BOIS-MARIE

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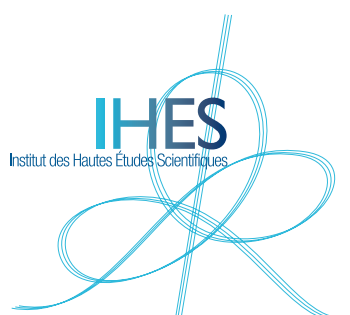

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IHES
Institut des Hautes Études Scientifiques

INSTITUT DES HAUTES ÉTUDES SCIENTIFIQUES

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IHES, founding member of **université** PARIS-SACLAY

Editorial

❝ *It is a noble and beautiful spectacle to see man raising himself, so to speak, from nothing by his own exertions; dissipating by the light of reason all the thick clouds in which he was by nature enveloped; mounting above himself; soaring in thought even to the celestial regions; like the sun, encompassing with giant strides the vast extent of the universe; and, what is still grander and more wonderful, going back into himself, there to study man and get to know his own nature, his duties and his end."* Rousseau also said that nature deserved attention as it *"does not lie"* whereas science is the fruit of *"the authority of men who seldom speak truth yet affirm a number of particulars that we must believe on their word, which is frequently founded on some borrowed authority."*

Using the above quote as the preamble to a scientific newsletter might, however, seem a little controversial. And yet, it is a pleasure to read Rousseau again in today's tumultuous and worried world, a world that is unsure about the future, that has to some extent lost a sense of rigour and seen certainties crumble. Extricating ourselves from the abyss of false assertions is a test, in an age where all sorts of disruptors come into play, with economic, environmental, social and political transformations. It requires us to rise above ourselves. We need to go back to the long timescale of scientific rigour and excellence, in a place devoid of any pressure. This is the atmosphere that can be found in Bois-Marie, at the heart of IHES, as soon as you enter through its gate.

Tribute should be paid to the people who have for the past 60 years maintained a haven of freedom dedicated to science, especially mathematics. It should be paid to the scientists who have built this institution's reputation, the first to do so being Grothendieck, whose life equalled his work in greatness and rigour.

For more than a century, a culture of freedom of research has also been widely maintained at Bell Labs laboratories, where people like to solve major problems. Like Claude Shannon, who built all the elements of information theory, we like to deal with fundamental questions. The discovery of the transistor, the Big Bang, photovoltaic cells, CMOS circuits, the invention of C and Unix, among others, are all technologies that transformed the 20th century and earned our predecessors nine Nobel Prizes.

Today at Bell Labs, we are thinking and building the digital platforms of tomorrow, those that will link the physical world to the virtual world, those that will hopefully contribute to the harmonious development of the world. But we know that we must keep the long timescale, the serenity, the curiosity and the freedom that prevail in any great discovery. And this is undoubtedly what guided us in our partnership with IHES, in Bois-Marie where *"nature does not lie."* To find man, in Rousseau's words *"mounting above himself; soaring in thought even to the celestial regions."*

Jean-Luc Beylat,
Nokia Bell Labs France President

content

Aspects of Geometric Group Theory

IHES hosted the "Aspects of Geometric Group Theory" Summer School from 8 to 19 July. Organised by E. Breuillard, R. Canary, I. Chatterji, P. Dani and F. Kassel, it brought together about a hundred young researchers who were able to follow the mini-courses with international experts.

A group is a fundamental mathematical object that encodes the natural concepts of symmetry and transformation. Geometric group theory is a field that studies the algebraic properties of groups through the topological and geometric properties of the objects on which they act. It acquired its identity as a distinct field in the 1990s, following the polynomial growth theorem of M. Gromov, Professor Emeritus of IHES, which shows that a polynomial growth group has a nilpotent subgroup of finite index.

For this school, we chose geometric aspects of the theory. F. Dahmani discussed Gromov hyperbolicity, which synthesizes the ideas of classical hyperbolic geometry and has given rise to a whole set of techniques. G. Walsh talked about the boundaries of hyperbolic spaces, and Y. Minsky covered the complex of curves, a hyperbolic graph and a powerful tool for studying the mapping class group of a surface of genus greater than 2. Y. Benoist spoke of arithmetic groups, a class of groups obtained as matrix groups, which in many cases elude hyperbolic techniques. K. Vogtmann showed how to construct Outer-space, to study the outer automorphism groups of free groups. The latter are the most natural infinite discrete groups, and understanding their group of automorphisms has many consequences. D. Wise explained CAT(0) cubic complexes, key to proving the virtual Haken conjecture, which explains the structure of hyperbolic manifolds of dimension 3. The geometrisation theorem, which classifies all varieties of dimension 3 and of which Poincaré's conjecture is a special case, was covered by F. Guéritaud. A. Wienhard focused on dimension 2, talking about hyperbolic structures on surfaces. R. Charney explained

Artin groups, which provide a general framework for braid groups. A. Erschler gave concrete examples of different growth rates in groups. K. Bux spoke of Thompson group, a group that emerged from logic and a subgroup of the group of homeomorphisms to the circle. The latter, a very classic group with a dynamic flavour, was presented by K. Mann.

