# bois-marie

INSTITUT DES HAUTES ÉTUDES SCIENTIFIQUES

## editorial

We can only measure what theory predicts, so the saying goes. And what better example than the detection of gravitational waves by LIGO's interferometers? This was a momentous achievement: the space-time distortion waves emitted by the coalescence of a black hole binary system reached us from one billion light-years away and they are $10^{-9}$ times smaller than an atom. Finding their signal in the surrounding noise was an amazing feat, bringing to mind the words needle and haystack. And yet the LIGO-Virgo project team officially announced the discovery on 11 February 2016.

Gravitational waves were predicted by Albert Einstein in his theory of general relativity and it became possible to detect them thanks to the discovery of the Schwarzschild solution – now known as a black hole – and to a century of theoretical and experimental developments. Crucial among these was the contribution of Thibault Damour, IHES permanent professor since1989. With his colleagues, he set out a new method used to describe the motion and gravitational radiation of a coalescing black hole binary system. Developing this method at IHES, drawing on new theoretical concepts and working closely with numerical simulation results, led to a new set of precise waveforms being defined for the detection and analysis of gravitational signals. This made it possible to interpret the signal detected and to measure the mass and spin of the two coalescing black holes.

Letting researchers carry out their research in complete freedom, sometimes over decades, is the Institute's very essence and the reason for its success. Whether enjoying the quiet of the woods, engaging in the impromptu exchanges made possible at IHES, or taking part in the 200 or so lectures, conferences and seminars organised there each year, scientists have a free rein in conducting their work.

A single scientific programme: curiosity; a single selection criterion: excellence. IHES' simple yet rare project brings together over 200 invited professors and researchers each year. This new issue of Bois-Marie will give you an overview of the range of scientific activity at the Institute.

The support of our partners and sponsors is key to keeping alive the dream of Léon Motchane, the Institute's founder, and I would like to thank you for your commitment to free and disinterested research.

Philippe Camus
IHES Campaign Co-Chairman

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## Cours de l'IHES

Once again, the *Cours de l'IHES* attracted a number of distinguished speakers:
L. Lafforgue (IHES), *"Catégories syntactiques pour les motifs de Nori"*
J. Pardon (Stanford University), "Contact Homology and Virtual Fundamental Cycles"
C. Villani (Institut Henri Poincaré), *"La théorie synthétique de la courbure de Ricci"*
H. Duminil-Copin (Université de Genève), *"Le modèle d'Ising en dimension d"*
T. Damour (IHES), "Gravitational Waves and Binary Systems"
E. Ullmo (IHES), *"La conjecture d'André-Oort"*
E. Rabinovici (Hebrew University of Jerusalem & IHES), "Topics in Quantum Field Theory and String Theory"

Videos of the *Cours de l'IHES* are available on the IHES Channel:

## Ruelle-Fest: recent advances in dynamical systems

The conference was organised by T. Damour and J.-P Eckmann, on 28 January, in honour of David Ruelle. A permanent professor at IHES from 1964, then an honorary professor from 2000, he has made a number of major and lasting contributions in several fields of physics. The two speakers were V. Baladi and H.H. Rugh.

## Huawei-IHES Workshop

This event, held on 13 April 2016 as part of the partnership with Huawei, dealt with the mathematical theories of information and communication technology. It was organised jointly for the second year running by the Huawei Mathematical and Algorithmic Sciences Lab and IHES. This annual workshop aims to provide a forum for scientific exchanges around mathematical topics that are key to development and innovation.

HUAWEI

# *Les Amis de l'IHES*

The public conferences organised twice yearly by *Les Amis de l'IHES* are proving very popular.

As part of the centenary of Einstein's general relativity, T. Damour gave a lecture on 26 November 2015, *"Relativité générale et trous noirs : un siècle de développements"*, during which he reviewed the lasting impact that the discovery of general relativity and black holes has had on present day physics and astrophysics. Many Bures-sur-Yvette residents were in the audience that day.
The conference given by S. Dehaene, a specialist in cognitive psychology, attracted a record-breaking audience, with 130 people coming to listen to a fascinating lecture on the origin of mathematical intuitions, *"D'où proviennent nos intuitions mathématiques ?"*
T. Damour will be on the lecture podium again next autumn, with a presentation on gravitational waves that will no doubt be once again very well attended.

In order to provide greater impetus to its activities and with the prospect of possible external funding, the association has decided to increase the number of public events to three per year. 2017 should therefore see a conference being held in February, another in the spring and a last one in the autumn. Details will be available on the IHES website.

*Stanislas Dehaene*

# Conference in honour of Arthur Ogus

A conference on algebraic geometry in honour of A. Ogus on the occasion of his 70th birthday took place at IHES from 23 to 25 September.

A. Ogus is a professor at the University of California in Berkeley, where he was also Chairman of the Department of Mathematics from 2012 to 2015. He has been invited to IHES on numerous occasions: the first being in 1974, the most important in 1977-1978 and the most recent from September to December 2015. He has also been invited by a number of French universities, including Université Paris-Sud (Orsay) in 1978-1979 and in 1991.
His area of research lies at the intersection of arithmetic and algebraic geometry. Many of his ideas, following the themes developed by A. Grothendieck and his colleagues found a natural home in France - at IHES in particular - where they were introduced, appreciated and discussed. Among the resulting long-lasting working partnerships in which A. Ogus was involved, the work undertaken with P. Berthelot from the early 1970s should be mentioned, together with the now classic publications that accompanied it: an introductory monography on crystalline cohomology (1978) and the article on the comparison between crystalline cohomology and De Rham cohomology (1983).
More recently, his interest in logarithmic geometry prompted by L. Illusie, A. Ogus has become one of its leading exerts and his hotly anticipated book on the topic is likely to also become a reference text. Those are just two examples of the strong links IHES has contributed to develop over the years between A. Ogus and some of the finest representatives of arithmetic geometry in the French mathematical school.

A. Ogus has always been very open-minded and generous in sharing his intuitions during his visits to France. In organizing a conference on the occasion of his 70th birthday and his four-month stay at the Institute, IHES wanted to be the first to acknowledge the considerable progress made thanks to him. The conference brought together many of the leading experts in A. Ogus's favourite areas of research. It enabled participants to glimpse into the future development of those topics to which he has made such significant contributions and which IHES is determined to continue to support.

Ahmed Abbes

Videos of the conference:

# *Topos à l'IHES*

The *"Topos à l'IHES"* conference, organised by O. Caramello, P. Cartier, A. Connes, S. Dugowson and A. Khelif thanks to a L'Oréal-Unesco For Women in Science fellowship, took place from 23 to 27 November 2015.

A. Joyal and I gave introductory lectures on the first two days, followed by three days of presentations: 11 plenary presentations and 11 short presentations, mostly given by young researchers. There were over 100 participants, especially during the first two days, which enabled many people to become familiar with the topic. Videos of the lectures and presentations have also been viewed extensively online.
The conference illustrated the fruitfulness and impact of the notion of topos – introduced by A. Grothendieck at IHES in the 1960s – on various mathematical fields such as algebraic geometry, number theory, mathematical logic, functional analysis, topology and mathematical physics.
The unifying nature of the notion of topos had already been glimpsed by Grothendieck, who compared the topos theme to a "bed" or a "deep river" realising a union between *"the world of continuum and that of discontinuous or discrete structures"*, that makes it possible *"to perceive with finesse, by the same language rich in geometric resonances, an "essence" which is common to situations most distant from one another"*
After Grothendieck's introduction of toposes as purveyors of cohomology invariants useful in algebraic geometry (in particular in relation to Weil's conjectures), new insights on the concept of topos emerged. According to W. Lawvere and M. Tierney, toposes can be seen as sorts of mathematical universes in which the familiar constructions on sets remain possible, but which have each their own properties. In addition, the theory of classifying toposes enables to associate to any mathematical theory of a very general form a topos which embodies its "semantic content".

