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## LPTMS - Laboratoire de physique théorique et modèles statistiques

Rapport Hcéres

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agence d'évaluation de la recherche  
et de l'enseignement supérieur

Section des Unités de recherche

## Evaluation report

Research unit :

Laboratoire de Physique Théorique et Modèles

Statistiques (LPTMS) – UMR 8626

University Paris 11



February 2009



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Le Président  
de l'AERES

Jean-François Dhainaut

Section des unités  
de recherche

Le Directeur

Pierre Glorieux

february 2009



# Evaluation report

## The research unit :

Name of the research unit : Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS)

Requested label : UMR

N° in case of renewal : 8626

Head of the research unit : Mr Stéphane OUVRY

## University or school :

Université de Paris 11

## Other institutions and research organization:

CNRS

## Date(s) of the visit :

December 8<sup>th</sup>, 2008

# Members of the visiting committee



## Chairman of the committee :

Mr Hubert SALEUR, Physique Théorique, CEA Saclay

## Other committee members :

Mr Yan FYODOROV, School of Mathematical Science, University of Nottingham

Mr Benoît DOUCOT, LPNHE, Université Paris 6

Mr Martin WEIGT, ISIV, Université de Turin

## CNU, CoNRS, CSS INSERM, (représentant INRA, INRIA, IRD...) representatives :

Mr Dominique DELANDE, CoNRS

Mr Pierre PUJOL, CNU (absent excusé)

# Observers

## AERES scientific representative:

Mr Jean-Michel ROBBE

## University or school representative:

Mr Alexandre REVCOLEVSKI, Vice-Président Recherche de la Faculté d'Orsay

## Research organization representative (s) :

Mr Christian CHARDONNET, représentant l'Institut de Physique du CNRS



## 1 • Short presentation of the research unit

- Numbers of lab members including researchers with teaching duties and full time researchers (22 + 2 emeriti), engineer (1), PhD students (10), technicians and administrative assistants (1)
- Numbers of HDR : 15 and of whom 8 are PhD students advisors
- Numbers of PhD students who have obtained their PhD : 12 and average length of a PhD during the past four years : 36 months
- Numbers of PhD students currently present in the research unit : 13
- Numbers of PhD students with fellowships : 12
- Numbers of lab members who have been granted a PEDR : 4
- Numbers of “publishing” lab members : 21 researchers with teaching duties and full time researchers + 2 emeriti

## 2 • Preparation and execution of the visit

The visit took place on december 8, 2008. The schedule was as follows:

- From 9 to 12.30 am, the committee listened to a general presentation by the lab. director, followed by presentations of the different groups and their activities by senior scientists
- From 2 to 3.45 pm, different members of the committee met with the groups individually and addressed scientific as well as organisational aspects of the lab
- From 3.45 to 6 pm, the committee met successively with the postdocs and students, with the 'tutelles', with the scientific committee of the lab, and with its present and future director
- Finally, the committee deliberated and agreed on the essential points of the report

The written documents provided to the committee were very carefully written, and covered thoroughly all the relevant questions. The general presentation by the director and the following research reports were of the highest quality.

The committee greatly appreciated the openness of the lab members, and felt the visit took place under the most excellent conditions.

## 3 • Overall appreciation of the activity of the research unit, of its links with local, national and international partners

The committee was impressed by the quality of the different research directions: each of the five groups is doing extremely good research, and each group has components which are comparable to the best in the field worldwide. The recent hires (including transfers of CNRS researchers from other units) are all excellent, and represent - especially at the senior level - a truly remarkable achievement. The energy of most of the lab members is high : the number of visitors, postdocs, organized seminars as well as the amounts of funding secured which are all very high, and contribute to a growing visibility and reputation of LPTMS at the French and international level.



The atmosphere in LPTMS appears totally positive, motivating and exciting, a fact confirmed by the postdocs and students who were unanimously pleased by their human and scientific experience.

