ICMAT

Quarterly newsletter
Instituto de Ciencias Matemáticas
CSIC-UAM-UC3M-UCM

Second quarter 2013

Editorial

Mathematics of Planet Earth 2013

Christianne Rousseau, Universidad de Montreal. It is now four years since I´ve raised the idea of MPE2013 and that the North American institutes in Mathematical Sciences decided to hold a special year of scientific activities on the theme of Mathematics of Planet Earth. Since then, the initiative has secured the patronage of Unesco and has acquired to the breadth of an international year with already 140 partners around the planet, all committed to organizing scientific and outreach activities on the theme.

The period from 2009 to 2011 was more concentrated on the planning of large scientific programs and workshops, while a lot of attention was also paid in 2012 to the planning of outreach activities, including the preparation of the MPE Exhibition. We currently are now observing a lot of energy for producing curriculum material which enable the teaching of mathematics with applications related to planet Earth to be enriched. MPE2013 was officially launched on December 7, 2012 at the same time as the Canadian launch. Since then, many countries have been holding national launches. The official European launch took place on March 5, 2013 at the Unesco Headquarters in Paris, during an MPE Day jointly organized by Unesco and the International Mathematical Union (IMU).

The Open Source MPE Exhibition was also launched at Unesco on March 5, 2013 (www.mpe2013.org/exhibition). This exhibition uses the Open Source platform Imaginary developed at the Mathematischen Forschungsinstituts Oberwolfach. Science museums and *(continued on p. 2)*

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The international initiative Mathematics of Planet Earth seeks to draw the attention of researchers to the great challenges facing our world and to show the public the potential of mathematical tools for dealing with these types of problems, which range from climate change to the study of infectious diseases. While this interdisciplinary field is still in the early stages of development and needs a boost, various experiences such as the studies on the earthquake in Lorca and the volcanic eruption on the island of El Hierro reveal the capability of this discipline for analyzing and helping to manage terrestrial phenomena.

Ágata Timón (ICMAT). Human activity had an influence on the disaster that struck the town of Lorca (Region of Murcia, Spain) on May 11th, 2011. From an analysis of the data recorded by an international team prior to and during the earthquake, the exploitation of the aquifers in the fertile valley where Lorca is located upset the balance of forces below the earth's surface, determining the nature of the quake, as can be verified by means of mathematical models.


NASA

Image of underwater eruption of El Hierro as Photo of the Year awarded by NASA

This is just one example of the applications of Geomathematics in the study of many aspects of Earth Sciences. In the opinion of experts, the number of researchers able to conduct this type of multidisciplinary research is increasing slowly but surely. However, in Spain *(Continued in p. 3)*

Mathematics of Planet Earth

Mathematics is an essential tool for modeling the Earth's climate

schools around the world can decide to download the modules, use them as such, or adapt them. So far, the modules on the website are short videos, interactive applications to be used on touch screens, and images. They come from modules submitted to the international MPE Competition. The winner of the first prize of that competition was Daniel Ramos from Spain with his module, Sphere of the Earth, which showed that maps of the spherical surface of the Earth on a plane must have distortions. The module is an interactive application in which the user selects a disc region and sees how various maps distort it.

> "MPE2013s outreach is now becoming very important with public lectures organized all around the world"

While MPE2013 started mainly as a scientific year, its outreach and school components are now becoming very important, with public lectures organized all around the world, MPE festivals, special weeks for schools, and several exhibitions planned. MPE2013 has no budget: it functions with partners commiteds to organize scientific and outreach activities using their own budget. This has worked well, and MPE2013 continues to spread around the world. Its success comes from the fact that it is so timely. The scientific community is becoming more aware of the importance of the planetary challenges: global warming with all its unknown consequences (more extreme weather events, incidence on the growing of vegetation, rising of the sea level, etc.), and the need to move to an economy of sustainability in view of the growing population of the Earth. At the same time, mathematicians like to solve mathematical problems. MPE2013 allows the beautiful mathematical problems behind the planetary problems to be highlighted with the hope of engaging a new generation of gifted researchers in these problems. Planetary problems are essentially interdisciplinary and MPE2013 provides an opportunity to build new partnerships with other scientific disciplines. On the outreach side, MPE2013 provides many examples for explaining to the public the importance of the mathematical sciences in the social and technological organization of our society, as well as in scientific research for A better understanding of the planetary challenges and the search for solutions.

> "The scientific community is becoming more aware of the importance of the planetary challenges"

MPE2013 is not only about planetary challenges. It concerns all aspects of the planet, for which mathematics is useful. For instance, mathematics provides tools for discovering our planet. Remote sensing enable our planet and its interior to be explored. Dynamical systems theory is the tool for describing planetary motions and the chaotic behavior of the Earth. Mathematical biology seeks to explain biodiversity, the functioning of ecosystems and evolution. It also enables successfully modeling the spread of epidemic diseases to be modeled successfully as well as helping to control them. Several of these subjects could be explained in schools and help to answerthe question "What is mathematics useful for?" Curriculum enrichment material is starting to be produced in many countries and posted on the web, for sharing with the planet.

> "TMPE2013 is not only about planetary challenges. It concerns all planetary aspects, for which mathematics is useful"

MPE2013 has started an unprecedented collaboration around the world for advancing studies on planetary research and increasing the outreach effort on Mathematics of Planet Earth topics. Activities are already been planned in 2013 and subsequent years. The spirit of MPE2013 will continue beyond 2013.

Christianne Rousseau is MPE2013 promoter and director and vice president of the International Mathematical Union (IMU)

Exploring the Earth with Formulas

this type of profile is still thin on the ground. "In the sphere of Spanish mathematics, the percentage of teams devoted to interdisciplinary subjects, and in particular those dealing with Earth Sciences, is still very low", says Carlos Parés, professor of Applied Mathematics at the Universidad de Málaga and coordinator for Mathematics at the Agencia Nacional de Evaluación y Prospectiva (ANEP).

> "Spanish mathematics has a certain deficiency in genuinely interdisciplinary research lines"

According to Parés, "Although this percentage is increasing and in some fields is clearly higher, it is still considerably less than in neighboring countries". Joaquim Bruna, director of the Centre de Recerca Matemática (CRM – Mathematical Research Center), agrees: "Spanish mathematics is in good health, but it has a certain deficiency in genuinely interdisciplinary research lines, in which there is real collaboration between mathematicians and experimentalists".

