# bois-marie

INSTITUT DES HAUTES ÉTUDES SCIENTIFIQUES

## editorial

Léon Motchane, the founder of IHÉS, was a visionary. In creating the Institute, he wanted to give researchers from all over the world a place of freedom and communication. Keen to offer IHÉS scientists a suitable site for research, he made it possible for the Institute to acquire the Bois-Marie estate in 1962. Today, the campus is an integral part of the Institute's identity; it also enjoys close proximity to a number of scientific institutions, their cooperation reinforced with the setting up of the Paris Saclay Campus. The Fondation mathématique Jacques Hadamard was created alongside the Campus, under the aegis of the Paris Saclay Foundation for Scientific Cooperation. Its aim is to reinforce research capacity in fundamental mathematics and its interfaces. IHÉS is one of its founding members, together with Université Paris-Sud 11, the CNRS, École polytechnique and École Normale Supérieure de Cachan. The new organisation should make the area even more attractive to mathematicians on the international scene.

As well as forging links with neighbouring research institutions, the Institute continues to reach out to the public in France and abroad. Encouraged by the success of the book, *The Unravelers, Mathematical Snapshots*, the Institute organised a day of conferences in the France Pavilion at the Shanghai World Expo in October 2010. Following on from this event, *The Unravelers* photo exhibition is currently touring many Chinese towns, thanks to the Alliances Françaises network. Other projects are in hand, such as "The Unravelers Tour in France", which I hope will meet with great success.

Jean Pierre Bourguignon

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## CARMIN

The Institut Henri Poincaré (IHP), CIRM (Centre International de Rencontres Mathématiques ), ICPAM (International Centre for Pure and Applied Mathematics) and IHÉS submitted a project, called CARMIN, for the reinforcement of their cooperation, in response to the call for "LabEx" (laboratories for excellence) proposals, which is one of the elements of the "investments for the future" to be funded by the French State's national loan. These institutes represent collective tools which contribute to the French mathematical community's international visibility.

## graduate course ED107

On Thursdays in February and March 2011, Pierre Vanhove gave a course on *Perturbative Calculation in Quantum Gravity* to young doctoral students of the Paris region.
www.ihes.fr/~vanhove/cours-gravite.html

## summer school 2010

The second IHÉS French-Asian summer school, which took place from 19 to 30 July 2010, dealt with *Singularities in Partial Differential Equations*. The next summer school will be organised at IHÉS in July 2012. Summer schools are entirely funded by the Société Générale Fund at IHÉS.

SOCIETE GENERALE

## nonlinear waves and dispersion

One year after an IHP trimester on this topic, which had been very successful, Frank Merle (Université de Cergy-Pontoise – IHÉS Chair) and Fabrice Planchon (Université Paris 13) organised a meeting where young speakers featured prominently, from 21 to 23 June 2010 at IHÉS.

## tribute to Lagrange and Poisson

The conference was organised by Jean-Pierre Bourguignon, Pierre Cartier and Yvette Kosmann-Schwarzbach (École Polytechnique), from 24 to 26 March 2010 at IHÉS to commemorate the 200th anniversary of the publication of important work by Joseph-Louis Lagrange and Siméon-Denis Poisson.

# inauguration of the **Hadamard Foundation**

The inauguration celebration of the Fondation mathématique Jacques Hadamard (FMJH) took place on 17 and 18 May 2011; in the morning of 17 May, it was held at Université Paris-Sud 11, in the presence of Valérie Pécresse, French Minister of Higher Education and Research, and in the afternoon of 18 May it took place at École polytechnique, in the presence of around 200 students.

The Foundation was created on 2 February 2011, following capital endowment from the French State, as part of the national Campus operation. The work of the Foundation will be to help the decompartmentalisation of both institutions and research themes, and also to promote international activites.

Various practical measures have already been taken, such as international scholarship programmes at masters and postdoc levels and support for conferences.

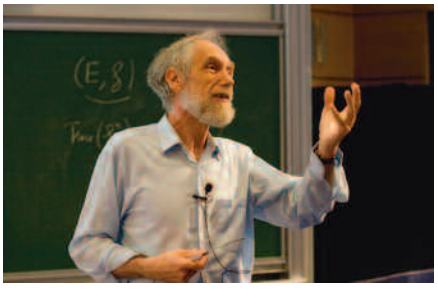
Partnership agreements are also being signed with major science education and training institutions in PR China.

*Valérie Pécresse, Université Paris-Sud, 17 May*

# kaleidoscopic view of **modern mathematics**

Claire Voisin and Sergiu Klainerman became the managing editors of Les Publications Mathématiques de l'IHÉS on 1st January 2010.

They organised the first ever Publications Mathématiques meeting, *Kaleidoscopic view of modern mathematics,* from 8 to 10 January 2011. IHÉS hosted the event on 8 January. It was a great day of conferences given in turn by Horng-Tzer Yau, Gerhard Huisken, Alain Connes and Cédric Villani. The next two days of conferences on 9 and 10 January took place at the Institut Henri Poincaré, and saw presentations made by: Tom Mrowka, Jean-Yves Welschinger, Jean-Pierre Demailly, Philippe Biane, Pierre Raphaël, Hiraku Nakajima, Benjamin Enriquez and Gérard Laumon.



*Alain Connes*

*"The conference made it possible for the journal's editors and some of its recent authors to meet. Presentations covered a wide range of topics, from mathematical physics to arithmetics. Some presentations were made by the editors, others by authors who had recently had articles accepted by the journal; Gérard Laumon's presentation on the "fundamental lemma" belonged to both categories. This was an interesting experience and we hope that it helped to confirm and communicate the wish to broaden the thematic scope of the journal, which was behind the constitution of the new editorial team."*

***Claire Voisin***

# three string generations at IHÉS

Conference organised at IHÉS from 16 to 20 May 2011 by Maxim Kontsevich, Nikita Nekrasov and Gabriele Veneziano, the aim of which was to celebrate the unity and diversity of modern theoretical and mathematical physics.

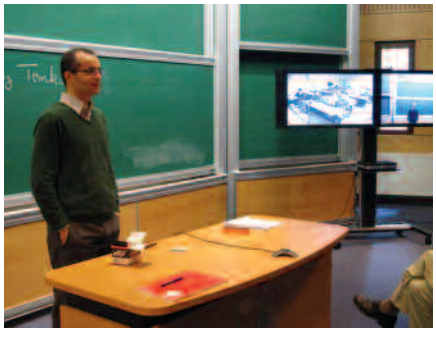
The idea for this event was also to bring together three generations of string theory specialists. At the centre, the second generation, born in 1960-1962, represented in this conference by Nathan Berkovits, Robbert Dijkgraaf, Michael Douglas, Igor Klebanov, Gregory Moore, Hirosi Ooguri, Samson Shatashvili, Cumrun Vafa, Erik and Herman Verlinde. With them, the two other generations: their advisers, the string theory pioneers, and their students. This international conference was supported by Foundation Compositio Mathematica, the Richard Lounsbery Foundation, the Collège de France and the Fédération de Recherche Interactions Fondamentales (FRIF).