We had planned one hour of exercises, prepared by the speakers, for every two hours of class in the superb Marilyn and James Simons Conference Center. The hundred or so students were divided into small groups of about ten people, and the configuration changed every day. These groups were scattered around Bois-Marie, in front of the blackboards outside, in two offices, two work rooms, on wooden tables in the park and even on the lawn. The weather was pleasant and the students enjoyed working in small groups very much, the exercise sessions being crucial to assimilating so much mathematics in such a short time. These groups encouraged discussions in an informal setting, either with other students or with speakers. The enthusiasm of these mathematical discussions at any times of the day was remarkable.

The students, housed in student residences in Paris, could live a Parisian experience while enjoying the idyllic setting of IHES. Most of the speakers were

housed in Ormaille and took advantage of their stay for mathematical exchanges. The overall logistics were perfectly orchestrated by É. Jasserand, which made of the organisation an easy scientific journey for us, and a unique experience for everyone.

Indira Chatterji,
Professor at Nice-Sophia
Antipolis University

Anna Wienhard

Hadamard Lectures

Maryna Viazovska is a mathematician, professor at EPFL. The Hadamard 2019 lectures, which took place at *Le Bois-Marie* in April and May, were an opportunity for her to demonstrate her exceptional talent.

Maryna Viazovska

What is the most efficient way to stack oranges? Is superimposing hexagonal layers, which is what greengrocers do, the best solution? The question, asked to mathematicians by J. Kepler in the 17th century, was not answered until 1998 by T. Hales.

The same question can be asked in higher dimensions. An answer was given by M. Viazovska in 2016, first in dimension 8 and then, with her co-authors, in dimension 24. These dimensions have periodic point configurations, a type of crystal with specific symmetries.

Physics suggests a generalisation, where it is necessary to minimise an energy that depends only on the distances between atoms. It is this generalisation that M. Viazovska resolved early in 2019 and presented in Bures. The method uses an idea from linear programming, Fourier transformation and modular forms.

Paradoxically, although we have known for centuries how to place glasses on a table as densely as possible, the broader variational problem remains open in two dimensions.
Put your thinking caps on!

Pierre Pansu,
Professor at Paris-Sud University,
Director of the FMJH

Ricardo Schiappa

Resurgence in mathematics and physics

This workshop, organised by M. Kontsevich and Y. Soibelman, was held from 11 to 14 June, with the objective of facilitating interaction between mathematicians and physicists interested in the phenomenon of resurgence.

Resurgence is the area of mathematics which studies analytic properties of functions (typically in one complex variable) obtained as a result of "resummation" of divergent series. An archetypical example is the Borel resummation $\sum_{n\geq 0} a_n x^n \mapsto \sum_{n\geq 0} \frac{a_n}{n!}\xi^n$ applied to the divergent series $\sum_{n\geq 0} n! x^n$, and giving the meromorphic function $\sum_{n\geq 0}\xi^n = \frac{1}{1-\xi}$.

In recent years the phenomenon of resurgence has received special attention in various branches of mathematics and quantum physics. In mathematics it appears e.g. in the Floer theory when studying the convergence of generating functions of Gromov-Witten or Donaldson-Thomas invariants. In physics it appears in relation to the questions of analytic dependence of partition functions and amplitudes on perturbative parameters and coupling constants.

Classical questions e.g. those about resurgence of WKB solutions of differential equations with small parameter have been reviewed recently from the point of view of new techniques, e.g. cluster varieties and wall-crossing structures.

As a result of this Renaissance of the topic of resurgence (or, as one could say "resurgence of resurgence") a conference which brings together mathematicians and physicists was a natural idea. The list of participants of the conference contained almost equal number of mathematicians and physicists.

One could hear on the same day talks devoted to resurgence and phase transitions (physics) and perverse schobers (mathematics). New ideas and areas of research which emerged in recent years were discussed during this 4-day conference. They included: Stokes phenomenon, topological and geometric recursion, resurgence for superconductors, wall-crossing structures, geometry of periodic monopoles and many others.

Maxim Kontsevich,
Permanent professor at IHES,

Yan Soibelman,
Professor at Kansas State University

Olivia Dumitrescu
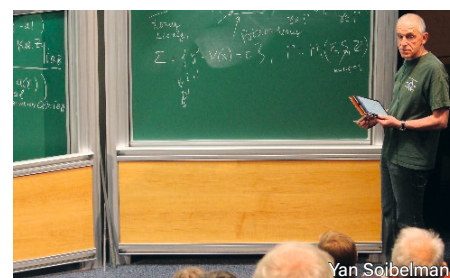
Yan Soibelman

Space Time Matrices

The "Space Time Matrices" conference, organised by T. Damour, J. Hoppe, and M. Kontsevich hosted 12 speakers from 8 different countries working on - or related to - the structure of space and time.

With 2 talks in the morning, 2 in the afternoon, and, on the middle day, one before dinner, the program was leasurely planned to leave ample time for discussions.

The opening lecture, on problems and prospects of the IKKT matrix model, was given by H. Kawai. J. Arnlind continued, giving an overview of his work on discrete surfaces. H. Steinacker talked about cosmological quantum space-time, and D. O'Connor concluded the day with nonperturbative aspects of membrane matrix models.