The LPTMS is a university lab., and takes its dual mission of teaching and research seriously. Some members belong to the CNRS, while others belong to the University and have teaching duties. The teaching load - when unofficial tasks are added to the official ones - is extremely heavy. The committee was particularly impressed by the fact that this load did not affect the research output of the most active Maîtres de Conférences and Professeurs. Nevertheless, it seems fair to suggest that all possible mechanisms to spread teaching (in particular, service courses) over the whole lab. should be explored.

The LPTMS has grown relatively quickly into one of the most visible theory labs in France. In its own speciality of statistical mechanics, it is becoming the equal of the top labs worldwide.

The LPTMS has reached this enviable situation due to a variety of circumstances, in particular the enlightened openness of the University administration. It is a fact however that a significant component of the LPTMS claim to fame comes from the contributions of some of its most senior members. While the young ones are brilliant and active and clearly will be fully able to replace their seniors at some point, the committee felt a certain concern when weighing the impact of the likely future retirements in several of the groups. The committee felt that, in order to prepare the future under the best conditions, several hires - probably more than the administration would likely propose - must be considered. These will be discussed below.

All lab members are extremely thankful of the work accomplished by the administrative and computer staff. This component of the lab is becoming ever more important as funding diversifies and requires grant administration, and more visitors pour in, and its contribution must be acknowledged.

In what follows, the contributions of different members of the lab are ordered by "teams". It is however a characteristic of LPTMS that most of its researchers have a variety of interests, and are able to collaborate at times on very different topics. In many ways, LPTMS is only *one* team, and this is, in the view of the committee, one of its essential qualities.

## 4 • Specific appreciation team by team and/or project by project

### Condensed matter physics

The condensed matter team represents a growing activity at LPTMS, with the hiring of a young Maître de Conférences in 2008. Two of the permanent members are also actively involved in chaos and quantum systems and cold atoms activities.

The research performed in this team is of an excellent quality and is very well recognized, in France and abroad. This team has developed strong collaborations with theorists and experimentalists in the Orsay area and in many other places, such as Grenoble, Moscow, Dresden, Budapest, ... The members of the team have signed most of their papers either with members of the LPTMS belonging to other teams or with external collaborators. During our visit, they expressed their satisfaction regarding their integration within the LPTMS. They said that they benefit from a friendly and stimulating atmosphere, and that ideas circulate rather intensely from one team to another. The total number of papers published in high quality peer-reviewed journals by the four permanent members during the 2005-2008 period is about 33, which reflects a high level of activity. Remarkably, each member of the team is working in his own direction, so the number of themes developed here is unusually large for such a relatively small team.

The most senior member is a leading expert on the physics of low dimensional strongly correlated electronic systems such as organic conductors and charge-density wave compounds. His work has stimulated a very fruitful experimental activity with the goal to observe very specific signatures of solitonic excitations in various electronic spectroscopies of such systems. A very original investigation of ferroelectricity and charge order in organic conductors is now extended to conjugated polymers, which sounds very promising. Another very active theme is the exploration of Kondo effects in mesoscopic situations where reservoirs have a discrete spectrum.



The results obtained here are deep and original, and they have greatly benefited from the state of the art expertise at LPTMS in the study of finite quantum systems. The interplay between concepts originally developed in the field of quantum chaos and problems inspired by mesoscopic physics has been particularly fruitful. Other very successful investigations of mesoscopic systems have been the subject of an intense collaboration with researchers from the Solid State Physics Laboratory at University Paris 11. Studies of dimensional crossovers in the quantum corrections to the conductance of diffusive networks have reached a very satisfactory agreement between theory and experiments. Recent and important developments on the influence of the lattice geometry on electronic dephasing processes raise many conceptual issues, and have been already tested by experimentalists. One team member has produced many important new results in the physics of quantum Hall states, including studies of composite fermions in bosonic systems, and new theoretical constructions for fractional states with non-Abelian quantum statistics, which may explain some of the recently observed incompressible states that do not fit in the standard hierarchical picture based on composite fermions. Finally, we should mention very original works done by one post-doc on the Zeeman spin-orbit coupling in antiferromagnetic conductors.