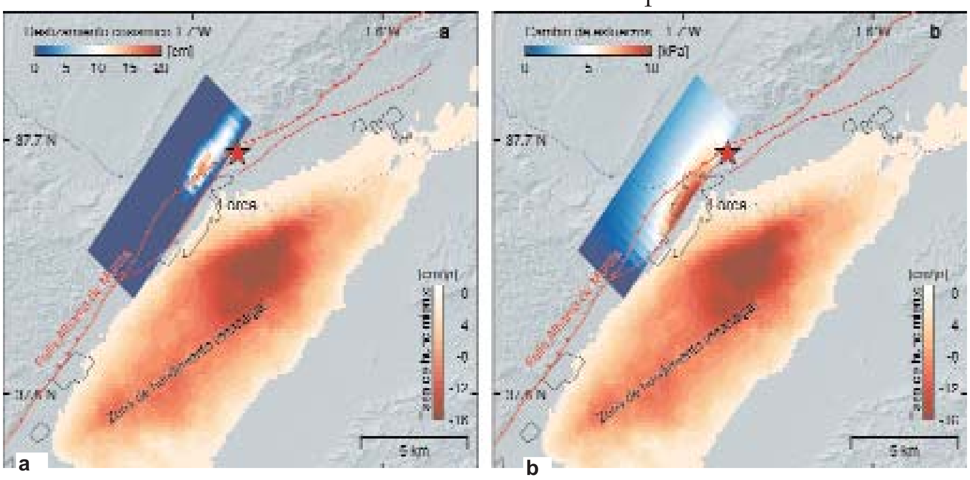
In many cases, mathematics appears to be far removed from real problems that affect people in their everyday life. While mathematical research projects are not necessarily expected to cure cancer or lead to renewable energy sources, many successful experiences show that they are able to do just that. "The capacity of mathematicians to contribute to global solutions is steadily becoming a reality, but time is running our for the planet", says Christiane Rousseau, vice-president of the International Mathematical Union (IMU) and director of the international initiative Mathematics of Planet Earth (MPE2013), which is being held this year. In fact, some of the greatest challenges facing Spain in the coming decades (such as desertification and tectonic plate movement) have already been successfully addressed through mathematics.

Useful tools

"Mathematics underlies many of the events that are reported every day in the press and can help to provide better knowledge of and exact answers to what is really happening. Mathematics has a big role to play and we hope it will get bigger in the future", says Rafael Orive, deputy director at the ICMAT and organizer of the congress "Mathematics and Geosciences: Global and Local Perspectives", due to be held at this center between November 4th-8th, 2013, as part of the MPE2013 commemorations in Spain.

One of the events that passed from the newspaper columns to scientific journals and vice-versa was the Lorca earthquake. The researchers, among whom was José Fernández from the Instituto de Geociencias (CSIC-UCM), came to the above mentioned conclusions by constructing an elastic displacement model that enabled them to study the deformation of the earth with information obtained by satellite measuring systems (using the synthetic-aperture radar interferometry technique) and GPS data. The geometry of the fault was estimated by using nonlinear global inversion techniques.

With this simulation they were able to analyze the phenomenon with precision, thereby showing that the seismic movement was centered at a very shallow depth below the earth's surface (2-4kms) along the Alhama de Murcia fault. The slip extended upwards to the surface through segments of earth with friction properties that changed from stable to unstable. Analysis indicates that the area of rupture along the fault is related to the variations in forces caused by the extraction of water from a nearby aquifer. In their article (1) published in Nature Geosciences, the researchers state that: "Our results imply that anthropogenic activity could influence how and when earthquakes occur".



Nature/P.J. González

a.Model of failure / dislocation of the earthquake estimated from satellite data and GPS, and its relation to the area of subsidence detected. The rectangle delimits the surface projection of the fault and the color the magnitude of slip in the earthquake. b Mechanical model discharge crust produced by the extraction of groundwater in the area of subsidence detected.

Inverse problems for exploring the Earth's interior

Mathematics proved fundamental in the realization of this study. "Mathematics figures in the processing of data obtained from observations", says José Fernández, co-author of the article, "as well as in the development of direct mathematical models which, by the use of methods for inverse-problem solving, enable the observed data to be properly interpreted".

Fernández is also participating in another international project on the volcanic eruption that took place on the island of El Hierro (Canary Islands) in October 2011. "Both processes have their origin beneath the Earth's surface and thus cannot be observed directly. Nevertheless, the use of geodesic and geophysical observations, both on the earth's surface and from artificial satellites, together with Mathematics have enabled the characteristics of the sources of these phenomena to be determined". In both cases, the "mathematical tool" has proved to be vital in obtaining the maximum amount of useful information from the observed data.

Furthermore, this tool is enormously hetergeneous; mathematics from many different fields are required to address the great variety of problems facing the planet. Says José Fernández, "The fields of mathematics involved, just to name a few, are sedimentation and diagenesis flow models; global change assessment models; wave propagation models; land surface classification; risk mapping analysis; parameter sensitivity analysis in inverse problems; stochastic models for processing terrestrial and spatial data; deterministic models; chaos theory applied to Earth Sciences; geo-statistics; deficient, incomplete or truncated data problems; time-series analysis; data processing; data representation; interfaces for reports in specific fields; linguistic information handling; nonlinear processes in Earth Sciences, and many more".

The mathematical tools are essential to extract the maximum information from the observed data.

A year for boosting Mathematics of the Earth

Nevertheless, as Carlos Parés pointed out at the beginning, in spite of these experiences the situation in Spain is far from ideal, and that is why initiatives such as MPE2013 are important: On one hand, for creating meeting spaces where such pressing problems for the planet can be discussed, and on the other hand, for carrying these discussion over to society at large. "Public dissemination of research results in an understandable, accessible and striking way is very important for providing Geomathematics with a much-needed boost", says José Fernández. Initiatives such as this are powerful platforms for reaching this objective.

"The celebration of MPE2013 comes at a very opportune moment, especially in Spain, where applied and interdisciplinary mathematics still have a long way to go", says Joaquim Bruna, director of the CRM. That is why several Spanish institutions have got together to launch a series of activities that will take place within the MPE2013 framework, ranging from scientific workshops to dissemination activities for students.

The program of events can be found at the following website: http://www.icmat.es/mathearth.

Multidisciplinary only on paper

“"Mathematics and Geosciences: Global and Local Perspectives" (MATHGEO) will take place in Madrid from 4 to 8 November.

Despite the good reputation enjoyed by interdisciplinary research, there are several reasons why its development in Spain is being held up: the traditionally theoretical nature of research in the country, and "a certain tendency to give more importance to research in pure mathematics", says Carlos Parés.

Furthermore, work in these fields requires a great deal of time to find a common language with scientists working in other areas, to understand properly the phenomena to be studied, and to implement and validate the models, etc.. says Parés, "Evaluation, both individual and in calls for projects, is mainly based on the number of articles published in high-impact journals, so this investment of time is not perceived as 'profitable' by research teams".

In this sense, "the Mathematics and Geosciences: Global and Local Perspectives" congress, organized at the ICMAT, seeks to bring scientists from different fields, both in mathematics and geosciences, into contact with each other in order to widen their scope of work and facilitate future joint research projects.

In the words of Rafael Orive, deputy director of the ICMAT and co-organizer of the congress: "The aim is to bring mathematicians and researchers from other fields together to use this discipline in their analyses. We'll be talking about Statistics simulation, Partial Differential Equations, mathematical models and so on… We also want representation from across the range of Spanish mathematicians and researchers who are working on the modeling of natural phenomena, as well as researchers from abroad who are involved in interesting strategic areas, in order to give momentum to Spanish science in these fields".