The second day started with M. Bordemann reviewing some of his work on noncommutative Riemann surfaces, continued with A. Tsuchiya talking about space-time structure in the IKKT model, N. Beisert on integrability and Yangian symmetry in planar Ads/CFT and A. Jevicki

about models of emergent space-time, while M. Kontsevich presented recent work on quantum minimal surfaces.

The last day saw a review of spectral aspects of membrane matrix models by D. Lundholm and a summary of index theorems for gauge theories by P. Yi, before A. Connes talked about the fine-structure of space-time, and J. Fröhlich concluded with quantum theory and causality.
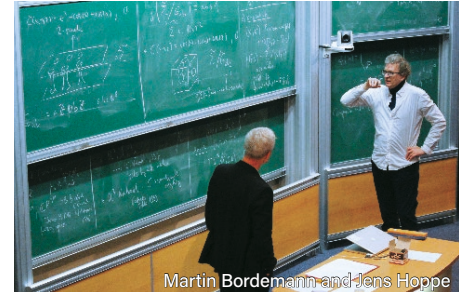
Jens Hoppe

"Space and Time,
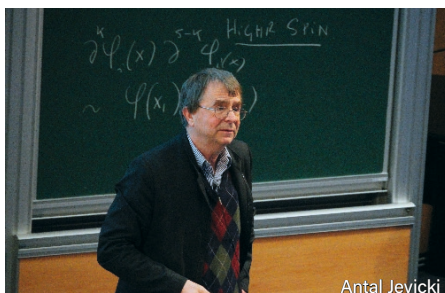*as obvious as it is mysterious"*
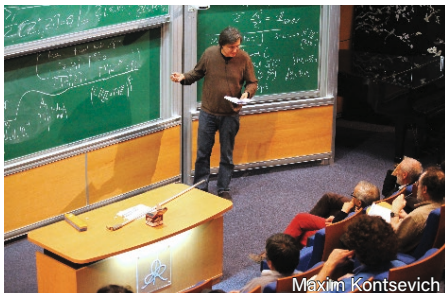
Maxim Kontsevich

Hikaru Kawai

Martin Bordemann and Jens Hoppe

Antal Jevicki

Denjoe O'Connor and Thibault Damour

George Linardopoulos, Teoman Turgut and Meltem Ünel

Distinction

FANNY KASSEL BECOMES CNRS RESEARCH DIRECTOR

Fanny Kassel's work is structured around the discrete subgroups of the Lie groups, in particular their actions on homogeneous spaces and their links with various geometric structures on manifolds. Since her arrival at IHES in September 2016, she has been organizing the "Geometry and Discrete Groups" seminar which covers a wide spectrum of topics at the crossroads of geometric group theory, differential geometry, Lie theory, topology and dynamic systems.

The "*Cours de l'IHES*"

Five years after their launch, the lectures continue to attract the interest of the scientific community, both at IHES and on the Institute's YouTube channel.

Started in 2014, the *"Cours de l'IHES"* present recent and important scientific results in various fields of mathematics and theoretical physics. They followed the *"Courses in Arithmetic and Algebraic Geometry"* which began a few years earlier, at the initiative of A. Abbes and L. Lafforgue by extending the topics covered.

Following the model of lectures at the Collège de France, IHES professors and guest speakers present their research work in series of four to six two-hour lectures. The lectures are public, accessible to all, but are mainly intended for doctoral students, postdoctoral fellows and senior researchers.

The programme, decided annually by the Scientific Council, reflects the variety of interests of the Institute's scientists and an effort is made to spread it over the duration of the academic year. A poster announcing the series of lectures and the subject of the summer school is widely disseminated at the beginning of the academic year.

Emmanuel Ullmo
Director of IHES

2018-2019 Programme

Thibault Damour
"From Classical Gravity to Quantum Amplitudes"
(October 2018)

Corinna Ulcigral
"Chaotic Properties of Area Preserving Flows"
(January/February 2019)

Mikhail Gromov
"Old, New and Unknown around Scalar Curvature"
(February/March 2019)

Maxim Kontsevich
"Bridgeland Stability over Non-Archimedean Fields"
(March/April 2019)

Joseph Ayoub
"Sur la conjecture de conservativité"
(April/May 2019)

Nader Masmoudi
"Inviscid Limit and Prandtl System"
(May/July 2019)

Alexander Goncharov
"Quantum Geometry of Moduli Spaces of Local Systems and Representation Theory"
(July 2019)

Cours de l'IHES start again in October 2018.
Full details on the IHES website:

Mikhail Gromov

Nokia-IHES Workshop

The first IHES - Nokia Bell Labs conference was held on October 2, 2018 at the Institute. It was organised by Philippe Jacquet and Emmanuel Ullmo as part of the partnership between the two institutions.

We had two excellent presentations that allowed us to immerse ourselves in the rich history of IHES and Bell Labs, the latter now present on the Paris Saclay campus.

Professor Aspect (*Institut d'optique*), internationally know as the physicist who produced the first experimental evidence of quantum entanglement theory that has since given rise to the second digital revolution, gave the first presentation.