To conclude, the team is very active and at the forefront of research in several notoriously difficult subjects. It is quite well connected to the external communities working on strongly correlated systems and on mesoscopic physics. The recent hiring of a Maître de Conférences with a strong expertise in numerical studies of strongly interacting many body systems will certainly strengthen the team and enhance its collaborations with the cold atoms group.

### **Quantum chaos and applications**

Vigorous research in the field of Quantum Chaos and its applications was always one of the trademarks of LPTMS from its foundation, and presently remains an important part in the external perception of the whole Laboratory. All members of the group are among world leaders in the research area, which is reflected in the number of invited talks at high-profile international meetings. In recent years the research output remained of excellent quality, with a few groundbreaking papers setting directions of research closely followed afterwards by similar teams elsewhere. As a specific example of such work, it is worth mentioning the discovered relation of statistics of nodal lines of eigenfunctions in generic quantum chaotic systems to percolation theory and further to the so-called Schramm-Loewner Evolution. This example not only inspired other physicists to look for similar relations in different systems of a rather diverse nature (as. e.g. zero vorticity lines in turbulent flows), but also generated a serious effort in Mathematical Physics and Probability communities to verify the above relation by rigorous tools.

The group remains one of the world centers of application of Random Matrix Theory to physics of disordered and chaotic systems, and actually beyond that remit. The knowledge in that important area transgresses the group boundary and involves active collaboration with a few colleagues from other research teams in the lab. The success of that common work is very impressive, with statistics of extreme values (see more on this below) being one of the topics where the leading position of LPTMS is undisputable.

If any matter of concern exists, it is related to the fact that incoming years two somewhat younger members of the group plan to concentrate for the most of their time on research directions different from Quantum Chaos. The average age of the remaining two members already exceeds 65 years (one has the emeritus status) which may raise a legitimate concern on the viability of the group in a few years perspective. Discussions of the matter with the group members resulted in a proposal to maintain the world-leading position of the group by appointing an active researcher of international standing working in the area of applications of random matrices to physics of chaotic and/or disordered systems. It was also suggested that it could be reasonable to change the group's name to "Applications of Quantum Chaos and Random Matrix Theory" in order to reflect both principal directions of the research in its title.

### **Statistical mechanics of disordered systems**

This is one of the leading team in this area of research in France and also in the world. It has been growing over the last few years, high-level and young-scientist appointments have been made, resulting in a well-balanced age structure of the team. Several PhD students and postdocs have been working or are currently working in the group.





The research activity in the team can be divided into three major areas, which are discussed in more detail below: Statistical physics of disordered systems, Interfaces statistical physics, computer science, and biology.

The first of these areas, the statistical physics of disordered systems, forms the core competence of the team. Research covers a broad range of subjects in both equilibrium (spin glasses, structural glasses, random media, disordered elastic media, fluctuation-induced forces, disordered quantum systems and quantum cavity method) and off-equilibrium statistical physics (stationary steady states, granular gases and fluids, depinning of elastics interfaces, glassy dynamics, soft matter and complex fluids, annihilation processes). Research in this area, and the methods developed there, form the solid basis of the leading role of the team in worldwide statistical-physics research, but also for the exploration of interfaces with the multi-disciplinary research areas 2 and 3. Besides the classically present spin-glass-related topics in the group, the young team members have added strong new competences in particular in research directions as non-equilibrium dynamics, complex fluids, colloidal systems, granular matter, elastic interfaces and polymers. The high visibility of the young members, and their strong independent research records are a sign of a successful personnel policy of the disordered-systems group.