*Olivia Caramello*

More recently, toposes have started being used as sorts of "unifying bridges" making it possible to link different mathematical theories together, to generate and study dualities and equivalences, to transfer ideas and results from one mathematical field to another and to demonstrate new results within a given theory.

Olivia Caramello

### IHES welcomes new professors and chair holders

*CNRS Research Director at IHES*

**Fanny Kassel,** mathematician, at Université Lille 1 (France). Her work focuses on pseudo-Riemannian homogeneous spaces. With this as a recurring theme, she has made deep explorations of fields as varied as Lie groups, hyperbolic geometry and spectral theory. She was awarded the CNRS Bronze Medal in 2015.

*Louis Michel chair*

**Eliezer Rabinovici**, physicist, holder of the Leon H. and Ada G. Miller Chair at the Racah Institute of Physics, Hebrew University of Jerusalem (Israel). His area of research is theoretical high-energy physics, in particular quantum field theory and string theory.

# 2015 IHES Synthetic Biology

In December 2015 a meeting was held at the IHES to explore the consequences of the newest developments in cellular and molecular biotechnology, comprising 29 invited speakers from seven countries and attended by about a hundred participants. Since recombinant DNA technology was pioneered in the 1970s, the molecular technology toolbox has been filled up with such a large variety of techniques that so-called "Synthetic Biology" is no longer a hollow phrase but has become reality, or at least almost so. These developments raise various issues, of course, in terms of potential benefits and risks. Experimentally modifying fundamental processes may give new insight into evolutionary pressures that produced biological systems as they are today, and may also lead to novel practical applications.
Biological evolution does not tend to produce radically new designs because typically natural selection has only variants to act upon that greatly resemble their ancestors in most ways. Big evolutionary jumps are vanishingly rare because random modification of fundamental processes is extremely unlikely to result in something that is viable. However, intelligent engineering is a much more focused process, and therefore the creation of new viable life forms that use fundamentally different processes is no longer unthinkable. During the meeting various contributors addressed a whole suite of methods that modify organisms in many fundamental ways.
For instance, the molecular machinery that handles genetic material can be made to use synthetic nucleotides (building blocks of DNA and RNA) and even new amino acids (building blocks of proteins). The organisms that result can have fundamentally new properties.
"Frankensteinian Science" may have a bad name, but it may have practical benefits too. Modified bacteria that produce therapeutic molecules on command may one day help to fight many a disease, and these bacteria may even be instructed to do this with precision. Just to give an example, one day diabetics might receive implants with bacteria that measure blood sugar levels and produce insulin only when necessary, thus abolishing the need of regular finger pricks and insulin injections.
Modifying genetic systems is already a big feat but, as participants of the meeting showed, synthetic biology does not stop there. For instance, new metabolic pathways have been designed and engineered to produce new compounds. It may be possible to design new metabolic pathways and to fine-tune cellular systems such as immune systems to produce new compounds and carry out new tasks.

Minus van Baalen, François Képès & Mikhail Gromov

*Mikhail Gromov*

# nonlinear waves trimester

A trimester on nonlinear waves, jointly organised by T. Duyckaerts (Univ. Paris 13), Y. Martel (École polytechnique), F. Merle (Univ. Cergy-Pontoise & IHES), F. Planchon (Univ. Nice Sophia-Antipolis), P. Raphaël (Univ. Nice Sophia-Antipolis), J. Szeftel (CNRS-Univ. Pierre & Marie Curie) and N. Tzvetkov (Univ. Cergy-Pontoise), took place at IHES from 2 May to 29 July 2016.

In addition to the regular seminars and working groups organised each week throughout the three months, there were three major events: two five-day conferences, from 23 to 27 May and from 20 to 24 June, and a summer school held from 18 to 29 July.

Over the course of the trimester, the programme brought together 80 leading scientists in the field, together with many students during the summer school. It was made possible with the support of the European Commission via an ERC Advanced Grant (Principal Investigator: F. Merle): "Blow up, dispersion and solitons (Blowdisol)" hosted by Université de Cergy-Pontoise. Contributions from Société Générale and the Clay Mathematics Institute were also essential to the organisation of the summer school which concluded this wonderful trimester.

**IHES trimester scientific objectives, programme of events and achievements**

Two of the IHES trimester organisers had already organised a thematic semester in the spring of 2009 called "Nonlinear waves and dispersion". The objective of this previous programme was to take stock, after almost twenty years of developments linked to the "model" nonlinear dispersive equations, from Korteweg-de-Vries to non-linear Schrödinger, as well as wave equations in their various forms. This work, initiated mostly in the United States by researchers with a background in harmonic analysis (C. Kenig, G. Ponce, L. Vega, J. Bourgain), naturally came across the pioneering efforts in Europe of J. Ginibre, G. Velo, J.-C. Saut, then H. Bahouri, J.-Y. Chemin, P. Gérard, F. Merle and many others after them.

The 2009 programme had been very successful, with a high participation rate from many high-calibre researchers invited from abroad, sometimes for the entire programme, and at least for a month.

In a way, the programme had marked the end point of a cycle of activity in the field of dispersive equations, centred around Cauchy problems for the various model equations. It had at the same time enabled a number of the then latest developments to be presented: the analysis of blow-up models such as focusing Schrödinger, together with concentration-compactness-rigidity methods (which have spread beyond dispersive models).

In some respects, current scientific activity in the field is much more varied than four or five years ago, as can be seen in the scientific activity undertaken during the thematic trimester at IHES: the analysis of the main dispersive toy models has shifted to tricky points relating to the asymptotic behaviour of solutions, be that in the precise dynamical description of blow-up models, in the progress made towards the soliton resolution conjecture, with the analysis of collisions between multiple solitons, or in studying the stability of breather-type solutions. The emergence of a corpus of clearly identified tools has also highlighted their versatility, their deployment on models other than dispersive models having proved productive, in particular on geometric dispersive equations that were out of reach until recently (for example, the analysis of blow-up dynamics for Schrödinger maps) and also, as already mentioned, to revisit parabolic equations. More generally, classification theorems on the behaviour of solutions of various nonlinear systems are now within reach; there was a full programme of presentations during the trimester (given by C. Kenig during seminars, Hadamard Foundation lectures and the summer school) on the recent results achieved by T. Duyckaerts, C. Kenig and F. Merle on the soliton resolution of solutions for energy-critical focusing nonlinear wave equation.