*Cumrun Vafa*

"*String theory is the interdisciplinary science, which combines methods and goals of physics and mathematics. One of the ambitious goals of string theory is to construct the fundamental theory of nature, combining quantum field theory and the theory of general relativity. Ideas originating in string theory find unexpected applications in mathematics, the most notable being the discovery of mirror symmetry, linking (complex) algebraic geometry and symplectic geometry. Mirror symmetry provides the mechanism for the geometric Langlands correspondence and gives the solution to the Schubert problem, the deformation quantization, the categorisation of the theory of knot invariants, the correspondence between two dimensional conformal field theories and refined Donaldson theory, to name just a few.*"

***Nikita Nekrasov***

# Paris-Tokyo arithmetic geometry seminars



*Ahmed Abbes*

The Paris-Tokyo Arithmetic Geometry Seminar is a video-seminar jointly organised between IHÉS and the University of Tokyo since 2010 by Ahmed Abbes (IHÉS-CNRS), Christophe Breuil (CNRS-Université Paris-Sud), Takeshi Saito (University of Tokyo), Atsushi Shiho (University of Tokyo) and Takeshi Tsuji (University of Tokyo). It takes place once a month, with speakers alternately from Paris and Tokyo.

A session took place on Wednesday 11 May 2011. The speaker was Michel Raynaud (Université Paris-Sud) who gave a presentation from IHÉS on *"Permanence following Temkin"*. On this occasion, the organisers and participants in Paris expressed their sympathy to the victims of the recent devastation in Japan and sent a message of support and friendship to their Japanese colleagues. IHÉS joins them in expressing wholehearted solidarity with the Japanese people.

The last session of the Paris-Tokyo Arithmetic Geometry Seminar took place on Wednesday 15 June 2011. The speaker was Tomoyuki Abe (IPMU, Tokyo), who gave a presentation from Tokyo on *"Product formula for* p*-adic epsilon factors"*.

Other joint IHÉS and University of Tokyo projects are planned for next year, including the *"Arithmetic Geometry Seminar in Tokyo"* conference, which will take place from 4 to 8 June 2012.

# arrival of **Ahmed Abbes**

Ahmed Abbes joined IHÉS on 1 May 2011 as a long term CNRS visitor. The Institute is very pleased to welcome this talented and dynamic mathematician.
A co-organiser of the Paris-Tokyo arithmetic geometry seminars, he is behind the new *"Arithmetics and Algebraic Geometry Course at IHÉS"* (see 2011 events page 16).

Ahmed Abbes is a mathematician specialised in arithmetic geometry. He studied at the École Normale Supérieure in Paris from 1990 to 1994. With a PhD in mathematics obtained in 1995 at Université Paris-Sud, he became a postdoc researcher at IHÉS in 1996. He was subsequently appointed CNRS research associate at Université Paris 13, then CNRS research director at IRMAR (Université de Rennes 1) from 2007.
Ahmed Abbes mainly studies geometrical and cohomological properties of bundles on varieties on perfect fields of characteristic $p>0$ or on $p$-adic fields designed for applications in arithmetic and algebraic geometry. His joint work with Takeshi Saito (University of Tokyo) enabled a significant breakthrough in the theory of ramification .
He is the author of a treatise presenting a systematic development of rigid geometry following M. Raynaud's approach, based on formal schemes up to admissible blow-ups. Ahmed Abbes received the CNRS bronze medal in 2005.

# departure of **Dirk Kreimer**

Dirk Kreimer received a von Humboldt Professorship in 2010. This award is given by the Alexander von Humboldt Foundation, following a nomination by a German research institution. It is the most prestigious scientific award in Germany.

Following this award, Dirk Kreimer has joined the Humboldt University of Berlin, where he leads the new Interdisciplinary Centre for Mathematical Physics and focuses on the interactions between mathematics and theoretical physics.
Dirk Kreimer came to France in 1991 intending to enter into regular contact with mathematicians interested in perturbative quantum field theory. His approach to renormalisation using Hopf algebras led him to work from the end of the 1990s with Alain Connes, with whom he formed a sincere friendship. His work focuses today on understanding the analytical structure of amplitudes in quantum field theory using mixed Hodge structures and on the use of matroids in spin field theories.
All those who have known him at the Institute will remember the 10 years he spent at IHÉS as a long term CNRS visitor very fondly. We wish him every success in his new post.

*Dirk Kreimer, Alain Connes*

*"Friendly Isolation*

*When I returned to Europe in the mid 90s from two postdoc years spent at the University of Hobart, Tasmania, I returned with many cherished memories of loneliness well spent: over there, solitude to think was provided in spades.*
*When I arrived five years later at IHÉS, I found that cherished sense of isolation again, but in much gentler beautifully cultivated surroundings: the ability to isolate yourself with your thoughts, in the middle of an intellectual epicenter of thoughtful reflection, is now the souvenir I will take with me from IHÉS.*
*Thanks to Alain for his friendship, and thanks to all at IHÉS for a wonderful decade in my scientific life."*

***Dirk Kreimer***

# departure of **Christophe Breuil**

Christophe Breuil, who came to IHÉS in 2002 as a CNRS long term visitor, moved to the Mathematics Department at Université Paris-Sud in September 2010.
A mathematician specialised in algebraic geometry and number theory, his research is on all aspects of the $p$-adic Langlands programme, which he started, with several researchers now working on it. With his students, he is looking to develop this programme for groups other than $GL_2(Q_p)$, specifically $GL_2(F)$ with $[F:Q_p] > 1$. He received the Grand Prix Jacques Herbrand from the Académie des Sciences de Paris in 2002. We also wish him every success.

## Laurent Lafforgue honorary doctor

The University of Notre Dame, Indiana, United States, awarded Laurent Lafforgue, IHÉS permanent professor, the title of honorary doctor on 22 May 2011.
On that occasion, he made two scientific presentations on the Langlands programme, a topic he has been working on for many years, and gave a public conference entitled *"Does basic research have meaning? A few remarks by a catholic mathematician"*.

## Royal Irish Academy gold medal

Samson Shatashvili, theoretical physicist, professor at Trinity College, Dublin and Louis Michel Visiting Chair holder at IHÉS since 2000, received the Royal Irish Academy Gold Medal on 24 November 2010, in recognition of his several groundbreaking discoveries in the fields of theoretical and particle physics.

## Peano prize

David Ruelle, honorary professor at IHÉS, received the 2010 Peano Prize on 18 November 2010 in Turin, for his book *La mente matematica* (Ed. Dedalo), translated from the original French version, which was published in 2008, *L'étrange beauté des mathématiques* (Ed. Odile Jacob).

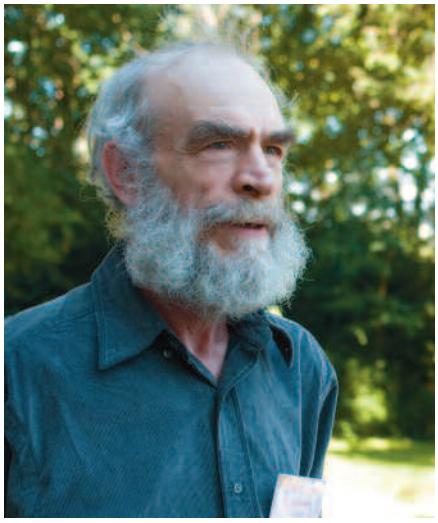
## Amaldi medal

Thibault Damour was awarded the Amaldi Medal during the 19th SIGRAV conference (Italian Society for General Relativity and Gravitation) which took place in Pisa (Italia) from 27 September to 1st October 2010.