The second area is a first of the two inter-disciplinary research directions developed within the group. Many combinatorial optimization problems (e.g. satisfiability, graph coloring) in theoretical computer science and many information-theoretical problems (e.g. coding, data compression, reconstruction) show some astonishing similarities to spin-glass models - which range from the formal structure of the problems to their large-scale behavior (e.g. phase transitions). Members of the disordered-systems team have made groundbreaking contributions in the application of statistical-physics tools to computer science problems. The application of the cavity method has led to one of the best algorithms in solving constraint-satisfaction problems (survey propagation, proposed at the end of the previous reporting period), and a patent has been obtained on this algorithm (in the current reporting period). It has to be mentioned that patents obtained in theoretical physics labs are very rare, and the patent can be seen as a successful bridge between basic theoretical research in the team and application-oriented research. On the other hand, the mathematical analysis carried through in the lab has led to major contributions in building a mathematically more rigorous basis to the methods used in disordered systems (like replica method, cavity approach).

The third big research area has been emerging in the last few years: the interface between statistical physics and biology is explored in two major directions. A first one is the analysis of physical processes related to bio-molecules (soft-condensed biological matter, in particular charged DNA-electrolyte interactions), the second one concerns more information-theoretical approaches to evolutionary and systems biology (neutral networks in RNA evolution, viral evolution, gene-regulatory networks) - and shows important parallels to the second research area. The biologically motivated works demonstrate in particular the high innovative capacities of the team, the interest to individuate challenges beyond the traditional borders of the own field of research, and to explore these challenges from new points of view. It is the committee's opinion that biologically related research inside the team should be strongly encouraged, also by an active personnel policy of the full lab (i.e. persons with experience in biological research should be hired to increase the biological expertise in the team). On a long run, biological applications of statistical physics might form the field of a new research team inside the LPTMS. However, at this moment in time, it seems best to keep this activity inside the disordered-systems group. Most team members are involved in more than one of the main research directions, and the approaches to biology taken in this moment are closely related to the core competences of the individual researchers involved.

To summarize, the disordered-systems team is a very healthy research team working on highest, internationally competitive scientific level. Its multidisciplinary focus toward some of the most innovative research directions beyond the traditional statistical-physics research has to be strongly encouraged, also via new permanent members.

### **Statistical physics and field theory: physics of low dimensional systems**

The team working on the physics of low dimensional systems has been extremely active and productive in the last few years, and some of its results have attracted worldwide notice. Like in many cases when the LPTMS is concerned, the activities of the members often stretch across boundaries, and some of the results mentioned in this section have been briefly alluded to elsewhere in the report.



A first major topic of research has been the study of the statistical features of extremas ("extreme statistics") in probability distributions. This is a problem which plays an important role in the physics of disordered systems, in number theory, and in optimization, among others. One of the key marks of the group has been to identify solvable models, where they have been able to study in details the influence of correlations on extreme statistics.

Among the remarkable results obtained in this area, one can mention in particular the work devoted to the probability distribution of extreme deviations from the mean in the physics of interfaces, with the elegant relationships uncovered with properties of Brownian motion, and the Airy distribution.

Another very interesting result in this area concerns the study of corrections and subleading effects to the Tracy Widom distributions describing the behaviour of the largest eigenvalue of random matrices. Yet other works worth mentioning include the statistics of extremes in Jespen's gas, and in the Bose gas, with applications to the problem of integer partitions.

The second major topic of research is to some extent a variation of the first, and concerns the detailed study of yet more sophisticated statistical features. These include the distribution of first time visits and corrections to the leading continuum limit in Brownian motion, or the study of various pairing problems such as Bernoulli's pairing (with potential applications in genomics).

The third major topic concerns features of exactly solvable statistical mechanics models, in particular loop models. These features include on the one hand physical aspects, such as the study of continuum limits or critical exponents of models which have an interest of their own (eg in polymers applications) and on the other hand play a role as toy models for more complicated problems. Particularly interesting in this case is the study of vertex models with non compact target spaces, with potential applications to string theory and the AdS/CFT conjecture. Another aspect concerns combinatorics. The team has been a truly original leader in this field, with major contributions in particular to the so-called Razumov Stroganov conjecture, whose connections with mathematics seem to be extremely deep.