Professor Verdu (Princeton University) gave the second presentation of the day. He retraced the history of information theory discovered by C. Shannon in 1948 and outlined the new perspectives for this science, which is all the more relevant in today's hyper-information society.

Philippe Jacquet,
MathDyn Activity leader, Nokia Bell Labs

Philippe Jacquet and Alain Aspect

Arithmetic Geometry in Carthage

In June, the Tunisian Academy Beit al-Hikma in Carthage hosted a Summer School and a conference on Arithmetic Geometry organised by A. Abbes, C. Breuil, M. Harris, A. Mézard and T. Saito.

The two successive events provided an opportunity to review the most advanced developments in various fields of arithmetic geometry and automorphic forms: p-adic Hodge Theory, p-adic Langlands program, ramification of an ℓ-adic etale sheaf, special values of L-functions and automorphic and motivic periods with particular focus on the conjectures of Deligne, Beilinson and Gan-Gross-Prasad.

The Summer School (June 17-21) included 5 mini-courses (3 hours each) by confirmed experts in their field and 5 talks by talented young mathematicians on closely related topics. The whole thing was designed to bring doctoral students, post-doctoral fellows and young researchers to the avant-garde of some of the most difficult current issues in arithmetic geometry. Participants (more than 65) came from the best institutions in the world. The week after, the conference brought together 18 speakers from France, Italy, Germany, China, Japan, Singapore, the United Kingdom and the United States. More than 85 participants were able to attend the talks.

These events were supported by several institutions: Beit al-Hikma, the Clay Mathematics Institute, the Foundation Compositio Mathematica, the International Centre for Theoretical Physics, the Université Paris-Saclay, the European Research Council and IHES. Beyond the purely scientific results,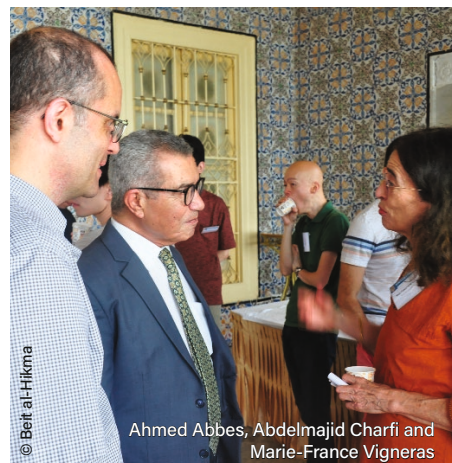 they were an excellent opportunity to bring together the Tunisian mathematical school with leading experts. Having a direct experience of mathematical research in Tunisia has enabled them to observe the extremely interesting developments made by the country in recent years.

Many young researchers attended both the Summer School and the conference in the exceptional venue of the historic Beit al-Hikma Palace, which generously hosted the conference. The discovery of Tunisian history and culture created an unforgettable atmosphere that encouraged everyone work their hardest, making these events truly successful, for both science and people.

The programmes and details of both events can be found on: http://www.ihes.fr/~abbes/GAC/gac.html

Ahmed Abbes,
CRNS research director at IHES

© Beit al-Hikma

Ahmed Abbes, Abdelmajid Charfi and Marie-France Vigneras

© Beit al-Hikma

Benjamin Schraen

Tribute to Jean Bourgain

Jean Bourgain, a permanent professor at IHES from 1985 to 1994, passed away on 22 December 2018 at the age of 64.

Jean Bourgain
(2014 summer school)

When he joined IHES in the mid-1980s, Jean Bourgain introduced the field of analysis. His main collaborations were with J. Lindenstrauss and V. Milman and his work touched on many central topics of analysis, Banach space geometry, ergodic theory, and partial differential equations. Bourgain's contribution was considerable, and he solved most of the open problems of the time in harmonic analysis such as harmonic measure, lambda-p sets, circular maximal function, oscillating integrals. He also made major progress in other areas such as theoretical computing.

He received the Fields Medal in 1994 but it is the quotation for the Steel Prize in 2018 that best summarises Bourgain's contribution to mathematics, presenting him as "*a giant in the field of mathematical analysis, which he has applied broadly and to great effect.*" Bourgain has also received the Ostrowski Prize, the Shaw Prize, the Crafoord Prize, and the Breakthrough Prize.

After his departure, analysis remains an important topic at the Institute, in particular with the chair in analysis, founded jointly by IHES and Cergy-Pontoise University, which I have had the pleasure of holding since 2009.

Frank Merle,
Professor at Cergy-Pontoise University and IHES

Two new triennial chairs created

Thanks to the generosity of two American donors, William R. Hearst III and Robert Penner, two triennial chairs have been created. They allow the Institute to invite internationally renowned professors for long periods, typically 3 months a year for 3 years. Interviews with the first holders of these chairs:

INTERVIEW WITH JOSEPH AYOUB, FIRST HOLDER OF THE ALEXZANDRIA FIGUEROA AND ROBERT PENNER CHAIR

How did your interest in mathematics start?

