Problems in mathematical physics and spectral theory

in honor of the 70th birthday of

Bernard Helffer

from the 23rd to the 26th of April 2019

https://www.math.sciences.univ-nantes.fr/Helffer2019/

Speakers:

Karine Beauchard
(ENS Rennes)
Pierre Bérard
(Université Grenoble Alpes)
Yannick Bonthonneau
(CNRS Rennes)
Monique Dauge
(CNRS Rennes)
Søren Fournais
(Aarhus University)
Patrick Gérard
(Université Paris-Sud)
Katie Gittins
(Université de Neuchâtel)
Alain Grigis
(Université Paris 13)
Colin Guillarmou
(Université Paris-Sud)
Frédéric Hérau
(Université de Nantes)
Thomas Hoffmann-Ostenhof
(Universität Wien)
Francis Nier
(Université Paris 13)
Jean Nourrigat
(Université de Reims)
Galina Perelman
(Université Paris-Est - Créteil Val-de-Marne)
Yanhui Qu
(Tsinghua University)
Julien Royer
(Université de Toulouse)
Peter Sternberg
(Indiana University))
Michael Sundqvist
(Lund University)

Scientific committee:
Nalini Anantharaman, Nicolas Burq, Isabelle Gallagher, Svetlana Jitomirskaya, Sylvia Serfaty, Steve Zelditch, and Maciej Zworski

Local organization:
Virginie Bonnaille-Noël, Nicolas Raymond, Joe Viola, and Xue-Ping Wang

FR n° 2962 du CNRS Mathématiques des Pays de Loire

GDR DYNQUA

Région PAYS DE LA LOIRE

Problems in mathematical physics and spectral theory (in honor of the 70th birthday of Bernard Helffer)

La conférence aura lieu du 23 au 26 avril 2019 pour les 70 ans de Bernard Helffer (professeur émérite à Nantes). Les thématiques abordées par la conférence se concentrent sur les domaines de recherche de Bernard Helffer, en particulier la physique mathématique, la théorie spectrale, la supraconductivité et les opérateurs de Schrödinger avec champs magnétique. La carrière de Bernard Helffer est exceptionnelle : auteur de plus que 250 articles, il a plus de 70 collaborateurs, il a encadré plus de 20 thèses et s'est impliqué dans des responsabilités collectives importantes pour la communauté comme la direction de la Société de Mathématiques Française (2010-2012).