*Carlos Kenig*

At the same time, a great deal of development on dispersive effects is being done on much more sophisticated models, often closer to physical reality. Even simpler yet "physical" models such as the (nonlinear) Dirac equation present difficulties not encountered to date with waves or Schrödinger. The IHES trimester enabled many researchers from different backgrounds to interact on fluid models such as water waves and more generally on wave/dispersive-type models, which appear in many "asymptotic" derivations of fluid phenomena. Dispersive effects have played a key role in the latest existence and asymptotic behaviour results, which were presented during seminars, the two conferences and the summer school. In the context of water waves, asymptotic behaviour is the area of chief interest, as are models that are increasingly sophisticated and close to physical reality (surface tension, finished depth, etc.)

New developments are occurring, in particular in the case of 2D, which is the most difficult: there is a phase shift phenomenon in the study of scattering which had not to date been studied on a quasilinear problem. All these results are promising, because they introduce new tools, liable to being applied in various ways in the field of dispersive fluid models and beyond.


Interesting developments are also to be found in the study of vortex filaments, in connection with geometric dispersive equations such as "Schrödinger maps" or mKdV, which were presented during the trimester. Even in a vacuum, understanding the geometry of space-time requires the analysis of sophisticated quasilinear wave equations; many achievements in the field of general relativity, some of which were directly influenced by the rapid progress in the analysis of dispersive models, were presented and discussed during the various trimester events.

Let us recall that this area of research has seen a number of major advances in recent years, including "the L2 curvature conjecture" (S. Klainerman, I. Rodnianski et J. Szeftel) and the linear stability of the Kerr family of metrics (M. Dafermos, I. Rodnianski, D. Tataru, etc.), two issues where an understanding of dispersive phenomena plays a key part. The formation of trapped surfaces (D. Christodoulou, S. Klainerman, I. Rodnianski) also forms part of asymptotic analysis, with tools very similar to microlocal analysis, and the trimester provided a forum for presenting the latest developments on these very active topics.

In addition, linear equations continue to generate significant work, in contexts closer to realistic physical models: "sophisticated" geometry (variable metrics, possibly not very regular, existence of boundary conditions, influence of the environment's geometry on propagation and dispersion).

A growing area of research should also be mentioned here, in a field of investigation that is at the interface of dispersive PDEs and probability; it has seen rapid development with the study of nonlinear dispersive equations, where the initial datum is almost certainly chosen in a space that is out of reach of deterministic theories.

The IHES trimester had a number of objectives: taking stock of this new cycle, started a few years ago, paying special attention to young researchers in the field, where the ever-growing complexity of the work is an increasing challenge in the early stages of one's career. Another objective was to bring together researchers for whom areas of convergence are even more obvious than they were in 2009: let us mention here the large French community engaged in the mathematical study of fluid models, kinetic theory, dynamical systems and partial differential equations linked to infinite-dimensional Hamiltonian systems. In the United States, the work around dispersive modems, fluid and nonlinear wave mechanics (in particular when linked to general relativity and mathematical physics) is expanding rapidly (as evidenced by the success of the large-scale thematic programme at MSRI in the autumn of 2015). There are now recognised areas of overlap among all these communities and the scientific activity of the IHES trimester has made it possible to bring together the various strands of research, by providing opportunities for productive interactions among scientists from different backgrounds.

**Conferences**

Two conferences were held over the course of the trimester: a first one in May, with the following speakers: M. Berti (SISSA), L. Bieri (University of Michigan), P. Bizon (Jagellonian University, Krakow), W. Craig (McMaster University), P. D'Ancona (Universita di Roma 1), M. Del Pino (Universidad de Chile), J.-M. Delort (Université Paris 13), E. Faou (INRIA & Université de Rennes 1), G. Fibich (Tel Aviv University), M. Hadzic (King's College London), O. Ivanovici (CNRS & Université Nice-Sophia Antipolis), S. Klainerman (Princeton University), H. Koch (Universität Bonn), T. Mizumachi (Kyushu University), K. Nakanishi (Osaka University), S.-J. Oh (University of California, Berkeley), G. Ponce (University of California at Santa Barbara), D. Smets (Université Pierre et Marie Curie), L. Thomann (Université de Lorraine), P. Topping (Warwick University), L. Vega (Universidad del Pais Vasco), M. Visan (University of California at Los Angeles).

A second conference took place in June, with the following speakers: T. Alazard (CNRS & ENS Paris), V. Banica (Université d'Evry Val d'Essonne), D. Cordoba (ICMAT), M. Dafermos (University of Cambridge), C. De Lellis (Universität Zürich), B. Dodson (Johns Hopkins University), P. Gérard (Université Paris-Sud), P. Germain (Courant Institute of Mathematics), C. Huneau (CNRS & Université Grenoble-Alpes), A. Ionescu (Princeton University), R. Jerrard (University of Toronto), T. Kappeler (Universität Zürich), R. Killip (UC Los Angeles), M. Kowalczyk (Universidad de Chile), D. Lannes (CNRS & Université de Bordeaux 1), A. Lawrie (University of California, Berkeley), E. Lenzmann (Universität Basel), A. Nahmod (University of Massachusetts, Amherst), F. Pusateri (Princeton University), B. Schlein (Universität Zürich), C. Sogge (Johns Hopkins University), V. Vicol (Princeton University), H. Zaag (Université Paris 13).

The two conferences aimed to present the latest results pertaining to the trimester participants' areas of research, in the widest possible sense; all the themes mentioned above were tackled: asymptotic behaviour of dispersive models, dynamics close to solitons, blow-up phenomena, infinite-dimensional Hamiltonian dynamics, stability of fluid/nonlinear kinetic models, Einstein's equations, stability of the Kerr model, critical dispersive equations, asymptotic behaviour of fluid models, be they dispersive or not.

**Summer School** SOCIETE GENERALE

*2016 Summer School*

The trimester ended with a two-week summer school, alternating mini-lectures, aimed at presenting active research topics, with more traditional presentations of research work.

The mini-lectures were given by R. Frank (California Institute of Technology), C. Kenig (University of Chicago), N. Masmoudi (Courant Institute of Mathematical Sciences), B. Pausader (Brown University), M. Procesi (Universita di Roma 1), R. Strain (University of Pennsylvania), D. Tataru (University of California at Berkeley). They showed the range and thematic depth of the trimester, as illustrated by the presentation titles (listed in the above order of speakers):

- "A microscopic derivation of Ginzburg-Landau theory";
- "Soliton resolution for the energy critical wave equation";
- "Stability of the 3D Couette Flow";
- "Asymptotic behavior for the cubic nonlinear Schrödinger equation on product spaces";
- "Recurrent and diffusive dynamics for the NLS equation on tori";
- "On the Vlasov-Maxwell System in the Whole Space;"
- "Two dimensional water waves".

The more traditional presentations were given by S. Bianchini (SISSA), R. Carles (CNRS - IMAG Montpellier), S. Gustafson (University of British Columbia), J. Krieger (EPFL), H. Lindblad (Johns Hopkins University), H. Matano (School of Science, University of Tokyo), N. Pavlovic (University of Texas at Austin), R. Pego (Carnegie Mellon University), S. Roudenko (George Washington University), G. Staffilani (Massachusetts Institute of Technology), T.-P. Tsai (University of British Columbia), N. Visciglia (Universita di Pisa), S. Wu (University of Michigan), on themes related closely or loosely to the topics of the previous mini-lectures.