## Compositio Mathematica prize

The Compositio Mathematica Foundation has chosen to award the first Compositio Mathematica Prize to Nikita Nekrasov, Davesh Maulik, Andrei Okounkov and Rahul Pandharipande for their article *Gromov-Witten Theory and Donaldson-Thomas Theory II* (Compositio Math. 142 (2006), 1286-1304).
This prize was awarded during the Compositio Prize Festivity at Amsterdam University on 2 July 2010.

# Mikhail Gromov, ForMemRS



*Mikhail Gromov*

Mikhail Gromov was elected Foreign Member of the Royal Society (United Kingdom) on 20 May 2011. With this distinction, The Royal Society recognises Mikhail Gromov as one of *"the most deeply original mathematicians of our time"*.

Mikhail Gromov joins the ten or so great French scientists who have also been elected Royal Society Foreign Members, among whom are Jean-Pierre Serre, Jacques Friedel, Edouard Brézin and, more recently, Pascale Cossart.
The Royal Society has around 140 Foreign Members across all disciplines out of a total of around 1450 Fellows. They are elected for life through a peer review process; eight new Foreign Members are elected each year.

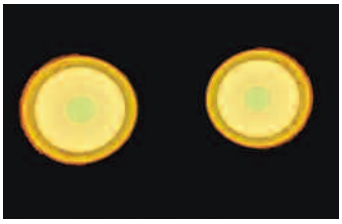
# Thibault Damour, knight of the Legion of Honour

Thibault Damour received the insignia of knight of the Legion of Honour on 6 December 2010 during a ceremony organised at IHÉS.

*Thibault Damour, Philippe Starck*

His friend Philippe Starck came to confer the distinction, as the two men have known each other for ten years and each holds the other in great admiration. Here is an extract from the coulourful speech given by Philippe Starck on this occasion:
*"We tried to meet regularly over the course of a few years so that he could teach me things. It was extraordinary!*
*He talked about quantum …, strings (…) I didn't understand anything. But actually, the point wasn't that I understood or not, because what was important for me was to hear the music, because I think there is a music to science. (…)*
*I also think that, if we're sensitive, there is obviously poetry, a poetry of mathematics, a poetry of science and that poetry is transposable in real life. And I live much better today thanks to the little I have understood by osmosis, in a very varied way, in a very very personal way and I thank him for that."*

# description of the last orbits of **binary neutron star systems**



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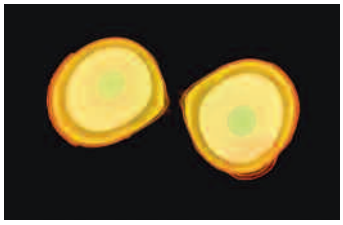

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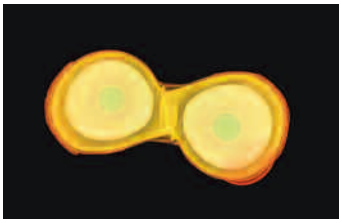

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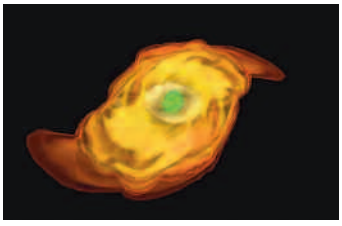

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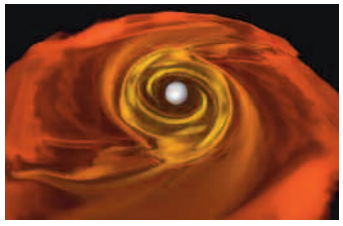

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The relativistic gravity theorists, Thibault Damour and Alessandro Nagar, with a team from the Albert Eintein Institute, Germany, have greatly advanced the description of the final orbits of binary systems of neutron stars.

An article describing this discovery was published by Physical Review Letters (PRL): *Analytic Modelling of Tidal Effects in the Relativistic Inspiral of Binary Neutron Stars*, Phys. Rev. Lett **105**, 261101 (2010).

This article is the result of a collaboration between a team of relativistic gravity theorists, Thibault Damour, permanent professor at IHÉS, and Alessandro Nagar, visiting researcher at IHÉS, and a team of "numerical relativity" specialists (all formerly together at the Albert Einstein Institute, a Max-Planck institute located in Golm, Germany) currently working in several institutions: Luca Baiotti (Osaka and Kyoto Universities, Japan), Bruno Giacomazzo (University of Maryland and NASA Goddard Space Flight Center, US) and Luciano Rezzolla, head of the numerical relativity group of the Albert Einstein Institute.

This article focuses on the description of the last few orbits before coalescence of binary neutron star systems and their experimental observation (which hopefully will happen soon) by the network of gravitational wave detectors LIGO / VIRGO - LIGO is in the United States and VIRGO is the French-Italian gravitational wave detector installed in Cascina, near Pisa.

The main result of the article is to have shown that the new analytical description (called "effective one body" or EOB) of the dynamics of binary systems, invented at IHÉS a few years ago (by Alessandra Buonanno and Thibault Damour) and recently developed at IHÉS by Thibault Damour and Alessandro Nagar, can be used to describe the gravitational signal emitted by the last orbits of a system of two neutron stars with a precision adequate for detection by LIGO / VIRGO.

The paper also shows that this detection will allow the measurement of the ratio between the mass and radius of neutron stars. This measure is potentially very important because it will give access to new information on the equation of state of ultra-dense nuclear matter, of which neutron stars are made. The results of this article were obtained by comparing the predictions of the IHÉS analytical method with the best (and to date longest) numerical simulations (on supercomputers) of the gravitational wave signal emitted by binary neutron star systems. These numerical results have been obtained recently thanks to the numerical methods developed at the Albert Einstein Institute.

Illustrations: numerical simulation of the last orbits of a binary neutron star system.
Credits: B. Giacomazzo (AEI), R. Kaheler (ZIB/AEI), L. Rezzolla (AEI)

# the Schlumberger Chair

## inauguration

Josselin Garnier and George Papanicolaou are the first holders of the Schlumberger Chair for Mathematical Sciences at IHÉS. From September 2010 to February 2011, they worked together on imaging projects. More specifically, they worked on a new type of robust beamforming method in complex media and on the improvement of resolution in imaging with indirect lighting resulting from the heterogeneities of the medium.

They have developed and analysed mathematical models to estimate the systemic risk of a large number of interacting agents each trying to spread their individual risk. They have also initiated a study of propagation of uncertainty for a classic problem in geophysics, which consists in estimating the speed of surface waves from the measurement of travel times (see article p. 8).

The Schlumberger inaugural conference was held on 17 and 18 November 2010 at IHÉS. The theme chosen and presented by Josselin Garnier, Habib Ammari, Patrick Joly, Felix Otto, Grégoire Allaire and George Papanicolaou was *"Multiscale Methods and Imaging"*.

Inaugural lectures by the first two holders of the Chair were given in the evening of 18 November. George Papanicolaou and Josselin Garnier presented with great clarity the work they have undertaken as part of the Schlumberger Chair, demonstrating the validity of creating this Chair at IHÉS. The resulting collaboration will be of benefit both to the scientific community and the world of industry.