I've always been very interested in maths. In my early teens, I had good grades in all subjects but maths was always a special interest of mine: in my spare time, I enjoyed solving maths problems. When I ran out of them, I made new ones up. I was particularly keen on plane geometry but I also liked calculating things and solving equations. During breaks, I often disappeared into the library to look through the *Encyclopaedia Universalis* in search of maths articles. This is how I became familiar with a number of modern concepts such as the classification of finite simple groups.

I was able to access bits of "advanced mathematics" at a very young age, when I found some papers in the storage room of our small apartment in Beyrouth. They were notes of the lectures on general topology which my father – a maths professor – had followed at the university. My mother, who was a librarian at the science faculty, knew someone who helped me lay my hands on a copy of *Differential Geometry and Symmetric Spaces* by Helgason. I remember having spent most of the summer holidays compulsively going through that book. I ended up reading it from start to finish and feeling I had understood everything!

> **"What I love most in mathematics is the coherence that emanates from a well-constructed theory."**

In 1998, straight after my baccalaureate, I was lucky enough to be admitted to Lycée Louis-le-Grand in Paris. That's when I understood that you could earn a living from mathematical research, which was a real revelation for me. It was my maths teacher, Hervé Gianella, who made me realise this and who encouraged me to take the École normale supérieure entrance examination. I had previously seen myself as becoming an engineer with a "proper" job and an "eccentric" hobby: reading maths books.

What is your connection with IHES?

The first time I heard about IHES was in connection with Alexandre Grothendieck. His name is inextricably linked with that of IHES. In a way, I first discovered IHES with the *Élément de Géométrie Algébrique* and the *"Séminaire de Géométrie Algébrique"*, which were largely prepared and drafted at IHES. It was much later that I came to IHES, and that was for a conference in honour of Luc Illusie.

I am very grateful to the scientific council for having chosen me as the first holder of Alexzandria Figueroa and Robert Penner Chair. It is a great honour of course and I am already looking forward to the time I will be spending at IHES. I don't yet know what impact my visits will have on my work but I will try to extract the maximum benefit from them.

How would you summarise your main contributions?

For a long time, I worked on a particular and crucial conjecture in motive theory called the "conservativity conjecture." The conjecture is very easy to state and offers a bridge, or rather a return path to two different kinds of objects. One is a motive, which is a very rich algebraic geometric object, the other is its realisation which is a topological object with no additional structure.

The conservativity structure turned out to be very difficult. Nonetheless, I devised a strategy to demonstrate it. Even if I haven't managed to make it work yet, I consider this unfinished business to be my most important contribution.

What inspired you so much to pursue your research and what do you find most exciting in what you do?

What I love most in mathematics is the coherence that emanates from a well-constructed theory. Once the right point of view has been identified, the right definition, the right context, what follows is more or less inevitable and the result is very coherent. I think I really value that coherence. Luckily, there is no shortage of well-constructed theories in algebraic geometry, which is probably one of Grothendieck's legacies.

I also like the writing stage. In fact, I think doing and writing maths are activities which cannot be separated. It's only when I write an article that I really understand the demonstration of a problem and the cogs and wheels in a theory. Unfortunately, the big questions I've addressed so far have turned out to be very tough. This is naturally the source of some disappointment but I am an optimist. What inspires me to carry on is definitely the hope of seeing the solution to these great questions one day. Another source of hope and inspiration is to have been witness to spectacular progress on other topics and in other mathematics fields. ∎

JOSEPH AYOUB's research is on the cohomology of algebraic varieties and the theory of motives. He studied at the École normale supérieure in Paris and obtained his doctorate at Paris 7 University under the supervision of Fabien Morel. He was a CNRS researcher at Paris 13 University, before becoming a professor at Zurich University in 2010.

Joseph Ayoub

INTERVIEW WITH ALEXANDER GONCHAROV, FIRST HOLDER OF THE GRETCHEN AND BARRY MAZUR CHAIR

How did your interest in mathematics start?

When I was a kid, I was fascinated by astronomy and nuclear physics. At the time, even in my small town in Ukraine, one could find some great popular science books on these subjects. For example, I remember a book titled *Entertaining Nuclear Physics*, by Mukhin, explaining the subject in a serious, yet entertaining way. I read it many times, as I had done with *The Three Musketeers*.

A little later, my interests shifted to mathematics: I enjoyed solving problems and reading the Kvant magazine (a popular science magazine in physics and mathematics).

In 1976 I was admitted to Moscow University. The first Monday in September I attended Israel Gelfand's seminar, which became the place where I grew up mathematically. I learned a great deal from D. Fuchs, J. Bernstein, S. Gindikin, Y. Manin and A. Beilinson. Moscow was a fantastic place to learn mathematics. But, for a young mathematician, it was not easy to survive the inevitable collision with officialdom. I was helped by Israel Gelfand and Simon Gindikin.

What are your research interests?

In mathematics, I like being at the cross-roads between different fields. Since the mid 1980s I have been studying integrals of algebraic geometric origin using methods of arithmetic geometry, often conjectural. This allows predictions to be made on the integrals without calculating them - I call this "arithmetic analysis." Studying such integrals is an old enterprise, which significantly motivated the development of algebraic geometry. Entirely new insights brought Grothendieck's idea of motives and, even more importantly, Beilinson's conjectures on mixed motives. Using these ideas as guiding principles, one can predict values of integrals by performing easy algebraic calculations, and that is at the very heart of what I do: I use integrals to get further insights into the theory of motives and I apply the motivic philosophy to the study of integrals.