*Oana Ivanovici*

**Conclusion**

The IHES trimester was a success, as evidenced by the large number of invited professors who stayed at the Institute for several weeks, several months even, for some of them (more than 80 invited professors over the course of the three months), and by the very high demand for the summer school which concluded the scientific programme. Although it is too early to assess the scientific impact of the trimester itself – beyond noting that the continuum of work from autumn at the MSRI to July in Bois-Marie seems to have accelerated a number of developments – a number of trends can be mentioned: the objective of classifying the behaviour of Hamiltonian partial differential equation models no longer seems unattainable, a complete solution to the soliton resolution conjecture for nonintegrable models has never been so close to being found; techniques arising from dispersive models are now prevalent in most of the work relating to mathematical physics equations, general relativity and fluid mechanics. It is striking to note that an increasing number of researchers are working indifferently on these various themes and that progress in one quickly spreads to related themes.

Yvan Martel, Frank Merle & Fabrice Planchon

# Arrival of Hugo Duminil-Copin

Hugo Duminil-Copin, holder of the IDEX Paris-Saclay Chair, joins IHES as permanent professor. He explains here how he came to choose the Institute.

Following E. Ullmo's suggestion, I was invited to give a lecture at the Institute during the winter of 2016. I remember being very pleased and flattered by this invitation. Like all mathematicians, I had heard nothing but praise about the prestigious Institute and its renowned panel of permanent researchers. I was therefore excited (and a little intimidated) to be able to rub elbows with those incredible scientists.

Looking back, it seems that Bures-sur-Yvette has acted as a great "attractor" in my life; without my conscious knowledge I seem to be unable to stray from it for too long. I grew up in Les Ulis, less than ten minutes' walk away from the Institute. I attended the Bures-sur-Yvette middle school, 15 minutes away in the opposite direction. After a time in Paris for my studies (I attended grandes écoles preparatory classes then the École Normale Supérieure in the 5th arrondissement), I came back to Orsay to obtain my Master's diploma in Probability and Statistics at Université Paris 11. I was then sent far away from Bures-sur-Yvette by W. Werner, who advised me to work on my thesis with S. Smirnov. I had settled in Geneva for several years, and was even awarded a permanent post, leading me to believe that my life would be spent some 500 kilometres away from Bures-sur-Yvette. I had not reckoned with E. Ullmo (or, more poetically, with fate) who brought me to the doors of IHES one rainy January morning. I had walked hundreds of times past Bois-Marie as a child, without the slightest idea of what lay behind the walls. I would have never thought that it concealed a paradise for mathematicians and physicists. The place instantly cast a spell on me, with its calm and serene rhythm, so conducive to creativity and inspiration.

IHES has the capacity to bring together physicists and mathematicians. The field of mathematical physics, which is the current topic of my research, lies at the heart of the Institute's work. Former permanent professors, D. Ruelle and J. Fröhlich, to name just two, have both left a profound mark on statistical physics; their work has revolutionised our understanding of lattice models, one of my favourite topics. Thus, I chose to speak about the Ising model, one of the most fundamental of these models.

Giving a *Cours de l'IHES* is both inspiring and stimulating. The audience consists of mathematicians and physicists from varied backgrounds, able to process knowledge relating to fields outside their main area of work. Crossed fertilisation through interaction among researchers in different fields is encouraged by the very structure of the Institute and has, as a consequence, a profound influence on permanent and invited professors' research. This philosophy fits perfectly with my vision of research, based on collaboration, interaction and interdisciplinarity.

For all these reasons, I realised straight away that I would take to IHES like a duck to water. I therefore immediately accepted the offer of a permanent post, which the Scientific Council made a few days after my arrival. As I write, I have not yet officially joined the Institute's ranks but my mind is already in Bures-sur-Yvette, where I look forward to benefiting on a daily basis from productive exchanges with the numerous invited researchers. I would like to take this opportunity to thank those among them who took the time to read these few lines.

H. Duminil-Copin

Hugo Duminil-Copin is one of the ten researchers to have been awarded the EMS Prize on 18 July 2016 at the 7th European Congress of Mathematics. The award recognized his *"considerable contributions to percolation theory, a branch of probability that is concerned with the behaviour of connected clusters in random graphs"*.

Hugo Duminil-Copin studied at Université Paris 11 and obtained an *"agrégation"* in mathematics at École Normale Supérieure de Paris. He then went to Université de Genève where, having obtained his doctorate (under S. Smirnov's supervision) in 2012, he became assistant professor (2013-2014) then full professor in 2014.

H. Duminil-Copin is a probabilist. He works on statistical mechanics models such as percolation, the Ising model, the Potts model in 2 or 3 dimensions, random walks in random environments. His research also has an impact on mathematical physics, complex analysis and combinatorics. In addition, he makes significant contributions to statistical physics. He also works on the study of stochastic models such as random walks in random environments.

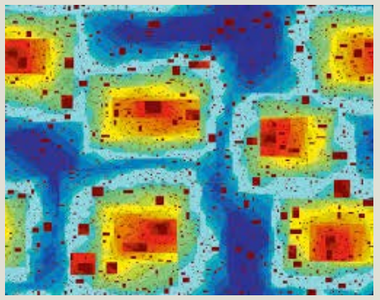


*Illustration of bootstrap percolation*

He has published 30 articles in the best journals in the field, alone or with a wide range of colleagues. Some of his results have earned him immediate international recognition, as well as many prizes (Peccot Lecture, Rollo Davidson Prize, Early Career Award of the International Association of Mathematical Physics, Oberwolfach Prize).

H. Duminil-Copin's positioning represents a very welcome scientific development at IHES. Probability has seen some spectacular progress recently, driven by specialists such as O. Schramm, W. Werner, S. Smirnov and M. Hairer.

For IHES, recruiting a probabilist represents an opportunity to embrace this flagship theme in modern mathematics and to diversify the Institute's scientific strategy.





*Francis Bach*

Created in 2006 as part of the 50th Anniversary Campaign, the Schlumberger Chair each year provides an ideal environment for a scientist to carry out their research at IHES over the course of around six months.

The chair provides the holder with considerable flexibility in organising scientific activities, with the possibility of inviting collaborators and organising events. Holders of the Schlumberger Chair are selected by the Scientific Council for their work on topics at the interface with high technology (see below).

F. Bach was the Schlumberger Chair holder from September 2015 to February 2016, working on statistical learning, optimisation and optimal transport.

For his part, F. Otto held the chair for two months in 2015 and two months in 2016.

The "Computational and Statistical Trade-offs in Learning" workshop was held on 22 and 23 March 2016 as part of the Chair.

One of the main objectives was to identify work on important ideas that had been carried out independently in certain communities and which could be of benefit to others.

Videos of the Schlumberger workshop are available on YouTube :

**Francis Bach**, currently a researcher at INRIA, has been head of the SIERRA project team since 2011; SIERRA is part of the Department of Computer Science at École normale supérieure de Paris.

His area of research is statistical learning, in particular for graphic models, artificial vision, image and audio signal processing, bioinformatics and brain imaging. He develops processing tools for massive and complex data. He has received many scientific awards, including the Microsoft Research Fellowship in 2002 (awarded to 12 students each in the United States) and the INRIA Young Researcher Prize in 2012.

**Felix Otto**, a mathematician, has been Director of the Pattern Formation, Energy Landscape and Scaling Laws lab at Max-Planck-Institut in den Naturwissenschaften, Leipzig (Germany) since 2010.

His areas of research are, amongst others, micromagnetism theory, stochastic homogenisation, Rayleigh-Bénard instability, etc.