*Philippe Lacour-Gayet*

*"The proposal of a six-month term to hold the Schlumberger Chair was perfect for me: it came at a time when I was highly motivated and intrigued by innovative types of research around imaging. The belief that IHÉS would provide the environment to develop these tracks was immediately attractive. Finally the idea of working with George Papanicolaou on these issues only strengthened this conviction. So I could only accept the proposal with enthusiasm. The first few months, with many results on imaging and other issues that have emerged over the course of my discussions with George Papanicolaou, fully satisfy me. They encourage me to believe that this semester is the beginning of an active and prolific period between IHÉS, Stanford University, the Université Paris Diderot and École Normale Supérieure, where I will be giving courses in the second semester and hosting a working group."*

***Josselin Garnier,***
***professor at Université Paris Diderot***

*"Joining the Schlumberger Chair was for me a unique opportunity to build a sustainable and productive relationship of high-level research between my university in Stanford and IHÉS. Our current and past students and our close collaborators in France and the United States will benefit greatly from working with us, Josselin Garnier and me, on research projects that are both innovative and interdisciplinary. We are already engaged on work on imaging, propagation of uncertainty and systemic risk. I am very satisfied with the progress on these issues in such a short period."*

***George Papanicolaou,***
***professor at Stanford University***

### Background to the Schlumberger Chair

The sources of inspiration for theoretical sciences are many: questions lying, sometimes for centuries, at the very foundation of sciences (such as in the creation of non-Euclidean geometries), problems arising from the development of high technology (such as seismic studies leading to the definition of wavelets), or concepts originating in neighbouring sciences (such as the systematic consideration of non-commutativity in mathematics stimulated by the success of quantum mechanics).

In the past few years, IHÉS has started to explore new sources of inspiration, such as high technology and biology, while maintaining its fundamental values: freedom of research, quest for excellence, interdisciplinarity, and also human and scientific diversity. Schlumberger Ltd. was a natural partner for a project on issues at the interface with applied research and of more direct interest to companies. Schlumberger Ltd. is a high technology company, whose products and services draw extensively from many scientific domains: physics, chemistry, geology, geophysics and mathematics. In many of these fields, the rigor necessary to innovate requires the knowledge created at the frontiers of fundamental research. Schlumberger has a tradition of deep interaction with the scientific community by locating its laboratories in close proximity to strong academic institutions, while maintaining a large internal research effort.

Schlumberger


Josselin Garnier
Educated at the École Normale Supérieure in Paris, he is professor of mathematics at Université Paris Diderot where he conducts his research in the Laboratoire de Probabilités et Modèles Aléatoires and in the Laboratoire Jacques-Louis Lions, Université Pierre-et-Marie-Curie. His main research interest is related to waves in random media. He received the Felix Klein Prize in 2008.


George Papanicolaou
Robert Grimmett Professor in Mathematics, Department of Mathematics, Stanford University, since 1993, after spending much of his career at the Courant Institute for Mathematical Sciences at New York University, he has received numerous prizes and awards, the two most recent being: William Benter Prize in Applied Mathematics 2010 and Josiah Willard Gibbs Lecture, 2011.

# imaging with noise

In sensor array imaging waves are used to probe an unknown medium. Different wave transmission and reception modalities can be implemented depending on the applications: non destructive testing, medical imaging, seismology. Travel time tomography, backpropagation or migration are well-known techniques to extract information from the array data. Recently new ideas have emerged from experimental observations such as super-resolution effects in time-reversal experiments or from theoretical concepts such as coherent interferometry or cross correlation methods. In particular the possibility to use uncontrolled ambient noise sources instead of controlled active sources has attracted a lot of attention especially in seismology. In this article we give a brief overview that explains the connection between these different ideas and we give the recent results obtained during our semester at IHÉS.

**Time-reversal Experiments.** Time reversal experiments were first carried out by Mathias Fink and his group in Paris. They were done with ultrasonic waves and have attracted considerable attention because of the surprising effects of enhanced spatial focusing and time compression in random media [Fink, Scientific American 281 (1999), 91]. A time-reversal experiment is based on the use of a very special device: the time-reversal mirror. It is a collection of transducers that can be used either as emitters or as receivers. In the first step of a typical time-reversal experiment, a point source emits a short pulse that propagates in a homogeneous or heterogeneous medium (see Figure 1). The time-reversal mirror is used as an array of receivers that record the wave signals. In the second step of the experiment, the time-reversal mirror is used as an array of emitters that re-emit the time-reversed recorded signals. The waves then propagate back into the medium. Due to the time reversibility of the wave equation it is expected that the wave refocuses on its original source location. What was not so expected is that the refocusing is better when the medium is randomly heterogeneous than when it is homogeneous. The mathematical analysis of enhanced time-reversal refocusing in random media has revealed that the time-reversal experiment can be interpreted as a correlation machine [1]: in the second step of the time-reversal experiment, the time-reversed wave revisits the same medium as the one that was probed during the first step of the experiment, and this is a key point. If the medium during the second step is exactly the same as the one during the first step, then the scattering with the heterogeneities of the medium can produce multi-pathing that builds up in a coherent way to produce a sharp focusing at the original source location. If the medium during the second step is not exactly similar to the original medium, then refocusing becomes poor and unstable.

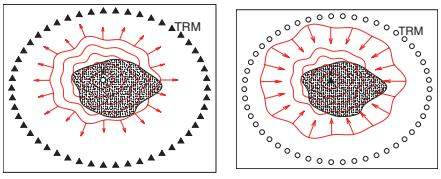



*FIG. 1: Ideal time-reversal experiment, with a time-reversal mirror (TRM) that completely surrounds the region of interest. The left picture plots the first step of the experiment. A point source at y emits a short pulse that propagates through the medium and is recorded by the time-reversal mirror. The right picture plots the second step of the time-reversal experiment. The time-reversal mirror re-emits the time-reversed recorded signals that propagate back into the medium and refocus at the original source location.*

In practice, the enhanced spatial focusing and time compression of signals in time reversal in random media (see Figure 2) have many diverse applications in detection and in focused energy delivery on small targets as, for example, in the destruction of kidney stones. Enhanced spatial focusing is also useful in sonar and wireless communications for reducing interference. Finally time reversal ideas have played an important role in the development of new methods for imaging in random media as described below.

**Coherent Interferometric Imaging.** The mathematical analysis of time-reversal

experiments has shown that the cross correlation of partially coherent waves is an important object. A new imaging method was then proposed in the context of sensor array imaging in random media.