Mathematics on Earth Planet in Spain

2013 is the Year of Mathematics of Planet Earth (MPE2013). This initiative involves more than one hundred institutions, also Spanish: the Institute of Mathematical Sciences (ICMAT), the Mathematical Research Centre (CRM), the Spanish Society of Applied Mathematics (SEMA) and the Royal Academy of Exact, Physical and Natural Science (RAC), among others, also wished to join the initiative with various activities.

Upcoming scientific activities

Mathematics and Geosciences: Global and Local Perspectives

Organized by: Instituto de Ciencias Matemáticas (ICMAT).

Collaborate: UCM, UPM.

Date: From the 4th to the 8th of november of 2013.

Description: conference dedicated to mathematics in the geosciences.

Place: Instituto de Ciencias Matemáticas. C/ Nicolás Cabrera, nº 13-15, Campus Cantoblanco UAM, 28049 (Madrid).

Special session of the Royal Academy of Exact, Physical and Natural Science

Date: 8th of may 2013.

Description: joint activity with the Academy of Portugal Sciences.

Place: Real Academia de Ciencias Exactas, Físicas y Naturales. C/ Valverde, 22th and 24th (Madrid).

Slow-Fast Dynamics: Theory, Numerics, Application to Life and Earth Sciences

Organized by: Centre de Recerca Matemàtica.

Date: from the 3th to the 7th of june of 2013 .

Description: scientific meeting of experts in the field of Slow-fast dynamics.

Place: Centre de Recerca Matemàtica. Campus de Bellaterra, Edifici C - 08193 Bellaterra (Barcelona).

Workshop on Emergence, Spread, and Control of Infectious diseases

Organized by: Centre de Recerca Matemàtica.

Date: 10th and 11th of june 2013.

Description: *Scientific workshop on mathematical tools for modeling infectious diseases.*

Place: Centre de Recerca Matemàtica. Campus de Bellaterra, Edifici C - 08193 Bellaterra (Barcelona).

Congress Special Session on Differential Equations and Applications (CEDYA)

Organized by: Sociedad Española de Matemática Aplicada.

Date: from the 9th to the 13th of september 2013.

Description: special session in the annual meeting of the SEMA.

Place: Universidad Jaime I de Castellón (Castellón).

"It is important to create an environment that encourages people to take the long range view"

Roger Brockett is a researcher at Harvard University

Ágata Timón/Lorena Cabeza. The intersection of mathematics and engineering has in Roger Brockett one of its biggest advocates. Professor of Computer Science and Electrical Engineering at Harvard University, he is also founder of the Harvard Robotics Laboratory. Pioneer in control systems theory, he has also made important contributions in the areas of dynamic systems, differential geometry and stochastic dynamics, as well as artificial intelligence, computer vision and robotics. Distinguished with several awards and honors, he has authored some 200 papers and supervised approximately 60 Ph.D. students, some of whom have gone on to become prestigious mathematicians and engineers all around the world. Brockett claims this leadership training to be one of his greatest achievements.

"Modeling it is the most creative part of applied mathematics"

Question: What is your research interest at the moment?

Answer: I'm interested in everything having to do with automatic control, and in particular with those aspects of the subject which are nonlinear and that have a geometrical flavor, such as mathematics from differential geometry. I usually work with stochastic processes, differential geometry, linear algebra, Poisson processes…

Q: You've been one of the pioneers of applying mathematics to engineering. What are the values that mathematics brings to this field?

A: Math has an ability to unify that can be carried over to other fields. For example, when somebody brings a new problem, you have an impulse to solve it in a more generic form. Mathematics is a nice way to see things in their natural and, in some senses, most general form.

Q: Where do you see the most relevant challenges for science in the future?

A: I think it is important to create an environment in which people are willing to take chances and work on things that may not pay off for a decade. We have to encourage people to understand that some problems can't be solved overnight, and some of them are very important. We wouldn't have transistors or microelectronics if people hadn't been able to take the long range view. I see no shortage of people willing to pay money today for having results tomorrow, but I do see a shortage of people willing to take the long range view.

Q: And what about the area between mathematics and engineering?

A: One of the ways to take an unformulated problem and make it into mathematics is the art of "mathematical modeling". I think it is the most creative part of applied mathematics. The things that come after that are important, but I would say they require less imagination. I started using differential geometry and control theory in 1969 and probably the most exciting period for me was five years afterward, when everyday you found new things that you could translate from the physical world into something nice and mathematical.

Q: Could you give us an example of how your research helped to solve a particular problem?

A: People from NASA told me once that when pilots had a new plane to fly, they liked to fly it like they used to do with the old ones, without learning new ways of doing it. So they asked me: "Is it possible, through feedback control, to make a new plane fly like an old plane?" Old planes usually flew like linear systems so the question was: can you somehow modify its dynamics in such a way that it feels like a linear system? So I wrote a paper on feedback linearization that involved some differential geometry and other techniques in control. That was quite a success. That was in the mid 1970's, so it's pretty much an "old story" now, but those ideas can be applied in robotics and some other areas.

Q: How did you start working in robotics?

A: It's in part a personal story. My wife and I have three boys, and as they became of college age they kept saying something like, "Dad, why don't you do something that we can understand? Robots are really interesting, why don't you do something with robotics?" So I started a robotics lab in part in response to that, but also I felt that the field of automatic control really had something to say about robotics problems. So it was a combination of serendipity and the feeling that this was what the field needed.

Q: Tell us a little about your research in this area.

A: Robotics has been influential in my research program in different ways. One of them is about the dynamic of robotic systems. The question was: was it possible to take something as complicated as a six-degree freedom robot and make its dynamics and kinematics seem simple? So we used some ideas from group theory to write out the dynamic equations for them in one universal form. Therefore, when you came to a new robot –and new robots are built all the time- you could just plug in parameters from that new design and use the same program to simulate the equation for its dynamics. That only applied to a limited class of systems, but it solved certain sorts of problems.

> "Flexibility and an ability to interact are the key elements"

Q: Where do you see the main goals in this field?

A: I would say that the main problem in robotics is to build a robot that we can easily program. Programming a robot to do something like painting is not very hard, but programming it to do something clever like being a household companion, that's very difficult.

Q: How far are we from seeing that?

A: I think that before long robots will be a support for elderly people and will take the place of pets, for example, tell grandma who won the election or come over when somebody says "come here". The technical problems associated with doing things like that will be soon solved, but there are more difficult issues like safety or situations in which something exceptional happens. The biggest problem is that we have a rather less mathematics available to address these questions. Differential geometry has been successful in some ways, but so far it hasn't been able to help us to solve this kind of problem.

Q: Robots that work as companions to elderly people must be intelligent machines but, how do you define "intelligence"?

A: There are these tests for defining what an intelligent being is, the so called "Turing test", but if you look at a fox, or any other animal, it would fail the classical Turing test completely. However, I don't think anybody would deny that animals have intelligence. So then you ask yourself: how can I get a test for things that actually move in the real world? And I believe that what passes for intelligence in human beings or animals is the ability to interact with the physical world. Flexibility and an ability to interact are the key elements.

Q: What other needs do you see in robotics?