He was awarded the Gottfried Wilhelm Leibniz Prize by the German Research Foundation in 2006 and the Gauss Lectureship by the German Mathematical Society in 2009. He is a member of the North Rhine-Westphalian Academy of Sciences and of the German National Academy of Sciences.

# Machine learning

Digital data is increasingly taking centre stage in science and industry, and in our daily lives too. One of the aims of machine learning is to give meaning to these huge amounts of data.

A major challenge in learning is the ability to "generalise", that is, to predict beyond the data observed. To achieve this, the traditional approach is to formulate the learning problem as an optimisation problem, using noisy data. My current research covers two issues: (1) stochastic optimisation methods for large data sets, for which it is necessary to develop algorithms which computational complexity is linear with data size, and (2) convex optimisation methods for common combinatorial optimisation problems in learning (such as for the problem of splitting data up in several groups, or "clustering").

Whilst at IHES, thanks to the Schlumberger Chair, I worked on both these issues. The interaction with the Institute's researchers and invited researchers, together with C. Villani's *Cours de l'IHES*, were of particular benefit.

Firstly, working jointly with V. Perchet (professor at ENSAE), we looked at how to use higher-order regularity in online optimisation, where only noisy data from the function to be optimised were available.

Then, using links between optimal transport theory and sub-modularity in combinatorial problems, I showed how a large part of the sub-modular analysis over the hypercube could be interpreted as an optimal transport property between two completely ordered sets. This led to new optimisation methods in polynomial time for a new class of continuous but non-convex functions.

Lastly, S. Arlot (professor at Paris-Sud, currently at IHES), A. Celisse (lecturer at université de Lille-1) organised a conference on the trade-off between computation time and statistical performance with international invited speakers, which provided a forum for presenting recent progress in our rapidly expanding field of research.

Francis Bach

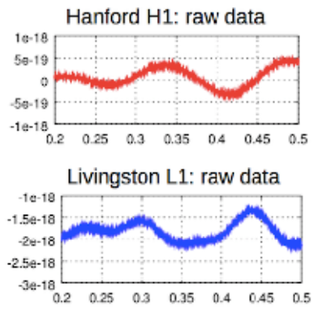
# gravitational waves and binary systems

Our theoretical understanding of the dynamics of two-body systems, and of how gravitational waves both affect the motion of binary systems and are generated by such systems, has greatly advanced since the 1980s. Many of these theoretical advances in what is called Analytical Relativity have had their source in works done in France. This article aims at giving a bird's eye view of these advances in Analytical Relativity, and notably of those obtained at IHES.

**For a more detailed article, including bibliographic information and other references, please visit the dedicated website: https://gravitational_waves.ihes.fr/**

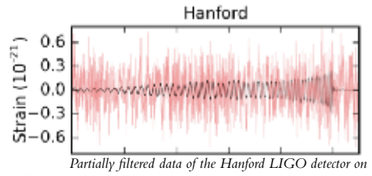
We know since the 1980s that the gravitational force between bodies propagates by retarded waves at the velocity of light. Indeed, the excellent agreement between the observations of binary pulsars (J.H. Taylor and collaborators) and the theoretical calculations, in general relativity, of the retarded two-body interaction (T. Damour and N. Deruelle) provides a direct experimental proof of the propagation properties of the gravitational field, and, in particular, an experimental confirmation that the speed of propagation of gravity is equal to the velocity of light to better than a part in a thousand. The binary-pulsar observations/theory agreement provided also the first confirmations of Einstein's theory in the strong-field regime (J.H. Taylor, A. Wolszczan, T. Damour, J.M. Weisberg, 1992).

Recently (B.P. Abbott et al., 2016a, 2016b), the LIGO-Virgo collaboration has announced the simultaneous observation (on the 14 September and 26 December 2015) by the two LIGO detectors of the arrival on Earth of the transient gravitational wave (GW) signals emitted by the coalescence of a pair of blackholes. This landmark discovery is both the first observation of gravitational radiation in the wave zone, and the first detailed experimental proof of the existence of the black holes predicted by Einstein's theory. It also marks the beginning of the long-awaited gravitational-wave astronomy.




*Raw data of the two LIGO gravitational-wave detectors on 14 September 2015 (presented on behalf of the LIGO-Virgo collaboration by E. Chassande-Mottin at the Académie des sciences, Paris, on 5 April 2016)*

This major observational discovery, which crowns more than fifty years of experimental development (starting with the efforts of J. Weber in the early 1960s), has been supported by many theoretical studies of the generation of gravitational radiation by potential sources. Some theoretical works done at IHES have contributed to this discovery by defining GW templates which have been used (matched-filter method) to extract the black hole coalescence signals from the noisy data recorded by the LIGO detectors.




*Partially filtered data of the Hanford LIGO detector on 26 December 2015(in red) and its comparison to a partially filtered theoretical GW template (in black) (B.P.Abbott et al., 2016b)*

**The effective one-body (EOB) Formalism**

The EOB formalism was created at IHES around 2000 (A. Buonanno, T. Damour and collaborators); the main aim was to provide a new theoretical framework allowing one to analytically describe the complete gravitational-wave signal emitted during the entire coalescence process of binary black-hole systems, covering inspiral, merger and the post-merger (ringdown) signal. It was conceived at a time where there were no numerical simulations able to describe the coalescence of binary black holes (BBH), and where the existing theoretical methods (based on straightforward post-Newtonian (PN) theory) were unable to describe the last orbits, before coalescence, of binary black holes.

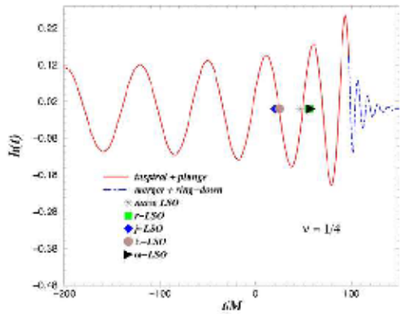
The EOB formalism made the following (quantitative and qualitative) predictions concerning both the dynamics of the coalescence, and the corresponding GW radiation:

- a blurred transition from inspiral to a "plunge" that is just a smooth continuation of the inspiral;
- a sharp transition, around the merger of the two black holes, between a continued inspiral and a ring-down signal;
- estimates of the radiated energy and of the spin of the final black hole resulting from the coalescence of the BBH.

These predictions of Analytical Relativity have been made years before Numerical Relativity (NR) simulations could describe the late inspiral and merger of binary black holes and have been broadly confirmed by subsequent NR simulations. Notably, the global shape of the complete coalescence waveform of a "non-spinning" BBH system, first computed by A. Buonanno and T. Damour (2000), is in rather good agreement with the results of the NR simulations initiated by the breakthroughs in 2005-2006 (F. Pretorius, M. Campanelli, J. Baker and collaborators).

In addition, the effects of the individual spins of the black holes were investigated within the EOB formalism, and were shown to lead to a larger energy release for spins parallel to the orbital angular momentum, and to a dimensionless rotation parameters $J/(GE^2)$ always smaller than unity at the end of the inspiral (so that a Kerr black hole can form right after the inspiral phase). Those predictions have been confirmed by subsequent numerical simulations.