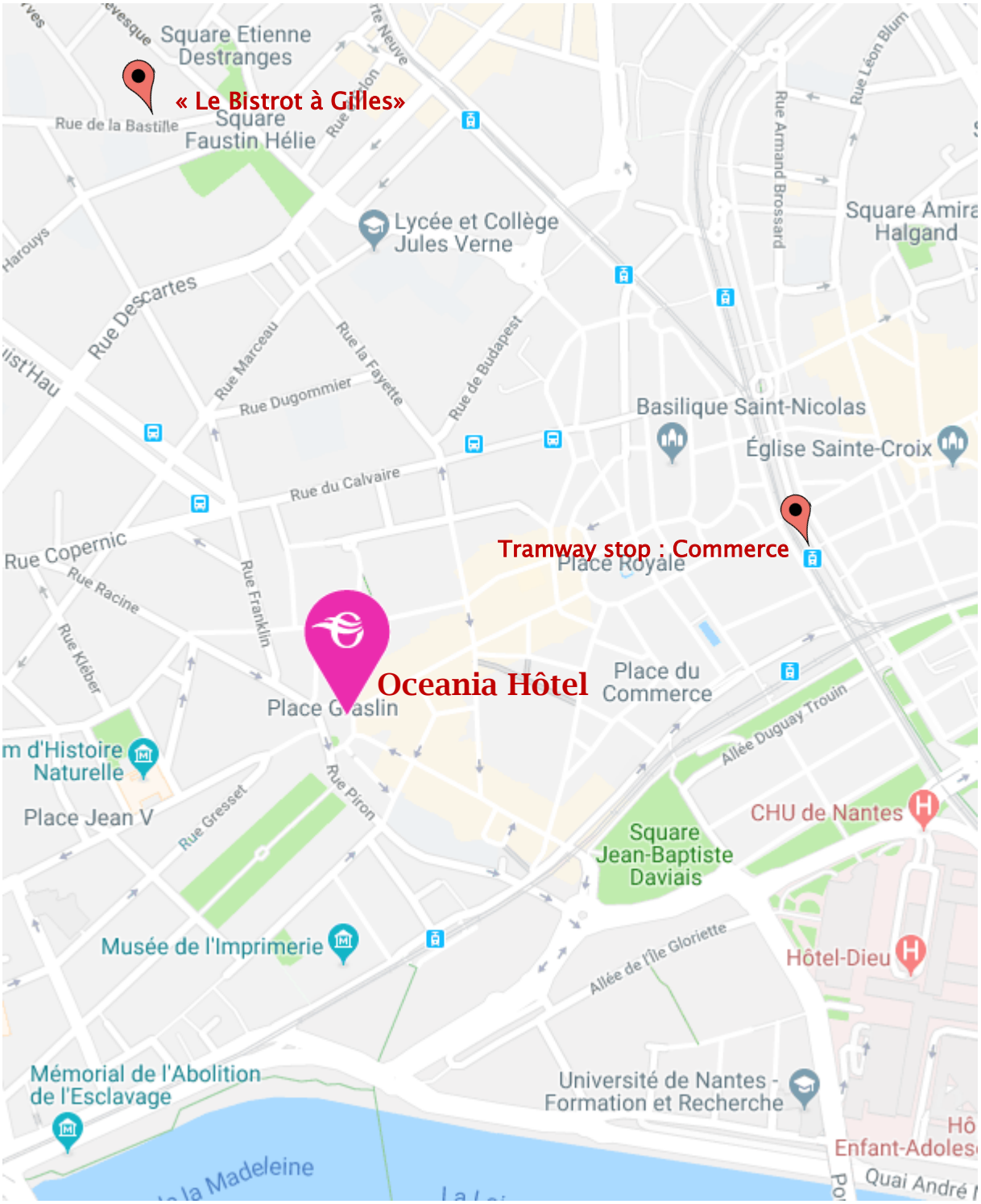
Professeur émérite, Bernard Helffer reste fortement impliqué au Laboratoire de Mathématiques Jean Leray (l'Université de Nantes et CNRS) et ses travaux d'envergure contribuent à augmenter la visibilité de la recherche en mathématique dans les Pays de Loire.

Les membres du comité scientifique sont Nalini Anantharaman (Université de Strasbourg), Nicolas Burq (Orsay), Isabelle Gallagher (ENS Paris), Svetlana Jitomirskaya (University of California, Irvine, USA), Sylvia Serfaty (Sorbonne Université et New York University), Steve Zelditch (Northwestern University, USA) et Maciej Zworski (University of California Berkeley, USA).

Les organisateurs sont Virginie Bonnaillie-Noël (CNRS), Nicolas Raymond (Université d'Angers), Joe Viola (Université de Nantes) et Xue-Ping Wang (Université de Nantes).

Hotel map

Oceania Hôtel de France Nantes
24 rue Crébillon 44000 Nantes



Coming to the Campus

From downtown : At the station "Commerce" take the tramway line 2 in the direction of "Orvault- Grand Val". Get off at the station "Michelet Sciences". The cost of a one-hour-valid ticket is 1,70 Euros and there are some vending machines at each stop. You can also buy a book of 10 tickets which costs 15,30 Euros.

From the train station : Upon your arrival at the main station (La Gare), take the North exit (Sortie nord) and walk in the direction of the tramway stop "La Gare" which is in front of the main entrance of the station. Take the tramway line 1 in the direction of "François Mitterrand", get off at "Commerce". Take the tramway line 2 in the direction of "Orvault-Grand Val" and get off at "Michelet Sciences".

Attention : The vending machines may not take non-France issued credit/Banking cards.

For detailed bus and tramway schedules please visit **TAN** (http://www.tan.fr).

From the Nantes-Atlantique airport (http://www.nantes.aeroport.fr) :

By bus : You can get to the city center by the airport shuttle bus (Navette Aéroport) in 20 minutes. The final stop of the shuttle is "Commerce" and there is one bus every 30 minutes. From there you can take the tramway line 2 in the direction of "Orvault Grand Val" and get off at "Michelet Sciences". The cost of a one-hour-valid ticket is 9,00 Euros, valid for tramway and shuttle bus.