When imaging with waves the unknown medium is probed with waves emitted from a set of sources and then the echoes are recorded

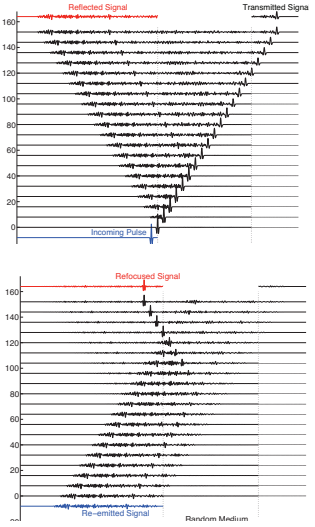



*FIG. 2: Time compression of signals in time reversal in random media (numerical simulations). The top picture plots the first step of the experiment. Each line is a snapshot of the wave profile at different times. The bottom blue line is the initial condition: a left-going wave is incoming from the left homogeneous half-space and enters the hetererogeneous region. The black lines plot the wave profile as it propagates in the heterogeneous region. The top red line plots the reflected wave that is recorded by the time-reversal mirror. The bottom picture plots the second step of the time-reversal experiment. The bottom blue line is the initial condition: it is the signal recorded at the end of the first step that is time-reversed and re-emitted by the time-reversal mirror. The top red line plots the reflected wave, which shows that a time-compressed signal emerges from the medium.*

at a set of receivers. In classical array imaging the data are collected in the form of the array response matrix (see Figure 3). The array response matrix is obtained column by column by emitting a pulse from each source location at a time and then recording the echoes at all the receiver locations. Then the recorded signals are processed to generate an image at search points (pixels) in the image domain of interest. This processing consists in backpropagating numerically the recorded signals, that are supposed to refocus on the locations of the main reflectors present in the medium, as is observed in time-reversal experiments.

This imaging method is very efficient when the medium is homogeneous or perfectly known, since it is then strictly equivalent to a time-reversal experiment in which the backpropagation is carried out numerically instead of physically. However, when the medium is heterogeneous and not perfectly known one has to backpropagate the recorded signals in a fictitious medium that is not the real one, and poor refocusing is observed. Coherent interferometric imaging is based on the backpropagation of local space-time cross correlations of array data and was introduced in order to improve images when the medium between the array and the object to be imaged is inhomogeneous and unknown [Borcea et al., Inverse Problems 21 (2005), 1419]. During our semester at IHÉS we have shown that the coherent interferometric imaging is in fact equivalent to a windowed beamformer energy function, that is, a quadratic function that involves only time gating and time delaying signals in emission and in reception. In this form coherent interferometric imaging can be implemented efficiently both in hardware and software, at a computational cost that is, ideally, comparable to the usual beamforming and migration imaging methods. We have also revisited the trade-off between image stability enhancement and loss of resolution from the point of view of its equivalence to a windowed beamformer energy imaging function [3].

**Ambient Noise Imaging.** The geological structure of the Earth can be explored by observing the propagation of elastic waves in the Earth crust. In classical seismology only the waves generated by earthquakes or by artificial explosions and recorded by a network of sensors (geophones) are used. Time-reversal experiments or active array imaging (using arrays of sources) are not possible in seismology since controlled sources of seismic waves are difficult to construct. However, even without any earthquake or explosion, a weak incoherent signal is recorded by seismographs: the seismic noise, whose frequency components around 0.1Hz consist mostly of surface waves produced by the interaction of the ocean swell with the coast. It turns out that these noise signals can be used to obtain travel time information. The main observation is that the cross correlation of the noise signals recorded at two sensors is related to the travel times between the sensors. As a consequence, the background speed of propagation can then be obtained from the estimated travel times between sensors in a network covering the region of interest, as was done in the Southern California region [Sabra et al., Geophys. Res. Lett. 32 (2005), L14311]. In fact the idea of exploiting the ambient noise and using the

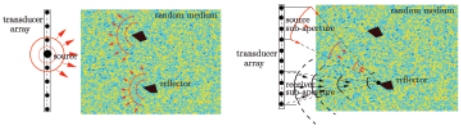



*FIG. 3: Coherent interferometric imaging. In the left picture a sensor array is used to probe an unknown medium in which reflectors are buried (one of the transducer is used as a source, the other transducers are used as receivers and record the echoes, which form one column of the array response matrix). In the right picture local cross correlations of recorded signals are backpropagated numerically and focus more or less on the locations of the reflectors.*

cross correlation of noise signals to retrieve information about travel times was first proposed in helioseismology [Rickett et al., The Leading Edge 18 (1999), 957]. It has been applied to background velocity estimation from regional to local scales, volcano monitoring, and petroleum prospecting [Larose et al., Geophysics 71 (2006), SI11].

These observations have motivated novel ideas for imaging. First of all one can explain mathematically the relation between cross correlations of noise signals and the travel time between the two points. This is motivated by the analogy between the cross correlation of the noise signals and a virtual time-reversal experiment in which one of the points is the original source, the other point is the receiver, and the noise source locations play the role of the virtual time-reversal mirror. This analogy (together with the Helmholtz-Kirchhoff identity, a variant of Green's identity) shows that, when the support of the random noise sources completely surrounds the region of interest, then the cross correlation of the recorded signals has a peak at the travel time between the sensors (see Figure 4). In many applications, however, the noise source distribution is spatially limited and the waves recorded by the sensors are dominated by the

flux coming from the direction of the noise sources. The cross correlations of the recorded signals then depend on the orientation of these sensors relative to the direction of the energy flux. This affects significantly the quality of the estimate for the travel time. As can be explained by stationary phase arguments, it is good when the line between the sensors is along the direction of the energy flux and bad when it is perpendicular to it.

When there is multiple scattering in the medium, as in an ergodic cavity or as in a randomly inhomogeneous medium, directional diversity of the recorded signals is enhanced by multi-pathing. This was studied in the context of time-reversal experiments and it has been shown that time-reversal refocusing can be enhanced in a randomly scattering medium. It turns out that it is possible to exploit the enhanced directional diversity of the multiply scattered waves for travel time tomography using cross correlations of ambient noise signals. Indeed the travel time between two sensors can be estimated even in unfavorable situations provided that special fourthorder correlation functions with auxiliary sensors are used [Stehly et al., J. Geophys. Res. 113 (2008), B11306]. By unfavorable we mean that the main component of the energy flux from the noise sources is roughly perpendicular to the ray connecting the two sensors. The fourth-order correlations can be used effectively for enhancing travel time estimation between the two sensors by exploiting the scatterers as secondary sources and by reducing the contribution of the primary flux.

Ambient noise signals can also be used for passive sensor imaging of reflectors embedded in the medium. Indeed, in the presence of reflectors, the cross correlations between any two sensors have, in addition to the main peaks at the travel times between them, other peaks at lag times related to travel times from the sensors to the reflectors. The analysis of the relation between the secondary peaks in the cross correlations and travel times between sensors and reflectors shows how to image the reflectors by suitably migrating the correlations [3]. The resolution of the image depends on the directional diversity of the noise signals relative to the sensor array and on the reflector location. When directional diversity is limited it is possible to enhance it by exploiting the scattering properties of the medium. However, scattering increases the fluctuation level of the

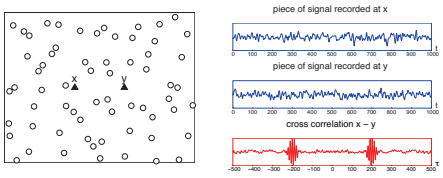



*FIG. 4: Ambient noise imaging (numerical simulations). When the spatial support of the noise sources (circles) extends over all space then the cross correlation of the signals recorded at x and y is symmetric and exhibits two peaks that are centered at plus and minus the travel time between the two points.*

cross correlations and therefore blurs the image. During our semester at IHÉS we have studied the trade-off between resolution enhancement and signal-to-noise ratio reduction due to scattering [4] and we have shown that it requires a deep understanding of wave propagation in random media and scaling issues. Following the coherent interferometric imaging ideas developed for broadband deterministic pulses, it is possible to form space-time local cross correlations of the cross correlations and migrate them. The use of iterated cross correlation can enhance dramatically the quality of the images (see Figure 5). These techniques are new and could certainly be improved and extended to other areas, such as microwave imaging, and they can in turn trigger new ideas in active array imaging.