It was suggested in 2002 that one could nourish and improve the EOB formalism by extracting strong-field information from NR simulations and translating them within the analytical EOB framework. In particular, it was emphasized that some, yet unknown, theoretical parameters entering the EOB description could be determined by "best fitting" them to appropriate numerical data. This EOB + NR strategy became possible after the NR breakthroughs of 2005-2006, and was independently pursued at IHES by T. Damour and A. Nagar and in the group of A. Buonanno in the US.




*First computation of the complete gravitational wave signal emited by the coalescence of two black holes (Buonanno, Damour, 2000)*

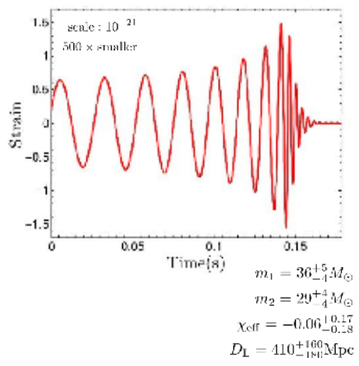
Combining several new theoretical improvements in the analytical side of EOB theory and notably the factorized and resummed waveform of T. Damour, A. Nagar and B.R. Iyer (2008, 2009) with the improvements obtained by fitting some EOB flexibility parameters to NR results, led to defining analytical "EOBNR" waveforms incorporating the best available analytical and numerical information.

The EOB description of the coalescence of binary systems of spinning black holes was similarly developed in the 2010's (A. Taracchini et al., T. Damour, A. Nagar). A class of such EOBNR gravitational wave templates have been used in the search and data analysis of the recent LIGO discovery.

The EOB formalism was also extended to the description of the gravitational-wave signal emitted by binary neutron star systems, up to the merger.

**The Blanchet-Damour-Iyer (BDI) Formalism**

Besides the EOB formalism, there are two other theoretical studies partially done at IHES wich have crucially contributed to the analytical knowledge of the motion and gravitational radiation of binary systems and which have been incorporated within the EOB framework. The first such theoretical tool is the Multipolar Post-Minkowskian (MPM) approach to the generation of gravitational waves by general sources (and, in particular, by binary systems). This formalism was initiated in the late 1980s and then developed from the 1990s up to recently (2014) into an efficient tool for analytically computing the emission of gravitational waves by general sources by L. Blanchet, T. Damour, and B.R. Iyer. The currently most accurate determination of the gravitational waves emitted by binary systems (due notably to L. Blanchet et al.) has been obtained by means of this formalism.




*EOBNR-IHES coalescence waveform for two non-spinning black holes of masses $m_1$=36$M_{sun}$, $m_2$=29$M_{sun}$, corresponding to the 14 September 2015 event*

**Dynamics of Binary Systems**

The analytic determination of the equations of motion of binary systems in general relativity has also been an important avenue of research at IHES.

It is traditional to characterize the level of accuracy of the analytic computation of the equations of motion of two bodies in terms of the so-called "post-Newtonian" level. The first post-Newtonian (1PN) level refers to equations of motion that include the first relativistic corrections (of fractional order $\sim v^2/c^2$, where v denotes a typical velocity and c the velocity of light) to the Newtonian equations of motion. This level of accuracy was reached long ago (notably by H.A. Lorentz and J. Droste in 1917 and by A. Einstein, L. Infeld and B. Hoffmann in 1938).

The general relativistic equations of motion of a binary system at the second post-Newtonian (2PN) level, and also at the second-and-a-half post-Newtonian (2.5PN) level, were first fully obtained by T. Damour and N. Deruelle in 1981. It is these equations of motion, valid up to corrections of order $v^5/c^5$, that first derived the combined effect of the propagation of gravity, together with all nonlinear relativistic effects and led to the first satisfactory theoretical explanation of the change of the orbital period in binary pulsars discovered by J.H. Taylor and collaborators.

The general relativistic equations of motion of a binary system at the next analytical order of accuracy, the third post-Newtonian (3PN) level (fractional corrections of order $v^6/c^6$) were first fully obtained in 2001 (T. Damour, P. Jaranowski and G. Schäfer). At this order of approximation, which corresponds to the three-loop level when translating the calculation in terms of Feynman-like diagrams (T. Damour, G. Esposito-Farèse, 1996), one had to use the efficient method of dimensional regularization to regularize the formal way of replacing the two gravitationally interacting extended bodies by point masses.

The general relativistic equations of motion of a binary system at the fourth post-Newtonian (4PN) level (fractional corrections of order $v^8/c^8$; four loops) were first fully obtained rather recently (T. Damour, P. Jaranowski, G. Schäfer, 2014). This result was obtained by completing the computations of the pure-near-zone-generated part of the dynamics (P. Jaranowski, G. Schäfer, 2013) by two other results:

- the contribution to the interaction potential coming from a matched near-zone-wave-zone self-force computation (D. Bini, T. Damour, 2013);
- the nonlocal-in-time interaction mediated by gravitational-wave tail effects, which was first obtained in (L. Blanchet, T. Damour, 1988) within the Multipolar Post-Newtonian formalism.

The 4PN-accurate dynamics has been recently transcribed within the EOB formalism (T. Damour, P. Jaranowski, G. Schäfer, 2015).

**Gravitational Self-Force (GSF) in Black Hole Backgrounds**

Let us also mention that the work of D. Bini and T. Damour (2013) is one example of a recent sequence of theoretical studies where the theory of black hole perturbations (à la Regge-Wheeler-Zerilli etc.) have been used to determine some of the high-PN-order contributions to the dynamics of binary systems.

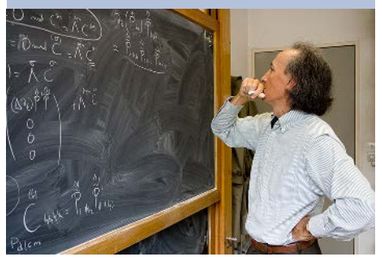
**Gravitational Wave Bursts from Cosmic (Super) Strings**

Another line of research pursued at IHES, and directly connected with gravitational-wave astronomy, is the discovery, and study, by T. Damour and A. Vilenkin (2000) of the emission of occasional sharp bursts of gravitational radiation emitted by cosmological-size strings (which could be the fundamental, or Dirichlet, strings of super-string theory). These (non-Gaussian) beamed bursts of gravitational radiation (which would stand above the previously discovered quasi-Gaussian stochastic background of GW emitted by cosmic strings ; A. Vilenkin 1981) are emitted by the cusps that generically form a few times during each oscillation period of a string. It was remarkably found that these bursts might be detectable by LIGO-Virgo even if the string tension is as small as $G\mu = 10^{-13}$.

Thibault Damour

Thibault Damour, permanent professor at IHES since 1989, has received many prestigious awards over the course of his career: Foundation Singer-Polignac laureate (1978), CNRS Bronze Medal (1980), "Paul Langevin" Theoretical Physics Prize (1984), Gravity Research Foundation Award (1994), Mergier-Bourdeix Prize, Einstein Medal (1996), Cecil F. Powell Medal (2005), Amaldi Prize (2010). He is a member of the Paris Academy of Sciences de Paris and of the Institut de France.

In 2016, Thibault Damour was one of the winners of the "Special Breakthrough Prize in Fundamental Physics" for his contribution to the historical detection of gravitational waves. He has also been elected honorary foreign member of the American Academy of Arts and Sciences and been awarded the 2016 Lodewijk Woltjer Lecture in April.