A: We need some different mathematics to help us understand the smoothed evolution systems versus the systems with discontinuities, like hitting a table. I have made some attempts to write about the subject on what we call "hybrid systems". They are a combination of two mathematically well developed and well understood subjects, namely an automata theory, and control systems governed by differential equations. When you put them together you find that a lot of new problems arise.

> "What passes for intelligence in human being or animals is the ability to interact with the physical world"

Q: Another important tool for robotics is computer vision, and you've also been working in this field.

A: There are already very practical machines that can do structured tasks very well. That it's great, but I think we need to regard computer vision much more as a contextual problem, maybe even as a real time problem. Once again, this is interaction of the world with the process, you simply can't treat it as… here is an image, make of it what you can. What interests me about computer vision is the insight of what human vision or animal vision is able to do. One third of our brain is devoted to vision. What's it doing? Is it an appropriate thing for nature to do? And if so, why is it so hard?

Q: The title of your talk in ICMAT is "Optimal Cyclic Processes and Sub-Riemannian Geodesics". Could you tell us what are you going to speak about?

A: In the physical world there are lots of things that produce processes that grow steadily, but they do it by going around in cycles. We breathe in and out, but our goal really is to take oxygen from the air and put it in our blood stream. The same with automobile engines: we just want the car to go, but the pistons go up and down in a cyclic process. What do these processes have in common? There are some rather recently understood aspects of differential geometry underlying these processes and when we optimize them they can be treated in a new way with nice mathematics associated. It's worth knowing more about it so you can get an additional window onto the world that explains these cyclic processes.

> "What interests me about computer vision is the insight of what human or animal vision is able to do"

"We want to draw the invisible landscape of the high seas"

Ágata Timón. Francesco d'Ovidio works at the interface between physics and biology at the Centre National de la Recherche Scientifique (CNRS) in France. His research work focuses on the relation between turbulence of sea currents and the structures of ecosystems in the global oceans. By means of mathematical tools, he is trying to identify the physical mechanisms (chaotic transport, mixing, segregation, etc.) and the main structures that make up the invisible landscape to which the life and behavior of marine organisms must adapt. We spoke to him when he attended the 2nd International Workshop on Nonlinear Processes in Oceanic and Atmospheric Flows, which was held last summer at the ICMAT.

Question: What are you main interests as a researcher?

Answer: At the moment I'm studying the relation between transport and ecosystems on the high seas.

Q: How did you arrive at this subject?

A: My background is in physics. I was interested in complex systems, which led me to the study of nonlinear dynamics, dynamical system theory, and so on. I started working on modeling for biology, and then after a postdoc stay at the Instituto de Física Interdisciplinaria y Sistemas Complejos (IFISC) in Palma de Mallorca I was drawn to chaotic transport and mixing in the oceans. Since then, this has been the most important research line in my career.

Mathematics, physics and biology come together in the work of Francesco d'Ovidio

Q: What do you mean by "mixing"?

A: The ocean is a turbulent system, which can be appreciated at different spatial-temporal scales. There's one particularly interesting system at the 10 to 100 kilometer scale, where structures of rotating turbulent flow are observed in the current field. These are the so-called "mesoscale vortices", which are the result of energy currents and may have a mixing effect.

Q: How do these structures affect the dynamics of the ocean?

A: The same contrasts we find in the atmosphere at scales of thousands of kilometers also appear in the ocean at scales of hundreds of kilometers. We see structures in the velocity field that are similar to a vortex and which probably determine the distribution of chlorophyll, for example, but which also influence many more factors in the ecosystem. My work consists in finding the relations between the currents (and therefore their velocity) and the distribution of certain factors of ecological interest ranging from chlorophyll to a specific type of plankton as well as the hunting strategies of predators.

Q: Do they also influence the behavior of the inhabitants of the ocean?

A: You can draw an analogy with the ecology of the earth: the physical characteristics of a landscape (a mountain or a river, for example) structure the environment. The living creatures present there have to adapt their hunting habits to the different characteristics of this environment. Something similar takes place in the ocean: the currents – especially those at the mesoscale – are equivalent to mountains or rivers. The idea is to draw this invisible landscape of the ocean's surface. One tends to think that the ocean is uniform, but it is far from being so.

Q: What's this ocean landscape like?

A: On the high seas the structures are changeable. Close to the coasts there is a fixed topography that imposes a physical structure, but the animals that live in the open seas find themselves in a dynamic landscape in which the mountains move at a speed that is scarcely any slower than their own. If the animal remains still, it might be in a valley at one moment only to find itself in a desert later. Living in a turbulent system is a very particular situation.

Q: What conclusions have you drawn from your analysis?

A: The big questions underlying our research have to do with conservation ecology. We want to identify the crucial structures behind the interaction between animals and the ocean in order to be able to monitor climate change and protect the zones that are in the greatest danger.

Q: How can these structures be studied?

A: One possibility is to use nonlinear dynamics. From a mathematical perspective, the point of departure is to consider the velocity field (the ocean current) as a dynamic system. There are hyperbolic and elliptic regions in this system that are like barriers or confluence zones of masses of water which can be identified as mathematical structures. For instance, the unstable varieties of the hyperbolic points in the velocity field act like barriers against transport.

> "Animals that live in the open seas find themselves in a dynamic landscape in which the mountains move"

Q: What are the advantages of this language?

A: Mathematics functions like a pair of spectacles that enable structures of the velocity field to be recognized. Certain interesting information can be extracted with this mathematics that would be difficult to recognize without it. So it enables you to understand how certain movements or distributions of marine organisms may be correlated with transport and mixing structures generated by the velocity fields. I haven't invented these techniques: they already exist in the dynamic structures. What we are trying to do is to develop the interface between the community of dynamic systems and oceanography.

Q: Are you working with mathematicians at the moment?

A: I'm stepping up contact with them to find out how to apply the mathematical tools that may help us to understand how the vortices change in relation to the surrounding water.

Q: What are the applications of this research work?

A: This is a very important question in ecology. Phytoplankton forms the basis of the ocean's food chain and is dispersed over wide areas. However, zones exist where it is confined, such as in vortices, which seem to determine how marine animals behave.

Q: So mathematics can also help to understand the behavior of these animals?

A: Yes, to a certain extent; mathematics is useful for describing the conduct of animals by means of time series; when they are looking for food, when they find food, and so on.

Q: What's your impression of this workshop?

A: It's very interesting, because it functions as an interface between nonlinear dynamics and geophysics. It provides a meeting point for deeper discussion on issues that are currently being addressed as well as analysis of the mathematical tools that could prove to be more useful.

"Fluid Dynamics for understanding the Southern Ocean"

In the more experimental part of his work, Francesco d'Ovidio gathers satellite data on ocean currents or on different types of phytoplankton, although he has also participated in oceanographic campaigns that have taken him as far as the Antarctic Ocean in search of observations in situ. In the modeling phase of this data, the main instruments employed come from nonlinear dynamics and dynamical systems theory.

D'Ovidio recently took part in research work, some of the results of which were published last year in the scientific journal Nature. In this article, an international team of researchers described the response of the bio-geological cycles and the ecosystem of the Southern Ocean to natural fertilization with iron. This scheme is aimed at stimulating the phytoplankton bloom, which captures CO_2 from the atmosphere and carries it to the ocean depths. While this is a commonly employed technique, it is still a much debated subject in the scientific community and the time scales of carbon capture are not entirely clear.