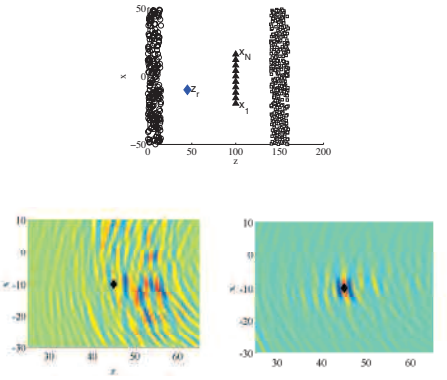


*FIG. 5: Reflector imaging using signals generated by ambient noise sources (numerical simulations). The configuration is plotted in the top picture: the circles are the noise sources, the squares are the scatterers, the triangles are the sensors, and the diamond is a small reflector. The image obtained by migrating the matrix of cross correlations of the recorded noise signals is plotted in the left bottom picture. The image obtained by migrating special fourth-order cross correlations is plotted in the right bottom picture.*

For further reading:

[1] L. Borcea, J. Garnier, G. Papanicolaou, and C. Tsogka, *Coherent interferometric imaging, time gating, and beamforming*, to appear in Inverse Problems.

[2] J.-P. Fouque, J. Garnier, G. Papanicolaou, and K. Sølna, *Wave propagation and time reversal in randomly layered media*, Springer, New York, 2007.

[3] J. Garnier and G. Papanicolaou, *Passive sensor imaging using cross correlations of noisy signals in a scattering medium*, SIAM J. Imaging Sciences **2** (2009), 396-437.

[4] J. Garnier and G. Papanicolaou, *Fluctuation theory of ambient noise imaging*, to appear in Compte Rrendu Acad. Sci. Paris Geosciences.

# final year for the campaign

In March 2008, IHÉS officially launched its second international fundraising campaign, carried out in France, the United States, Japan and China.

This major donor campaign will close at the end of the year ; the Institute intends to make use of these last few months to maintain its level of commitment and attract new donors.

Looking to the United States, the consolidation of the Friends of IHES, Inc. organisation bodes well in that respect. In 2010, the organisation's Board changed with the election of its new President, in the person of Renaud Dutreil. This appointment enabled new elected members to join the "Friends" Board, all very enthusiastic about IHÉS and keen to increase the organisation's visibility within New York business circles. The recruitment of an Executive Director will also enable the organisation to engage in sustained fundraising efforts, especially through the organisation of events, which are key to promoting the work of "Friends".

Efforts made towards China led to a few encouraging results. The Institute's visibility has increased there, but progress in the search for Chinese donors to the Chern Fund is slow.

Fundraising in France has been very successful, with a large increase, since the previous campaign, in the number of French organisations among the Institute's major donors: several large companies supported the Institute with very significant contributions.

It nevertheless remains important for IHÉS to have new institutions supporting it: strategic objectives are yet to be met, such as recruiting a sixth permanent professor or consolidating the Institute's attractiveness at the international level.

## Jean-Paul Gimon Chair

Created in 2005 in memory of Jean-Paul Gimon, former member of the IHÉS Board of Directors, and a highly valued adviser for the Institute as it launched its first ever fundraising campaign in 2001, this Chair will provide permanent funding for two months of research visits at the Institute each year.

Jean-Paul Gimon was always mindful of making a place like IHÉS accessible to young people and in particular to those from developing countries; for this reason, the Chair bearing his name is intended for young people, with the priority given to researchers from Africa.

*"On 19 May 2011, the Institute organised a ceremony in honour of Jean-Paul Gimon who played a key role at a difficult time for IHÉS. The Institute wanted to express its profound gratitude to him through the creation of a Chair. He was in fact the person who encouraged the Institute to undertake its first fundraising campaign and provided the resources to make that campaign a reality. That was back in 2000, and IHÉS was experiencing a worrying financial situation. Since then, over 30 million euros has been raised in France and worldwide. This is thanks also to new key figures who have rallied to the IHÉS cause. In this regard, I would like to thank Renaud Dutreil, Chairman of LVMH Inc., who has agreed to take over in representing Friends of IHES, Inc. in the United States, setting up an effective team and making "Friends" a very dynamic organisation, which plays an important role in the Institute's international influence.*

*As Chairman of the Board of Directors of IHÉS, I also welcome the commitment of new institutions to the Institute, and particularly Huawei Technologies France, who recently made a significant gift to IHÉS.*

*Other sources of satisfaction are the numerous awards received by IHÉS professors, but also efforts made in recent past years to improve the Institute's visibility through creative initiatives such as the public conference held at the World Expo in Shanghai or the book,* The Unravelers, Mathematical Snapshots. *Without this enhanced visibility, the 50th Anniversary Campaign would not have been so successful."*

***Philippe Lagayette***

# campaign in the United States

## renewal of the Board of Friends of IHES, Inc.

11 years into its existence, the organisation has elected a new President and three new members.

Friends of IHES Inc. was set up in 1999 mainly to help IHÉS increase its visibility in the United States. There are historical links between IHÉS and the United States, going right back to the very early days, when Léon Motchane convinced Robert Oppenheimer to join the Institute's Board of Directors and to help guide its first steps. Since then, hundreds of American researchers have been invited to the Institute. Many IHÉS permanent professors have also contributed to the vitality of exchanges between the Institute and the American scientific community.

Since its inception, "Friends" has helped IHÉS considerably in terms of visibility, and also in terms of funds raised and transferred to the Institute. The organisation is now a real asset for the Institute.

In May 2010, Renaud Dutreil, Chairman of LVMH Inc. was elected President of the Board of Directors of Friends of IHES, Inc. Following this election, new members, who come from the corporate world in New York, joined the organisation. These new arrivals will hopefully lead to an increase in the activity of "Friends" and improvements in identifying and convincing new donors.

*Reception at the Ambassador, Permanent Representative of France to the United Nations, Gérard Araud, at the French Residence, New York, on 12 May 2010*

## 2011 - 2012 US campaign

A new campaign has been launched by Friends of IHES, Inc, with a financial target of 3 million dollars to be raised in 2011 and 2012.

Priority is to be given to securing funding for American visitors, who represent around 30% of the visitor programme at IHÉS. An endowed United States Fund will be set up to provide permanent funding for some of the American visiting researchers. In addition, Friends of IHES, Inc. will be reaching out to foundations, with a view to entering into new partnerships aimed at providing multi-annual grants for the support of American visitors.

In a new departure, "Friends" is creating a "Corporate club", to bring it into closer contact with new American companies, with a number of high profile events, which we hope will soon become well known in New York business circles.

### Support from CIC

The New York subsidiary of CIC has long been a supporter of the work carried out by Friends of IHES, Inc. thanks to Serge Bellanger, who was a fervent admirer of IHÉS and of the excellence of French mathematics. Friends of IHES, Inc. is very happy to see the partnership continue in 2010 and 2011 and warmly thanks CIC for its support.