Finally, the fourth topic concerns the quantum Hall effect, the physics of anyons and of random Aharonov-Bohm vortices, and the study of two dimensional Brownian motions where in particular interesting results about the Hausdorff dimensions of winding sectors of Brownian paths have been obtained.

The overall reach and visibility of the group in this period have been remarkable. The committee felt a bit worried by the fact that two of the youngest and most productive members were however in the process of leaving (for personal reasons, or as the result of a promotion), raising the question of whether the group would remain at this level in the immediate future. While a promising young researcher has already been hired in the team to help to compensate the losses, the committee felt that another hire in related areas ought to be considered. The physics of low dimensional systems indeed, while at times a little far from immediate experimental applications, does play a crucial role in the bigger field where the lab aims to excel.

While regretting the losses, the committee felt it was certainly a very good sign for the LPTMS that its bright youngsters were offered the opportunity to move into other excellent labs.

### **Classical and quantum fluids**

This team is actually composed of two sub-groups: the largest one works on quantum fluids, the smallest one on classical fluids, mainly colloidal fluids. The two sub-groups are essentially disconnected, and have been grouped together mainly for historical reasons; a different sub-structure inside LPTMS would be possible.

The scientific activity of the Classical Fluids team has been completely renewed over the last few years, because of retirements of several members and the arrival of new ones. The new fields of research, statistical physics of soft matter and especially of colloidal fluids, are active with numerous very important contributions from the group. The published papers are important, both qualitatively and quantitatively, and well recognized in the community. The projects towards a deep understanding of fundamental processes in strongly coupled charged systems are interesting and timely. This team certainly has the ability to continuously produce excellent scientific results. The interaction with the "Disordered systems" group inside LPTMS is a very positive point which should be reinforced during the next few years.



The scientific activity of the Quantum Fluids team is excellent: papers are published in the best journals and have an important impact in the community. Members of the group - and most noticeably the group leader - are very frequently invited in the most famous international conferences. In the area of ultra-cold atomic gases, the LPTMS is widely recognized as one of the best places for theoretical studies in France and in Europe. It has a good connection with the best experimental groups throughout the world and this is clearly beneficial for everybody.

Some members of the group also take part in other groups at LPTMS (“Quantum Chaos” group on one side, “Condensed Matter” group on the other side). This is a very profitable characteristic feature of LPTMS which enriches the scientific activity and should be continued.

There is a large number of post-docs and visitors in the group, some of them being major senior scientists in the field. Together with the organization of an internal seminar, this makes the group very energetic and attractive. Furthermore, the whole LPTMS benefits from the involvement of the Quantum Fluids group in various collaborations (for example, inside the Institut Francilien de Recherche sur les Atomes Froids).

The Quantum Fluids group has collaborations with the other groups inside the LPTMS at a satisfactory level. Altogether, this proves that a relatively small structure devoted to theoretical physics like LPTMS is very valuable in the international competition.

During the last few years, there have been several PhD students in the group, although the number could probably have been larger considering the attractiveness of the group and sources of available money. Although some members of the group (and, of course, primarily the enseignants-chercheurs) are involved in teaching, a larger involvement would probably result in a larger flux of students.

The scientific projects of the group do make a lot of sense, as they concentrate on “hot” topics in the area of ultra-cold atomic gases: Bose-Einstein condensates, Fermi degenerate gases, dipolar gases, low-dimensional systems, transport in disordered systems, etc. The members of the group have the expertise and the capabilities to produce important and original results in this area. However, these projects are mainly follow-ups of what has been developed in the last few years. What are the main issues in the area of cold atoms and how they could be solved, is not very clear. It could be desirable that the group tries to open different and more risky directions of research. In the past, the group members have been reactive and able to follow rapid changes - partly driven by new and/or unexpected experimental results - in this field; the committee thus believes that the group will be able to maintain its high scientific level in the following years.