By taxi : At the main entrance of the Hall 4 you will find a taxi shelter where you can call for a taxi to pick you up. The cost is around 40 Euros.

Once on the campus : Walk to **building 2 (Amphi Pasteur)** where the conference will take place (see map 2).

Accommodation

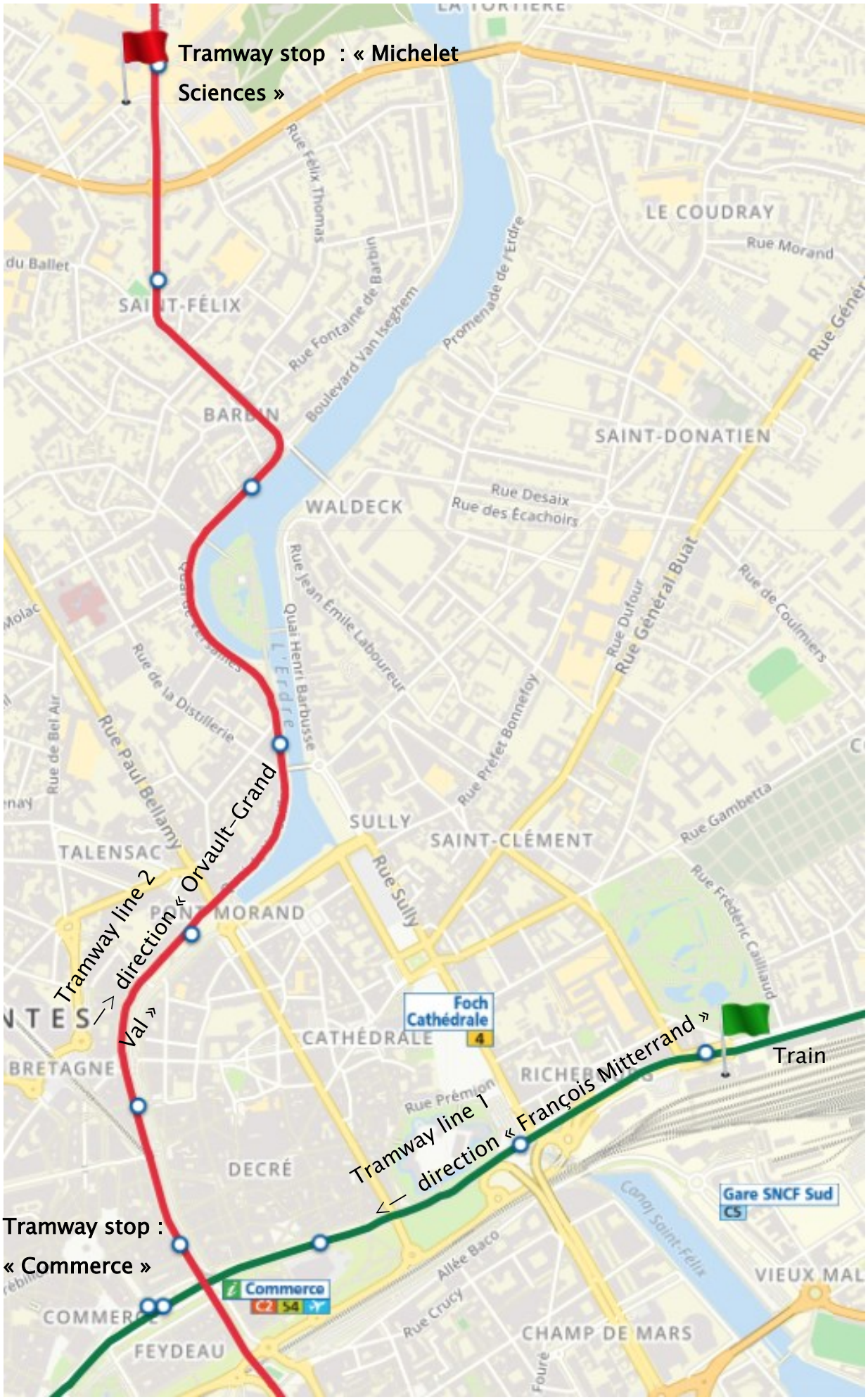
The speakers of the conference will be accomodated in the hotel (10 minutes' walk from the Commerce station)
« Océania Hotel de France »
24, rue de Crébillon
44000 Nantes
+33(0)2 40 73 57 90