How has your relationship with the Institute evolved over the years?

I visited IHES for the first time in June 1990, just after the USSR opened its borders. Since then, my main motivation to come to IHES has been Maxim Kontsevich - we met almost forty years ago, and have been discussing mathematics ever since.

Yet, at IHES one gets the chance to meet many new people, which makes life delightfully unpredictable. For example, in 1996 I met Dirk Kreimer, and learned about amazing computations he and David Broadhurst were doing in quantum field theory. I suggested that one should apply techniques of arithmetic analysis in perturbative calculations of Feynman integrals. In particular one should upgrade correlation functions to their motivic avatars - motivic correlation functions - which lie in the motivic Galois Hopf algebra. That led to new insights and raised new type of questions.

The many contacts with physicists I have had since then can be traced back to these discussions at IHES.

Since January 2019, I am the first holder of the Gretchen and Barry Mazur Chair at IHES and that is a great honor for me. I am delighted to be here and especially grateful for the chance to give a series of lectures at IHES.

What do you find most exciting in what you do?

I get excited when sensing a mystery in mathematics. For example, the motivic symmetries show up only a posteriori. Yet in the real Hodge realisation one can make them visible by writing a single Feynman integral. It seems therefore that mathematical ideas underlying the quantum field theory paradigm will play an essential role in our description of the motivic world. ■

Gretchen and Barry Mazur Day

Barry Mazur and William R Hearst III

A former student of mathematics, American philanthropist William R. Hearst III has been supporting IHES since the 2000s. In calling this triennial chair the Gretchen and Barry Mazur Chair, he is paying tribute with this new donation to his former professor, Barry Mazur and his wife, Gretchen.

E. Ullmo organised an event in Gretchen and Barry Mazur's honour on July, 5 to inaugurate the new chair, with presentations from A. Goncharov, K. Česnavičius, Z. Gao, P. Colmez and B. Mazur.

"Mazur explained how to apply Grothendieck algebraic geometry to the resolution of arithmetic questions. This was the starting point for what we now call "arithmetic geometry", a subject that has been very successful, including Wiles' work on Fermat's last theorem and Faltings' work on Mordell's conjecture," explained E. Ullmo. *"As a mathematician and director of the IHES, I am delighted with Will's choice of name for this chair."*
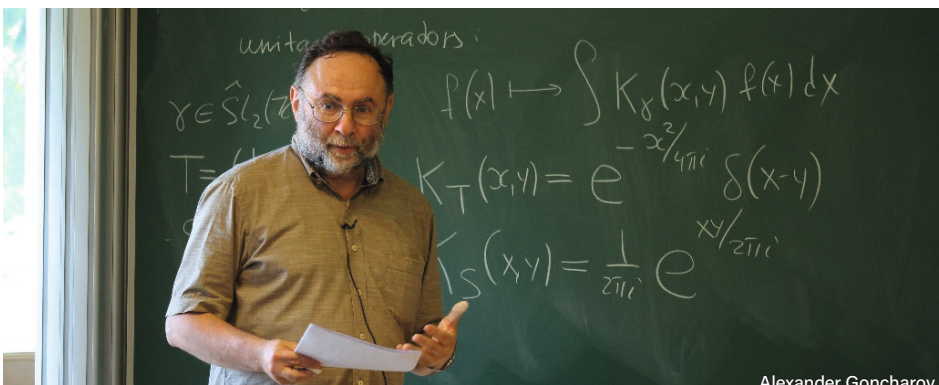
Alexander Goncharov

ALEXANDER GONCHAROV, professor of mathematics at Yale University since 2010, has worked on various fields of mathematics and mathematical physics, such as the theory of motives, Hodge theory, representation theory, higher Teichmüller theory and its quantisation.

High school students visit IHES

Since 2015, IHES has been welcoming high school students from the Versailles academy. This immersion in the heart of fundamental research is increasingly popular.

About a hundred high school students (a majority of girls) from the academy met on a Saturday morning at the Bois-Marie site for a guided tour allowing them to discover the setting in which researchers can conduct their work. Two lectures were then given in the Marilyn and James Simons Conference Center. The young people all came out with stars in their eyes.

For the past four years, IHES has welcomed about a hundred new high school students in the spring, who volunteer and are chosen by their school. The success with students is such that not all applications can be met. They are always very interested both by the guided tour and the two conferences, asking increasingly relevant questions. We can only hope that these visits will contribute to increasing vocations, especially among young girls.

Once again this year, on Saturday 18 May, the Institute welcomed 110 students, about 70% of whom were girls. After the visit, E. Di Nezza and O. Glorieux spoke with great enthusiasm about some of the aspects of their research, while ensuring they did not cover issues that were too technical.