*"Like many others, I have always placed mathematics at the forefront of key disciplines and I am proud and pleased to see France – and IHÉS in particular – taking such a prominent role in their development, for the furtherance of science and intelligence.*

*IHÉS created a unique community of international scientists with significant achievements in mathematics and theoretical physics, in an environment of extraordinary intellectual freedom and independence.*

*The campaign launched in 2011 in the United States aims to provide American researchers with new opportunities to work at IHÉS. It is crucial for Friends of IHES, Inc., making a fresh start in 2011, to organise scientific events to reach out to new US supporters, corporations and foundations willing to support fundamental research in mathematics.*

*Developing exchanges between the United States and France will contribute to the expansion of academic excellence of both nations and to the benefit of the world's scientific community. Supporting this cause means taking one step closer towards understanding the world."*

***Renaud Dutreil***

# **finance breakfast meeting** at the Consulate General of France in New York

*Yuri Tschinkel, Eugene Durenard*

*Luc Hardy, David Goldman*

*"Some New Directions at the Interface between Finance and Mathematics: Bottom-Up Finance"* was the theme explored during the "Finance breakfast meeting" organised by Friends of IHES, Inc., on 12 May 2011.

The event, which took place in the elegant setting of the Consulate General of France in New York, represented an opportunity for scientists and finance specialists, together with leading business people, to interact and exchange views on the topical subject of financial mathematics, which was heavily criticised after the severe financial crisis in 2008.

*Véronique Carpentier, Thierry Simon, Jim Simons*

Two scientists, whose work covers both mathematics and finance, made brief presentations on this topic: Eugène Durenard, Partner, Orion Investment Management Ltd., and Petter Kolm, Director of the Mathematics in Finance M.S. Program at the Courant Institute of Mathematical Sciences, New York University.

Eugène Durenard made the first of the presentations, during which he shared his thinking on current developments in financial mathematics. In his view, financial theory has long been based on a "top-down" approach, which is seen today as having had a disappointing track record. A change of paradigm is clearly needed and the beginnings of it are already emerging. This new approach is multi-faceted and is primarily based on the investigation of the market as a complex system where large scale patterns emerge from elementary interactions of reasonably simple agents. It should allow a unified framework to study the various phenomenological features (such as the asymmetric behaviour of agents or non-linearities in macro-economics) that are central to the design of efficient and profitable survival strategies in the global marketplace.

Eugène Durenard concluded his talk by explaining that the new direction in mathematical finance should come from the confluence of recent research in complex systems, control theory, autonomous adaptive agents and some aspects of mathematical biology.

The event was also an opportunity to demonstrate the high quality of events now offered by Friends of IHES, Inc.. We hope that many other events of this level will be organised soon.

*"… Links between the Insitute and the United States are very strong. They were so from the start, with the famous Institute for Advanced Study (IAS) in Princeton providing a sort of blueprint for the Institute. These links are just as strong today: the Institute has no fewer than 30% American mathematicians, physicists, biologists and computer scientists within its ranks. Further reinforcing the links between the Institute and the United States is a key objective for Friends of IHES.*

*This morning, we wanted to bring together the worlds of finance and mathematics. French mathematicians represent a valued talent pool on Wall Street, and sometimes a controversial one (mathematicians are admittedly easy targets for criticism!). For my part, I am pleased to see that French training and expertise are so appreciated here …"*

***Extract from Philippe Lalliot's speech, Consul General of France in New York***

# campaign in the People's Republic of

## world expo in **Shanghai**

For more than 10 years, IHÉS has been undertaking projects aimed at increasing its visibility within the Chinese scientific community and attracting more Chinese researchers.

The Shanghai World Expo was a great opportunity to get in touch with the Chinese public, and also with students and researchers. Which was why IHÉS applied to organise a conference in the France Pavilion, *"meeting the Unravelers"*, a scientific conference for the general public, consisting in a series of short presentations. The conference, which was initially planned over a half-day, had to be extended to a full day, to satisfy the many registration requests received. In the end, over 200 people came to listen to leading scientists who were there to share some of their current research work or certain aspects of mathematics that they find particularly interesting.

Four of the eight presentations dealt with mathematical physics and how geometry contributes to our understanding of the Universe: Liu Kefeng (Zhejiang University) *Mathematics born of physics*, Long Yiming (Chern Institute of Mathematics, Nankai University) *The solar system seen by a mathematician* and Hu Sen (University of Science and Technology of China) *Searching for the geometry of the universe*. Cédric Villani (Université de Lyon I - Institut Henri Poincaré) spoke of how galaxies evolve, using an analogy from gas kinetics. Other speakers were: Jean-Pierre Bourguignon (CNRS-IHÉS), Josselin Garnier (IHÉS-Université Paris Diderot), Li Ta-Tsien (Institut Sino-Français de Mathématiques Appliquées), George Papanicolaou (IHÉS-Stanford University). They touched on a wider range of themes, including flexible polyhedra, imaging in seismology, mathematics in finance and the golden ratio.

*Li Ta-Tsien*

IHÉS thanks the Consulate General of France in Shanghai, Yao Yi-Jun and his wife, Xu Mingyu, for their invaluable help and active contribution to the success of the day, together with the event sponsors: EADS, Saint-Gobain, Société Générale and LCL Banque privée

*Hu Sen, Liu Kefeng, George Papanicolaou, Josselin Garnier, Cédric Villani*

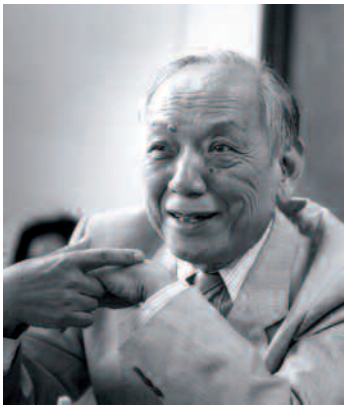

*Inauguration of the exhibition in Beijing by Jean-Pierre Bourguignon*

## The Unravelers **exhibition**

The Paris - Île-de-France Pavilion at the World Expo, where the travelling exhibition *The Unravelers* was shown from 16 to 23 October 2010, was the starting point for the exhibition's long tour across China, via the Alliances Françaises network. Nine major cities have chosen to show it between November 2010 and September 2011: Nankin, Canton, Jinan, Xi'an, Beijing, Hangzhou, Chongqing, Macao and Tianjin. The publication by Higher Education Press of the Chinese version of the book, *The Unravelers*, complements the exhibition, with texts by Chinese scientists added to the original version. This book, edited in France by Éditions Belin, is the work of J.-F. Dars, A. Lesne and A. Papillault.


*Exhibition in Xi'an*

# donations for the **Chern Fund**



## Chern Shiing-Shen

Chern Shiing-Shen is one of the greatest geometers of the 20th Century. His contribution to differential geometry in particular was major, and had multiple applications. Professor Chern would have celebrated his 100th birthday in 2011. The Chern Institute of Mathematics, Nankai University (Tianjin, China) and MSRI (Berkeley, United States), two institutes that owe their creation to him, will be organising celebrations from 24 to 28 October 2011 (at the CIM) and from 30 October to 5 November 2011 (at MSRI). IHÉS will be organising a day of conferences in his memory on 17 November 2011.

The Chern Fund is a fund set up to finance Chinese scientists invited to the Institute. In providing this support, it helps meet three broader objectives: intensifying scientific exchanges between China and France, promoting scientific research without any programme constraints and increasing the visibility of IHÉS within Chinese scientific communities (in mathematics, theoretical physics and at the interface between mathematics and biology).