Restaurants in Nantes

Les tables de Nantes : http://www.lestablesdenantes.fr

Le Melocotton (jazz club near Océania) : 9 rue de l'Heronniére Tues.-Sat. 5pm-2am

Map 1 : Train station – Campus



Map 2: Campus Sciences – Amphi Pasteur

Laboratoire de Mathématiques Jean Leray : Information and facilities

Maths Building (n°10 on map 2)

Organizing committee contact :

- Joe Viola – Mobile phone +33 (0)6 67 40 49 26

Laboratory secretary :

- Stéphanie Benoit – Office 130 – Phone +33 (0)2 51 12 58 78
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Department secretary :

- Brigitte Joubert – Office 141 – Phone +33 (0)2 51 12 59 00

Wifi network and internet access

To connect to the wifi network "univ-nantes":

After starting the browser you will have access to the web page of the University of Nantes.

Enter the login and the password that you will find on the backside of your badge.

Check the box "*J'ai pris connaissance de la charte d'utilisation et j'en accepte les termes*."

You can print documents in the computer room 127 (please bring a usb key).

To have access to the room, please see the secretaries or organizers.

The library – Centre Régional de Documentation Mathématique (CRDM)

http://www.math.sciences.univ-nantes.fr/CRDM/

Access: Building 25 (directly accessible by Mathematics building)

Office hours: Monday to Friday : 9:00 am to 17:30

Librarians:

Claude Jouault : Phone +33 (0)2 51 12 59 02

Anh Hong : Phone +3 (0)2 51 12 59 55

List of participants

Alphonse	Paul	Université de Rennes 1
Anné	Colette	LMJL - CNRS
Beauchard	Karine	ENS Rennes
Ben Said	Mona	Université Paris 13
Benea	Cristina	Universite de Nantes
Bérard	Pierre	Université Grenoble Alpes
Bonnaillie-Noël	Virginie	CNRS
Bonthonneau	Yannick	CNRS
Boulkhemair	Abdesslam	Université de Nantes
Camus	Jacques	Université de Rennes 1
Carron	Gilles	Université de Nantes
Costabel	Martin	Université de Rennes 1
Dauge	Monique	Université Rennes 1 et CNRS
Fournais	Soren	Aarhus University
Franceschi	Valentina	FMJH & IMO, Université Paris Sud
Gendron	Germain	Universite de Nantes
Gérard	Patrick	Université Paris-Sud
Gittins	Katie	Université de Neuchâtel
Grébert	Benoît	Université de Nantes
Grigis	Alain	Université Paris 13
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Guillopé	Laurent	Université de Nantes
Helffer	Bernard	Université de Nantes
Hérau	Frédéric	LMJL - Université de Nantes
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Lavigne	Enguerrand	Université de Rennes
Le Peutrec	Dorian	Université Paris-Sud
Meyer	Yves	CMLA ENS Cachan

List of participants

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Royer	Julien	Université de Toulouse
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Sandier	Etienne	UPEC
Sjöstrand	Johannes	IMB - Université de Bourgogne
Sternberg	Peter	Indiana University
Sundqvist	Mikael	Lund University
Vigneron	François	UPEC
Viola	Joe	LMJL - Université de Nantes
Vu Ngoc	San	Université de Rennes 1
Wang	Xue Ping	Université de Nantes
Zahra	Royer	LMJL - Université de Nantes

Program

	Tuesday April 23rd
11h-12h30	Welcome (Amphi Pasteur, Building 2)
12h30-14h30	Lunch*
14h30-15h30	**Jean-François Nourrigat :** *More on pseudodifferential calculus norms (joint works with L. Amour, L. Jager and R. Lascar)*
15h30-16h30	**Yanhui Qu :** *The structure of the spectra for several classes of discrete Schrödinger operators*
16h30-17h	Coffee break
17h-18h	**Frédéric Hérau :** *A Korn-Wirtinger inequality*