The students asked many questions of the two researchers, not only about the content of their presentation but also about their personal background, their motivations and, more generally, about the life and work of a researcher. All these clearly very interested students were encouraged to dare to do mathematics, to have faith in themselves, not to limit themselves in their ambitions. This is especially true of the girls, with too few of them choosing scientific studies despite the good results they obtain in science in middle and high school.

Evelyne Roudneff,
Regional mathematics inspector,
Versailles academy

Eleonora Di Nezza

Testimonials

"[…] The setting is really beautiful and peaceful, with a stunning wood, it's a wonderful place! It was very funny to imagine that every day, the researchers all have tea together at 4pm sharp to talk through their ideas.
Both conferences were really great. The speakers were young and dynamic and were good at sharing their knowledge with us. They spoke to us naturally, about themselves and their careers, showing that they were not so different from us and that anything was possible!
The first speaker explained his work in geometry, with ways of counting the number of integer coordinates in a circle within a reference frame.
[…] Then the second one told us about curvature. It was based on the Mercator planisphere compared to a globe and proved to us why the planisphere did not represent distances correctly.
[…] She explained how to calculate curves in planes, with vectors, and it was really fascinating.
That's it, so - a very positive assessment of this outing!
Thank you very much for this opportunity you have given us."

Eléonore D. – "Première S" student (Year 11 - science stream baccalaureate)

"I enjoyed the visit a lot, it really gave you an idea of what it's like to be a researcher […]"

Géraldine G. – "Terminale S" student (Year 12 – science stream baccalaureate)

IHES on social media

For several years now, IHES has been sharing its scientific news with a wide audience through social networks.

With a Facebook page created in 2013, a Twitter account launched in March 2018 and a large network of contacts on LinkedIn, the Institute is increasingly active on the Internet. But the real core of IHES' presence on social networks is its YouTube channel: all major conferences, and the "Cours de l'IHES lecture series", are filmed and shared online. On it, you will find lectures given by prestigious mathematicians such as P. Scholze, J.P. Serre, and I. Daubechies.

To a large extent, this video library exists thanks to the Labex CARMIN, a consortium of four institutes including IHES, IHP (Institut Henri Poincaré), CIRM (Centre International de Rencontres Mathématiques) and CIMPA (Centre International de Mathématiques Pures et Appliquées), which was created in 2013 to make advanced mathematical research available to scientists around the world.

Through its presence on social networks, the Institute contributes to disseminating very high-level mathematical knowledge to a wide international audience. A big thank you to all those who follow us!

THE IHES COMMUNITY

3 200 members

500 followers

275 members

24 000 members

engaged and **growing** community

Emmanuel Ullmo and Michael R. Douglas (2017)

1999 - 2019 : the 20th anniversary of Friends of IHES

Friends of IHES is the foundation that supports the Institute in the United States and fosters relationships with American researchers and donors.

There are many productive links between IHES and the United States. Their roots can be found in the support and advice offered by Robert Oppenheimer to IHES founder Léon Motchane. Each year, this strong relationship is confirmed by the number of visits by scientists from American institutions. For more than 60 years, Americans have been the largest contingent of researchers invited to IHES.

In order to nurture these links, Bernard Saint-Donat, a mathematician closely associated with IHES – where he worked with Pierre Deligne and Alexandre Grothendieck – founded Friends of IHES in 1999. This American foundation's aims are to promote IHES and to help it raise funds. Since its creation, Friends has organised a number of events which helped mobilise the network of the Institute's former visitors and professors, to make IHES' mission known widely and to obtain high-level support in the United States.

With the current chairman and president, physicist Michael R. Douglas, Friends

continues to grow. The year 2019 is particularly intense, with a scientific breakfast organised at the Flatiron Institute in New York on 30 May. This new research institute was created by philanthropists Marilyn and Jim Simons, and some 20 guests joined the physicist and former invited researcher Christian Borgs (cofounder of the Microsoft Research New England center). His presentation on "Large Networks: from Mathematics to Machine Learning" met with an enthusiastic receptio.

In November, Friends will be organising its 6th New York gala at the Harvard Club on the theme of game theory. Constantinos Daskalakis (MIT), who has received the Rolf Nevanlinna Prize in 2018, is the guest of honour for the evening, presented by Sylvia Nasar (Columbia University's Graduate School of Journalism) the author of John Nash's famous biography, *A Beautiful Mind.* A photo expedition will be presented to the guests, which will review the 20 years of scientific cooperation with the United States (information and bookings: www. ihesgala.org).

Cercle des mécènes
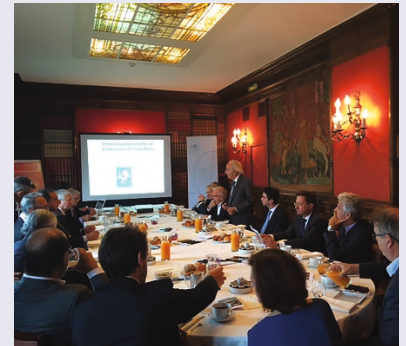
The Institute gathered together its major donors for the fourth year running. They were able to take part in science events as part of the *Cercle des mécènes* programme.

This includes Emmanuel Ullmo giving a director's lecture at IHES, the topic of which was "Kronecker's Youthful Dream."

