, Univ. de Naples (Italie)
Uri MAOR, Tel Aviv Univ. (Israël)
Enzo MARINARI, Univ. de Cagliari (Italie)
Alexander MATVENKO, JINR - Dubna (Russie)
Nikolai MEDVEDEV, Ins. Cinét. Novosibirsk (Russie)
Anita MEHTA, Clarendon Lab. - Oxford (UK)
Ramon MENDEZ-GALAIN, Univ. de Montevideo (Uruguay)
Jean-Louis MEUNIER, Sophia-Antipolis - Nice
Jacques MEYER, IPN - Lyon
Fréderic MILA, Univ. Paul Sabatier - Toulouse
Pronob MITTER, Univ. Montpellier II
Sergey MOLODTSOV, CERN (Suisse)
Ugo MOSCHELLA, Univ. de Côme (Italie)
Thomas MÜLLER, Inst. Laue-Langevin - Grenoble
Innocent MUTABAZI, Univ. du Havre
Taro NAGAO, Osaka Univ. (Japon)
Henri Claude NATAF, Lab. Géophysique - Grenoble
Carolina NEMES, Heidelberg-Max Planck Inst. (Allemagne)
Roland NETZ, MPI - Teltow (Allemagne)
Bruce NORMAND, Univ. de Bâle (Suisse)
Enzo ORLANDINI, Univ. de Padoue (Italie)
Andrew OSBALDESTIN, Loughborough Univ. (UK)
Gergely PALLA, Univ. Eötvös (Hongrie)
Olivier PARCOLLET, Rutgers Univ. (USA)
Paul PEARCE, Univ. de Melbourne (Australie)
Karlo PENC, Inst. Phys. Budapest (Hongrie)
Catherine PEPIN, Oxford Univ. (Angleterre)
Bengt PETERSSON, Univ. de Bielefeld (Allemagne)

Valentina PETKOVA, Sofia (Bulgarie)
Toni PICH, Univ. de Valencia (Espagne)
Iveta PIMENTEL, Univ. de Lisbonne (Portugal)
Alain POCHEAU, Univ. St. Jérôme - Marseille
Didier POILBLANC, Univ. Paul Sabatier - Toulouse
Alain PUMIR, Inst. Non Linéaire de Nice
Anton REBHAN, Vienna Univ. (Autriche)
Thomas REISZ, Univ. Heidelberg (Allemagne)
Patrick RICHARD, Univ. Rennes
Vincent RIVASSEAU, CNRS-SPM
Jonathan ROBBINS, Bristol Univ. (UK)
Janusz ROSIEK, Univ. de Varsovie (Pologne)
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