	Wednesday April 24th
9h-10h	**Søren Fournais :** *Second order lower bound to the ground state energy of dilute Bose gases*
10h-10h30	Coffee break
10h30-11h30	**Mikæl Persson Sundqvist :** *Magnetic model operators*
11h30-12h30	**Thomas Hoffman-Ostenhoff :** *On the multiplicities of eigenvalues : some results and open problems*
12h30-14h30	Lunch*
14h30-15h30	**Katie Gittins :** *Courant-sharp Robin eigenvalues for the square*
15h30-16h30	**Alain Grigis :** *Remarques sur les billards dans les triangles et les polyèdres*
16h30-17h	Coffee break
17h-18h	**Patrick Gérard :** *From one integral system to another : solving two inverse spectral problems on the Hardy space*

20h	Gala dinner**

	Thursday April 25th
9h-10h	**Colin Guillarmou :** *The Ruelle-Taylor spectrum of Anosov actions*
10h-10h30	Coffee break
10h30-11h30	**Yannick Bonthonneau :** *Exponential localization for pure 2D magnetic wells*
11h30-12h30	**Galina Perelman :** *Blow up dynamics for the hyperbolic vanishing mean curvature flow of surfaces asymptotic to Simons cone*
12h30-14h30	Lunch*
14h30-15h30	**Peter Sternberg :** *A Ginzburg-Landau type problem featuring highly disparate elastic constants*
15h30-16h30	**Monique Dauge :** *A conjecture for the Strongly Attractive Robin problem in a polygon*
16h30-17h	Coffee break
17h-18h	**Karine Beauchard :** *Null controllability of hypoellliptic PDEs*

	Friday April 26th
9h-10h	**Julien Royer :** *Local energy decay for the periodic damped wave equation*
10h-10h30	Coffee break
10h30-11h30	**Francis Nier :** *Persistent cohomology and Arrhenius law, Part.I (joint work with D. Le Peutrec and C. Viterbo)*
11h30-12h30	**Pierre Bérard :** *A story about Sturn, Courant, Gelfand and Arnold's last published paper*
12h30-14h30	Lunch*

*Lunches will be at the University Restaurant "La Lombarderie" (see map 2).

**The gala dinner will take place at the restaurant « Le Bistrot à Gilles» (see map 3).

Titles and Abstracts

Null controllability of hypoelliptic PDEs

Karine Beauchard, *ENS Rennes*

We study the null controllability of linear parabolic equations, posed on the whole space $\mathbb{R}^n$, by means of a source term locally distributed on a subset ω of $\mathbb{R}^n$. We want to understand to which extent the results known for the heat equation still hold for degenerate parabolic equations of hypoelliptic type. We want to identify their geometric control condition. First, we will recall the geometric control condition for the heat equation (the 'thickness' of the control support ω) and the proof of its necessity and sufficiency for null controllability. We will in particular recall Kovrijkine's argument to prove the spectral inequality for the Laplacian on $\mathbb{R}^n$, and the Lebeau-Robbiano's method. Then, we will adapt this strategy to hypoelliptic equations. By emphasizing a variante of the Lebeau-Robbiano's method (that does not require a diagonal decomposition), we will prove the null controllability of Ornstein-Uhlenbeck equations, from thick control supports ω. Then, by adapting Kovrijkine's proof, we will prove a spectral inequality for Hermite functions with a thick observation set, and deduce the null controllability of these equations from thick control supports ω.

This is a joint work with Karel Pravda-Starov and Philippe Jaming.

A story about Sturm, Courant, Gelfand, and Arnold's last published paper

Pierre Bérard, *Université Grenoble Alpes*

In his last published paper (Topological properties of eigenoscillations in mathematical physics, Proc. Steklov Institute Math. 273 (2011) 25–34), Arnold discusses the extension of Courant's nodal domain theorem to sums of eigenfunctions. He describes Gelfand's strategy in the 1D-case ("Courant-Gelfand theorem"): the zeros of any linear combination of the n first eigenfunctions of the Sturm-Liouville problem

$$-y''(s) + q(x)\,y(x) = \lambda\,y(x) \text{ in }]0,1[\,, \text{ with } y(0) = y(1) = 0\,,$$

divide the interval into at most n connected components. However, Arnold concludes that "the lack of a published formal text with a rigorous proof ... is still distressing."