U. PIERRE ET MARIE CURIE

KEOPS2 oceanographic campaing took place on board Marion Dufresne research french vessel

That is why these researchers have been monitoring the deposited particulates from the sea's surface to the ocean bed in the region of the Antarctic circumpolar current. According to their results, a substantial portion of the biomass bloom sinks to below 1,000 meters, where it remains isolated from the atmosphere for hundreds of thousands of years.

The research work that provided these results was undertaken as part of the KEOPS2 oceanographic campaign, in which a new sampling system was used on the basis of real-time recognition of transport structures by means of analysis of data taken from satellites and surface buoys. With this research, the team aims to identify fluid dynamic niches that may provide a natural isolated environment for studying the evolution of biophysical processes over time, such as plankton growth by iron fertilization or the export of atmospheric CO_2 as phytoplankton sinks to the ocean depths.

"You can find interesting mathematics by studying even the most modest objects."

ICMAT.

Nigel Hitchin was born in 1946. He studied mathematics in Oxford, and obtained his PhD from there in 1972 under the supervision of Brian Steer and Michael Atiyah. Currently, he is Savilian Professor of Geometry at Oxford University.

Question: Why did you choose mathematics ahead of any other subject?

Answer: It was a gradual narrowing down from among other subjects I liked. For quite a while at school I thought about Engineering but then I gave up most other subjects to study just maths and physics.

Q:Besides mathematics, which activities do you like most?

A: Reading, theatre, cinema.

Q: A movie, book or play you'd recommend?

A: I've always liked Harold Pinter plays: sparse, carefully balanced, things happening which are left unsaid.

Q: How was your first encounter with mathematical research?

A: Not so good, in fact I thought about giving up in the middle of my first year as a graduate student. I couldn't find a topic I really liked, or could make any contribution to, and I found it difficult to adjust to a new way of thinking. In the end I encountered a couple of papers which I found interesting and spent a long time figuring out what they were saying in my own terms.

Q: What did you like most about your early experiences with mathematical research?

A: The first is the feeling you get when you finally produce a neat proof. The second is the gradual appreciation that in trying to understand what is going on you have actually proved something new.

Q: Which scientist impressed you most during your career?

A: That has to be Michael Atiyah, not only because he was my de facto supervisor but also for his taste and the way he presents mathematics in his lectures. And of course the fact that his theorems have been enormously important!

Q: If you could have a one hour blackboard discussion with an ancient mathematician, whom would you choose to meet and what would you discuss?

A: Bernhard Riemann: what was he really trying to do in introducing such a generalization of what was then known as geometry? He introduces the Riemannian metric as the simplest way of measuring length but was he seriously considering alternatives?

Q: Do you have a particular theorem or formula you especially like?

A: The Atiyah-Singer Index Theorem. I first got involved with this by studying vanishing theorems for the Dirac operator in my thesis but then I used it in a new situation to calculate the dimension of the moduli space of instantons. Since then I seem to have used the Riemann-Roch theorem, which is a special case, over and over again in my work.

Nigel Hitchin leads one of the ICMAT Laboratories, the result of agreements with renowned mathematicians

Q: What is your favourite mathematical book?

A: The collected works of Elie Cartan. I'm not a Cartan expert but there is a wealth of information there which is very relevant today. He didn't have the modern language of fibre bundles to describe what he was doing, and it can be hard to do the interpretation. On the other hand his notation is enviably concise.

Q: How would you describe/sketch your research interest in a few lines?

A: I'm interested in problems in differential and algebraic geometry which are stimulated by questions in theoretical physics. Physicists grow up with a different sense of intuition from mathematicians and so when they focus on a piece of mathematics they tend to see features that we don't and to make conjectures that we wouldn't normally do. The question then is to see how this works in mathematical language.

Q: Which recent results in your field would you highlight?

A: One of the topics I have worked on and which has a strong following at ICMAT is the moduli space of Higgs bundles. I initially saw this as an example of a gauge-theoretical hyperkähler quotient. In other words a construction which came from physics applied to a natural space of connections. When I started working out the details over 25 year ago I saw to my surprise that it had interfaces with all sorts of areas: topology, integrable systems, Riemannian geometry. In the past few years it has gained a new status in the geometric Langlands programme as viewed by physicists like Edward Witten and number theorists like Ngo Bao Chau.

"I don't like the big challenges. For me the point of doing research is to find out how things work"

Q: Which particular mathematical problem do you consider especially challenging?

A: I don't like the big challenges, the million-dollar problems. For me the point of doing research is to find out how things work. You need intuition to suspect that there is something worth revealing but you can find interesting mathematics by studying even the most modest objects.

Q: Which subjects in mathematics outside your field would you like to learn more about?

A: Number theory: often the words, especially the geometric expressions, sound familiar but you know that there is a radical difference from working over the complex numbers.

Q: In the future, where do you think the interaction between different branches of mathematics may be more fruitful?

A: String theory has been the area of theoretical physics with the most recent interaction with mathematics and nowadays string theorists are getting jobs in mathematics departments rather than physics ones. Perhaps it is time for the mathematical end of other physics disciplines such as condensed matter theory to have a stronger interaction with mathematics. But who makes the first move?

Q: Do you have any message or advice you would like to share with young mathematicians?

A: If you are just starting to do research, don't give up too soon. It takes time to change your attitude to the subject and to have confidence that you can make a significant contribution.

Hitchin Laboratory at the ICMAT

Nigel Hitchin with Luis Alvarez igel Consul and Marina Logares (ICMAT), two of the organizers of the Indo-Spanish Conference on Geometry and Analysis.

The ICMAT laboratories are agreements with prestigious mathematicians for creating leading research groups at the Instituto de Ciencias Matemáticas. The Nigel Hitchin Laboratory is an initiative to foster interaction and collaboration between Professor Hitchin, his group at the Mathematical Institute of the University of Oxford and the geometry group at ICMAT led by Oscar García-Prada. This collaboration will concentrate on various interfaces between Geometry and Physics, including Higgs bundles, Generalised Geometry and Poisson Geometry.

We have asked Professor Hitchin about this program.

Question: What can you tell us about the ICMAT- Laboratory?

Answer: It is only just starting, but it is an exciting opportunity to share ideas with like-minded researchers.

Q: What do you think about the programme?

A: I would like it to represent a range of mathematical ideas, not just the ones which are currently strong in Madrid. This is important in selecting postdoc appointments.

Q: Could you tell us about your experience at the "Nigel Hitchin LAB Retreat: Topology of moduli spaces of representations"?

A: I think this worked very well and was a genuine sharing of ideas, not just a presentation of recent work. I picked up several new threads and was given a reason to pursue others which had been put on the back-burner.

Large Deviations for the Stochastic Lotka-Volterra Problem

Carlos Escudero Liébana, ICMAT & UAM.