A scientific breakfast also took place in Paris in May. On this occasion, it is Slava Rychkov, a permanent physics professor since 2017, made a presentation on the Feigenbaum constraint and the renormalisation group, a fascinating story which has its conclusion taking place at IHES.

For more details of the programme : www.ihes.fr/en/ support-ihes/major- donors/#cercle-des- mecenes

IHES' 50th anniversary at IAS (2008)

First gala of Friends of IHES (2012)

recollections from...

Tal Horesh

After a PhD at Technion, Tal Horesh joined IHES as a postdoctoral fellow in mathematics in September 2017 with Fanny Kassel.

In the fall of 2016, my husband and I were starting our last year of PhD, and had started looking for a post-doc for the following year. It was a confusing time. First of all, we had moved twice during that summer, which was very exhausting (we lived in a couples' on-campus housing during our studies at the Technion, and the Housing Oce suddenly decided to move us to another apartment, only to move us again one month later to our previous apartment, which now had a new wall, built during our absence, that split the living room in two. At the time I was outraged, but today I can appreciate how well this incident prepared us for the wonders of French bureaucracy). Secondly, after having done all my studies in the same small department (and country), it was time to go out to the big world. But where in the world? How do you even start looking? Well, I was told to go on *MathJobs*, and so I did.

The usual process: going over hundreds of positions, filtering those which fit me mathematically. Some further filtering is required due to the infamous two-body problem; how far will we be willing to commute in order to continue living together? Then, Excel sheets: position, location, deadline, teaching load. On my sheet, there is one position which just sounds just too good to be true: the research topic is "discrete subgroups of Lie groups"; they offer housing; my husband has an offer from a place that is very close by; there is no teaching; it is next to Paris! So I applied. And the following summer, we packed all our belongings, left our cat with my parents, and got on the plane to Paris.

On my first day at IHES, I felt like Cinderella at the ball. F. Kassel, my host whom I had never met in person, welcomed me with a hug. I. Peeters, a secretary in charge of post-docs and a superhero, took me to my gigantic new office ("*who will I be sharing this office with?*", I asked. "*No one*", she replied). At lunch, where I was expecting a standard student cafeteria with plastic trays and a queue to the cashier, I found

a restaurant, with table cloths, a 3 course meal, and WINE. Yes, you could definitely say it was love at first sight.

In the following days, it slowly began to dawn on me that I am now surrounded by some of the greatest scientific minds of our time. The next-door neighbor is M. Kontsevich. The man with whom I had a fascinating conversation at lunch was P. Cartier. They were not on the top of Mount Olympus, scattering down celebrity star dust - they were greeting me in the corridors and chatting with me at lunch, as though it was not the case that they were mathematical superstars, and I was fresh out of my PhD. And so my journey at IHES began.

As I already mentioned, my host was F. Kassel, whose passion and excitement about mathematics are nothing if not an inspiration. What is more, she has this rare talent of engaging people around her into mathematics; soon enough, a group of post-docs was beginning to form around her. At first it was just J.-P. Burelle and myself, and we were soon joined by X. Zhang, O. Glorieux, K. Vokes and P.-L. Blayac (three postdocs and one PhD student, respectively). IHES may be a place where you go to meet and learn from world-famous senior scientists, but to me it was just as meaningful to be a part of this vibrant group of young researchers. We organized study groups, went to conferences together, and shared more beers than I could possibly count.

This was my first experience of being a part of a research group, and this one was even led by a woman! After having acquired all my mathematical education in a department with no female faculty members, and with only four PhD students in pure math, this experience was life-changing. Thanks to

> "Math was no longer just sheets of paper being filled with calculations behind my closed office door - it became a social thing"

Fanny's monthly seminar "Geometry and Discret Groups" which is attended by mathematicians from other institutions in the Paris area, my scope of mathematical interactions expanded rapidly. I often attended seminars in other institutions, and gave talks myself. Collaborations and friendships were formed. Math was no longer just sheets of paper being filled with calculations behind my closed office door - it became a social thing.

While my mathematical horizons were expanding, IHES became a second home for me, to the point where its incredible staff felt like my second family. I. Peeters, my knight in shining armor, who fought innumerous bureaucratic battles for me; the always elegant C. Gourgues who would assist me with literally anything, from booking seminar rooms to managing hair emergencies; F. Bachelier, despite whose best efforts I still can't manage the "UBUNTU" system; E. Hermand, the big boss, who once spent a morning in the police station with me after our apartment had been broken into; the super-cool V. Touchant, who greets me in Hebrew, and I must say her accent is flawless; the charming chef, P. Gourdon with his kitchen staff, Fatima, Satou and Hayette - who would (perhaps too) often spoil me with a second dessert; G. Foffano, whose experience in academia and infinite kindness made her a big source of support for me at the time when I was going crazy over job applications; and, last but not least, É. Jasserand, who saved me in situations that are far too embarrassing to be described here.

These days I am finishing my two-year stay at IHES, and as I reflect on it, the joy of all these great memories is being diluted with a pinch of sadness, for having to leave. I am forever grateful for the opportunity I have been given to start my mathematical journey in IHES - this place really changed my life. I'll miss you guys.