Many French companies have become partners of this project; the Institute hopes to also attract Chinese donors and is working actively to that end.

Since its creation in 2002, the Chern Fund has received the support of Professor Shiing-Shen Chern who was personally involved in the development of the Chern Fund, by making a financial contribution to it, through his own foundation. Since he passed away, the Chern family has maintained its full support to the project. In November 2010, the Chern Foundation made a new additional donation. IHÉS would like to express warmest thanks for her trust to May Chu, Shiing Shen Chern's daughter and the Foundation's President.

Another major gift came to the Institute recently for the Chern Fund, from the "Fondation d'entreprise EADS". EADS is also one of the Institute's long-standing partners. Over the past ten years, various projects have been set up at the Institute thanks to its support.

*Louis Nirenberg (first receipient of the Chern medal) and May Chu during the International Congress of Mathematicians at Hyderabad, August 2010*

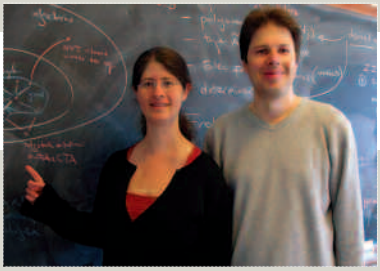
# **Huawei Technologies** Fund

A new fund set up to finance invited researchers of all nationalities was created by the French subsidiary of Huawei Technologies at the beginning of the year.

This Chinese high technology company has opened two research centres in France, one in Lannion (Brittany) and one in Cergy-Pontoise (near Paris). Since its inception, Huawei Technologies has always viewed research as an essential means to improve its ability to meet market requirements but also provide highly innovative technical tools. Which is why this leading Chinese group decided to support fundamental research in mathematics and chose IHÉS for that purpose, both because of the freedom offered to its researchers and the excellence of the work carried out there. The Huawei Technologies Fund at IHÉS will support 2 months of research visits each year in perpetuity.

*Leo Sun (Huawei France Managing Director), Jean-Pierre Bourguignon, François Quentin (Huawei France President), Philippe Lagayette*

# point of view by ...



## Shelly Garion and Sefi Ladkani

**The European Post-Doctoral Institute for Mathematical Sciences (EPDI), formed of ten institutes spread throughout Europe, exists since 1995 to encourage the mobility of young scientists at the European level.**
**Testimony collected in March 2011.**

We are a married couple of mathematicians currently staying at IHÉS as EPDI laureates. We both graduated at the Hebrew University of Jerusalem, Israel. Sefi's research is in representation theory and homological algebra and Shelly works in group theory. Both areas of research are in the general field of algebra, so although each of us carries out his/her research independently, we try to assist and support each other in general questions and issues that arise during our work.

In his research, Sefi focuses on the theme of derived equivalence and its combinatorial aspects, especially concerning categories arising from combinatorial data appearing naturally in algebraic, combinatorial and topological contexts. Derived categories, and more generally triangulated categories, have found applications in diverse areas of mathematics and mathematical physics, forming also bridges between various domains of algebra and geometry.

Shelly investigates finite simple groups. Finite groups naturally occur when considering the symmetry of mathematical and physical objects, the finite simple groups can be seen as their building blocks. She focuses on the study of the combinatorial and probabilistic aspects of these groups, utilizing techniques from number theory and algebraic geometry.

A common aspect of our work is the quite frequent use of computer programs in order to experiment and check several instances of a problem, before formulating claims and assertions which are then proved in full generality using rigorous methods.

We started our stay in Europe in 2008 by visiting IHÉS for two months and then we moved to Bonn. Later, we were both selected as European Postdoctoral Institute (EPDI) laureates for the years 2009-11. This is a two-year postdoctoral fellowship allowing one to carry out research at prestigious institutes in Europe. This has several advantages at this early stage of the career; it allows to focus on research without many external disturbances as well as to establish contacts and discuss ideas with researchers at these institutes, which differ from ordinary universities by the fact that there are relatively few, but very well known, permanent members, and most other scientists are visitors from all around the world.

We were very happy that we were both selected for this fellowship, as this enabled us to continue living together while developing our careers, which is not at all trivial but was extremely important to us.

We started our EPDI itinerary in 2009 by staying one year at the Max-Planck-Institute for Mathematics (MPIM) in Bonn, located at the heart of this pleasant city on the river Rhine. In Bonn there is a lot of mathematical activity, both at the MPIM itself in the form of weekly seminars and various workshops as well as at the University of Bonn and the Hausdorff Institute.

Bonn is also well known as the city of Beethoven and indeed there are many classical music events around the year, from Schloss concerts in the summer to piano competitions and conducting courses in the winter. The surrounding landscape around the Rhine is particularly pleasant.

In 2010 we moved to IHÉS at Bures-sur-Yvette, a small town south of Paris. This quiet and tranquil place has inspiring surroundings allowing one to concentrate on research and think of mathematical problems in the relaxed atmosphere among the woods of the Bois-Marie forest. One does not have to worry too much about everyday life here, as the staff of IHÉS takes care of many aspects. Accommodation is provided at the well equipped Ormaille residence, and lunch is served at the cafeteria allowing also informal interaction among researchers.

Nevertheless, IHÉS is close enough to Paris with all the possibilities this metropolis has to offer. Professionally, there are many universities so that seminars, conferences and other activities are being held regularly. During leisure time, one can enjoy the cultural and historical gems that Paris is full of.

Our stay in Europe provided us with many professional opportunities. We could conveniently travel in order to participate in scientific meetings and give talks at various institutions. Easy travel also facilitated collaboration with other scientists as personal contact is still important even in our current digital era.

We will always have pleasant memories from the time during our EPDI fellowship. It gave us a unique cultural experience as well as the opportunity to practice new foreign languages.

## 2011 events

"The Unravelers Tour in France"
26 September - 6 October: École Normale Supérieure Lyon
7 - 8 October: CIRM, Luminy
10 - 21 October: Université de Montpellier
31 October - 11 November: Université de Strasbourg
14 - 30 November: Université 1, Nancy
1st December 2011 - 6 April 2012: Nord-Pas de Calais region
Dates to be set for Rennes, Orléans and Grenoble.
Details of this event can be found on the Institute's website.

"The Unravelers Tour in China"
June : Alliance Française in Chongqing
July : Alliance Française in Macao
August - September : Alliance Française in Tianjin

From 7 to 9 September, IHÉS
Joint master opening for students of Hadamard Foundation founding institutions.

12 September, IHÉS
Afternoon on Arithmetical Geometry on the occasion of Takeshi Saito's 50th birthday.

From 17 to 21 October, IHÉS
*Differential Equations and Galois Theory* Conference as part of the celebration marking Evariste Galois's bicentennial, co-organised by Y. André, A. Buium, P. Cartier, J.-P. Ramis and H. Umemura .

17 November, IHÉS
Celebration of Chern Shiing-Shen's centenary.

October, November 2011 - January, February 2012 on Thursdays, IHÉS
*Arithmetics and Algebraic Geometry Course*, organised by A. Abbes, C. Breuil and L. Lafforgue.

July 2012 (dates to be confirmed), IHÉS
*French-Asian Summer School*

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For more information: www.ihes.fr

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