Abstract

The Lotka-Volterra system of differential equations is a classical model of population dynamics that describes the dynamics of two interacting populations: predators and preys. This problem admits a natural generalization in which the interactions among preys and predators become random. Such a stochastic version of the Lotka-Volterra system both has desirable features, for instance allowing the extinction of the species, and poses a certain number of mathematical questions. Herein we will focus on a large deviation approximation to the random problem. Although this constitutes a simplification of the full probabilistic problem, it still suggests an open question in the theory of dynamical systems.

The Lotka-Volterra system of differential equations [1, 2]

$$\frac{da}{dt} = -\mu a + \lambda ab \qquad (1a)$$

$$\frac{db}{dt} = \sigma b - \lambda ab \qquad (1b)$$

is a classical model of population dynamics that describes the dynamics of two interacting populations: predators, herein denoted as a, and the preys, herein denoted as b; μ, λ and σ denote positive parameters. The term proportional to μ takes into account the loss of predators, the term proportional to σ models the growth of preys and the term proportional to λ takes into account the growth of the predator population due to predation and the concomitant loss of preys.

The analysis of dynamical system (1a) and (1b) starts with the calculation of all fixed points, that in this case reduce to two:

$$a_0 = 0, \qquad b_0 = 0, \qquad (2)$$

and

$$a_1 = \frac{\sigma}{\lambda}, \qquad b_1 = \frac{\mu}{\lambda}. \qquad (3)$$

The first fixed point corresponds to a state in which both species are extinct, and the second to a state in which both species are equilibrated. The linear stability analysis of fixed point (a_0, b_0) reveals it is saddle, with two real eigenvalues, one positive and one negative. Fixed point (a_1, b_1) is not hyperbolic, since a linear stability analysis of it yields two purely imaginary fixed points. The second part of the linear stability analysis is therefore inconclusive, while the first part reveals that the fixed point corresponding to extinction is unstable and in consequence unreachable for the system unless initially set on it. The picture of the phase space can be completed by noting the existence of the conserved quantity:

$$\mathcal{K} = a^{\sigma} b^{\mu} e^{-\lambda(a+b)}. \qquad (4)$$

The existence of this quantity implies that fixed point (a_1, b_1) is truly a center. In other words, the region of phase space in which $a > 0$ and $b > 0$ is filled by closed trajectories surrounding (a_1, b_1). These trajectories correspond to periodic solutions $a(t)$ and $b(t)$, see for instance figure 1, where a numerical integration of system (1a) and (1b) is shown.

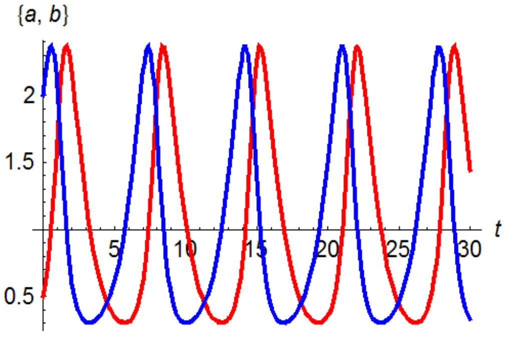


Figure 1: Example of numerical solution of system of differential equations (1a) and (1b) for $\mu = \sigma = \lambda = 1$. The red line, which represent the predators, is initialized at $a(0) = 1/2$; the blue line, which represent the preys, is initialized at $b(0) = 2$. The evolution is shown from $t = 0$ to $t = 30$.

For longer trajectories (i. e. for smaller $\mathcal{K} > 0$) the system arbitrarily approaches the extinction state, but never reaches it, as previously mentioned. This suggests that if some noise is introduced into the system, the extinction state will be eventually reached. To put this observation into a more formal context we first have to introduce noise in a natural way. In order to do so we consider the stoichiometric relations

$$A \xrightarrow{\mu} \emptyset, \quad B \xrightarrow{\sigma} 2B, \quad A + B \xrightarrow{\lambda} 2A, \qquad (5)$$

where A represents the predators and B represents the preys; these relations represent exactly the same interactions described by equations (1a) and (1b). Indeed, if these reactions happen at deterministic rates then the Lotka-Volterra equations are the exact description of the set of processes (5) (in a suitable continuum limit). Therefore a natural stochastic version of the Lotka-Volterra system is simply considering the set of reactions (5) as a set of Poisson processes with the indicated parameters. Although the master equation that dictates the time evolution of the resulting Markov process can be readily written, finding its solution both constitutes a difficult problem and provides us with a too large amount of information. Thus the introduction of an approximation scheme is clearly justified. In this case we concentrate on a large deviation theory that assumes for the probability distribution

$$\mathcal{P}(N_A, N_B; t) \approx e^{-S}, \qquad (6)$$

where N_A denotes the number of individuals of species A (predators) and N_B denotes the number of individuals of species B (preys), and the approximately equal sign $\approx$ is to be understood in the usual sense of large deviations [3]. S is an appropriate cost or action (following the usual language of mechanics) functional. The derivation of a suitable action functional in the present case is a technical issue so we will not reproduce it herein. The interested reader can check the details of the procedure in [4].

Once the action functional is derived, the next step is finding the trajectories that minimize it. These deterministic trajectories are the most probable events of the random system. As usual, such trajectories can be found as solutions of a suitable Hamiltonian dynamical system. One possible Hamiltonian for the case under study is

$$H = -\mu(p_a - 1)q_a + \sigma p_b(p_b - 1)q_b - \lambda p_a(p_b - p_a)q_a q_b. \tag{7}$$

Obviously this Hamiltonian corresponds to a four-dimensional dynamical system. All of the fourth coordinates p_a, p_b, q_a and q_b correspond to auxiliary mathematical variables without a direct physical meaning. However, the main quantities of interest, i. e. the numbers of predators and preys, are given respectively by $N_A(t) = p_a(t)q_a(t)$ and $N_B(t) = p_b(t)q_b(t)$. In order to understand the consequences of our large deviation theory on these quantities we need to analyze the associated dynamical system.

The equations of motion corresponding to Hamiltonian (7) are

$$\frac{dq_a}{dt} = \frac{\partial H}{\partial p_a} = -q_a[\mu + \lambda q_b(p_b - 2p_a)] \tag{8a}$$

$$\frac{dp_a}{dt} = -\frac{\partial H}{\partial q_a} = \lambda p_a q_b(p_b - p_a) + \mu(p_a - 1) \tag{8b}$$

$$\frac{dq_b}{dt} = \frac{\partial H}{\partial p_b} = -q_b(\lambda q_a p_a + \sigma - 2\sigma p_b) \tag{8c}$$

$$\frac{dp_b}{dt} = -\frac{\partial H}{\partial q_b} = \lambda q_a p_a(p_b - p_a) - \sigma(p_b - 1)p_b. \tag{8d}$$