Exponential localization for pure 2D magnetic wells

Yannick Bonthonneau, *CNRS, Université Rennes 1*

I will present results obtained with Nicolas Raymond and San Vu Ngoc. We consider low-lying eigenvalues of a semi-classical magnetic Laplacian in the whole plane, with magnetic field B. We assume that the field has a global positive (and non-degenerate) minimum B_0 at 0 (and that minimum is not attained at infinity). Then the bottom of the spectrum is known to take the form $\{b_0h+(nC+C')h^2+\mathcal{O}(h^3),\ 0\leq n\leqslant h^{-1}\}$, for some positive constants C, C'. Each such eigenvalue λ_n is simple.

The corresponding eigenfunctions (u_n) have to be localized around 0 as $h\to 0$. However, the precise speed at which they concentrate has not yet been determined. In general, according to the best estimate in the litterature, with $\phi(x) = |x|\tanh|x|$, for each $n\geq 0$, there is an $\epsilon > 0$ such that

$$\int e^{2\epsilon\phi(x)/h^{1/2}}|u_n|^2dx \leq 2\|u_n\|^2_{L^2}.$$

This implies that the eigenfunctions concentrate in a neighbourhood of size $h^{1/4}$ of 0. Under the assumption that the magnetic field is bounded, has slow variations at infinity, and is analytic in $\mathbb{R}^2$, with a holomorphic extension to a uniform neighbourhood of $\mathbb{R}^2$ in $\mathbb{C}^2$, we prove the better estimate

$$\int e^{2\epsilon\phi(x)/h}|u_n|^2 dx \leq 2\|u_n\|_{L^2}^2.$$

In particular, the eigenfunctions concentrate in a neighbourhood of size $h^{1/2}$ of 0. This scale is sharp.

A conjecture for the Strongly Attractive Robin problem in a polygon

Monique Dauge, *CNRS, Université Rennes 1*

Recent results due to K. Pankrashkin, M. Khalile and T. Ourmières-Bonafos exhibit corner induced modes and edge induced modes in the strongly attractive limit for the Robin problem in a polygon. Each corner is associated with a normalized Robin operator in an infinite sector of same opening. This operator has a finite number of eigenvalues. The discrete spectrum of this operator is described in a certain sense by the eigenvalues of a model mixed Robin-Neumann problem in a special quadrilateral domain.

After recalling the main points of this theory, we present the numerical approximation by the finite element method of the model mixed Robin-Neumann problem associated with each value of the opening angle. These experiments clearly support the following conjecture: The transition openings where the number of discrete eigenvalues steps up are the odd fractions of pi (i.e. pi/3, pi/5, etc).

Second order lower bound to the ground state energy of dilute Bose gases

Søren Fournais, *Aarhus University*

The energy of the dilute Bose gas has attracted much attention in recent years. Though the correct formula was already known to physicists more than 50 years ago, the proof of the leading order term was only rigorously established by Lieb and Yngvason in 1998. In this talk, I will discuss recent work on the leading correction term in the energy expansion. The focus will be on the lower bound.

From one integrable system to another : solving two inverse spectral problems on the Hardy space

Patrick Gérard, *Université Paris-Sud*

At the starting point of this talk are two integrable Hamiltonian systems in infinite space dimension. The first one is the Benjamin–Ono equation and was introduced about forty years ago in Fluid Mechanics. The second one is the Szegö equation and was introduced about ten years ago as a model of a non dispersive Hamiltonian evolution. Both systems admit a Lax pair structure, involving operators on the Hardy space of the disk enjoying special commuting properties with the shift operator : Hankel operators and Toeplitz operators. I will focus on the inverse spectral problems for these Lax operators, on the similarities in the strategy for solving them and on the dramatically different outputs.