# IHES, the early years

*"Scientific research is not a natural phenomenon that occurs automatically in universities, rather, it is an activity that needs nurturing, can be cultivated and provides those countries that have an abundance of it considerable additional prestige and political power".* Léon Motchane, the founder of IHES, had strong opinions. Determined to offer outstanding scientists a place conducive to the unfettered development of their research, he took inspiration from the model of the Institute for Advanced Study (IAS) at Princeton and created IHES in 1958, dedicated to theoretical sciences: mathematics, physics and their interactions.

**Léon Motchane**

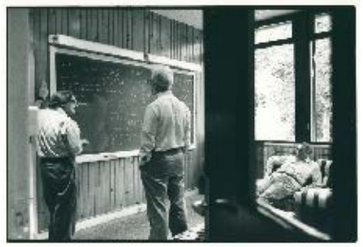
Léon Motchane was born in Saint-Petersburg in 1900. He studied in Lausanne and even worked there for a year as a physics assistant. Although he left academia for business, he continued to take a keen interest in mathematics, physics and sociology. During the war, he contributed to the Éditions de Minuit, in which he published two essays, including *"La Pensée patiente"* ("Patient thought") in 1943, under the pen name of Thimerais. His love of mathematics led him to submitting a thesis at the age of 54 and to planning the creation of the Institute. Motchane was clear about two things: fundamental research needed to be supported by major industry leaders and researchers had to enjoy complete freedom in their decisions. These two aspects are the Institute's keystone. *"The truly modern aspect of scientific research lies in the fact that the work of an industrialist, of an engineer, and that of a theoretical physicist or a mathematician, however abstract, are not that far removed from one another, and the success of the latter becomes essential for the former."* (Note on fundamental research, Motchane, 1959)

*Founding general assembly, 27 June 1958*

**Creating the Institute**

Together with Maurice Ponte (CSF), Pierre Dreyfus and Fernand Picard (Régie Renault), Motchane secured the first grants required to set up his Institute. This initial and very active support enabled him to quickly enlist the help of other leaders of major groups (especially in the petroleum and automotive industries).

On 27 June 1958, Motchane, who had undertaken the bulk of the preliminary work, declared in Joseph Pérès's office (Institut de France) that he wanted to *"stop the French haemorrhage to the United States"*: the Institute was born and Motchane became its first director.



*IHES in the 60s*

**Les Publications mathématiques de l'IHES**

Right from the creation of IHES, Motchane wanted to launch a scientific journal. Working from Northwestern University, Illinois, Dieudonné coordinated the publication of the first issue of *Publications Mathématiques* with Motchane, in the autumn of 1958, before he had even officially taken up his post as a permanent professor in the mathematical section with Alexander Grothendieck at the start of 1959.

Motchane had already acquired some experience of publishing during the war. Although he was used to mathematical publications – he had drafted many of the treatises of the Bourbaki "*Éléments de mathématique*" – Dieudonné was impressed by the quality of the printing of the "blue books". Talking of the proofs of the first edition, he said to Motchane: *"First proofs of Wall's article safely received. As regards typography, it's excellent, pleasing to the eye and very clear; one could wish that all journals were printed this way, I think we're going to set the tone!"*

**Choosing « Bois-Marie »**

When the Institute was created in 1958, it did not have its own premises. The first seminars were held in two rooms, lent by the Thiers Foundation in Paris. That did not hinder the development of the mathematical section but for their part, physicists were worried about the Institute's permanent establishment During a meeting with renowned physicists who supported Motchane's project, they set out their request: the Institute should be located next to a centre of experimental physics. Although physics at IHES was theoretical, it could not cut itself off from experimental physics. They therefore suggested that the Institute establish itself near the modern laboratories that had just been built in Orsay, where a branch of the Paris University Faculty of Science had opened at the end the 1950s. Motchane bought the "Bois-Marie" site from Charles Comar and IHES established itself there in 1962.

*Algebraic Geometry Seminar in the music pavilion*

**The spirit of the place**

Whereas physicists were used to working in a laboratory, the same could not be said of mathematicians, who traditionally worked at home and met for seminars, the number of which increased significantly after the second world war. When the Institute was created, the idea of a place where one could meet to interact and perhaps have an office was a novel one. The first mathematics laboratories emerged a few years, in the mid-1960s (Centre de Mathématiques Laurent Schwartz at Ecole polytechnique, mathematics laboratory associated to CNRS in Strasbourg).

During the Institute's early years, the music pavilion served both as library and conference hall. In particular, it became the place where Grothendieck's famous *"séminaire de géométrie algébrique"* (SGA) was held, ensuring the international renown of IHES from the very beginning.

Lastly, IHES also adopted from IAS the custom of serving tea daily, a tradition conducive to discussion and one that is still appreciated.

Welcoming invited researchers, organising major conferences, fortuitous interaction, these are all IHES hallmarks that endure to this day.

This text is taken from the "Scientific heritage at IHES" exhibition, designed and produced by Anne-Sandrine Paumier (IHES), and organised as part of the "European heritage Days".

The archive documents presented in the exhibition, together with a selection of IHES historical archives, have been digitised thanks to a grant from Diagonale Paris-Saclay. To find out more: www.ladiagonale-paris-saclay.fr/nos-actions/jep2016



# international campaign

## A dinner with major donors

*"With 7 Fields medallist out of ten permanent professors recruited by IHES since its creation, the Institute attracts some of the greatest names in the world of basic research. It is important for a company like BNP Paribas to support excellence in science. We use advanced mathematics on a daily basis to manage our own and our clients' risks"* explained Jean-Louis Bonnafé, Director and Chief Executive Officer of BNP Paribas at the dinner held in honour of the Institute's major donors on 20 May 2016 in Paris.

The event represented an opportunity to celebrate both the one million-euro contribution from BNP Paribas to the IHES endowment funds and the completion of the challenge-gift from American philanthropists Marilyn and James Simons. IHES met the challenge of raising over 5 million euros in less than four years, triggering the matching mechanism that would double all the gifts received in that period. During a very personal speech, J. Simons recalled the great French mathematicians who had influenced his work, including M. Berger, former IHES Director (1985-1994).

*Jim Simons, Emmanuel Ullmo, Marwan Lahoud, Jean-Laurent Bonnafé*

Among the distinguished guests who attended the dinner, together with the Institute's board members, were T. Damour, H. Duminil-Copin and M. Kontsevich, permanent professors at IHES, J.-P. Bourguignon, President of the European Research Council and former Director of IHES and J.-C. Trichet, former President of the European Central Bank.

## One million-euro gift from the Caisse des Dépôts

The first partnership between IHES and the Caisse des Dépôts dates back to 1962, when the latter granted a loan to the Institute, enabling it to purchase the Bois-Marie site where is has been located ever since.

The Ormaille Residence provides accommodation for around 200 invited researchers who visit the Institute each year; ensuring the proper maintenance and renovation of the properties is of great importance to IHES. With a first one million-euro gift in 2003, followed by the setting up of an "infrastructure fund" endowed with a two million-euro contribution in 2008, the Caisse des Dépôts makes a direct contribution to the quality of basic research.

The Caisse des Dépôts joined the Board of Directors in 2014 as a founder member and its most recent gift made it the Institute's top donor in France. *"The Caisse des Dépôts has once again proven its lasting commitment to basic science and IHES is deeply grateful for its support"* stated E. Hermand, IHES General Secretary.