This is a four-dimensional Hamiltonian dynamical system that is polynomial and for which, of course, there is a first integral of motion that coincides with the Hamiltonian and that we will call the energy E. This system has exactly 5 fixed points: three of them lie on the $E = 0$ manifold, the fourth one in some manifold with $E > 0$ and the last one in another manifold with $E < 0$. These last two fixed points are hyperbolic (all their eigenvalues have a real part different from zero) and they are not connected to any other fixed point. So we will concentrate on the dynamics on the $E = 0$ manifold; these three fixed points are

$$(q_a, p_a, q_b, p_b)_1 = (0, 1, 0, 0), \tag{9a}$$

$$(q_a, p_a, q_b, p_b)_2 = (0, 1, 0, 1), \tag{9b}$$

$$(q_a, p_a, q_b, p_b)_3 = (\sigma/\lambda, 1, \mu/\lambda, 1). \tag{9c}$$

The first two of these fixed points are hyperbolic, while the third one has four purely imaginary eigenvalues. Furthermore, this dynamical system has two invariant planes

$$P_1 = \{p_a = 1, p_b = 1\}, \tag{10a}$$

$$P_2 = \{q_a = 0, q_b = 0\}. \tag{10b}$$

One may check that the dynamics on P_1 is exactly that of the classical Lotka-Volterra system (1a) and (1b). One consequence of this is that we know $(\sigma/\lambda, 1, \mu/\lambda, 1)$ is truly a center when restricted to this plane. In P_2 the dynamics reduces to

$$\frac{dp_a}{dt} = \mu(p_a - 1), \tag{11a}$$

$$\frac{dp_b}{dt} = -\sigma(p_b - 1)p_b, \tag{11b}$$

so the dynamics is exactly integrable in this plane. Thus using what we have learned about the dynamics in both invariant planes we now know exactly both stable and unstable manifolds of $(0, 1, 0, 1)$: these are the axis $(q_a, 1, 0, 1)$, $(0, 1, q_b, 1)$, $(0, 1, 0, p_b)$, and $(0, p_a, 0, 1)$. In fact, fixed point $(0, 1, 0, 1)$ is connected to $(0, 1, 0, 0)$ along the line $(0, 1, 0, p_b)$. The dynamics along this line flows from $(0, 1, 0, 0)$ to $(0, 1, 0, 1)$. We also know exactly the full unstable manifold of $(0, 1, 0, 0)$, which is characterized by the axis $(0, 1, 0, p_b)$ and $(0, p_a, 0, 0)$. So we know that $(0, 1, 0, 1)$ is connected only with $(0, 1, 0, 0)$ and with infinity. We also know that $(0, 1, 0, 0)$ is connected through its unstable manifold with $(0, 1, 0, 1)$ and with infinity. We know nothing about its stable manifold beyond the linear stability analysis.

Now we move to fixed point $(\sigma/\lambda, 1, \mu/\lambda, 1)$. We know this fixed point is truly a center (and thus stable) when restricted to plane P_1, but we do not still know it is really stable in all four dimensions. In fact, it could in principle have stable and unstable orbits flowing towards and from it. Furthermore we know that a hypothetical orbit flowing to $(\sigma/\lambda, 1, \mu/\lambda, 1)$ should connect it with infinity, because we know exactly the unstable manifold of $(0, 1, 0, 0)$. So there is just one thing to know in order to complete the picture of the phase space: is there a connection flowing from $(\sigma/\lambda, 1, \mu/\lambda, 1)$ to $(0, 1, 0, 0)$?

Conjecture: The fixed points $(\sigma/\lambda, 1, \mu/\lambda, 1)$ and $(0, 1, 0, 0)$ of the dynamical system specified by Hamiltonian (7) are not connected.

The trajectories solving differential equations (8a), (8b), (8c) and (8d) show oscillatory dynamics. One example is depicted in figure 2, where a numerical integration of this system is represented. In this case the undulating behavior shows a varying amplitude, and we have numerically detected this variation is sometimes periodic.

The existence of a trajectory connecting $(\sigma/\lambda, 1, \mu/\lambda, 1)$ to $(0, 1, 0, 0)$ would mean there exists an optimal way of connecting the states with populations $N_A = \sigma/\lambda, N_B = \mu/\lambda$ and $N_A = N_B = 0$. In other words, this would mean the existence of an optimal route to extinction. This is important for the large deviations theory because computing the action along this hypothetical trajectory and employing formula (6) would lead to an exponentially large time to extinction [5]. However, the numerical results in [6]

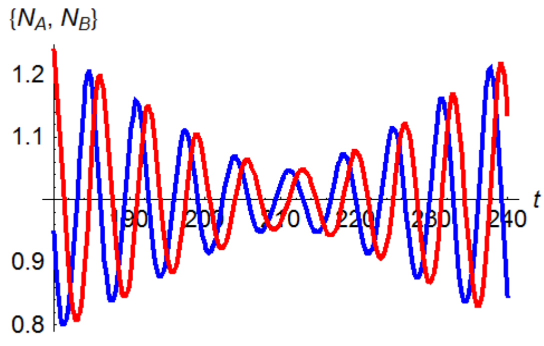


Figure 2: Example of numerical solution of system of differential equations (8a), (8b), (8c) and (8d) for $\mu = \sigma = \lambda = 1$. The red line, which represent the predators, is initialized at $N_A(0) \approx 1/2$ ($q_a(0) = 1/2$ and $p_a(0) = 1.0001$); the blue line, which represent the preys, is initialized at $N_B(0) \approx 2$ ($q_b(0) = 2$ and $p_b(0) = 1.0001$). The evolution is shown from $t = 180$ to $t = 240$.

indicate that the time to extinction is much shorter, and in particular algebraic rather than exponential. This suggests in turn that the mentioned orbit does not exist. Note that this does not imply there are no optimal trajectories towards extinction. These trajectories do exist and fall in manifolds with $E \neq 0$ [7], and their existence is fully compatible with algebraic times to extinction. However, none of these orbits is a heteroclinic connection.

Acknowledgments: The author is grateful to Daniel Peralta and Pedro Torres for discussions. This work has been partially supported by projects MTM2010-18128, RYC-2011-09025 and SEV-2011-0087.

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The Hitchin Laboratory takes its first steps

Nigel Hitchin is a researcher at the University of Oxford.

A glimpse of the future development of the theory of moduli spaces of representations and Higgs bundles was caught during the Nigel Hitchin Laboratory Scientific Retreat held in La Cristalera (Miraflores de la Sierra) from March 11th to March 15th. This was the first important activity at the Laboratory, entitled "Topology of Moduli Spaces of Representations", during which international experts highlighted the open problems that will determine the future of the discipline in sessions conducted by Nigel Hitchin (Oxford University).

"The structure of the activity was conducive to discussion and enabled important problems to emerge that will be the subject of research in the coming years", says Óscar García Prada, ICMAT researcher and organizer of the laboratory.

"It was a delight to listen to renowned researchers posing questions they believe will inspire future research lines: we had the opportunity and the privilege to glimpse the future of the discipline", says ICMAT doctoral student David Fernández who attended the meeting. Furthermore, as Fernández also remarks, the small number of participants, some 25 in all, made it a friendly and informal event.

The Nigel Hitchin Laboratory is an initiative undertaken by the ICMAT Geometry group headed by Oscar García Prada. Its main aim is to stimulate collaboration between Hitchin and his group at the Oxford University Institute of Mathematics and the ICMAT Geometry group, especially in fields such as Higgs bundles, general geometry and Poisson geometry.