Courant-sharp Robin eigenvalues for the square

Katie Gittins, *Université de Neuchâtel*

Let Ω be a square in $\mathbb{R}^2$ of side-length π. Consider the eigenfunctions of the Dirichlet Laplacian acting in $L^2(\Omega)$. In particular, those that achieve equality in Courant's Nodal Domain theorem. These eigenfunctions and their corresponding eigenvalues are called Courant-sharp. We also consider the corresponding Courant-sharp Neumann eigenvalues of Ω.

A result due to Pleijel asserts that the Courant-sharp Dirichlet eigenvalues of the square are the first, second and fourth (a complete proof of this result was given by Bérard and Helffer). Helffer and Persson-Sundqvist proved that the Courant-sharp Neumann eigenvalues of the square are the first, second, fourth, fifth and ninth.

The Robin eigenvalues of the Laplacian with positive parameter interpolate between the Neumann eigenvalues and the Dirichlet eigenvalues. We discuss whether the Robin eigenvalues of the square are Courant-sharp when the Robin parameter is large, small respectively.

This is based on joint work with B. Helffer (Université de Nantes).

Remarques sur les billards dans les triangles et les polyèdres

Alain Grigis, *Université Paris 13*

Nous présentons un état des lieux sur le problème de l'existence de trajectoires périodiques et de la structure de leur ensemble pour le billard dans des domaines à bord géodésiques. En particulier nous examinons les triangles dans le plan euclidien, sur la sphère et dans le plan hyperbolique et aussi les polyèdres dans l'espace euclidien.

The Ruelle-Taylor spectrum of Anosov actions

Colin Guillarmou, *CNRS, Université Paris-Sud*

We consider abelian Anosov actions on a manifold, which is generated by a set of commuting vector fields. We define a notion of joint resonant spectrum for this class, using some formalism developed in the 70's by J. Taylor.

This is joint work with Bonthonneau, Hilgert and Weich.

A Korn-Wirtinger inequality

Frédéric Hérau, *Université de Nantes*

In kinetic theory or in other fields, some control of the gradient by the symmetric gradient of the macroscopic velocity of a system of particle may be necessary, since only the second quantity appears naturally in physical equations. This type of inequality is known on bounded domains with or without axisymmetries. In this talk, we present a version on the whole space equipped with a probability measure, and give an example where this type of tool may be useful. This is a joint work with K. Carrapatoso, J. Dolbeault, S. Mischler, C. Mouhot, and C. Schmeiser.

On the multiplicities of eigenvalues: some results and open problems

Thomas Hoffmann-Ostenhof, *Vienna University*

Bounds to the multiplicities of eigenvalues, mostly for membranes, are discussed. Related open problems are mentioned as well as observations concerning nodal domains.

Persistent cohomology and Arrhenius law, Part I. (joint work with D. Le Peutrec and C. Viterbo)

Francis Nier, *Université Paris 13*

I will explain that the counting or accurate computation of exponentially small eigenvalues of semiclassical Witten Laplacians in any degree has essentially nothing to do with Morse theory. The topological construction that we introduced in a former work with D. Le Peutrec and C. Viterbo has a better understanding within the nowadays well-known framework of persistent (co)homology. Our analysis also provides a spectral version of the stability theorem of persistent homology, which enables to follow the semiclassical asymptotic expressions as the semiclassical parameter tends to 0, from a generic situation where asymptotic formulas are easily computed (e.g. when the potential is a generic Morse function) to general cases which sometimes appear in the applications.

More on pseudodifferential calculus norms (Joint works with L. Amour, L. Jager and R. Lascar.)

Jean-François Nourrigat, *Université de Reims*

We give an estimation of the norm of a pseudodifferential Weyl operator by the norm of the symbol in a class of Hörmander type, (defined with a quadratic form), multiplied by a determinant depending on this quadratic form, with explicit constants, independent of the dimension, which may go to infinity. We are also interested in the following question. Given a bounded operator, is it possible to know, by its action on coherent states, if its Weyl symbol, or perhaps its anti-Wick symbol, are continuous functions in the phase space. In both cases, an explicit formula for the symbols is given. These formulas may also be written like the Campbell Hausdorff one. Some examples in Physics will be briefly shown.