*Renovation of one of the pavilion at the Ormaille Residence*

### The IHES Circle of Donors

As part of its new fundraising campaign, the IHES Circle of Donors aims to bring together the partners, companies and individuals who share a love of science and who undertake to preserve the way research is conducted at IHES. The Circle was launched on 1st July following an invitation by the two campaign chairmen, Ph. Camus and A. Lévy-Lang, together with around twenty participants.

Circle members fund the Institute's operational budget, offering real encouragement to the Institute's scientists.

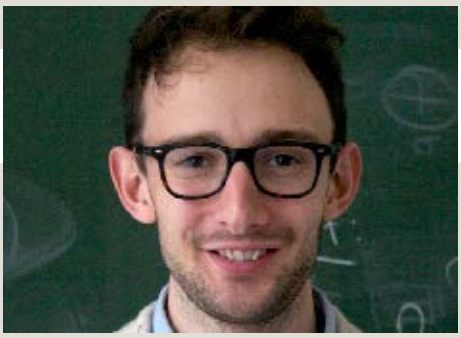
### Thibault Damour's week in New York

When the Albertine bookshop invited T. Damour to New York for a talk on Proust and Einstein, he decided to also give two conferences, organised by Friends of IHES, on the recent detection of gravitational waves. A specialist in general relativity, he and several collaborators developed in 2000 a new method, which provided the first prediction of the gravitational wave signal observed by LIGO in September 2015. The students of the City University of New York Graduate Center and members of IHES' American network in the audience enjoyed listening to T. Damour giving an account of this extraordinary discovery and communicating his enthusiasm for it.

There was a more literary theme to his talk on 23 June, when he spoke of the concept of time

for Proust and Einstein. This was an unusual presentation, which delighted both scientists and Proust specialists, who had gathered together in the prestigious Fifth Avenue bookshop.

# point of view by...



Christopher M. Daw is a young British postdoctoral researcher in mathematics. He obtained his PhD at University College London in 2014 then spent a year and a half at the Institute as a William Hodge Fellow. He has just taken up a post at the University of Reading.
The program, funded by EPSRC, enables two postdocs in mathematics or theoretical physics to undertake a research visit at IHES for one or two years.

From 1st October 2014 to 26th January 2016, I was a post-doc at the IHES, thanks to the William Hodge Fellowship. Named after the famous British mathematician, this is a fellowship, financed jointly with the EPSRC, which enables young researchers in mathematics and physics to spend time at the IHES. Since its inception, the IHES has been a home, temporary or permanent, to many of the most talented physicists and mathematicians in the world. I have always been attracted to the Institute because of the rich history of mathematics for which it has been responsible.
Before my stay at the IHES, I was a PhD student of Andrei Yafaev at University College London. There I became interested in so-called "unlikely intersections" in Diophantine geometry. An "unlikely intersection" is the phenomenon that occurs when two geometric objects of small dimension meet inside a space of much larger dimension. I am interested in when a fixed object in a Shimura variety has many unlikely intersections with the so-called "special subvarieties". Emmanuel Ullmo, now the director of the IHES, has been at the forefront of this subject for many years and I particularly wanted to visit the Institute in order to have the chance to work with him.
The interests of the permanent professors at the IHES are broad and they are happy to discuss with young and experienced researchers alike. Despite his administrative duties, Emmanuel always made time for me and I was able to learn a lot from him. We worked together on the problem of describing the limit of a sequence of probability measures on a Shimura variety when such measures are associated with special subvarieties. Our collaboration has continued beyond my stay, through many emails and conversations over Skype, and it has added a new dimension to my research.
The IHES is situated in Bois-Marie, a forest close to the small village of Bures-sur-Yvette. It is the perfect place to work, with its views of the surrounding woodland from the large office windows. In the centre of Bures, there are the essential conveniences, including a small grocery store, a bakery, a butcher, and a pharmacy. Just outside the village one can find a supermarket. Orsay is very close by and I regularly attended the arithmetic geometry seminar at the Université Paris-Sud. However, one can easily access the whole of Paris by train and I felt spoilt for choice when it came to talks going on in the city. I was also fortunate enough to be invited to speak about my own work, in Paris and in several other places only a few hours away.
I lived a short walk from the Institute in the Ormaille residence where, on summer evenings, researchers would gather to play volleyball. I was provided with a spacious studio apartment equipped with everything I needed. The IHES goes to great lengths to make things easy for its visitors. Each day, Monday to Friday, at 1pm, there is a three course meal and at 4pm there is tea and biscuits. Both are an excellent opportunity to discuss with others. Each year, the Institute welcomes many well-known mathematicians from around the world, for conferences held at the IHES, to give courses, or simply as visitors. There is also a growing number of post-docs coming to the Institute and I made many new friends during my time there. We would often take the RER into Paris together, to go for dinner or to explore the city. At the weekends, we would regularly play tennis at Cité Universitaire.
Unfortunately, when I arrived in France, my French was essentially non-existent. However, near the residence, there is a small language school called ALFAP where, on Tuesday and Thursday evenings, I would spend two enjoyable hours learning French with other newcomers to the area. At tea, once I felt a little more confident, I was able to practise speaking French with the native speakers, who were all very patient! I feel that, by the end of my stay, I had made great progress.
At the IHES, I was able to pursue my work intensely and cultivate a greater understanding for its place in the wider mathematical landscape. I was surrounded by people of inspiring ability and I was able to mature as a researcher. I very much look forward to my next opportunity to visit!

# 2016/2017 events

**7-9 September 2016, IHES**
Freshers' welcome for the FMJH Master's program

**September 2016, IHES**
Cours de l'IHES: J. Miller, "Equivalence of Liouville Quantum Gravity and the Brownian Map"

**17 September 2016, IHES**
Open day, as part of the European Heritage Days

**10 October 2016, IHES**
Freshers' welcome for the Hadamard PhD School of Mathematics

**12 October 2016, IHES**
6th Itzykson seminar on nonequilibirum statistical physics

**October 2016, IHES**
Cours de l'IHES: S. Zhang, "Faltings Heights and L-functions"

**10 November 2016, IHES**
Conference by T. Damour organised by *Les Amis de l'IHES*

**December 2016, IHP**
Cours de l'IHES: T. Damour, *"Ondes gravitationnelles et systèmes binaires"*

**March 2017, IHES**
Cours de l'IHES: C. Soulé, "On the Arakelov Theory of Arithmetic Surfaces"

**March 2017, IHES**
Cours de l'IHES: H. Duminil-Copin, "Sharp Threshold Phenomena in Statistical Physics"

**April 2017, IHES**
Cours de l'IHES: M. Kontsevich, "Resurgence and Quantization"

**2-5 May 2017, IHES**
Mini-workshop organised by H. Duminil-Copin

**17-28 July 2017, IHES**
Summer school: "On Spectral Properties of Large Random Objects", organised by N. Curien, H. Duminil-Copin, J.-F. Le Gall, S. Nonnenmacher

**IHES YouTube channel has now more than 5000 subscribers. Videos of scientific events:**

IHES
Institut des Hautes Études Scientifiques

*Photos* : Fonds IHES, M.-C. Vergne - *Réalisation* : C. Brisson, M. Caillat, V. Touchant-Landais