Alberto Enciso, at the head of the ICMAT initiation into research programme

Alberto Enciso, Ramón y Cajal researcher at the Instituto de Ciencias Matemáticas (ICMAT), will be the new director of the JAE School of Mathematics, the introductory summer course in research that forms part of the CSIC program "Junta para la Ampliación de Estudios (JAE)". The school is aimed at undergraduate and graduate students who are interested in mathematical research and who throughout a month will be introduced to scientific research by working closely alongside front-rank researchers.

In 2011, Alberto Enciso was awarded the Real Sociedad Matemática Española (RSME) José Luis Rubio de Francia Prize, which is conferred on the best young mathematicians in our country. Enciso is engaged in different areas related with mathematical physics, partial differential equations and differential geometry.

Alberto Enciso, new director of the School of Mathematics of the CSIC JAE

Agenda

New Trends on Harmonic Analysis in ICMAT

Madrid, from october 2012 to july 2013
www.icmat.es/NTHA

April-june 2013
Research Term on Real Harmonic Analysis and Applications to Partial Differential Equations.

From 27th to the 31st of may 2013
Harmonic Analysis, PDEs and Geometry: A joint Workshop of the ANR-Harmonic Analysis at its boundaries and the ICMAT-Severo Ochoa.

May-July 2013
Research Term on Operator Algebra Methods in Harmonic Analysis and Quantum Information.

From the 10th to the 14th of june 2013
Workshop on Operator Spaces, Harmonic Analysis and Quantum Probability.

John Allen Paulos conjugates mathematics, literature and journalism at the Residencia de Estudiantes

SINC/Olmo Calvo

John Allen Paulos is one of the most famous mathematicians disseminators of late.

“Innumeracy”, an educational book on mathematics, published in 1988, became a worldwide success and its author, John Allen Paulos, one of the most famous disseminators of mathematics of recent years. This year, on March 13th, as part of the season of talks "Matemáticas en la Residencia", Paulos gave a talk entitled "Stories, Statistics, and the News", at an event organized by the ICMAT in collaboration with the CSIC Associate Vice-president of Scientific Culture and the Residencia de Estudiantes.

Antonio Calvo Roy, president of the Spanish Association of Scientific Communication, introduced the talk in which Paulos compared mathematical logic with literature and analyzed the most frequent numerical mistakes made in the media. In his clear, direct and ironic style, Paulos pointed out the fallacies of reasoning that are sometimes used to defend a particular argument on paper. He also spoke about the erroneous interpretation of statistics, and in general about the importance of mathematical thought in both the transmission and interpretation of news items. "Facts do not speak for themselves; they must be interpreted, and it is not always clear how this is done", says Paulos, who is a professor of mathematics at Temple University in Philadelphia (USA), where he specializes in Logic and Probability Theory.

> “Facts do not speak for themselves; they must be interpreted”

The ICMAT participates for the first time in the 4ESO+empresa program

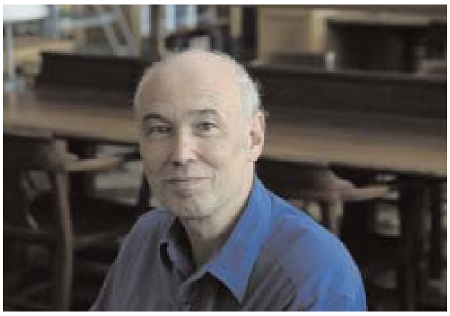
ICMAT

Students and researchers during a visit to the ICMAT.

On 19th, 20th and 21st of March, the Instituto de Ciencias Matemáticas (ICMAT) welcomed 4th grade secondary school students in order for them to experience at first hand how mathematical researchers work at a center of excellence. During their stay, 14 students from two secondary schools in Madrid visited the CMAT facilities and got to know the researchers themselves. Furthermore, these students also participated in a creative mathematical workshop, a database workshop, a talk on interdisciplinary science and a round-table discussion on the prospects of research as a professional career. This scheme forms part of the Community of Madrid’s "4ESO+empresa" program and provides young people with the opportunity for educational stays at companies and research centers.

In the words of Manuel de León, director of the Institute, the aim is to "show these young people what actually goes on at research centers such as the ICMAT as well as helping to encourage a scientific vocation". The students were able to "experience at first hand what mathematical research is all about,” as well as to see that “science is a living thing, in continuous effervescence, from which new results are obtained every day”. This is the first time that the Institute has participated in a scheme that is expected to grow in the coming years.

Belgian mathematician Pierre Deligne awarded the 2013 Abel Prize


DNVA/Cliff Moore

Pierre Deligne is a researcher at the Institute for Advanced Study in Princeton

On March 20th, the Norwegian Academy of Sciences and Letters announced the winner of this year's Abel Prize. He is the Belgian mathematician Pierre Deligne, currently residing in the USA, who was previously awarded the Fields Medal in 1978. Among his outstanding contributions are the building of bridges between hitherto isolated fields of mathematics, such as algebraic geometry and number theory, as well as the proof of one of the last Weil conjectures, which concerns the identification of the properties of a geometric object in a purely algebraic way.

The Abel Prize carries a cash award of six million Norwegian krone (€800,000) and is regarded as equivalent to the Nobel Prize for Mathematics. In the official words of awarding committee, Deligne, who is at present emeritus professor of the Institute for Advanced Study at Princeton (USA), has been distinguished "for his seminal contributions to algebraic geometry and for their transformative impact on number theory, representation theory and related fields".

Mathematics for climate change and related risks

Sudden changes in climate, sustainable development, fluid dynamics, climate models and ocean-atmosphere interaction are just some of the subjects to be addressed at the "Workshop on Mathematics of Climate Change, Related Hazards and Risks", which will be held between July 29th and August 2nd in Guanajuato (Mexico).

This activity is organized around the 2013 Mathematical Congress of the Americas and forms part of the Mathematics of Planet Earth worldwide program. Applications are now open for this event, which will be attended by 40 young scientists coming mainly from South American and the Caribbean, as well as nine prestigious researchers.

The program will stretch over five years and is sponsored by the International Council for Science (ICSU), the International Mathematical Union (IMU), the International Union of Theoretical and Applied Mechanics (IUTAM), the International Union of Geodesy and Geophysics (IUGG), the International Council for Industrial and Applied Mechanics (ICIAM) and the Centro de Investigación en Matemáticas de México.

ICMAT

Quarterly newsletter

Instituto de Ciencias Matemáticas

Number 2. II Trimester 2013

Editing:
ICMAT
C/ Nicolás Cabrera, nº 13-15
Campus de Cantoblanco, UAM
28049 Madrid SPAIN

Editorial comittee:
Manuel de León
Ágata A. Timón
Carlos Vinuesa
Kurusch Ebrahimi Fard

Production:
Divulga S. L.
C/ Diana 16 - 1º C
28022 Madrid

Coordination:
Ignacio F. Bayo
Lorena Cabeza
Ágata Timón

Design:
Lorena Cabeza
Andrea Jiménez

Contribution:
Carlos Escudero

Photography:
ICMAT, *Nature*, Edinburgh University, Harvard, Pierre et Marie Curie, SINC/Olmo Calvo, DNVA/Cliff More

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