Blow up dynamics for the hyperbolic vanishing mean curvature flow of surfaces asymptotic to Simons cone

Galina Perelman, *Université Paris-Est - Créteil Val-de-Marne*

We consider the hyperbolic vanishing mean curvature flow of surfaces in $\mathbb{R}^8$ asymptotic at infinity to Simons cone:

$$C_4 = \left\{X = (x_1, \cdots, x_8), x_1^2 + \cdots + x_4^2 = x_5^2 + \cdots x_8^2\right\}.$$

We show that the flow admits finite time blow up solutions $(\Gamma(t))_{0<t\leq T}$ that blow up by concentration of the stationary profile: there exists a smooth minimal surface M asymptotic at infinity to Simons cone such that

$$\Gamma(t) \sim t^{\nu+1} M, \text{ as } t \to 0,$$

where ν is an arbitrarily large positive number.

This is a joint work with Hajer Bahouri and Alaa Marachli.

Magnetic model operators

Mikael Persson Sundqvist, *Lund University*

In the semi-classical analysis of the magnetic Schrödinger operator some model operators appear repeatedly. In this talk we review some results about some of these operators, and present some recent results by W. Assaad about the situation when the magnetic field has a jump discontinuity along a curve.

The structure of the spectra for several classes of discrete Schrodinger operators

Yanhui Qu, *Tsinghua University*

We will discuss the structure of the spectra for three classes of discrete Schrodinger operators—Sturmian Hamiltonian; Thue-Morse Hamiltonian and Almost Mathieu operator. As an application, we can either get a formula, or obtain a lower bound for the Hausdorff dimension of the related spectrum.

Local Energy Decay for the Periodic Damped Wave Equation

Julien Royer, *Université de Toulouse*

In this talk we consider the local (or global) energy decay for the wave equation with damping at infinity. We are in particular interested in the case of a periodic (or asymptotically periodic) setting. The global energy for the contribution of high frequencies is estimated under the usual geometric condition (extended to unbounded domains by N. Burq and R. Joly). Then we observe that the

contribution of low frequencies behaves like the solution of some heat equation. We will see how this emerges from the spectral analysis of the damped wave equation.

A Ginzburg-Landau type problem featuring highly disparate elastic constants

Peter Sternberg, *Indiana University*

We carry out an asymptotic analysis of a variational problem relevant in the study of nematic liquid crystalline films when one elastic constant dominates over the others, namely

$$\inf E_\varepsilon(u) \quad \text{where} \quad E_\varepsilon(u) := \frac{1}{2}\int_\Omega \left\{ \varepsilon\,|\nabla u|^2 + \frac{1}{\varepsilon}\,(|u|^2-1)^2 + L\,(\operatorname{div} u)^2 \right\} dx.$$

Here $u : \Omega \to \mathbf{R^2}$ is a vector field, $0 < \varepsilon \ll 1$ is a small parameter, and $L > 0$ is a fixed constant, independent of ε. We identify a candidate for the Γ-limit E_0, which is a sum of a bulk term penalizing divergence and an Aviles-Giga type wall energy involving the cube of the jump in the tangential component of the $\mathbf{S^1}$-valued nematic director. We establish the lower bound and provide the recovery sequence for this candidate within a restricted class. Then we consider a set of variational problems for E_0 arising for a choice of domain geometries and boundary conditions. We demonstrate that the criticality conditions for E_0 can be expressed as a pair of scalar conservation laws that share characteristics. We use the method of characteristics to analytically construct critical points of E_0 that we observe numerically. This is joint work with Dmitry Golovaty (Akron) and Raghav Venkatraman (Carnegie Mellon).

Gala Dinner – Wednesday April 24th at 8:00 pm

Restaurant "Le Bistrot à Gilles"

Map 3

Address : 11bis rue de la bastille 44000 Nantes.

The restaurant is close to the tramway line 2 (10 minutes' walk) and the hotel Océania.

Tramway stop : Place du Cirque

https://www.nantes-tourisme.com

Château des Ducs de Bretagne
4, place Marc Elder 44000 Nantes

Passage Pommeraye
rue de la Fosse
44000 Nantes

Les Machines de l'île
Parc des Chantiers
Bd Léon Bureau
44200 Nantes

Laboratoire de Mathématiques Jean Leray

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UNIVERSITÉ DE NANTES

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Mathématiques des Pays de Loire

Région PAYS DE LA LOIRE

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