Some members of the committee expressed concerns on the fact that too much of the group activity and visibility depends on the group leader, so that the mid-term future is not entirely clear, and should be prepared carefully.

## 5 • Appreciation of resources and of the life of the research unit

The resources and material conditions seem adequate by French standards. The lab enjoys high quality administrative and computer staff, who contribute greatly to the good quality of life. The atmosphere is very pleasant.



## 6 • Recommendations and advice

– Strong points :

Within the well defined subfield of theoretical physics where it has decided to concentrate, the lab has attained, in a rather short period, an excellent international reputation. The lab has components which are fully comparable with the best in the field worldwide. It enjoys a particularly stimulating atmosphere, with a great deal of cross collaborations. The lab has managed several excellent hires in the last few years. It has been very successful in obtaining funding from all possible sources, bringing in a constant flow of visitors and postdocs.

– Weak points:

There is no weak point. If anything has to be mentioned, it is a slight concern of the committee that the lab could have more student oriented activities, - eg, a regular colloquium. The committee is well aware of the organizational difficulties this implies in Orsay.

– Recommendations :

The committee wishes to commend the director for the excellent and dedicated work he has accomplished. The committee enthusiastically supports the proposal put forward for the new director.

The committee felt that two hires should be considered in the immediate future. One to reinforce the quantum chaos group, one (most preferably senior) to reinforce the condensed matter group - especially to strengthen the interface with the cold atoms group. Other hires should absolutely include someone to fully restore the balance of the low dimensional systems group, and someone able to strengthen the biological physics activity. A hire in soft condensed matter physics and maybe a hire at the interface of physics and computer science should be considered in the near future.

On top of this, several members of the lab - both junior and senior - are still expecting well deserved promotions: the committee recommends that everything possible should be done to hasten them, and this may have to include creation of a new Professor job for the lab.

The committee realizes that its recommendations include an anomalously large number of hires. As stressed earlier, the committee felt indeed that the lab owed some of its considerable reputation to the recruitment of well established but sometimes rather senior researchers. Looming retirements in almost every of the teams in this lab might weigh heavily on it, and the transition has to be prepared with utmost care. Certainly, the committee felt this lab was one of the jewels of the Orsay campus in physics, and should be granted privileged status should cuts become necessary in the next few years.

Note de l'unité	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A+	A



Le Président de l'Université Paris-Sud 11

à

Monsieur Pierre GLORIEUX  
Directeur de la section des unités de recherche  
**AERES**  
20, rue Vivienne  
75002 Paris

Orsay, le 11 mars 2009.

N/Réf. : 53/09/GCo/LM/LS

Objet : Rapport d'évaluation d'unité de recherche  
N° S2100012363

Monsieur le Directeur,

Vous m'avez transmis le trois mars dernier, le rapport d'évaluation de l'unité de recherche « Laboratoire de Physique Théorique de Modèles Statistiques » - LPTMS – UMR 8626, et je vous en remercie.

L'université se réjouit de l'appréciation portée par le Comité sur cette unité et prend bonne note de ses suggestions.

Le directeur d'unité Monsieur Marc MEZARD a envoyé les modifications suivantes à apporter sur la composition de l'unité :

« ... 1. Short presentation of the research unit  
— Numbers of lab members including researchers with teaching duties and full time researchers (**23** + 2 emeriti), engineer (1), PhD students (**13**), technicians and administrative assistants (1)  
— Numbers of HDR : 15 and of whom 8 are PhD students advisors  
— Numbers of PhD students who have obtained their PhD : 12 and average length of a PhD during the past four years : 36 months  
— Numbers of PhD students currently present in the research unit : 13  
— Numbers of PhD students with fellowships : **13**  
— Numbers of lab members who have been granted a PEDR : 4  
— Numbers of "publishing" lab members : **23** researchers with teaching duties and full time researchers + **1** emeritus ... »

Je vous prie d'agréer, Monsieur le Directeur, l'expression de ma sincère considération.

Guy COURRAZE  
Président